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General Director's Word

In the name of Allah The Most Gracious The Most Merciful

All praise be to Allah and peace and Blessings be upon the Prophet Muhammed

Sirte University Scientific Journal is an official refereed journal. It published peer-reviewed research in the fields of humanities and applied sciences.

As one of its mission has been to improve the scientific research in order to broaden the people's knowledge and serve the local community, and since the scientific research has been widely recognized as of one of the main standards on which universities' performances and contributions are assessed in all over the world, we had to do our utmost to ensure the publication of the 2^{ed} issuance of 10th volume- Dec. 2020) which includes the humanity and sciences volumes.

It is worth mentioning that the SUSJ, in a very short time and with very limited resources, has made significant and tangible achievements, namely, the spearheading of research culture, exchanging of expertise, boosting the spirit of cooperation and encouraging researcher to publish their valuable research papers in different scientific fields.



As the University's President and the General Director of the journal, I am so delighted to present you with the current edition of the journal. It is also my great pleasure to extend my gratitude to the University's faculty members, graduate students, researchers and reviewers who have all contributed in the publication of this issue and hoping that the editorial board has selected the most valuable research papers to be published in this edition. I should mention here that we, very much, welcome any comments and/or suggestions which could help in improving the next editions.

Finally, I commend all the hard work and efforts exerted by the Editorial Board and to all people who have contributed, directly or indirectly, in bringing this issue into life.

Peace be upon you

The General Director

Editor in Chief's Word

In the name of Allah The Most Gracious The Most Merciful

It remains my great honour to serve as Editor-in-Chief of the *Sirte University Scientific Journal (SUSJ)*, and it is my pleasure to take this opportunity to thank everyone involved in the continuing success of the journal, and we would never have made it this far without the enthusiasm and assistance of the journal's Editorial Board, and its readers. There are two special groups who are also included in the above, our referees and our authors. Without the referees' valuable comments, the quality of the papers would not be as high as it is. Without the authors' choice of SUSJ in which to publish their best work, the journal's contribution to our community simply would not be as great as it is. It is also thanks to the hard work of both our authors and our referees that our publications enable all our readers to keep up with the latest developments within our sphere of research as early as possible.

We look forward to your most serious and effective efforts, which aspire members of the editorial board and its general director, also aspire to the university in the dissemination of scientific research in all fields of human and applied sciences.



Although every effort has been made to make this journal errors-free and as scientific as possible, no work is perfect and this journal is not an exception. Therefore, we appreciate it if you could give us your feedback, suggestions and ideas in order to improve the next issues.

May Peace be Upon You

Editor in Chief

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Evolution of Grain Size in 34CrNiMo6 Steel as a Function of Thermo-mechanical Process Route

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Abstract

The main purpose of the isothermal deformation processes is to quantify the austenite grain size at different deformation conditions and determine the stress strain behaviour of the 34CrNiMo6 low alloy steel. In this study we have simulated the deformation process conditions experienced in the large scale forging of 34CrNiMo6 low alloy steel in order to understand and optimize the thermo-mechanical process parameters that determine microstructure and thus the final mechanical properties. Isothermal hot working tests over the temperature range of 900°C - 1260°C, strain rates of 0.1, 0.5 and 1s⁻¹, and strains of 0.4, 0.6 and 0.8, while a range of microscopy methods will be used for microstructure analysis. The peak stress and peak strain for initiation of dynamic recovery (DRV) and recrystallization (DRX) at different temperatures and strain rates were calculated. The relation between grain size diameter and both of Zener-Hollomon parameter and deformation temperatures with changing of strain rate at both austenitising temperatures of 1100°C and 1260°C were determine. All these data are going to be used through the general constitutive equations to determine the hot working constants.

Keywords: Grain Size, Environmental, 34CrNiMo6, Thermo-mechanical process, Zener-Hollomon parameter.

1. Introduction

The worldwide demand for increasing energy efficiency in power generation or for drilling for oil in deeper seas has necessitated the manufacture of bigger sections, [1, 2]. In general metal forming processes, such as forging of steels, attempt to improve a desired microstructure, which leads to improve mechanical properties, at the same time as producing a near-net shape, which for large sections can only be done at elevated temperature [3]. The 34CrNiMo6 is a quenched and tempered low alloy engineering steel with a high hardenability, containing nickel, chromium and molybdenum. It has good toughness properties with CVN (Charpy V-notch) values averaging

around 80J. Thus is an ideal material for large forgings where high tensile strength properties and impact toughness are a requirement [4].

The microstructure, which is formed after the deformation or after heat treatment processes, is significantly affected by the austenite grains size, where a small austenite grain size is preferred to improve impact toughness and strength. Many investigators have reported that the prior austenite grain size plays a significant role in controlling of some mechanical properties of steels. For instance, the strength and impact toughness of the 17CrNiMo6 steel can be improved with the refinement in the prior austenite size[1]. Moreover, The refinement of martensitic structure was obtained by reducing the quenching temperature from 1200°C to 900°C, and the refinement of prior austenite grains can prompt the refinement of martensitic packets and blocks, which resulting in enhanced of the yield strength and toughness simultaneously [2, 3].

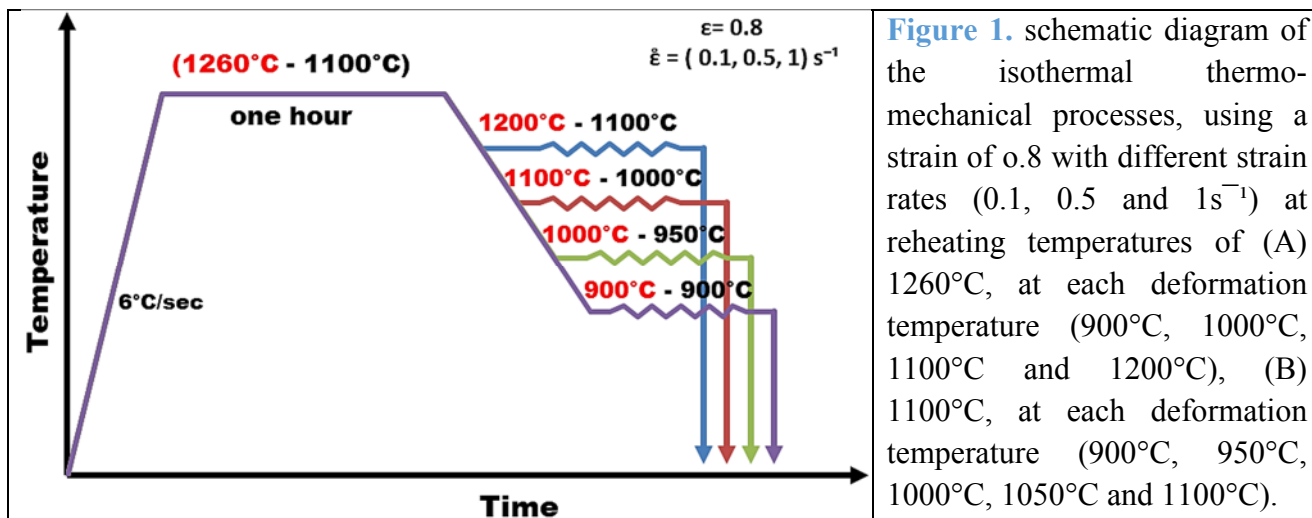
2. Experimental procedure

The chemical composition of the 34CrNiMo6 low alloy steel used in this work is given in table (1). The specimens were austenitised either at 1260°C or 1100°C for one hour (according to the holding time estimation). After that, the specimens were cooled in 60sec to a particular deformation temperature. The one hit of isothermal deformation process takes place, using a strain of 0.8 with strain rates of 0.1 s⁻¹, 0.5 s⁻¹ and 1 s⁻¹ at each deformation temperature of 900°C, 1000°C, 1100°C or 1200°C, respectively after austenitised at 1260°C, and deformed at 900°C, 950°C, 1000°C, and 1100°C, respectively after austenitised at 1100°C. Finally, the specimens were water quenched to room temperature as shown in figures (1).

Table 1: Chemical composition (wt %) of 34CrNiMo6 alloy steel

Element	Acceptable W% range	Measured W%
C	0.33-0.35	0.33
Cr	1.45-1.7	1.52
Ni	1.6-1.7	1.66
Mo	0.2-0.3	0.23
Mn	0.4-0.7	0.51
Pmax	0.015	0.009
Si	0.15-0.35	0.22
Smax	0.01	0.01
Almax	0.01	0.004

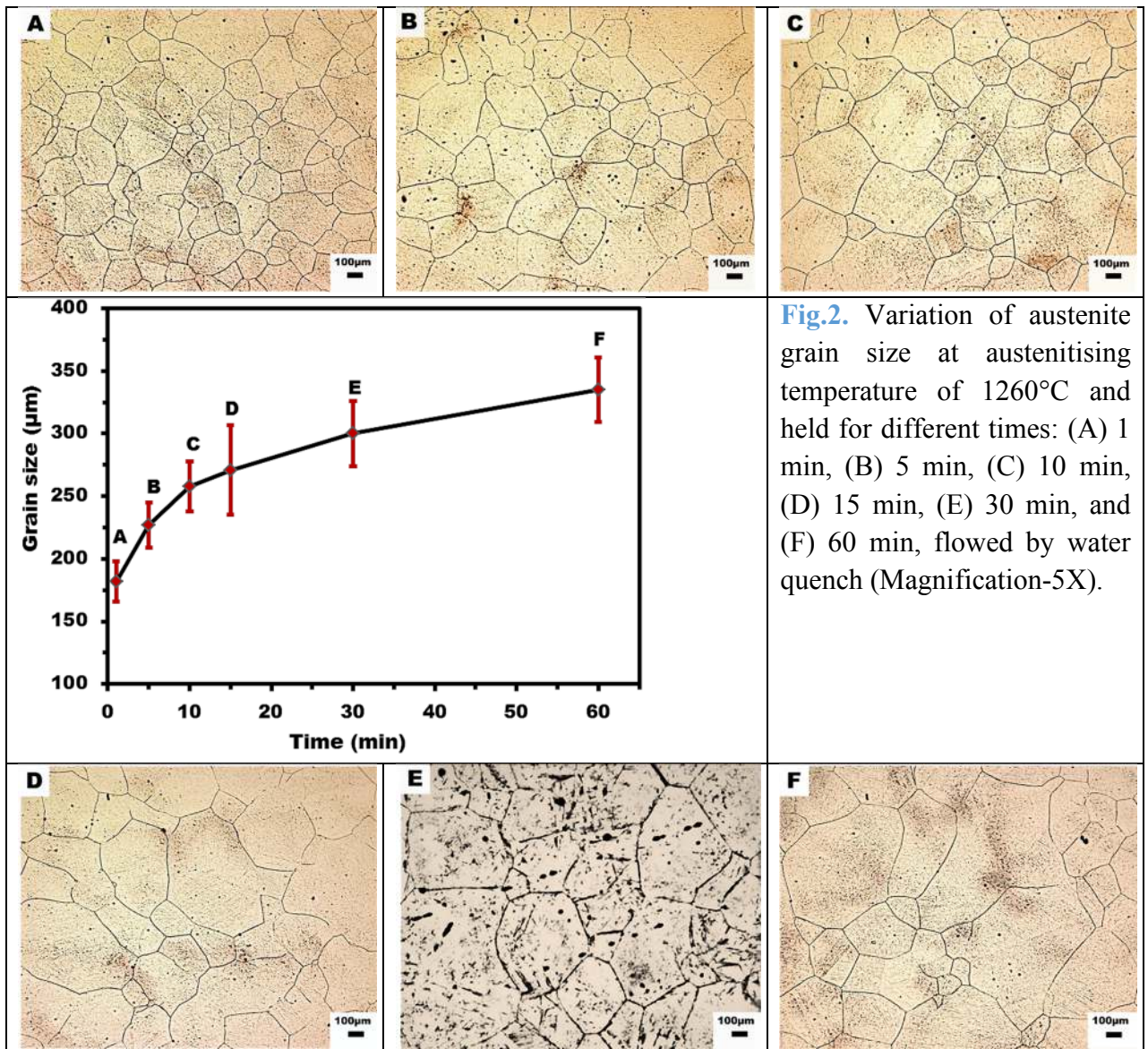
V	0.05-0.12	0.07
Cumax	0.3	0.13
Snmax	0.05	0.01



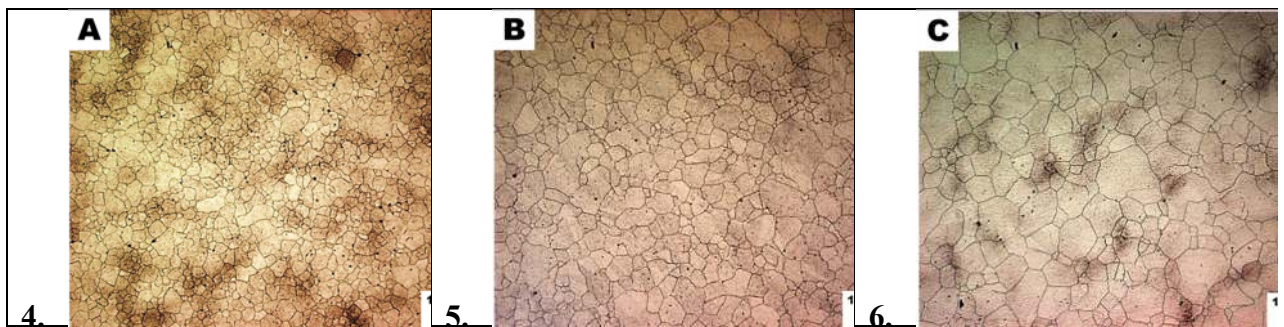
3. Results and discussion

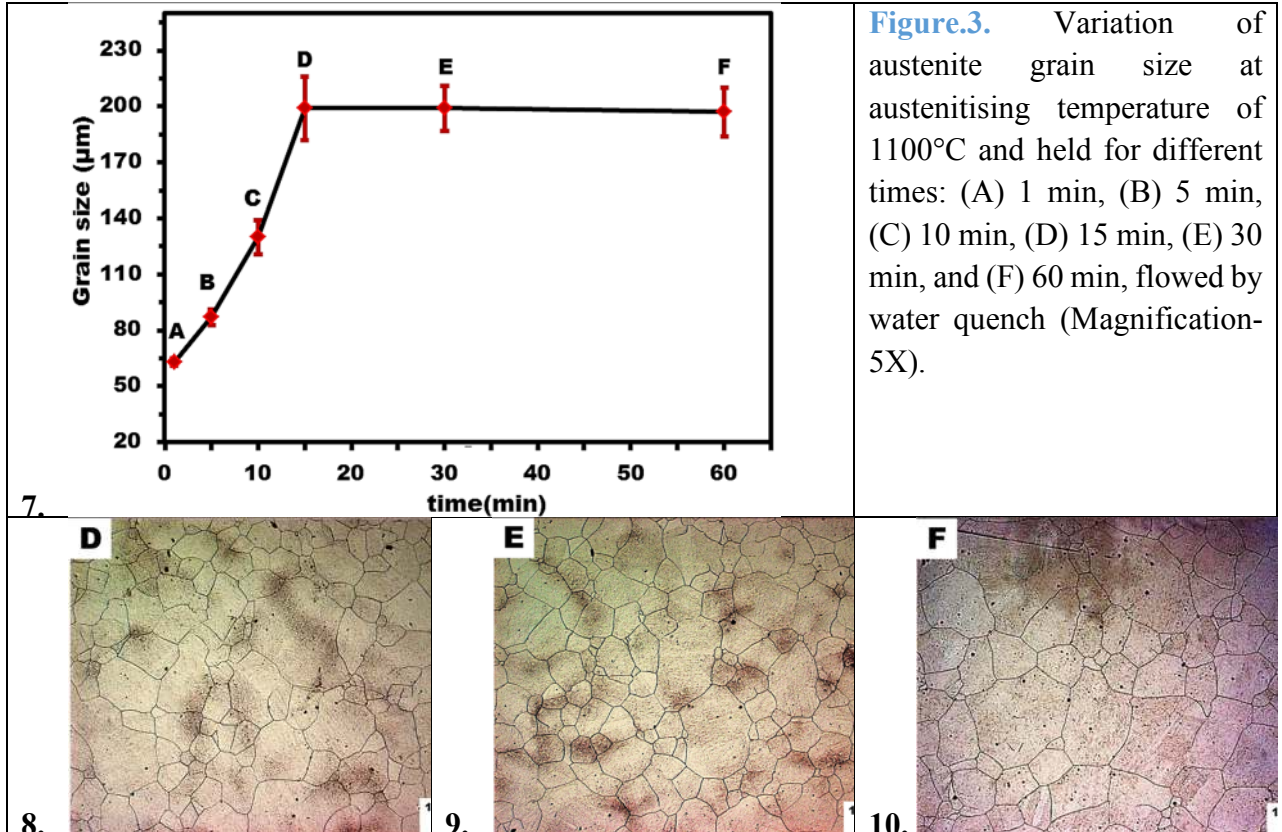
1.1. Austenitising temperatures and holding time

- The austenite grain growth is affected by both the austenitising temperature and the holding time, but the effect of austenitising temperature is more strongly than the holding time[4]. The austenitising temperature of 1260°C was used to try to optimize the thermo-mechanical process parameters. To attempt to refinement austenite grain size, the austenitising temperature of 1100°C also was used, to make a comparison to investigate the effect of this change on the austenite grain size. Moreover for all experimental specimens, one hour was the holding time for both reheating temperatures of 1260°C and 1100°C as shown in figures (2, 3). Where the biggest grain size was got with the suitable holding time, while after this time the increase in grain size will be slightly small compared to the bigger increase in heating time. To try to simulate a real large scale forging process for 34CrNiMo6 steel by holding the samples for a long period of time in the austenitising temperature before the deformation process.



3.





11.

3.2 . Flow curves and optical microstructure at austenitising temperatures of 1260°C and 1100°C

Figure 4(a)-(f) shows the true stress–strain curves of the 34CrNiMo6 low alloy steel at two austenitising temperatures followed with different deformation temperatures, 0.8 strain, and different strain rates. The effects of deformation temperatures and strain rates can be seen in all curves, where the lower deformation temperature the higher flow stress was obtained, at the same time at the higher strain rate the higher flow stress was achieved. For the reason that, high temperatures and low strain rates gives longer time for energy accumulation and higher ability to move at grain boundaries for the nucleation and growth of dynamically recrystallised grains and dislocation faded. Therefore, flow stress is decreases at low strain rates and high temperatures [4].

A single peak was observed in all the flow stress curves. In the case with austenitising temperature of 1260°C, as can be seen in figure 4(d)-(f), the flow stress increased to the peak and then slightly decreased to a steady state accompanied by dynamic recrystallisation at all deformation temperatures and strain rates. Where in this case, when the stress reach its peak value dynamic recrystallisation softening take place and the peak flow stress slowly decrease, after that hardening and recrystallisation softening balance and the flow stress curve reached to steady state. Excluded from that the deformation temperature of 1000°C with strain rates of 0.5 s^{-1} , and 1 s^{-1} and the deformation temperature of 900°C with all strain rates, where the flow stress increased to a peak and then

continuous increasing to reach the steady state in the end. The reason for that may be the return to the resulting massive elongated grains with small percentage of recrystallized grains especially at deformation temperature of 900°C which is approximately the recrystallisation stop temperature. The percentages of recrystallisation at 900°C approximately were approximately 11%, 6% and 5% at strain rates of 0.1, 0.5 and 1 S⁻¹ respectively.

The peak stress and peak strain with various influencing factors are shown in Table (2). The peak flow stress increases with increase of deformation strain rate, where for example at the deformation temperature of 1000°C the peak stress was 88, 110, and 124 MPa when deformation strain rate was 0.1, 0.5 and 1 S⁻¹, respectively. Also, the peak flow stress increased with decreased deforming temperature, where for example at the strain rate of 0.1 S⁻¹ the peak stress was 44, 57, 88 and 145 MPa when deformation temperature was 1200, 1100, 1000 and 900 °C, respectively. In addition, increasing of strain rate and decreasing of deformation temperature will cause delay of the beginning of dynamic recrystallisation. As shown in the table (2) the peak strain ranges from 0.26 to 0.44.

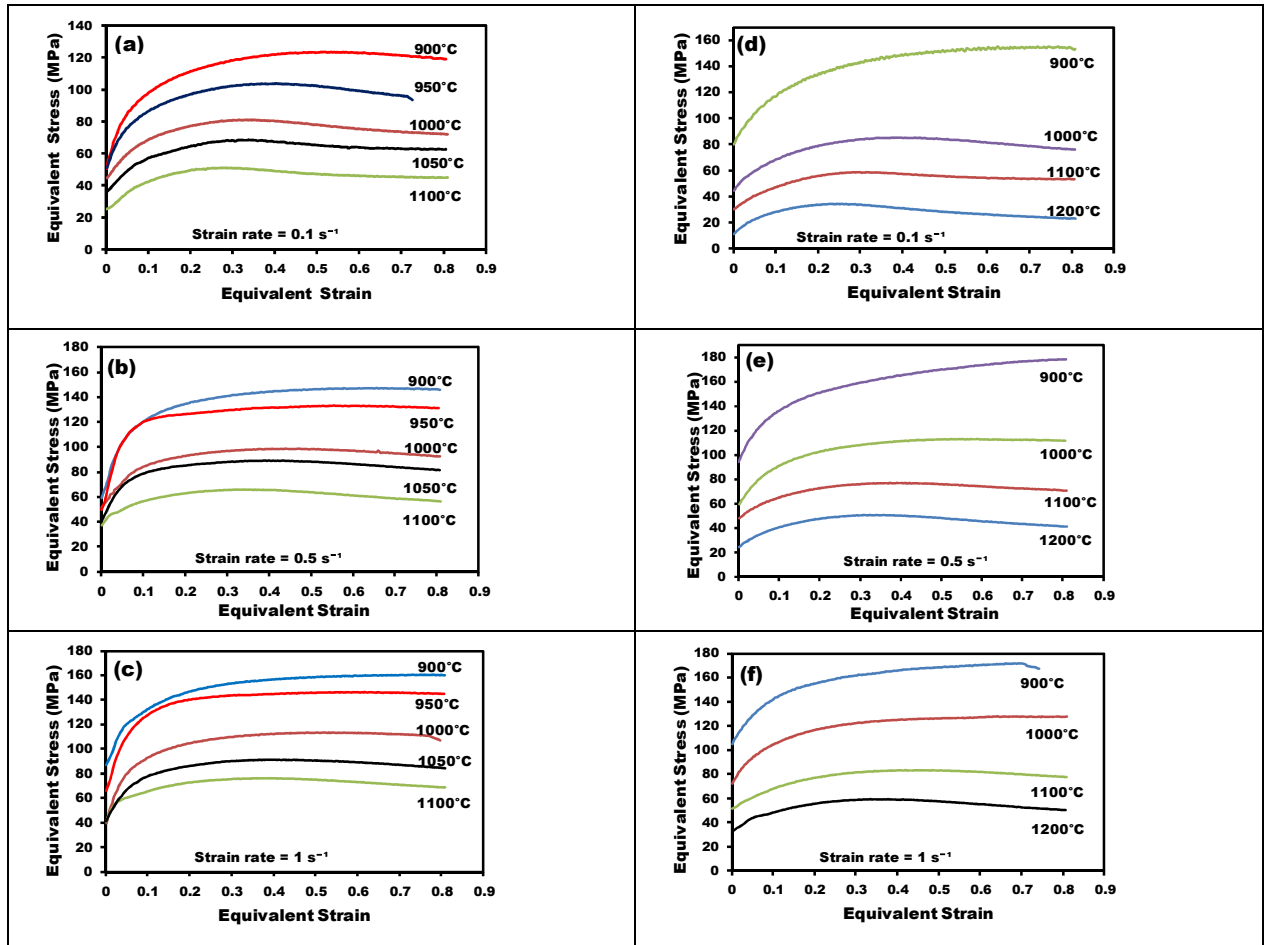


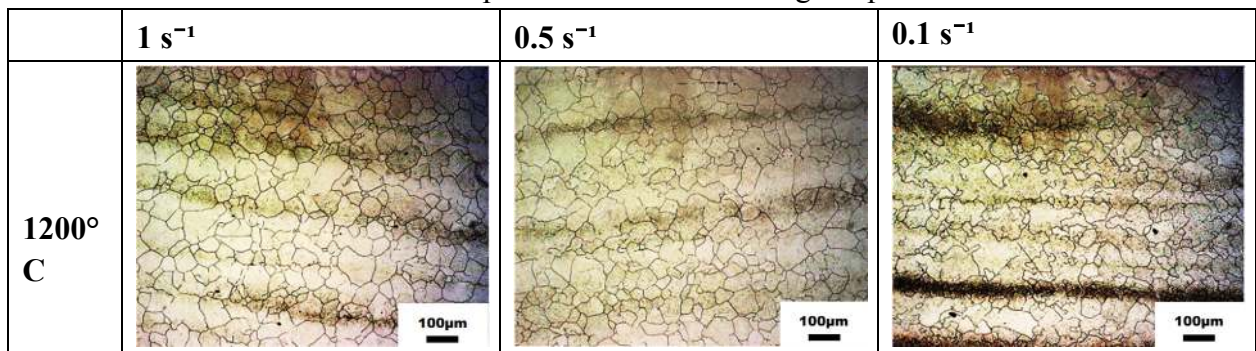
Fig.4. The true stress-true strain curves, after austenitising for one hour [(a, b, c) at temperature of 1100°C, and (d, e, f) at temperature of 1260°C] followed by deformed at various temperatures, 0.8 strain and Strain rates of (a, d) 1 S⁻¹, (b, e) 0.5 S⁻¹, and (c, f) 0.1 S⁻¹.

Table 2: Shows the peak stress, and peak strain with different deformation temperatures and strain rates.

Austenitising temperature (C°)	$\dot{\epsilon}^{\circ}$ (s ⁻¹)	Deformation temperature	ϵ_p	σ_p (MPa)
1260	1	1200	0.34	64
		1100	0.42	84
		1000	0.64	124
		900	0.70	167
	0.5	1200	0.31	56
		1100	0.37	77
		1000	0.59	110
		900	0.8	170
	0.1	1200	0.26	44
		1100	0.32	57
		1000	0.44	88
		900	0.77	145
1100	1	1100	0.39	76
		1050	0.37	91
		1000	0.50	113
		950	0.62	147
		900	0.78	161
	0.5	1100	0.34	66
		1050	0.39	90
		1000	0.44	99
		950	0.56	133
		900	0.66	147
	0.1	1100	0.28	51
		1050	0.34	68

	1000	0.34	81
	950	0.40	104
	900	0.52	124

While in the case with austenitising temperature of 1100°C, as can be seen in figure 4(a)-(c), the true stress-strain curves in general the characteristics of the flow stress curves at temperatures 900°C, 950°C, 1000°C, 1050°C and 1100°C, approximately are similar to the flow stress curves with austenitising temperatures of 1260°C. At strain rate of 0.1 S⁻¹ almost in all flow stress curves a single peak was observed, where the flow stress increased to the peak and then slightly decreased to a steady state. Furthermore, at 0.5 and 1 S⁻¹ a single peak of flow stress curve was observed, apart from the case of 900°C and 950°C with both strain rates, and 1000°C with just 1 s⁻¹ strain rate, where the flow stress increased to a peak and then continuous increasing to reach the steady state in the end. In this case, the dynamic recovery occurred where the work hardening dominant at the beginning of deformation that makes the flow stress increased. Then hardening and softening achieved balance when deformation reached a certain degree, flow stress curve reached steady state. Because of some alloying elements in the chemical composition of experiment steel, the dynamic recrystallisation is retarded. Consequently, the steel has a high recrystallisation temperature. As the deformation temperature is 900°C with the strain rates of 0.1, 0.5 and 1 s⁻¹ for both austenitising temperatures as seen in figures (5) and (6), there are some nuclei germinated dynamically on the original grains boundary of deformed grains. The percentages of recrystallisation at deformation temperature of 900°C with austenitising temperature of 1100°C were approximately 24%, 15% and 23% at strain rates of 0.1, 0.5 and 1S⁻¹, respectively. These percentages are higher comparing with that ones at the same deformation temperature and austenitising temperature of 1260°C.



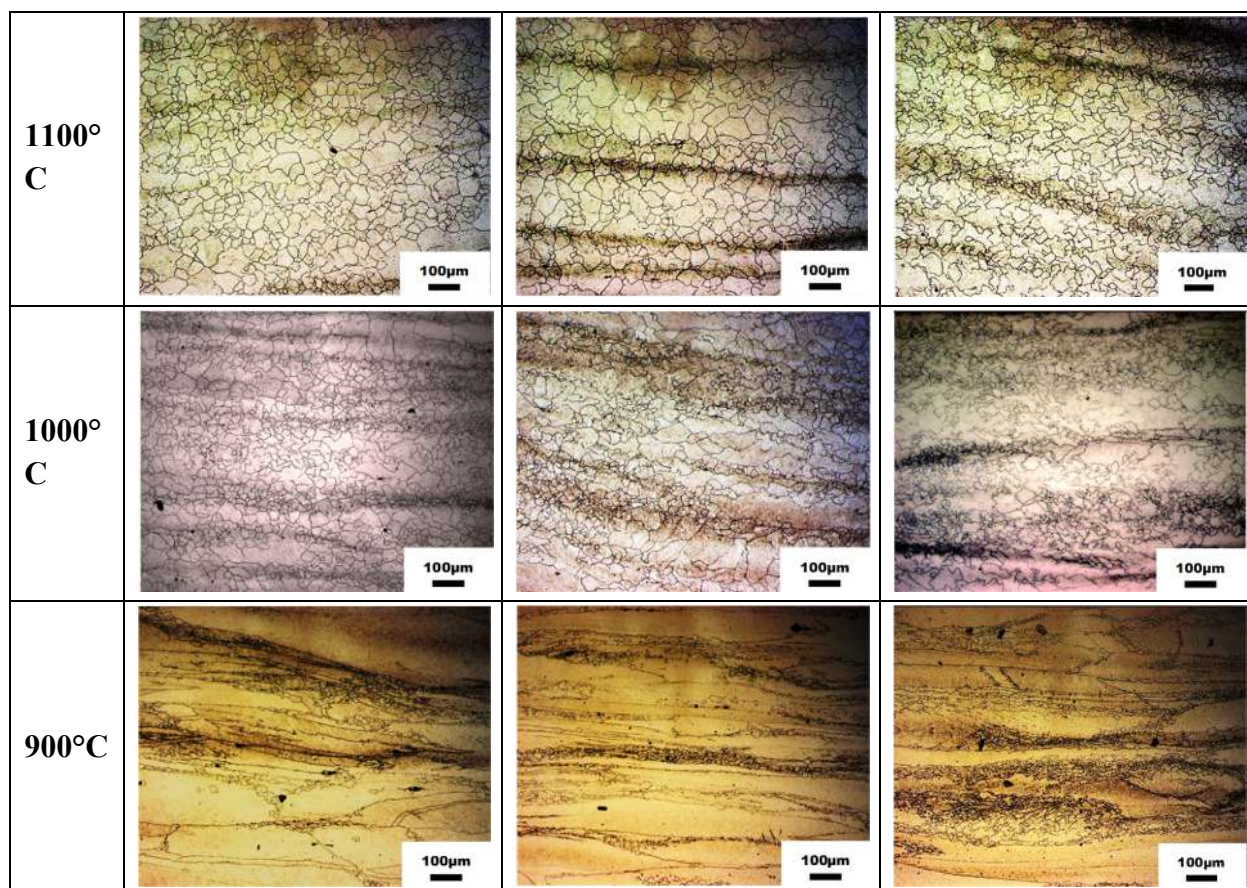


Fig.5. Variation of austenite grain size after austenitising for one hour at temperature of 1260°C and deformed at different temperatures and different strain rates followed by water quench (10X).

3.3 . The relation between grain size diameter and deformation temperatures

The relationship between the grain size and deformation temperatures with changing of strain rate at both austenitising temperature are shown in figure 7 (a, b). As can be seen at reheating temperature of 1100°C, there was a difference in grain size accompanied with change in the strain rate almost at all deformation temperature where the most of the small grain sizes was obtained with strain rate of 0.5 S^{-1} . Whereas, at reheating temperature of 1260°C, the difference in grain size was just at deformation temperature of 1200°C, while at deformation temperatures of 1000°C and 1100°C there was no big difference and the grain size nearly the same.

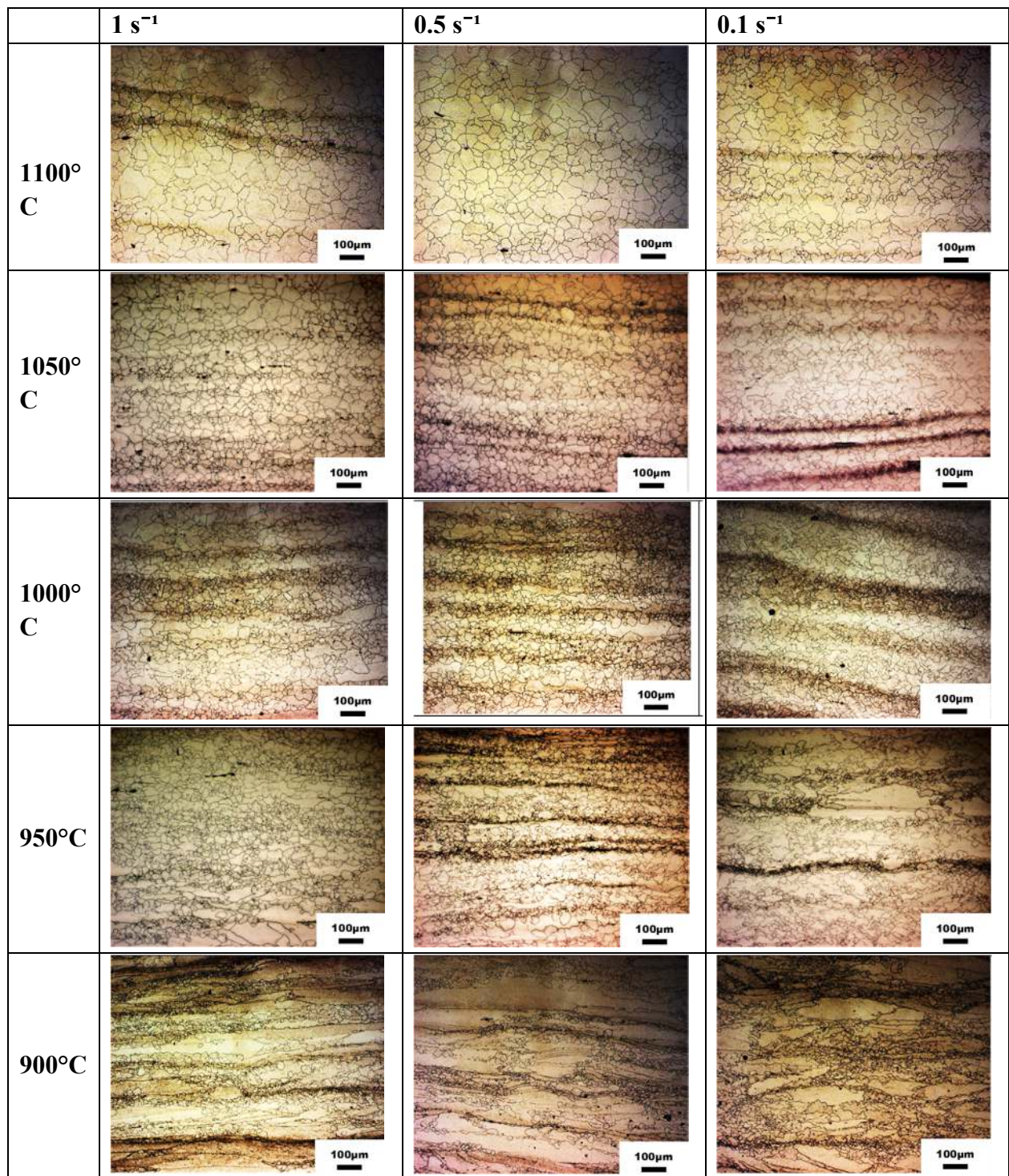


Fig.6. Variation of prior austenite grain size after an austenitising for one hour at temperature of 1100°C and deformed at different temperatures and different strain rates followed by water quench (10X).

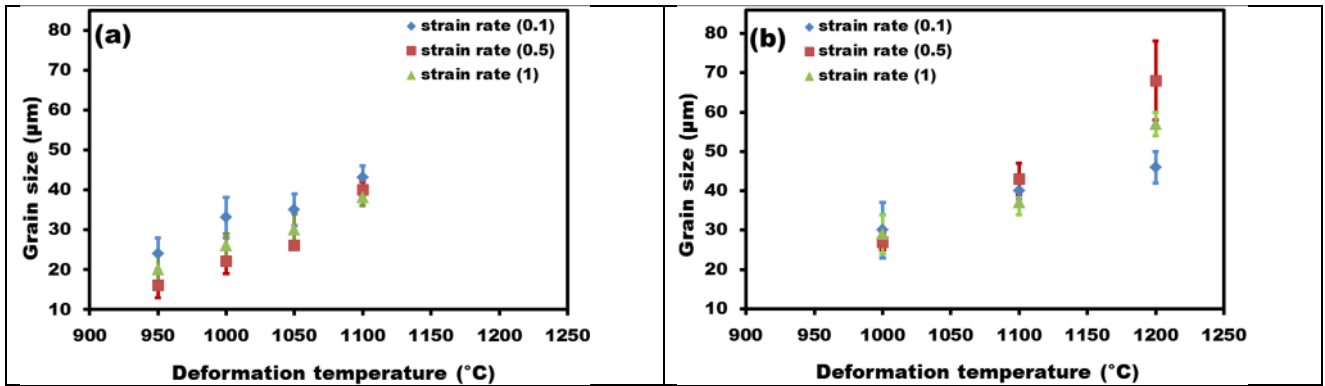


Fig.7. The relation between grain size and deformation temperatures at an austenitising temperature of (a) 1100°C, (b) 1260°C.

12.

3.4 The relation between grain size diameter and Zener-Hollomon parameter

The main influence factors on Zener-Hollomon parameter (Z) are the strain rate and deformation temperature, but in manufacture process, the equivalent strain rate generally depends on manufacturing equipment. The strain rates of 0.1, 0.5, and 1 S^{-1} were used with all deformation temperatures. From the figure (8), the smaller Z was got with bigger grain size and that's happening with decrease of strain rate and increase of deformation temperature which facilitate the recrystallisation. Inversely, the bigger Z resulted with smaller grain size, and that's happening with increase of strain rate and decrease of deformation temperature, that causes facilitate of the dynamic recovery.

From linear regressions of the results in figure (8), a good relation between grain size and the natural logarithm of Zener-Hollomon parameter was got with reheating temperature of 1100°C, which represented in equation [$d = -4.1\ln(Z) + 173$]. Whereas the linear regressions of the results at reheating temperature of 1260°C was lower because of the data slightly scattered at higher temperature of 1200°C, which represented in equation [$d = -4.2\ln Z + 187$].

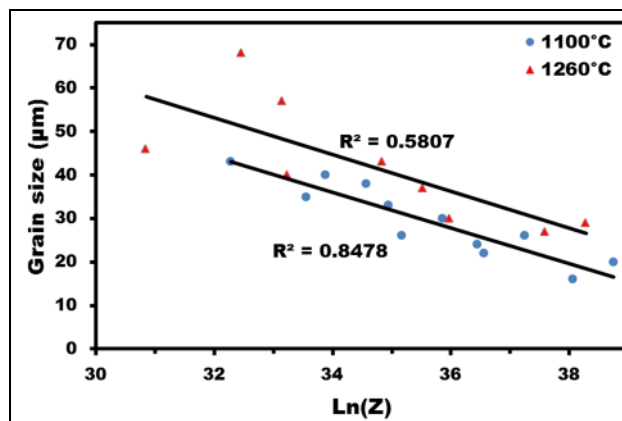


Fig.8. shows the relationship between the grain size diameter and the $\ln(Z)$ in the isothermal processes with one hour reheating temperature of 1100°C, 1260°C and deformed at different temperatures and different strain rates.

3.5 Flow curves and optical microstructure at different strains:

The true stress–strain curves of isothermal processes austenitising for one hour at temperature of 1260°C and cooled down to deformed at temperature of 1000°C with strains of 0.4, 0.6, and 0.8 and strain rates of 0.1, 0.5, and 1 S⁻¹ with each strain, as shown in Figures (9). The flow stress curve with strain rate of 0.1 S⁻¹ a single peak was observed, where the flow stress increased to the peak and then slightly decreased to a steady state. While at strain rates of 0.5 and 1 s⁻¹ the flow stress increased to a peak and then continuous increasing to reach the steady state in the end. The percentages of recrystallisation at strain of 0.6 and strain rates of 0.1, 0.5 and 1s⁻¹ were approximately 41%, 38% and 37% respectively, as shown in figure 10 (b, e, h). While at strain of 0.4, the recrystallisation occurred with percentages less than that occurred at strain of 0.6, where the percentages at strain rates of 0.1, 0.5 and 1S⁻¹ were approximately 29%, 26% and 24% respectively, as shown in figure 10(a, d, g).

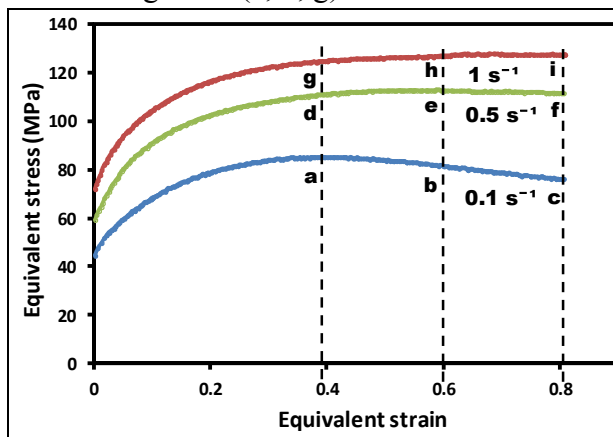
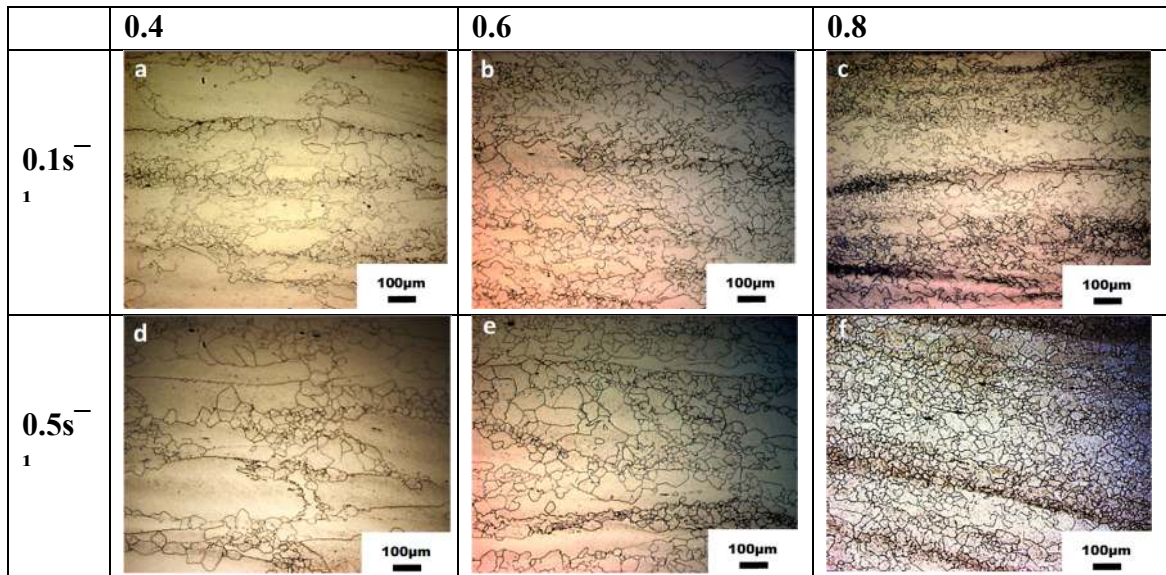
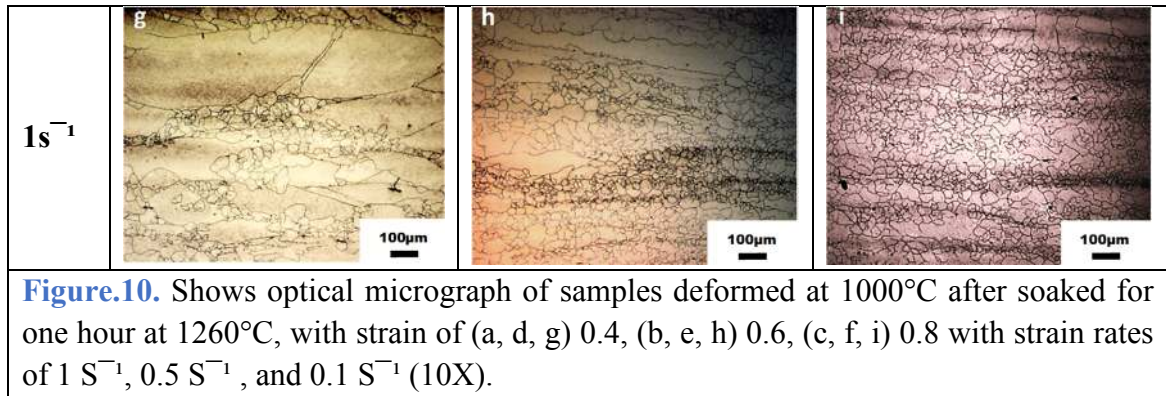


Figure.9. True stress – true strain curves with one hour reheating temperature at 1260°C and deformed temperature of 1000°C and strains of 0.4, 0.6, 0.8 with each strain rates of 0.1, 0.5 and 1s⁻¹.





4. Conclusions

- The fine and equiaxed grains of material lead to improvement in toughness as well as strength. So, at all isothermal processes with two reheating temperatures, the investigation shows that, using an austenitising temperature of 1100°C gives better equiaxed grains and higher recrystallisation percentage than using an austenitising temperature of 1200°C.
 - The smallest grain sizes were observed at an austenitising temperature of 1100°C and strain rate of $0.5 S^{-1}$ with all consequent deformation temperatures.
- The steel has a high recrystallisation temperature, and 900°C is approximately the recrystallisation stop temperature where some nuclei germinated dynamically on the original grains boundary of deformed grains, thus in order to refine grain size the thermomechanical processing must be performed above this temperature.
- At deformation temperature of 900°C with an austenitising temperature of 1100°C, the percentage of recrystallisation were approximately 24%, 15% and 23% at strain rates of 0.1, 0.5 and $1S^{-1}$ respectively, which were higher when compared with the same percentage at an austenitising temperature of 1260°C, which reduced to approximately 11%, 6% and 5% at the same strain rates respectively.
- A good relation between grain size and the natural logarithm of Zener-Hollomon parameter was got with reheating temperature of 1100°C, While the linear regressions of the results at reheating temperature of 1260°C was lower because of the data slightly scattered at higher temperature of 1200°C.
- The percentages of recrystallisation at strain of 0.6 and strain rates of 0.1, 0.5 and $1s^{-1}$ were approximately 41%, 38% and 37% respectively. Whereas at strain of 0.4, the recrystallisation occurred with percentages less than that occurred at strain of 0.6, where the percentages at strain rates of 0.1, 0.5 and $1S^{-1}$ were approximately 29%, 26% and 24% respectively.

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The Most Important Causes of Delays in Highway Construction Projects: Libyan Investigation Based

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Abstract

The study is laying its foundation on quantities' statistical data collected from current and former consultants who have had the opportunity to investigate the delaying of the construction such as projects, identifying the system bottle-necking and accelerate the system performance by overcome any delaying obstacles. The purpose of this study is to investigate the most important causes of delays in Libyan highway construction projects. The participants, who were a representative segment of Libyan people all commented on 35 possible reasons for delay and their views were evaluated using data analysis techniques (Relative importance index (RII) by the SPSS program and average index calculation) to report on the data collected. Within the limits of the data analysis the results revealed that; the effective delays are caused by mainly six reasons which including the following; obstacles from government, poor contract management by consultant, delays in payment by clients to implementing companies, ineffective planning by contractor and inaccurate scheduling, poor site management, and sluggishness in the decision-issuing process from clients.

Keywords: *Libya, causes of delay, Highway, construction Project*

1. Introduction

Across the globe, the construction industry faces challenges in guaranteeing the completion of projects on time. This problem also heavily affects the construction industry in Libya. There are complex ranges of reasons lead to delay in construction that make it tedious problem to model and overcome. Mapping such reasons stand behind disruption in schedule of the highways construction in Libya is essentially the aim of this study. By accurately identifying the system flaws, it leads to

effectively optimizing the performance of operations and reducing the time lapse beyond the schedule or totally avoid it.

One of the main reasons for embarking on this study is the unimpressive performance of previous projects in Libya. In developed countries, study usually based on the application of critical factors to monitor, control and ensure that the outcome of a project is predictable. However, such study is limited in developing countries, such as Libya. Therefore, typically, the actions of the developed countries emulated in order to assist in eliminating delays in the construction of highways. Nonetheless, to determine the effectiveness and application of the existing study findings, it is important to conduct a study on the causes of such delays in Libya.

The objective of this paper is to investigate the causes of delay in highway construction projects in Libya, as perceived by both consultants and public clients; this will have done by using a survey questionnaire.

2. Literature view

Highway construction projects involve several parties because of their interdisciplinary nature. For the employer (usually the public), time is of great importance, as the highway construction field is anxious about project completion dates.

Highway construction jobs that completed on time are termed as being successful. [18] agreed with this, suggesting that a project will be deemed to be successful if the actual time spent on construction is less than or equal to the time allocated. In addition, they reported that highway construction projects usually include a relationship between time and functions and the actual cost. Therefore, it is suggested that time delays will relate to increased costs for the overall project.

Everybody wishes to deal with a client who aims to complete the construction projects in a shorter period of time. In their reports, [15] suggested that timely project deliveries with 100% ability to accurately predict completion dates are one of the things needed by clients in the construction industry. Contractors are seen to seek the use of advanced technological tools and techniques in order to realise the demands of contracted projects. Alternative procurement methods are employed to reduce highway construction delays, including the use of construction management, design-build-operate and build-own-operate-transfer project delivery methods, and project management [24]. By these approaches, the importance of the time and costs for construction projects is emphasised. Nonetheless, there are frequent delays with both measurable and immeasurable associated costs.

[3] stated that “delay in construction can have a number of consequences in a project, such as late completion, lost productivity, acceleration, consequential damages, increased cost, and contract termination” (p. 242). Thus, it can be asserted that project delays have negative effects, ultimately resulting in increased costs.

[25] on his research conducted, he divided delays into two categories: disruptions and interruptions. The former is defined as sufficiently adverse conditions that can slow the project down without

necessarily bringing it to a standstill. Although disruptions do not affect the overall schedule of the project, which lead to construction delays. On the other hand, interruptions are an adverse state of affairs that cause the project to come to a standstill for at least an hour.

According to [7], delays do not only affect the financial terms of the contractor, but also expose the employer to serious economic and financial risks, such as the loss of market opportunities and higher interest rates. They can affect other activities set out in the programme because of the interdependence of the nature of a highway construction project. Arguing that a change in a project can emanate from many other factors, [9] Confirmed that many of these are interrelated. This means that delays can result from the slightest disruption or interruption.

An incident can have an effect if its impacts on clients, contractors, regulators or any other of the series of people or groups that interact with the building project [3], pp,243. Usually, when countless delay events occur, caused by different parties, this results in a delay to the whole project [7]. However, this is a very complex matter, which can create uneasiness in such projects. [7] pointed out that “investigating how these events affect the various project activities and the contract completion date for purposes of justifying and quantifying delay claims has been a matter of the greatest difficulty.”

[3] added that the parties experiencing damages from delays, as well as the ones responsible for them would need more time to reorganise themselves. It is commonly understood that when a delay occurs, a party or some parties must be held responsible, and that the cost needs to be covered somehow. Thus, it is vital to assess and resolve any claims that are cause the delays. However, this is seen as a challenge, because multiple parties may be involved in a delay, making the task of apportioning blame extremely difficult [7]. Highway construction projects present the notion of delays as a form of risk.

Activity delays may not necessarily result in the same issues as project ones. Nevertheless, it can be argued that a delay involving any single event in the construction industry can result in a disturbance to overall performance and create unnecessary confusion among the parties involved. [25] established that delays have a great impact on productivity. He further argued that construction project delays are the main cause of losses of productivity, resulting in loss of time.

Delays in construction require one of the parties to take responsibility and so be able to compensate the other for losses. This leads to problems when the employer, the contractor or neither party is responsible [11]. Compensation claims arise from time lost causing a cost overrun. Delays on the part of the employer result in the contractor making compensation claims for prolonged project delivery times leading to additional overhead costs. However, if a delay is caused by the contractor, it can result in liquidated damages [11]. The owner of the project should be paid compensation for any loss in benefits (profits) that may have emanated from the project being completed according to plan. Delays in this kind of project will increase costs [3]. According to [18], time is an important factor for cost evaluation in a construction project. It was also stated, that the construction period correlates to actual cost. Therefore, an increase in this has a direct impact, with increases in

additional costs eating away at the company's profit.

In the NEDO report, [20] argued that the success of a project depends on management efforts made to complete the project on time. These are useful in reducing and controlling costs. As a result, [28] also claimed that a project delay has severe implications on the cost and quality of the work. Therefore, it follows that delays affect the overall success of the project. [22] argued that the timely completion of construction projects is seen as a criterion for success. This view cements the fact that in the construction industry, time is a factor that used to measure the extent of success.

According to the current literature, delays are a major factor in causing cost overruns that are circumstantial and associated with claims. A cost overrun means exceeding an actual cost, as defined in the budget. Therefore, this can be derived from the difference between the actual cost and the estimated one, expressed as a percentage of estimated costs [9]. Determining that a delay is an existing cost in projects will assist in identifying possible solutions put forward to avoid cost overruns. Studies on cost overruns have focused on the risk factors that lead to them. The [9], generally held that highway construction projects are exposed to many environmental risks, such as the complexity of the design and planning, the presence of other interest groups and the economic and political environment. As a major construction risk, a cost overrun is often seen with apprehension, due to its negative implications for all stakeholders involved in the project. Other authors, particularly [17], have added that a cost overrun results in the loss of clients' confidence. There is a suggestion that it can result in deterring the decision of the client to invest in future projects.

For the client, rising costs means costs exceeding what was agreed upon at the beginning of the project, and this results in a reduction in return on investment. This affects the ultimate user because the additional costs are passed the form of higher rental charges, tolls and prices. The contractor also suffers significant loss of earnings when not finishing a job on time as well as negative word of mouth. The result that they may not be able to receive continued funding to complete the project due to concerns about additional risks,[17].

Overrun costs have resulted in the loss of clients' confidence, adding investment risks [17]. The global highway construction industry suffers from cost overruns that are a direct result of project delays. To clients, the implication is that cost overruns are any costs additional to the ones agreed for the project [17]. The client demands value for the money invested, and has the potential to tarnish a contractor's reputation, resulting in a massive lack of confidence from potential future clients [17]. Therefore, the increased costs resulting from delays undoubtedly have a negative result for both the contractor and the client. Delays to a contract often result in higher costs, claims or liquidated damages. Unquestionably, additional high costs raise concerns when identifying factors associated with delays and when looking into possible means of eliminating, or at least minimising them during the delivery of a project. However, there are some studies been done in developing countries and identified the major causes delay in road construction projects. Such as,[21]they are indicated that the five major causes a delay in Nigerian construction projects which is a Lack of funds to finance

the project to completion, changes in drawings, lack of effective communication among the parties involved, lack of adequate information from consultants; and slow decision making. In Tanzania, construction projects [12] stated that the major causes of delay, Design changes, Delays in payment to contractors, Information delays, Funding problems and Poor project management.

[13]analysed the main cause's construction projects in Egypt and they found that the most important were; Political insecurity (instability); Financial difficulties of contractor; Escalation of material prices (inflation); High cost of skilled labour; and Difficulties in getting work permits from government. In summary, literature stated that the delay cause by different factors based on the environment and different countries. However, this study will focus in Libyan construction projects.

3. Methodology

The previous studies highlighted the fact that the survey was one of effective manner of cost to collect and analyze significant number of responses from the various parties involved to achieve the better statistical analysis of data [26]. Therefore, the questionnaire was designed based on the general questions that were previously used to find the delay factors in the construction industry [4]. The purpose of the survey is to discover the main delay factors that arise in highway construction in Libya. Project managers, engineers and other professions were requested to take part in the survey and share their knowledge and opinions gained by their experience in Libya to answer a questionnaire regarding highway construction.

The questionnaire was divided into two parts. The first part related to common factors that may cause a delay to the construction of highways, which cannot be controlled by either the client or the contractor. These factors include ground conditions and bad weather that is due to the Sahara climate that causes blowing dust to occur regularly. The second part consists of questions that are caused by any of the parties involved neglecting their responsibilities. These parties are categorised into four categories, which are client, contractor, subcontractor and consultants.

The probability of the factors being the main factor delaying the construction of highways was divided into five headings as follows: strongly agree, agree, neither agree or disagree, disagree and strongly disagree as shown in Table (1). The scale started from 1 to 5 where 1 is strongly agreed and 5 represents strongly disagrees. Even though the main language in Libya is Arabic, however the survey was only designed in English. People within Libya, America and the UK took part in this survey. To avoid the need to collect data from everyone individually, the Survey monkey website was utilized to carry out this survey thus making it easier to collect the data from different professions in less time.

Table 1. Relationship between the average index and scale

Average index	Scale
$1 \leq \text{Average index} \leq 2$	Strongly Agree
$2 \leq \text{Average index} \leq 3$	Agree
$3 \leq \text{Average index} \leq 4$	Neither agree nor disagree
$4 \leq \text{Average index} \leq 5$	Disagree
$\text{Average index} > 5$	Strongly disagree

I. Survey data analysis

The data analysis was carried by calculation the Average index, where it calculated the average of each of the 35 factors that have been included in the survey. The data was also analysed by the Statistical Package for Social Science (SPSS) programme to get a more accurate result as this programme uses a more complex method to analyse the data by using the relative important index. The formulas used to calculate the Average index and relative important index is as follows:

II Average Index

$$\text{Average index calculation} = \sum \frac{PiU}{Ui} \quad (1)$$

Pi= Respondents classification of reason for delay

U= Number of participants with identical weight on a given reason for delay

III Relative important index (RII)

$$RII = \frac{\sum W}{AN} \quad \text{Where:} \quad 0 \leq RII \leq 1 \quad [23] \quad (2)$$

A= the highest scale for survey is (5)

$$W = 5n1 + 4n2 + 3n3 + 2n4 + 1n5$$

$$RII = \frac{5n1+4n2+3n3+2n4+1n5}{5N} [15]$$

Where:-

n1= number of respondents for Strongly Agree.

n2= number of respondents for Agree

n3= number of respondents for neither agree nor disagree

n4= number of respondents for Disagree

n5= number of respondents for strongly disagree

N= Total number of respondents.

4. Data and analysis

This section provides an analysis of the results, which were obtained from the questionnaire. Thirty-five possible reasons were provided which significantly contributed towards the delaying of the construction of the highways in Libya. These were analysed by two methods: the calculation of the average index and the relative important index (RII), using the SPSS program.

The data was collected from the 76 questionnaires that were distributed there were only 64% of the questionnaires returned, will illustrates in the next three Figures (1), (2), and (3) in terms of skills science and qualifications profile and years of experience. This study verifies the most important reasons for delays in highway construction projects in Libya by using two ways the average Rating calculation and the relative importance index (RII) using SPSS program [14]. The investigation is based on data collected from questionnaires. Males from different disciplines who had different levels of experience in their professional fields completed the questionnaires as described in Table (2) . The comparative significance of the individual factors was calculated and ranked, and the same was done for the groups [6]. The principal objective of this analysis is to determine the major reasons for delays in highway construction in Libya. After identifying these causes, suggestions are given for ways to eradicate them or reduce them to the minimum possible delays.

This survey analysis is to establish the importance of various reasons for delays in highway construction in Libya. Because not all factors have the same influence on delays in highway construction, *average index calculation* [2]. In addition, relative importance index (RII) used to distinguish between the various factors [8]. All the process information gathered from the questionnaire, which was distributed to a sample of Libyan people, was then analysed a by a statistical computer software program (SPSS).

Average Index Results;

$$\text{Average index} = \sum \frac{P_i U_i}{U_i} (3)$$

P_i= Respondents classification of reason for delay

U= Number of participants with identical weight on a given reason for delay

$$\text{Average index for first sample Obstacles from government} = \frac{27*1+14*2+4*3+2*4+2*5}{27+14+4+2+2} = 1.73$$

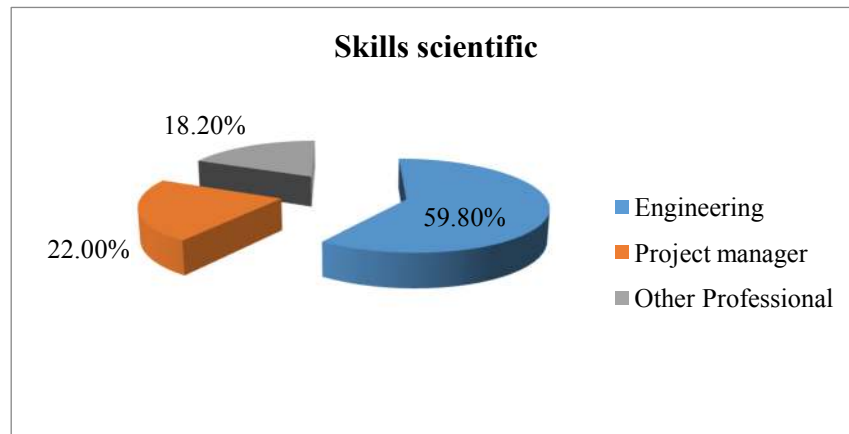


Figure (1): The percentage of scientific skills for the Libyan people who responded to the survey

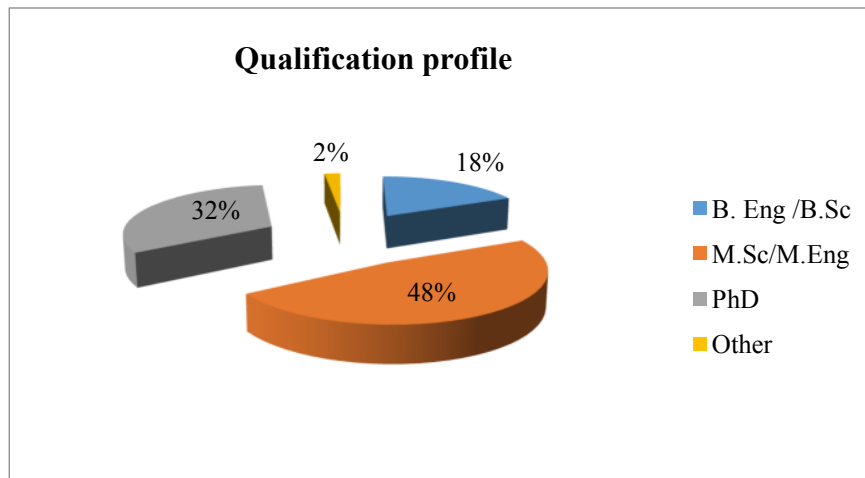


Figure (2): The percentage qualification profile for the Libyan people who responded to the survey

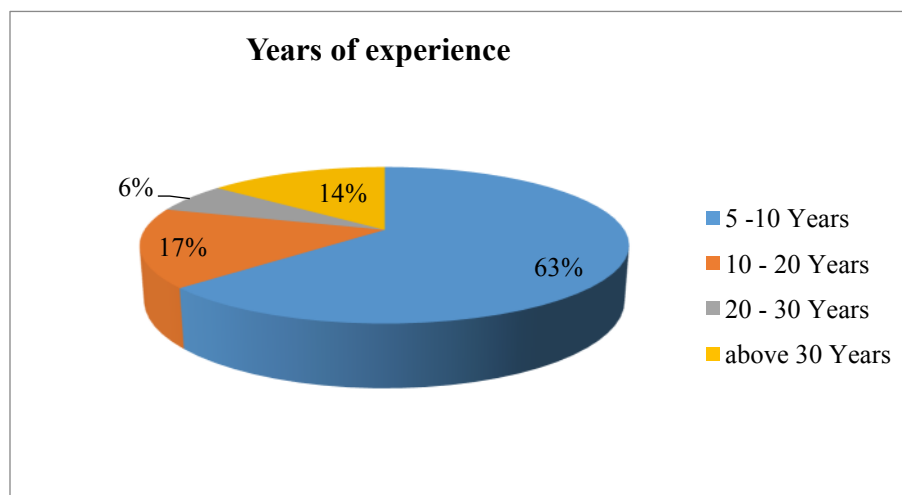


Figure (3): The percentage Years of Experience for the Libyan People who responded to the Survey

Table 2. The factors percentage (%) with total survey respondent N (49) and ranking

Attitude of	Factors	1	2	3	4	5	Ranking
Project	Obstacles from government.	55.10%	28.57%	8.16%	4.08%	4.08%	1
Consultants	Poor contract management by consultant.	36.73%	46.94%	10.20%	4.08%	2.04%	2
Clients	Delays in payment by clients to implementing companies.	38.78%	42.86%	8.16%	8.16%	2.04%	3
Contractor	Ineffective planning by contractor and inaccurate scheduling.	20.41%	57.14%	16.33%	4.08%	2.04%	4
Contractor	Poor site management.	36.73%	32.65%	18.37%	6.12%	6.12%	5
Clients	Sluggishness in the decision-issuing process from clients.	26.53%	44.90%	18.37%	6.12%	4.08%	6

(1)=Strongly Agree (2) =Agree (3) =Neither agree nor disagree (4)=Disagree (5)=Strongly disagree

5. Discussion of the results

This section provides discussion of the results, which were obtained from the questionnaire. These were analysed by two methods: the calculation of the average index and the relative important index (RII), using the SPSS program. However, this study will only focus on the delay factors with a very high impact: less than **2.16** when calculated by the average index; and above **0.773** when calculated by the RII. These include Table (3):

Table 3. The delay factors with a very high impact calculated by the average index and the RII

No	Factors	Method of analysis:	
		Average index	RII
1-	Obstacles from government.	1.73	0.852
2-	Poor contract management by consultant.	1.88	0.834
3-	Delays in payment by clients to implementing companies.	1.92	0.823
4-	Ineffective planning by contractor and inaccurate scheduling.	2.10	0.782
5-	Poor site management.	2.12	0.781
6-	Sluggishness in the decision-issuing process from clients.	2.16	0.773

Although the government must firstly be supportive of the projects in the country and that, they are undertaken correctly and supplemented without delays, the results of the analysis showed the opposite practice. Thus, the government was the main obstacle, which resulted in delays to the establishment of the Libyan highway projects. The government also caused significant problems for local and foreign companies who had signed a significant number of contracts with them. This has led to the disintegration of those particular contracts, which has resulted in losses to the state budget.

Consultant contract management was the second important factor contribute in delaying of operations execution followed by the funding issue was ranked as the second highest factor by all the respondents for delays in the construction of the Libyan highway projects. Funding difficulties were also identified as the main principal factor for delays within Malaysian construction projects [1] and [5]. Overall, the inability to regularly pay contractors for work which had been undertaken had impeded progress and had caused delays. In addition, the failure to provide adequate financial resources to contractors ultimately led to their inability to complete the required goals of the designated projects [19].

Accurately scheduling of operations and contractor effectively planning laid forth in the scale of affecting project timing site management was ranked fifth with the highest number of factors. This indicated that construction in Libya was not well managed, and had poor planning, estimation and site management. Overall, these factors have resulted in significant delays for Libyan highway construction [10]. In order to prevent this, proper planning, and accurate estimations are required. In addition, the sites need to be properly managed in order for efficiency to be increased.

The study findings conclude that the obstacles the government put in place contributed to the main reasons for delays in highway construction of Libya, which caused issues affecting contracts between companies and their client. This result was a surprise as the government that is supposed to be a catalyst in the completion of the project due to possessing financial resources to finance such projects from the Country treasury however; the government seemed to be causing the problem. Funding and finance difficulties from the contractor and delay in payment by the client to the contractor were also causing a delay. Additional delays in Libya were attributable to scheduling, control issues and contractual relationships.

6. Conclusions

Based on the study and scrutiny of a group of previous studies regarding the reasons for delays in the setting up of projects, which have varied in their effect from one project to another and from one place to another. Thus, thirty-five reasons have been studied for the delays within the construction of the Libyan highways in order to determine those of significant importance. The results were discussed the analysis of those ratios, which were obtained from the quantitative survey in accordance with their level of impact from high to low. However, this paper focused only for the most six important reasons leading to delay in the construction of the Libyan highways with average index between (1.73 -2.16).

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An Application of Multidimensional Scaling in Fault Detection of Smart Grids

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Abstract

Monitoring smart grids and detecting faults in such huge networks has recently become an active area of research. The huge amount of data transferred from the measurement units to the control center makes it difficult to detect faults in a reasonable amount of time. Some existing methods have been investigated and tested on many IEEE models such as wavelet transform, principal component analysis (PCA) to extract the abnormal behavior of signals under monitoring [1]. However, such techniques pose difficulties in detecting different faults properly. In this paper, the multidimensional scaling (MDS) is investigated as an alternative technique for reducing the dimensionality of the data to lower dimensions, while maintaining the necessary information needed for fault detection. MDS is then used to investigate the behavior of some IEEE models under different types of faults in order to detect and locate the faulty bus bars.

Keywords: *Multidimensional scaling, MDS, fault detection, smart grid, cluster analysis.*

1. Introduction

Smart grid is a term widely used nowadays to describe a complete power system that has the capability to monitor its elements and take necessary steps to protect them throughout the whole network. The power system network can be categorized into high voltage, medium voltage, and low voltage networks, and also can be categorized into four basic categories: generation, transmission, distribution, and consumer [2]. Challenges are expected in such a huge network. One of these challenges is detecting and locating faults at early stage for prevention of the fault propagation from one area to another 2003 blackout that hits the Eastern United States and Canada is an example of

cascading faults. The fault started in a small area and eventually propagated to cover such a huge area as mentioned above. Smart grids are now equipped with phase measurement units (PMUs) to form a wide area measurement system (WAMS) based on the global positioning system (GPS). WAMS is used to take the measurements of voltage, current, and phase of the components of the smart grid. These measurements are collected at a small interval of time, which produces an enormous amount of data. Therefore, it is difficult to process these data in a limited amount of time.

Recently many applications based on WAMS have emerged to deal with this issue such as instability analysis [3], fault detection [4-6], etc. In this study, a MDS is used to monitor the behavior of some of IEEE models under abnormal operations by visualizing the data in a lower dimensional space. Many researches have been published recently on fault detection on power systems using different approaches to locate the faults. Wavelet transform combined with artificial neural network (ANN) approach has been used to detect faults on transmission lines [3]. This method showed reasonable results but failed to detect some voltage sags on 230-kV transmission lines [3]. Another approach is based on a hybrid framework consisting of symmetrical component analysis, wavelet transform, principal component analysis (PCA), and support vector machine (SVM) [4]. This method has an excellent result of fault detection on IEEE 14 bus system with accuracy of 99.9%. The only drawback of this approach is the high computational complexity. As a result, applying this approach on larger systems will increase the computational complexity due to the huge input data that need to be processed. Therefore, it is critical to develop a novel technique that combines high accuracy with lower computational complexity and cost. In this paper, MDS is used to detect and locate faults in smart grids through two models, IEEE 14 and IEEE 39 Bus systems. A metric MDS has been used to observe and analyze the behavior of bus bars under abnormal operations. Symmetrical and asymmetrical faults have been applied to different bus bars to test the capability of MDS to visualize the data in two-dimensional space. Faulty bus bars tend to have a larger Euclidean distance than the others. Finally clustering analysis has been used to locate the faults.

The current study provides the background of the main multidimensional scaling approaches, presents the proposed fault detection algorithm, and illustrates the clustering analysis with case study results. Also, it can be a platform on which to build further MDS studies to provide a comprehensive picture.

2. Methodology

MDS is used widely to depict the relationships between objects in huge systems in such a way that the distance between any two objects reflects the dissimilarity between them [5-7]. A dissimilarity matrix D can be constructed in order to measure the dissimilarity between any two objects i and j , based on the mean of Euclidean distance [8]. MDS is divided into two major categories: metric-MDS and non-metric-MDS [9], [10]. In this paper metric MDS has been used since the measurement

is numerical data and precise information is available. MDS has been used in many fields such as psycho physics [11], chemical engineering [12], computer network [13], etc. The following symbols that will be used in this paper as follows:

- Total number of objects is n .
- Proximity p_{ij} represents the dissimilarity between any two objects i and j .
- To measure the dissimilarity between any two objects i and j , an Euclidean distance d_{ij} between these objects is expressed as follows:

$$d_{ij} = \sqrt{\sum_a^m (x_{im} - x_{jm})^2} \quad (1)$$

where x_{im} and x_{jm} are the coordinates of the objects i and j respectively.

The following are always true: $d_{ii} = d_{jj} = 0$ and $d_{ij} = d_{ji}$.

- m is the total number of samples for each object.
- Y is an $n \times m$ matrix that contains the observed data.

$$Y = \begin{pmatrix} y_{11} & \cdots & y_{1m} \\ \vdots & \ddots & \vdots \\ y_{n1} & \cdots & y_{nm} \end{pmatrix} \quad (2)$$

- O is the number of dimensions in the desired space $\mathbb{R}^O$.
- X is an $n \times O$ matrix representing the coordinates of the object in the desired space.
- f is a function to transform the proximity p_{ij} to the desired space $\mathbb{R}^O$ and it is written as $f(p_{ij})$. There are many functions in literature to transform proximities such as:

$$f(p_{ij}) = a + b \cdot p_{ij} \quad (4)$$

$$f(p_{ij}) = a + b \cdot \log(p_{ij}) \quad (5)$$

$$f(p_{ij}) = a + b \cdot \exp(p_{ij}) \quad (6)$$

Equations (4), (5), and (6) are called Linear, Logarithmic, Exponential transformation respectively. Choosing the proper transformation depends on the characteristics of the input data [9].

The objective of MDS is to find a set of lower dimensional coordinates that represents objects such that the distance between any two objects is as close as to their proximities in the original coordinates system. In other words, in the desired space any two points are located close to each other if their similarity is high, whereas the distance between them is large and distinguished if their dissimilarity is high [14]. To achieve this goal, it is necessary to utilize a proper raw stress function $\sigma_r(x)$.

$$\sigma_r(x) = \sum_{i,j} [f(p_{ij}) - d_{ij}(X)]^2 \quad (7)$$

When the distance between objects is high, we will end up with high raw stress function. To avert the scale dependency, a formula of (stress – I) can be used instead of $\sigma_r(x)$ [9]. The formula of (stress – I) is defined in equation (8).

$$\text{stress - I} = \sigma_1 = \sqrt{\frac{\sum_{i,j} [f(p_{ij}) - d_{ij}(X)]^2}{\sum [d_{ij}(X)]^2}} \quad (8)$$

The square root here is used because the value normalized raw stress is normally small in practice. Adoption of the square root leads to easiness of discriminating the goodness of fit [15]. Another formula suggested by [16] is called (stress – II), which can be adopted as an alternative.

$$\text{stress - II} = \sigma_1 = \sqrt{\frac{\sum_{i,j} [f(p_{ij}) - d_{ij}(X)]^2}{\sum [d_{ij}(X - d')]^2}} \quad (9)$$

where d' is the average distance of all the Euclidean distances d_{ij} . Table 1 gives a guide line for the goodness of fit by using stress – I formula [15].

Table 1. Goodness of fit

stress – I	Goodness of fit
> 0.20	Poor
0.1	Fair
0.05	Good
0.025	Excellent
0	Perfect

In order to minimize stress – I, an optimal X in the desired space $\mathbb{R}^0$ must be determined.. Further, the parameters of the function f must be defined. There are many algorithms available in the literature to achieve this task [9]. In this paper an algorithm suggested by [17] is used to minimize the raw stress in order to find the optimal X configuration. Figure 1 summarizes the algorithm used to minimize the raw stress function.

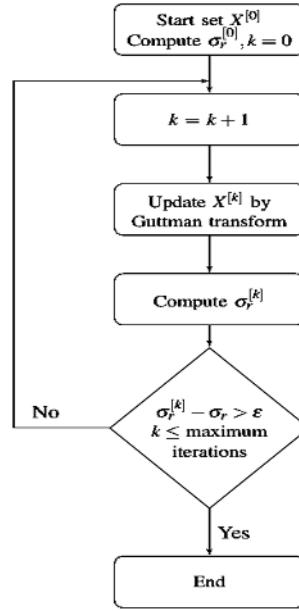


Figure 1. Minimization algorithm's flowchart.

Minimizing the raw stress may give an indication for the goodness of fit. To be more confident with the results, the Scree plot can be used to further test the goodness of fit.

In order to construct the proposed fault detection algorithm, the distance matrix D must be created as follows:

$$D = \begin{pmatrix} d_{11} & \cdots & d_{1j} \\ \vdots & \ddots & \vdots \\ d_{i1} & \cdots & d_{ij} \end{pmatrix} \quad (10)$$

The idea here is to transform the matrix D to O- dimensional space. The distance matrix is squared as follows:

$$D^2 = [d_{ij}]^2 \quad (11)$$

J matrix is defined as,

$$J = I - n^{-1} \cdot 1 \cdot 1' \quad (12)$$

where I is the identity matrix, 1 is $n \times 1$ vector with all elements as 1, $1'$ is the transpose of vector 1.

Matrix B is constructed as,

$$B = -\frac{1}{2} J D \cdot J \quad (13)$$

Now assume we need to transfer the matrix B to a matrix X such that

$$X = \begin{pmatrix} x_{11} & \cdots & x_{10} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{n0} \end{pmatrix} \quad (14)$$

where, $X_j = (x_{j1}, \dots, x_{jO})$ represents the location of object j in the desired space $\mathbb{R}^O$.

The goal here is to obtain X that satisfies the following relation:

$$B = -\frac{1}{2} JD^2. J = XX' \quad (15)$$

Using the Eigen decomposition on the term $-\frac{1}{2} JD^2. J$ gives $-\frac{1}{2} JD^2. J = Q \Delta Q'$, $B = Q \Delta Q' = XX'$, where Q is a matrix of the Eigenvectors of the matrix B , and Δ is a diagonal matrix of the Eigenvalues $\lambda_1, \lambda_2, \dots, \lambda_n$ of the matrix B . Q' is the transpose of matrix Q . Now $B = Q \Delta Q' = (Q \Delta^{0.5})(Q \Delta^{0.5})' = XX'$, then $X = Q \Delta^{0.5}$.

In the last step, the Eigenvalues $\lambda_1, \lambda_2, \dots, \lambda_n$ are arranged such that $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_n \geq 0$. Then the largest O Eigenvalues and their Eigenvectors are selected, where $Q \ll m$. As a result the coordinates of the object j in the target space $\mathbb{R}^O$ are $X_j = (x_{j1}, \dots, x_{jO})$. Choosing the appropriate number of dimensions O requires minimizing the raw stress function to satisfy the criteria that given in Table 1.

In order to locate and define the faults, clustering analysis process is required. Clustering analysis is widely used in data processing to divide a set of data into groups that have common features. Many algorithms are available in the literature. K-means cluster is a clustering technique that is commonly used to divide a set of data into k clusters [18]. The steps of K-means cluster are given in the flowchart in Figure 2.

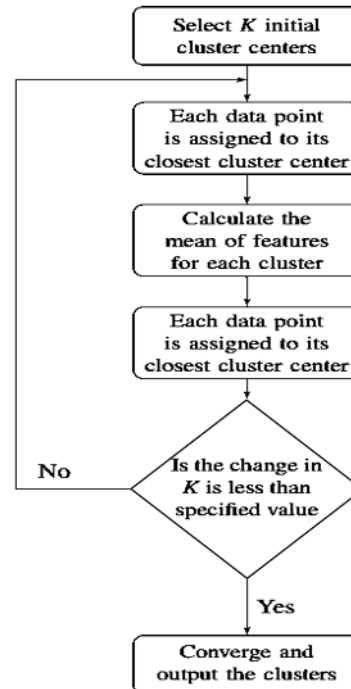


Figure 2. Flowchart of K-means cluster

3. Case Study and Results

The proposed method has been applied to IEEE 14 bus system as well as IEEE 39 bus system. The main idea is applying symmetrical and asymmetrical faults to each bus bar in the selected benchmark models. The selected models are built by using PSCAD software. Then the results were exported to Statistical Package for the Social Sciences software (SPSS) to make the required MDS analysis. Figures. 3 and 4 show the single line diagram of IEEE 14 bus system and IEEE 39 bus system respectively. Further clustering analysis was carried out to classify the faulty bus bars. The data were collected during faults at a rate of one sample per ms and a window of 250 ms was used to study the behavior of bus bars during the fault period.

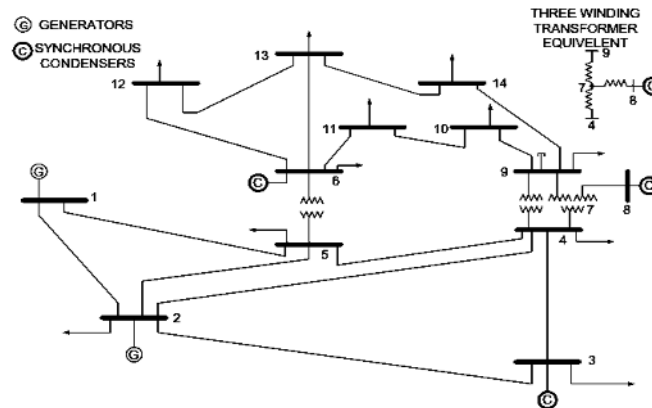


Figure 3. IEEE 14 bus system.

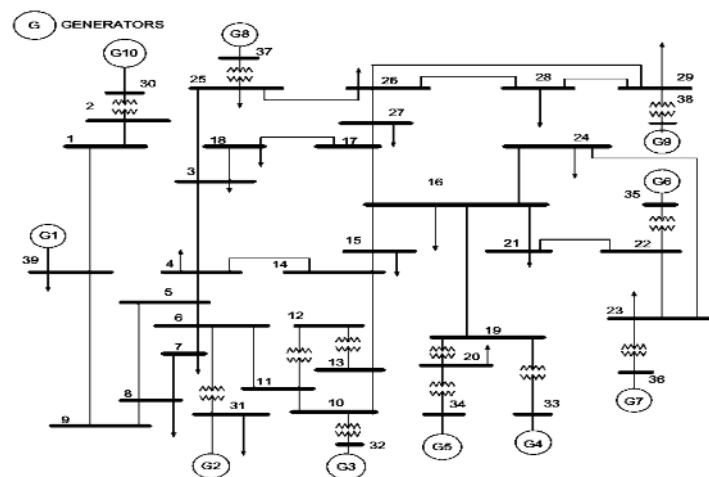


Figure 4. IEEE 39 bus system.

1.1. Symmetrical Faults

First, the symmetrical faults on both models are studied based on applying a short circuit fault to all of the three phases of the faulty bus bar. Then the data are exported to SPSS to perform MDS analysis. A Scree plot as well as the goodness of fit measurements were used to select the appropriate number of dimensions. Figure 5 and 6 show Scree plots of the Normalized raw stress for IEEE 14 and 39 bus system.

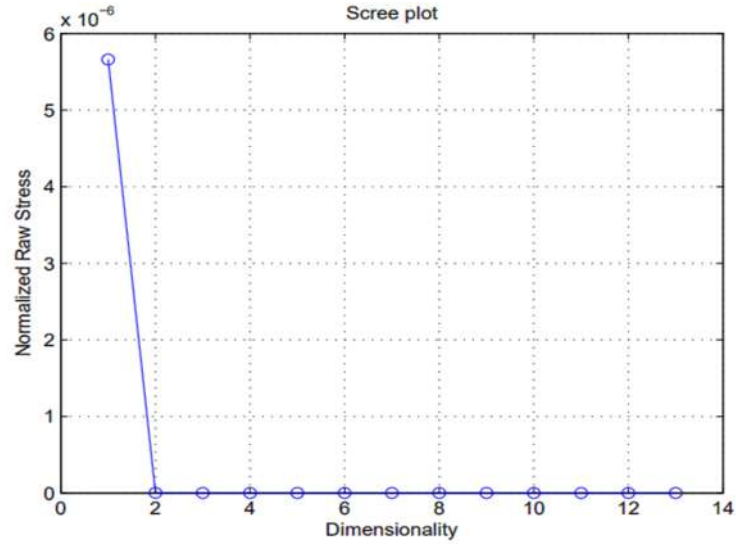


Figure 5. Scree plot of the Normalized raw stress for IEEE 14 bus system

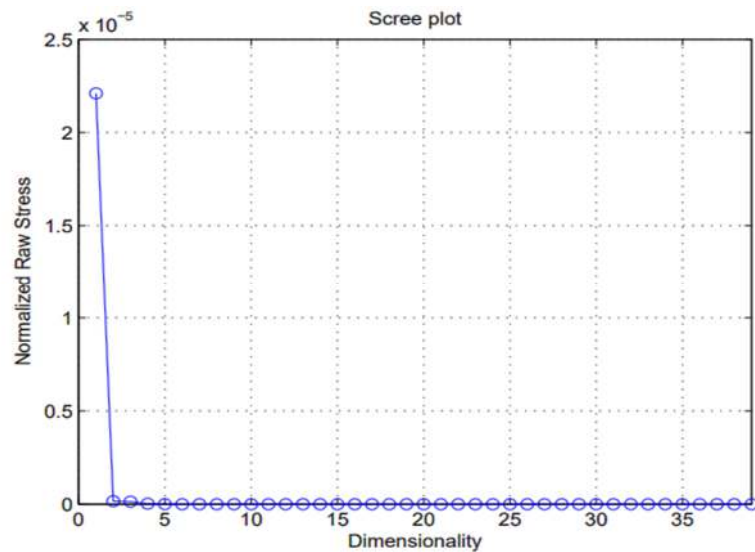


Figure 6. Scree plot of the Normalized raw stress for IEEE 39 bus system.

It can be noticed from Figures 5, and 6 that the normalized raw stress sharply decreases when moving from 1 dimension to 2 dimensions, and then it stabilizes at 0.00000. The other measurements are determined to ensure the goodness of fit for the case of symmetrical fault on the IEEE 16 bus system at a number of dimensions $O = 2$. The data provided in Table 2 shows excellent goodness of fit, therefore the number of dimensions is selected to be 2. The same procedures have been carried out for the collected data at each fault produced. Table 3 show the scree plot and goodness of fit measurements for the case of symmetrical fault on the IEEE 39 bus system at a number of dimensions $O = 2$. The results again prove that 2 dimensions are appropriate to visualize the system.

Table 2. Goodness of fit measurements at $O = 2$ on the IEEE 14 bus system.

Measurement	Value
Normalized Raw Stress	0.00000
Stress – I	0.00005
Stress – II	0.00007

Table 3. Goodness of fit measurements at $O = 2$ on the IEEE 39 bus system.

Measurement	Value
Normalized Raw Stress	0.00000
Stress – I	0.00004
Stress – II	0.00049

The main advantage of MDS its capability to reduce the huge amount of data in order to visualize the system in two-dimensional space. Consequently, it will be simple to monitor and cluster the system. A matrix of 39×250 data samples was reduced to a matrix of 39×2 that contains necessary information to detect and locate the faulty bus bars. The size of data was reduced by 125 times, which confirms the proposed approach is very effective. Figures 7 and 8 display the visualization of the IEEE 14 bus system with a fault in bus bar 5 and IEEE 39 with a fault on bus bar 16 respectively. As it can be seen from both figures that faulty bus bar and the affected bus bars tend to have larger Euclidean distances than the healthy bus bars. Moreover, the faulty bus bar has the largest Euclidean distance measured from the origin. Figure 7 shows the bus bars 4, and 5 are located away from the rest of the buses while in Figure 8 bus bars 15, 16, 17, 21, and 24 are located away from the rest of the bus bars. Based on both Figures 7, and 8 it can be noticed the faulty bus bars 5 in the first case and bus 16 in the second case have the largest Euclidean distance from the origin.

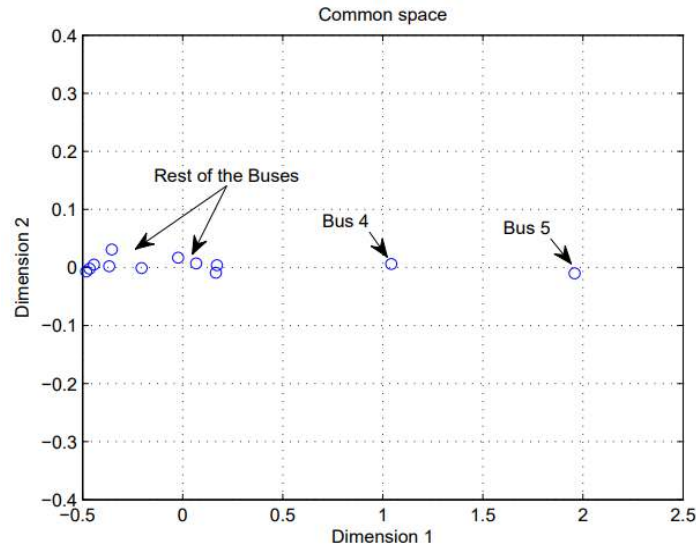


Figure 7. Visualization of IEEE 14 bus system with fault on bus 5

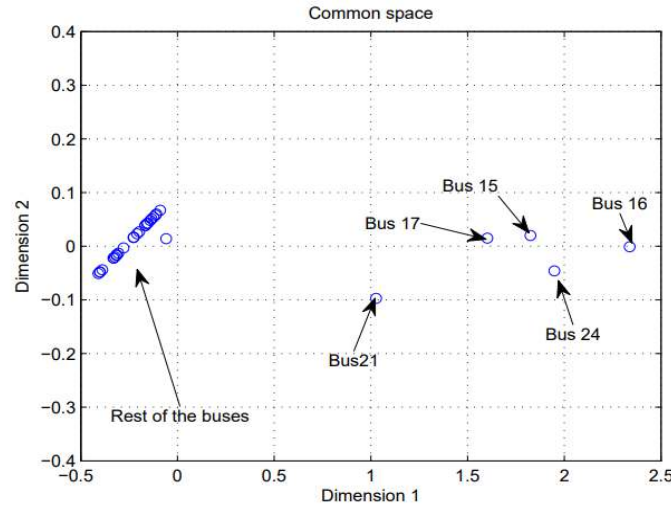


Figure 8. Visualization of IEEE 39 bus system with fault on bus 16

1.2. Asymmetrical Faults

Asymmetrical faults that include one phase to ground short circuit has been applied to all the buses on both models. Although the change in voltages across bus bars was less than the changes in the case of a symmetrical fault, the proposed method was able to distinguish the faulty bus bars as it did in the case symmetrical faults. The dimension $O = 2$ was selected again for the same reasons explained earlier. Figures 9 and 10 show the visualization of the results.

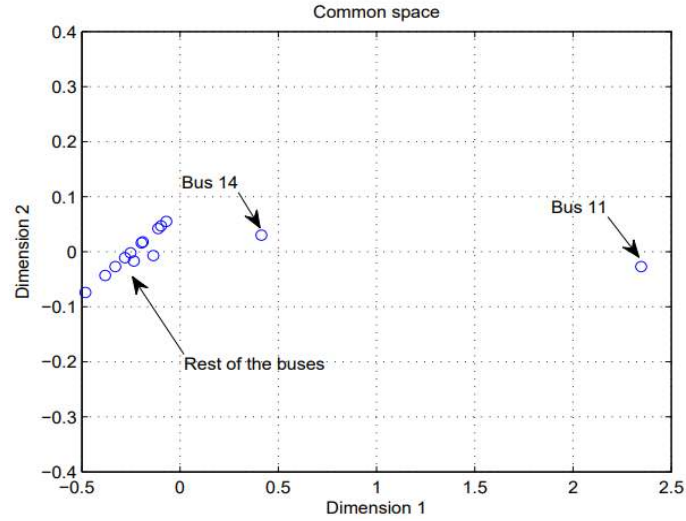


Figure 9. Visualization of IEEE 14 bus system with asymmetrical fault on bus 11.

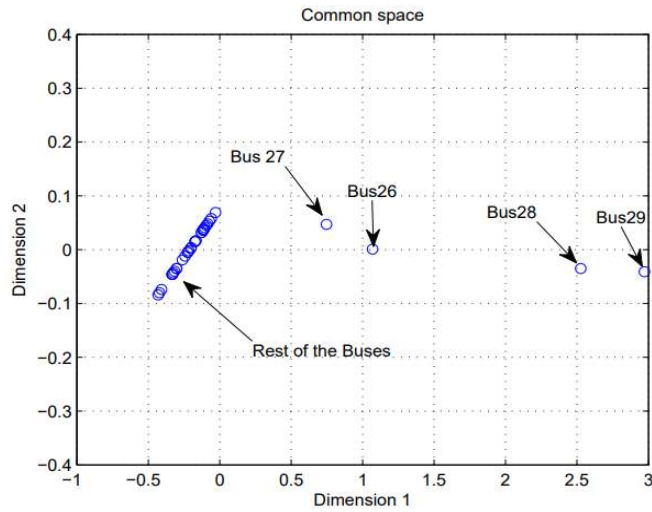


Figure 10. Visualization of IEEE 39 bus system with asymmetrical fault on bus 29.

1.3. Clustering Analysis

A K-means cluster technique is then applied to the result data to classify and determine the faulty bus bar and the affected ones. The data is divided into two clusters, healthy and faulty. This technique was able to classify the data properly and then the center of the healthy cluster was used to determine the exact place of the short circuit since the short-circuited bus bar will have the largest Euclidean distance measured from that center. Figure 11 and 12 show the results of applying K-means cluster on IEEE 39 symmetrical fault on bus 16, and IEEE 14 symmetrical fault on bus 5.

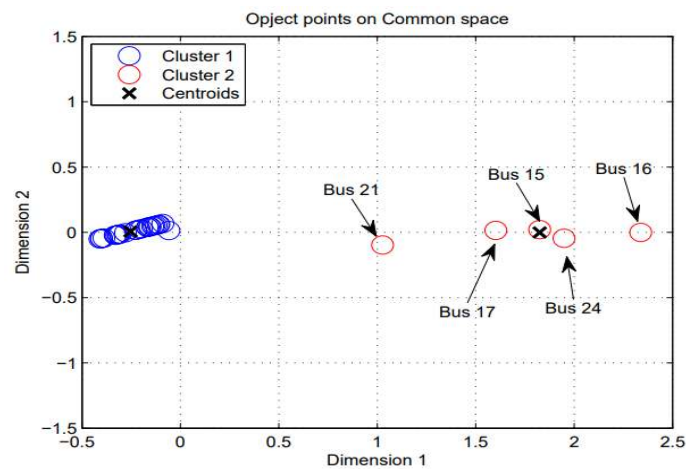


Figure 11. Clustering analysis of IEEE 39 Bus system with symmetrical fault

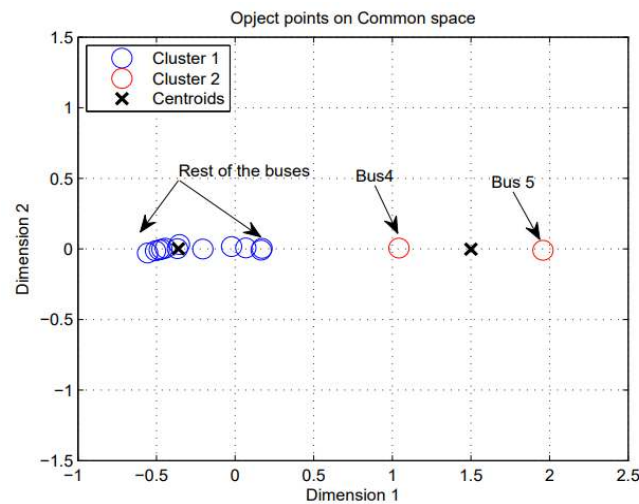


Figure 12. Clustering analysis of IEEE 14 Bus system with symmetrical fault

4. Conclusions

MDS was used in this paper to detect and locate faults in power grids by using different IEEE benchmark power systems. The current study can be a platform on which to build further MDS studies that related to the power systems. Reducing the dimensionality of the data to visualize the system and detect the faulty bus bars was the main target of this paper. Many measurements have been taken to ensure the goodness of fit. Visualization of the system in two-dimensional space showed a perfect fit with stress – I less than 0.001 in all cases studied in this paper. Scree plot was used in this paper to test the effect of increasing the number of dimensions of the desired space. The Scree plots showed that using a number of dimensions more than two will not improve the goodness

of fit. Visualization of the results of the mentioned models under different symmetrical and asymmetrical faults revealed that the faulty bus bar always has a greater Euclidean distance than the others. Healthy bus bars appeared close to each other on the desired space while the affected bus bars located between the faulty bus bar and the healthy bus bars. Finally, a k-means cluster technique was used to classify each bus bar to faulty, or health cluster. The proposed cluster technique was able to detect the faulty bus bars and healthy bus bars.

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The evaluation of Aluminum Alloy Corrosion in Gabraun and Desalination Waters

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Abstract

The aim of this study was to investigate the effect of Gabraun and Desalination waters on corrosion of aluminum alloy. The corrosion tests were carried out at room temperature. The test solutions (electrolyte) used were Gabraun and Desalination water samples. Weight loss method was used. From the results obtained, it was found that the weights of all the specimens after the tests were decreased. Also it was found that the average corrosion rate of Aluminum immersed in Gabraun water is little bit greater than the average corrosion rate of Aluminum immersed in Desalination water. The results showed that the color of the specimens surfaces immersed in Gabraun water was changed to white-gray color and the color of the specimens surfaces immersed in Desalination water was change to black-gray color. During the corrosion tests period, the Gabraun and Desalination water in the beakers was decreased about 50mL/week. The presence of some alloying elements like iron (Fe), copper (Cu) and Zinc (Zn) are susceptible to the corrosion processes. The Pourbaix diagrams showed Gabraun water and Desalination water are a corrosive mediums. The Langelier Saturation Index (LSI) showed that the Gabraun and Desalination water samples are not corrosive medium.

Keywords: *Aluminum alloy, Gabraun water, Desalination water, weight loss method, corrosion rate, Pourbaix diagram, LSI.*

1. Introduction

The Gaberoun Lake is an inspiring natural art formed deep in the Libyan Desert, which managed to survive the Great Sahara's harsh conditions and sand effects throughout the

age. The lake is about 7.5 meters deep, oddly cooler on the surface than it is in a meter and half below, where it becomes significantly hotter as water depth increases[1]. Aluminium (Al) is an important structural engineering material, its usage ranking only behind ferrous alloys[2]. Moreover, Aluminum is the most heavily consumed non-ferrous metal in the world and the principal elements which are alloyed with the pure aluminum to improve its tensile strength and hardness are copper, silicon, manganese, zinc, magnesium and nickel[3, 4]. In addition the relatively pure Aluminium presents good corrosion resistance due to the formation of a barrier oxide film that is bonded strongly to its surface (passive layer) and, that if damaged, re-forms immediately in most environments; i.e. re-passivation[2]. This protective oxide layer is especially stable in near-neutral solutions of most non-halide salts leading to excellent pitting resistance. Nevertheless, in open air solutions containing halide ions, with Cl^- being the most common, Aluminium is susceptible to pitting corrosion[2]. Although aluminium is a very reactive metal with a high affinity for oxygen, the metal is highly resistant to most environments and to a great variety of chemical agents. This resistance is due to the inert and protective character of the aluminium oxide film which forms on the metal surface [5]. The oxide film is extremely thin, between 50 and 100 Angstroms, it forms a protective barrier between the metal and the surrounding medium as soon as the metal comes into contact with an oxidizing environment, such as water. Aluminum corrosion products in water are white to translucent[6]. At low temperatures an amorphous (non crystalline) alumina (Al_2O_3) film forms at first which then becomes Boehmite ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ or $\text{AlO} \cdot \text{OH}$) and finally Bayerite ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$)[6]. The physical-chemical stability of the oxide film determines the corrosion resistance of the aluminium. This stability is dependent upon the pH value of the environment, since the oxide film is stable within the pH range of about 4 to 8. Below and above these values, acid dissolution yields Al^{3+} ions and the alkaline dissolution leads to the formation of $\text{Al}(\text{OH})_4^-$ ions[5]. When aluminum is exposed to alkaline conditions corrosion may occur, and when the oxide film is perforated locally, accelerated attack occurs because aluminum is attacked more rapidly than its oxide under alkaline conditions, the result is pitting. In acidic conditions, the oxide is more rapidly attacked than aluminum, and more general attack should result[7]. Corrosion in aluminium alloys is generally of a local nature, because of the separation of anodic and cathodic reactions and solution resistance limiting the galvanic cell size. The basic anodic reaction is metal dissolution[2, 5]: $\text{Al} \rightarrow \text{Al}^{3+} + 3\text{e}^-$, while the cathodic reactions are oxygen reduction: $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$, or hydrogen reduction in acidified solution such as in a pit environment as a result of Aluminum ion hydrolysis: $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$ [2, 5]

For the corrosion system of Ti6Al4V in naturally aerated 3.5% NaCl solution, the charging current density increases with the potential[8]. The voltage median evolution of AA5083

Aluminum samples exposed to a 3.5% NaCl solution suggests that the main corrosion process is crystallographic pitting for about the 1st day, but alkaline pitting later[9]. Agung Setyo Darmawan et al[10] Investigated corrosion resistance of 5052 aluminum to increasing salinity in sea water, aggressive NaCl solutions with concentrations of 3.5%, 4%, and 5% were used as artificial sea water corrosion medium and the temperature was 35°C. The results showed that the higher concentration leads to greater corrosion rate. Aisha H. Al-Moubaraki et al[11] investigated The corrosion behavior of Al 7075, Al 2024, and Al 6061 in the red sea water and the results revealed that the corrosion rates of Al alloys decreased with time. Deepa et al[12] concluded that 6063 aluminum alloy undergoes corrosion in phosphoric acid medium and in sodium hydroxide medium and the corrosion rate increases with an increase in the concentration of phosphoric acid medium as well as sodium hydroxide medium also corrosion rate increases with an increase in temperature. Seruga M. & Hasenay D[13] found that the results showed the corrosion of Al in soft drinks is a very slow and corrosion of Al in these drinks occurs principally due to the presence of acids. Nemcova *et al.*[14] studied the corrosion resistance of Aluminum Alloy in the Aqueous solution of Urea, the results showed low corrosion resistance in aqueous solution with chloride ions. Kemal Nişancioğlu[15]. Studied pitting and uniform corrosion of Aluminum alloys and effectiveness of cathodic protection in reducing these corrosion forms. The results revealed that in stagnant waters or presence of low flow rates, pitting may occur.

Sanni *et al*[16] studied the silicone oil as Corrosion Inhibitor for Aluminum Alloy in Aggressive Environment (3.5% NaCl solution) and found that the inhibitor showed a lower corrosion rate values as compared with the corrosion rate samples without inhibitor. Mohammad Asadikiya et al[17] investigate that the inhibition effect of sodium diphosphate on the aluminum in water-ethylene glycol solution can be due to forming a stable passive film on the surface of aluminum. Paulina Arellanes-Lozada et al[18] studied the Inhibition of Aluminum Corrosion in Sulfuric Acid by Poly(1-vinyl-3-alkyl-imidazolium Hexafluorophosphate), the results showed that PILs displayed low efficiencies as corrosion inhibitors against uniform corrosion. The various equilibrium of the Al-H₂O system has been clarified by Pourbaix in a potential versus pH diagram (shown in the Fig. 1). It is revealed that aluminum corrodes in the range of 4 < pH < 8 forming Al³⁺ ions at low pH values and AlO₂⁻ ions at high pH values. Aluminum should show passivity (solubility constant < 10) forming Al₂O₃·3H₂O at near-neutral pH values and immunity at very negative potentials[19]. The potential of Aluminum at 25°C is -1.66V[20].

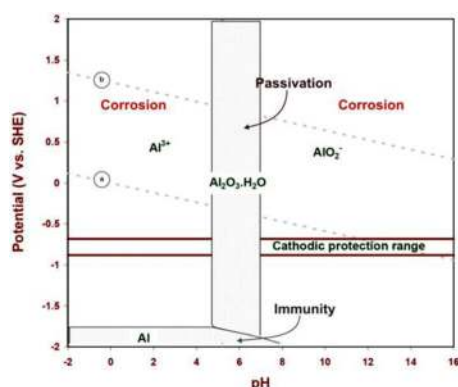


Fig.1 E-pH corrosion diagram (Pourbaix Diagram) for Al/H₂O system at 25 °C[19].

2. Experimental work

2.1. Materials

The material used in this study is Aluminum Alloy with chemical composition obtained by X-ray diffraction as shown in Table 1, which analyzed in the faculty of science, sebha university

Table (1). Chemical composition of Aluminum alloy before immersion

Al (mass %)	Si (mass %)	Fe (mass %)	Ca (mass %)	Th (mass %)	Zn (mass %)	Cu (mass %)	Cl (mass %)	S (mass %)	Mn (mass %)	Ni (mass %)	Ga (mass %)	Co (mass %)	Others (mass %)
94.9	2.19	1.06	0.649	0.543	0.104	0.090	0.089	0.0867	0.0846	0.077	0.0247	0.0107	balance

Ten (10) specimens were used in this study and cut from metal bars with rectangular cross-sectional areas and have dimensions of 36-40mm long, 25mm width and 5mm thickness as shown in Figure (1).

Five (5) specimens were used for Gabraun water and Five (5) specimens were used for Desalination water (treated water). All the surfaces of the specimens were cleaned and washed well and polished with 800 and 1200 grit emery papers to remove oxides and contaminants.

2.2. Corrosion tests

Gabraun, water and Desalination water were used as test solutions in this study, and a number of 600 ml beakers were used and filled by these types of water. All the specimens were completely immersed in the filled beakers. Each specimen was put in one beaker.

All the specimens were cleaned and weighed before and after the corrosion tests. All the tests were carried out at room temperature. The corrosion test period was 50 days for all the specimens. The chemical analysis of the used Gabraun water and Desalination water are shown in Table (2) and Table (3) were done in faculty of science, sebha university.

Table (2) The analysis of Gabraun's water before tests

Parameter	Gabraun water before immersion
ph	9.66
Conductivity ($\mu\text{S}/\text{cm}$)	162500
Salinity (ppt)	27
TDS (mg/L)	24780
Total Alkalinity(mg/L)	430
Hardness Ca^{++} (mg/L)	83
Hardness Mg^{+2} (mg/L)	28
SO_4 (mg/L)	37
K^+ (mg/L)	34
Na^+ (mg/L)	135
Cl^- (mg/L)	95
Total Hardness (mg/L)	384

Table (3) The analysis of Desalination water before tests

Parameter	Drinking water before immersion
ph	8.77
Conductivity ($\mu\text{S}/\text{cm}$)	103.7
Salinity (ppt)	0.1
TDS (mg/L)	51
Total Alkalinity(mg/L)	25
Hardness Ca^{++} (mg/L)	22
Hardness Mg^{+2} (mg/L)	13
SO_4 (mg/L)	0.5
K^+ (mg/L)	9.5
Na^+ (mg/L)	25
Cl^- (mg/L)	3.9
Total Hardness (mg/L)	38

In order to predict the tendencies of Gabraun and Desalination water to precipitate or dissolve calcium carbonate, the Langelier Saturation Index (LSI) was designed to measure calcite formation and used as a measure of corrosion. Also this index indicates the driving force for scale formation and growth in terms of pH as a master of variable[21].

In order to calculate the LSI, it is necessary to know the alkalinity (mg/L, as CaCO_3 , or calcite), the calcium hardness (mg/L Ca^{+2} as calcium carbonate), the total dissolved solids (TDS) (mg/L TDS), the actual pH, and the temperature of water ($^{\circ}\text{C}$)[21].

LSI is defined as the following equation[21]:

$$\text{LSI} = \text{pH} - \text{pH}_s \dots\dots\dots(2)$$

Where:

pH is the measured water pH.

pH_s is the pH at saturation in calcite or calcium carbonate and is defined as[21]:

$$\text{pH}_s = (9.3 + A + B) - (C + D) \dots\dots\dots(3)$$

$$A = \{\log_{10}[\text{TDS}] - 1\} / 10$$

$$B = -13.12 \times \log_{10}(^{\circ}\text{C} + 273) + (34.55)$$

$$C = \log_{10}[\text{Ca}^{2+} \text{ as } \text{CaCO}_3] - [0.4]$$

$$D = \log_{10}[\text{alkalinity as } \text{CaCO}_3]$$

The LSI indicates three situations[21]:

If LSI is negative: No potential to scale, the water will dissolve CaCO_3 .

If LSI is positive: Scale can form and CaCO_3 precipitation may occur.

If LSI is close to zero: Borderline scale potential.

2.3. Corrosion rate calculations

The rate of corrosion of aluminum in water depends on several parameters coupled to water: pH, temperature, electric conductivity, elements in the water and movements of the water. It also depends on the alloy composition, elaboration technique (extrusion, rolling etc), heat treatment and surface state[22]. The composition, size and quantity of alloy constituents such as Al_3Fe , $\text{Al}_6(\text{Mn}, \text{Fe})$, $\text{Al}(\text{FeSi})$ or pure silicon affect the corrosion rate. If the constituent's corrosion potential is different from the aluminum matrix galvanic corrosion effects will appear. This will increase the corrosion rate[22].

The corrosion rate was calculated by using the following relation[23]:

$$\text{Corrosion rate} = \frac{W \times 365}{\rho \times A \times T} \dots\dots\dots(4)$$

Where:

W = weight loss (g)

365 = number of days per year (day/year)

A = the area of the specimen exposed to the solution (cm²)

ρ = the metal (Aluminum) density (2.7g/cm³)

T = exposure time of the specimens (50 days)

3. Results and Discussion

It was seen that the color of the surfaces of all the specimens before the immersion in this study was as shown in Figure (2).

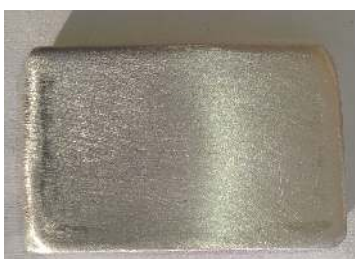


Figure 2 photo for Aluminum alloy before immersion in all the types of water

After two weeks from the immersion the color of the specimens surfaces immersed in Gabraun water start to change to white-gray color as shown in Figure (3) and the color of the specimens surfaces immersed in Desalination water start to change to dark-gray color as shown in Figure (4). These changes of colors attributed to the chemical reaction between the aluminum specimens surfaces and the both types water, Gabraun water and Desalination water, it is suggested that these reactions produced corrosion products with white-gray color and dark-gray color, respectively, while Aluminum corrosion products in water are white to translucent[6]. Moreover when aluminum is exposed to alkaline conditions corrosion may occur[7], this is compatible to the results obtained in this work that show the pH of Gabraun water is 9.66 as shown in Table 2, which indicates that corrosion is occurred and produced from the cumulative of the corrosion products. In the pH range of about 4 to 8.5, aluminum is passive (protected by its oxide film)[24], however the pH of the Desalination water is 8.77 and the corrosion of Aluminum alloy was occurred, this is due to the presence of some alloying elements like iron (Fe), copper (Cu) and Zinc (Zn) which are susceptible to the corrosion processes

As can be seen in figure 3 and figure 4, small spots are appear on the surfaces, these spots are attributed to pitting corrosion which occurred from the presence of chlorine ions (Cl⁻) in the test solutions.



Figure 3 photo for Aluminum alloy after immersion in Gabraun water



Figure 4 photo for Aluminum alloy after immersion in Desalination water

Furthermore the color of the Gabraun water and Desalination water didn't change until the end of the experiments which remained colorless. In addition, after one week from the immersion, it was seen that the level of the water in each beaker was decreased about 50 ml, this lack of the water was attributed to change of the temperature from 25°C to 37°C and this lack of water was substituted continuously until the end of the experiments.

All the Specimens were cleaned after the end of corrosion tests by the Tap water, and distilled water and then weighed and compared by their weights before the tests, it was found that the weights of all the specimens after the tests were decreased as shown in Tables 4 and Table 5. These results were expected to be the result of the chemical reaction between the both types of water and Aluminum alloy specimen surfaces.

Table (4) The results of the corrosion test for Aluminum alloy specimens in Gabraun water.

No. Specime	Weight before immersion (g)	Weight after immersion (g)	Weight loss (W) (g)	Area(Cm ²)	Corrosion rate cm/year
1	12.2840	11.9051	0.3789	24.1	0.04250
2	12.2517	11.8752	0.3765	24.1	0.04228
3	12.3990	12.0160	0.383	24.1	0.04296

4	12.3182	11.9425	0.3757	24.7	0.04112
5	13.3759	12.9661	0.4098	26.5	0.04181

Table (5) The results of the corrosion test for Aluminum Alloy specimens in Desalination water

No Specime	Weight before immersion (g)	Weight after immersion (g)	Weight loss (W) (g)	Area(Cm²)	Corrosion rate cm/year
6	12.2046	11.8326	0.372	24.1	0.04173
7	13.2953	12.8881	0.4072	25.9	0.04250
8	12.1513	11.7783	0.373	24.7	0.04082
9	12.0553	11.6885	0.3668	24.1	0.04115
10	12.7646	12.3747	0.3899	25.3	0.04166

Table (6) The average corrosion rate (cm/year) of Aluminum in Gabraun and Desalination water

Type of water	Gabraun water	Desalination water
Average Corrosion rate (cm/year)	0.04213	0.04157

Referring to the Table 6, the results show that the average corrosion rate of Aluminum immersed in Gabraun water is little bit greater than the average corrosion rate of Aluminum immersed in Desalination water, this is because of the presence of higher chlorine ions (Cl^-) and sulfides (SO_4) in Gabraun water than in Desalination water as shown in Table 2 and Table 3.

According to the pourbaix diagram in figure 1, It is revealed that aluminum corrodes in the range of $4 < \text{pH} < 8$ forming Al^{3+} ions at low pH values and AlO_2^- ions at high pH values and the potential of Aluminum at 25°C is -1.66V [19, 20]. Likewise, the pH of the Gabraun water is 9.66, hence, this result show that Gabraun water is a corrosive medium, and the pH of Desalination water is 8.77, this number is more than pH 8, hence the Pourbaix diagram in Figure 1 shows Desalination water is a corrosive medium for Aluminum Alloy as well.

Table 7. Results of The Langelier Saturation Index (LSI)

No.	Water sample	LSI
1	Desalination water	+0.362
2	Gabraun water	+2.482

According to the results obtained from the Langelier saturation index (LSI) shown in table 7, it was found that the LSI for Gabraun water and Desalination water samples are positive this indicates that scale can form and CaCO_3 precipitation may occur. While the results

obtained from the corrosion tests of aluminum alloy, showed that Gabraun and Desalination water are corrosive medium. From this result, the Langelier saturation index (LSI) cannot give the expected results when Aluminum Alloy immersed in both Gabraun and Desalination water.

Table (8). Chemical composition of Aluminum alloy after immersed in Gabraun water

Al (mass %)	Si (mass %)	Fe (mass %)	Ca (mass %)	K (mass %)	Zn (mass %)	Cu (mass %)	Cl (mass %)	S (mass %)	Mn (mass %)	Ni (mass %)	Ga (mass %)	Co (mass %)	Others (mass %)
87.8	4.08	2.24	1.73	1.67	0.34	0.264	0.189	0.293	0.257	0.251	0.079	0.0321	Balance

Table (9). Chemical composition of Aluminum alloy after immersed in Desalination water

Al (mass %)	Si (mass %)	Fe (mass %)	Ca (mass %)	Th (mass %)	Zn (mass %)	Cu (mass %)	Cl (mass %)	S (mass %)	Mn (mass %)	Ni (mass %)	Ga (mass %)	Co (mass %)	Others (mass %)
80.5	5.64	3.60	3.38	2.44	0.570	0.412	0.638	1.52	0.348	0.427	0.128	0.0512	Balance

According to the comparison between the chemical composition of the Aluminum alloy before the immersion in Table 1 and after the immersion in both the Gabraun and the Desalination water in Table 8 and Table 9, respectively, it was found that the amount of aluminum is decreased but the other elements are increased. This result was due to the chemical reaction between the Aluminum Alloy and the test solutions, that produced Aluminum Oxide (Al_2O_3), which is appear on the surface of the specimens as a white-gray color after immersed in Gabraun water and dark-gray color after immersed in Desalination water. Furthermore, the presence of Iron in the chemical composition of the Aluminum Alloy with this amount shown in the Tables above is detrimental to corrosion due to its low solubility and hence ability to form constituent particles which are cathodic to the Al-matrix such as Al_3Fe [2]. And also the presence of Iron may affect on the color of Aluminum oxide.

Table (10). Chemical composition of Aluminum alloy after immersed in Gabraun water

Al_2O_3	SiO_2	Fe_2O_3	CaO	K_2O	ZnO	CuO	Cl	SO_3	MnO	NiO	Ga_2O_3	Co_2O_3	Others
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(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)	(mass %)
89.2	4.69	1.72	1.3	1.08	0.27	0.178	0.102	0.393	0.179	0.172	0.0571	0.0243	Balance

Table (11). Chemical composition of Aluminum alloy after immersed in Desalination water

Al ₂ O ₃ (mass %)	SiO ₂ (mass %)	Fe ₂ O ₃ (mass %)	CaO (mass %)	ThO ₂ (mass %)	ZnO (mass %)	CuO (mass %)	Cl (mass %)	SO ₃ (mass %)	MnO (mass %)	NiO (mass %)	Ga ₂ O ₃ (mass %)	Co ₂ O ₃ (mass %)	Others (mass %)
82.6	6.56	2.80	2.57	1.51	0.385	0.280	0.346	2.06	0.244	0.295	0.0935	0.0391	Balance

Referring to Table 10 and Table 11, one of the components of aluminum Alloy after immersion is Iron(III)oxide or ferric oxide(Fe₂O₃) which has sometimes black or reddish-brown color, while the other oxides have a white color. So the color of the surfaces of the specimens immersed in Desalination water was suggested to be affected by the color of ferric oxide (Fe₂O₃), this is because ferric oxide on the surfaces of the specimens immersed in Desalination water has an extra amount than that immersed in Gabraun water as shown in Table 10 and Table 11. According to this result, the color of the surface of the specimens immersed in Desalination water appear more darker than that immersed in Gabraun water.

4. Conclusions

The results of the current study reached to the following conclusions;

- 1- The colors of the Gabraun and Desalination water used for Aluminum alloy specimens corrosion tests were not changed.
- 2- the color of the specimens surfaces immersed in Gabraun water changed to white-gray color, while the color of the specimens surfaces immersed in Desalination water changed to black-gray color.
- 3- The color of the specimens surfaces after immersion was suggested to be dependent on the color and amount of Ferric oxide.
- 4- The average corrosion rate of the specimens immersed in Desalination water is less than that immersed in Gabraun water.
- 5- After two weeks from the immersion of the specimens, the amount of water decreased about 50ml from each beaker, this resulted from the raise of the room temperature between 25°C to 37°C, this lack was substituted continuously during the test period.
- 6- The Langelier saturation index (LSI) does not give an expected results when Aluminum Alloys immersed in both Gabraun and Desalination water.

- 7- Small spots are appear on the surfaces, these spots are attributed to pitting corrosion.

Further works

The increase of the alloying elements shown in table 8 and table 9, will be studied in the further works.

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Effects of Water Stress and Nitrogen Fertilization on Growth Yield and Grain Production of Barley

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Abstract

Reclamation of new lands was and still going in rather slow rate not parallel to the increase in population. Therefore increasing the efficiency of production of the existing land will contribute to the solution of this problem. Barley is one of the most important winter cereal crops grown mainly in areas where limited water supply is a feature and crops depend upon rainfall.

The present study was conducted to investigate the effect of water stress and N fertilization on growth yield and grain production of barley and N uptake by plants and N behavior in the soil under investigation. The experiment was carried out under greenhouse conditions in a "Randomized complete Block (RCB) design with three replicates the soil has sandy clay loam and salinity was 7.15 dS/m but sodicity was 11.0. However, total carbonate and organic matter content were 2.05% and 0.71% respectively. The fresh weight of barley increased by increasing period of growth up to elongation and then slightly decreased at the heading stage. Also, the highest fresh and dry matter weight of Barley in general, was obtained by application of N as ammonium sulphate under soil moisture at 100% F.C. Application of N fertilized increased grains yield compared with the unfertilized plants. In addition, application N as ammonium sulphate showed an increase over when urea was used with about 13.7%. Applying N as two equal doses was more effective than when applied as one dose. The relative increase due to splitting the amount of applied N was 147.5% and 132.6% when urea and ammonium sulphate were used respectively. The highest grains yield was obtained by applying N as two doses of ammonium sulphate when soil moisture was maintained around 75% of the soil field capacity.

Keywords: Barley, Urea, Ammonium, sulphate, Field capacity, water stress.

1. Introduction

Food habits of people are changing towards increasing consumption of animal protein. Reclamation of new lands was and still going in rather slow rate not parallel to the increase in population. Therefore increasing the efficiency of production of the existing land will contribute to the solution

of this problem. Wheat as well as, Barley are the most important cereal crops in the world. Barley is one of the most important winter cereal crops grown mainly in areas where limited water supply is a feature and crops depend mainly upon rainfall. Barley like any other crops is affected by the agronomic practices, such as irrigation and nitrogen fertilization.

Barley is nutritious and its protein content can be higher and it has a large amount of dietary fiber important for intestinal function and lowering blood cholesterol (Newman, 1984). It is salt tolerant, Barley has the advantage over other cereal crops has less water requirement to grow and produce satisfactorily (FAO, 1987).

Ligon and Benoit (1966), found that the increased soil moisture tension resulted in decreases in total leaf area development, quality and stalk weigh. Hussien and Khadr (1979) and Hussien et. al. (1978) found that the vegetative growth decreased with 80% depletion of soil moisture but was unaffected by 60,40, or 20% depletion. Misra (1976), Misra et al (1980) and Shaaban et al (1983) and Chaturvedi and Sinha (1981) reported that straw and grain yield of barley increased by increasing number of irrigation up to (3, 4 and 5) irrigations, respectively.

El-Monayeri et. al. (1983) found that plant height, fresh and dry weights plants as well as moisture %, decreased with increasing moisture stress. Khattari and Till (1993) found that the 80% of F.C. level. Hooda and Kalra (1977) stated that irrigation increased the grain yield of barley.

Also, Farahat (1978) demonstrated that depletion of available soil moisture decreased in spike length, grain index and yields of grain and straw. Sinsinwar and Singh (1980) reported that maximum grain yield of Barley was obtained with one supplementary irrigation at tillering.

Cannel et al. (1958) showed that nitrogen concentration in plants increased by decreasing soil moisture levels. Radner and Vasiler (1973) showed that N content of barley grains decreased by increasing the number of irrigations. Shevelukha et. al. (1978) found that the highest yields obtained with soil moisture content (60 – 70%) of yield capacity.

Abd-Alla (2004) and El-Kallal (2005) indicated that the increase in nitrogen fertilization level from the level 50 to the levels 100 and 150 Kg N/ha gave significant increase in grain and straw yield of barley and wheat crops.

Osman et. al. (1992) emphasized that the plant and total dry matter production plant were significantly greater by the application of 45 – 60 Kg N/fad and spraying barley plants at tillering stage with 6%. Abo El-Khair (1995) found that application of 400 mg N/Kg soil in three forms of urea, ammonium nitrate and ammonium sulphate to the soil increased the N content of all forms of N.

Orphanos and Krentos (1980) found that fertilizer N correlated positively with N content of the levels of the leaves, straw and grains of barley. Richards et al (1996) studied the effects of applied N on soil nitrate N content after harvest of barley. They found that applying N up to the economic optimum rate was associated with small increases in soil nitrate after harvest (4 Kg N/ha).

The present study was conducted to investigate the effect of water stress and N fertilization on growth yield and yield production of barley (*Hordeum Vulgare* L) and N-uptake by plants and N

behaviour in the soil under investigation.

2. Materials and Methods

A pot experimental was carried out under greenhouse conditions, soil used in this investigation was collected from the surface layer (0 – 30 cm), it has a sandy clay loam. PE pots were filled with 10 Kg soil/pot. All pots received P (superphosphate 6.5% P) and K as potassium sulphate (42 % K) at rates 6 and 20 mg/Kg soil, respectively during seed-bed preparation. Twenty five seeds/pots were planted, and when the seedling were 10 day old, only 20 plants were left in each pot. The experiment was carried out in Randomize Complete Block (RCB) design including two factors as follows:

1- Moisture stress, 3 moisture regimes (WFC%):

$$M_1 = 100\% \quad , \quad M_2 = 75\% \quad , \quad M_3 = 50 \%$$

2- N – treatment including 2 forms of N being as follows:

a- Urea fertilizer in (1 and 2) dose.

b- Ammonium sulphate fertilizer in (1 and 2) dose.

c- Control without N

Treatments were carried out in 3 replaces. Some main chemical and physical analysis were carried out according to methods outlined in Page et. al. (1982) and Klute (1986).

3. Results and Discussion

Soil Characteristics:

To achieve the aims and objectives of this study, soil used in this investigation was collected from the surface layer (0 – 30 cm); the soil was sandy clay loam. Some physical and chemical properties of the soil are presented in Table (1).

The soil salinity and sodicity were 7.15 dS_m^{-1} and 11.0 respectively. However, total carbonate and the organic matter content were low (2.05 and 0.71%) respectively. These low levels of, O.M content confirm the rapid decomposition of O.M under arid conditions

A pot experiment was conducted in the greenhouse to study the effect of soil moisture stress and N fertilization on barley (*Hordeum Vulgare*) yield and its chemical composition for N at different stages of growth i.e, tillering, elongation, heading and harvesting.

Table 1. Some physical and chemical properties of soil under study:

Criteria	I. Values	Criteria	II. Values
III. Particle-size distribution:		IV. Soluble cations, meq/100	
V. Sand %	54.4	VI. Ca^{++}	19.3
Silt %	18.1	Mg^{++}	10.4
Clay %	VII. 27.5	Na^+	40.9
Texture class	VIII. sandy clay loam	K^+	0.8
IX. Saturation percentage, %	51.0	X. Soluble Anions, meq/100g	
Field capacity, %	20.50	$\text{CO}_3^{2-} + \text{HCO}_3^-$	4.0
Wilting point	10.50	Cl^-	41.0
EC (1:1 water extract), dS/m	7.15	SO_4^{2-}	26.5
pH (1:1 water suspension)	7.50	XI. Available nutrients, mg/kg	
Organic matter, %	0.71	N	23.0
Total N, %	0.23	P	0.5
CaCO_3 %	2.05	K	40.00

The dry matter yield for the different samples were recorded . At the end of experiment soil samples were taken for chemical analysis. The obtained result will be discussed under the following subheading:

1- Vegetative Growth Stages:

1-1- Fresh Weight:

The data in Table (2) and Figure (1) represent the fresh weight of barley increased by increasing period of growth up to elongation and then slightly decreased at the heading stage. This trend was highly recognized under irrigation to maintain soil moisture level about 100% of the soil field capacity. The height relative increased was noticed during the elongation stage, followed by tillering stage while at heading stage the differences were narrowed. The relative values over the 50% FC treatment were 120.9 and 167.1% for 75% and 100% FC for during the tillering stage. For the

elongation and heading stages the corresponding relative values were 241.2% & 352.8 and 174.9 & 147.7% respectively.

Regarding the effect of N addition, the data revealed that N application increased fresh weight of barley during growth stage compared with control.

Concerning the differences between N sources, the data showed slight changes between Urea and ammonium sulphate (AS). The highest fresh weight of barley in general was obtained by application of N as (AS) under soil moisture at 100% FC.

1-2- Dry Weight:

The data in Table (2) and Figure (2) indicate that the dry weight increased progressively up to the heading stage, it can be seen that increasing soil moisture content from 50 to 100% FC which increased the dry matter accumulation. With regard to the effect of N application as different sources, the data presented high increases and (AS) was superior.

Table 2. effect of soil moisture regime and nitrogen fertilization on fresh and dry matter yield of barley at different stages of growth

Growth stages	Weight	Moisture regime as % of F C (M)	Nitrogen fertilizer and splitting {N} 60 Kg N/Faddan					
			Ua	Ub	AS a	AS b	Control	Mean
Tillering	Fresh	100%	10.38	13.99	11.75	16.54	4.60	11.47
		75%	7.51	11.71	5.77	11.31	4.31	8.12
		50%	6.21	7.33	5.36	6.36	3.03	5.66
		Mean	8.03	11.01	7.62	11.40	4.01	
		LSD _{0.05}	M=1.303 N=1.682 MxN= 2.914					
	Dry	100%	1.14	1.74	1.45	2.15	0.59	1.41
		75%	1.00	1.65	0.85	1.75	0.54	1.15
		50%	0.93	1.16	0.83	1.01	0.40	0.86
		Mean	1.02	1.51	1.04	1.63	0.51	
		LSD _{0.05}	M=0.384 N=0.496 MxN= n.s.					
Econsat	Fresh	100%	26.22	37.33	34.74	36.42	8.81	28.70
		75%	17.87	24.95	18.56	21.86	8.02	81.25
		50%	7.41	11.36	8.46	9.68	4.11	8.20
		Mean	17.16	24.54	20.58	22.65	6.98	

		LSD0.05	M=2.864 N=n.s. MxN=6.404					
	Dry	100%	3.14	5.17	5.02	5.22	1.55	4.02
		75%	2.34	3.59	2.63	3.43	1.48	2.69
		50%	1.37	1.91	1.57	1.68	0.81	1.46
		Mean	2.28	3.55	3.07	3.44	1.28	
		LSD0.05	M=0.515 N=0.665 MxN= 1.500					
Heading	Fresh	100%	17.53	24.46	19.50	24.61	6.61	18.54
		75%	20.76	21.82	21.61	22.97	6.57	18.74
		50%	11.87	13.74	12.82	17.35	5.94	12.34
		Mean	16.72	20.00	17.97	21.64	6.37	
		LSD0.05	M=1.931 N=2.494 MxN=n.s.					
	Dry	100%	5.17	5.60	6.23	6.60	2.10	5.14
		75%	5.38	5.82	5.52	6.00	2.00	4.94
		50%	2.99	3.73	3.74	4.20	1.76	3.28
		Mean	4.51	5.05	5.16	5.60	1.95	
		LSD0.05	M=0.677 N=0.874 MxN= n.s					

Control= Without N fertilization, U= urea, AS= ammonium sulphate, a= one dose, b= two doses.

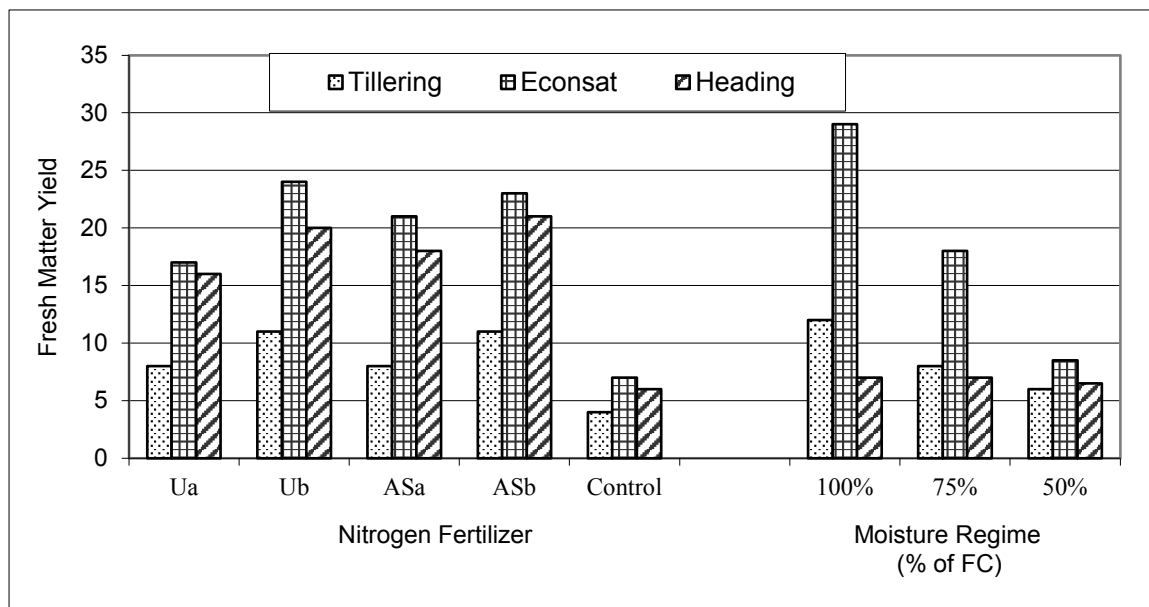


Figure 1. Effect of soil moisture regime and nitrogen fertilization on fresh matter yield at different growth stages.

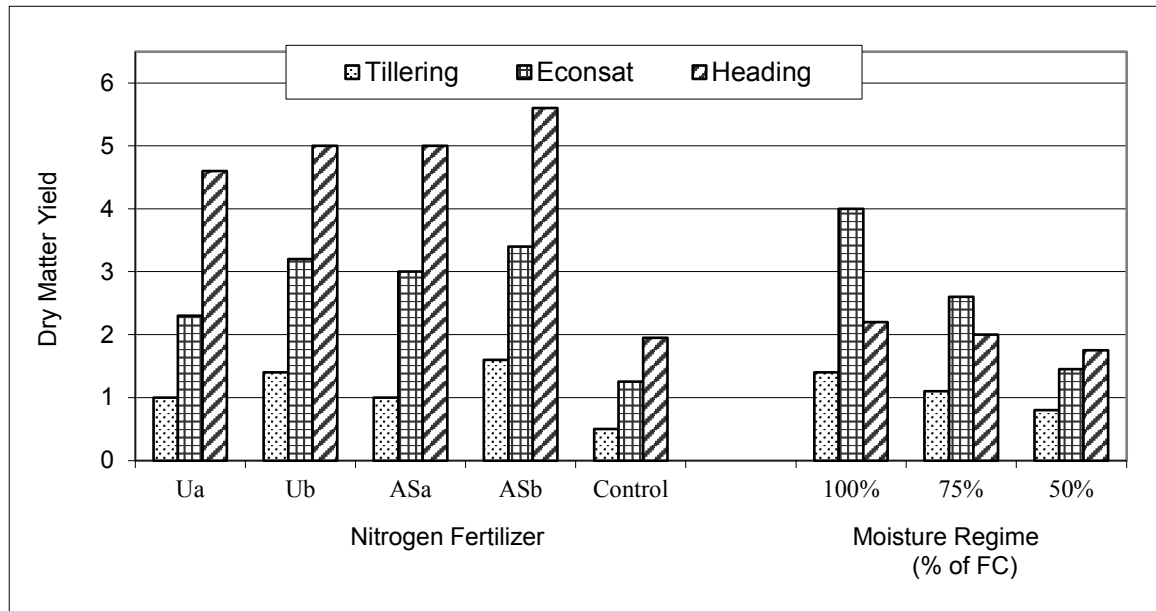


Figure 2. Effect of soil moisture regime and nitrogen fertilization on dry matter yield at different growth stages.

In addition, applying (N) fertilizer as 2 doses was favorable than as one dose were: 148.0 and 156.7% for U and AS respectively at the tillering stage. The Corresponding relative values were 155.7% and 112.1% at the elongation and heading stages respectively.

Concerning the interaction between N application and soil moisture regime; the data showed that the highest dry matter yield was obtained by applying (AS) as 2 doses when soil moisture was maintained around 100% of the F.C. This was true for the different stages of growth.

1-3- Chemical Composition:-

1-3-1- Nitrogen Content:

The data in Figure (3) indicate that increasing soil moisture from 50% to 100% of the F.C. showed slight increase in N%. This was true for the elongation and heading stages of growth while at tillering

stage it showed a slight decrease. This means that soil moisture increased the absorption of (N). N% gradually decreased through the tillering stage to heading stage. Regarding the effect (N) application, it can be relatively noticed that there were high increases due to N treatments. The differences between N source were slight.

1-3-2- Nitrogen Uptake:

The data in Figure (4) show that N uptake increased considerably at the elongation stage compared with the tillering stage while the amount of N uptake at the heading stage showed slight differences. Soil moisture increased the N uptake by barley plants. The relative values of 75% and 100% F.C. over the 50% F.C. treatment are 128.8% & 156.7%; 189.9% & 309.1% and heading stages respectively. The N uptake markedly increased by N application. As showed slight increases compared with urea. In addition, splitting the added N as 2 doses was superior that adding N as one dose

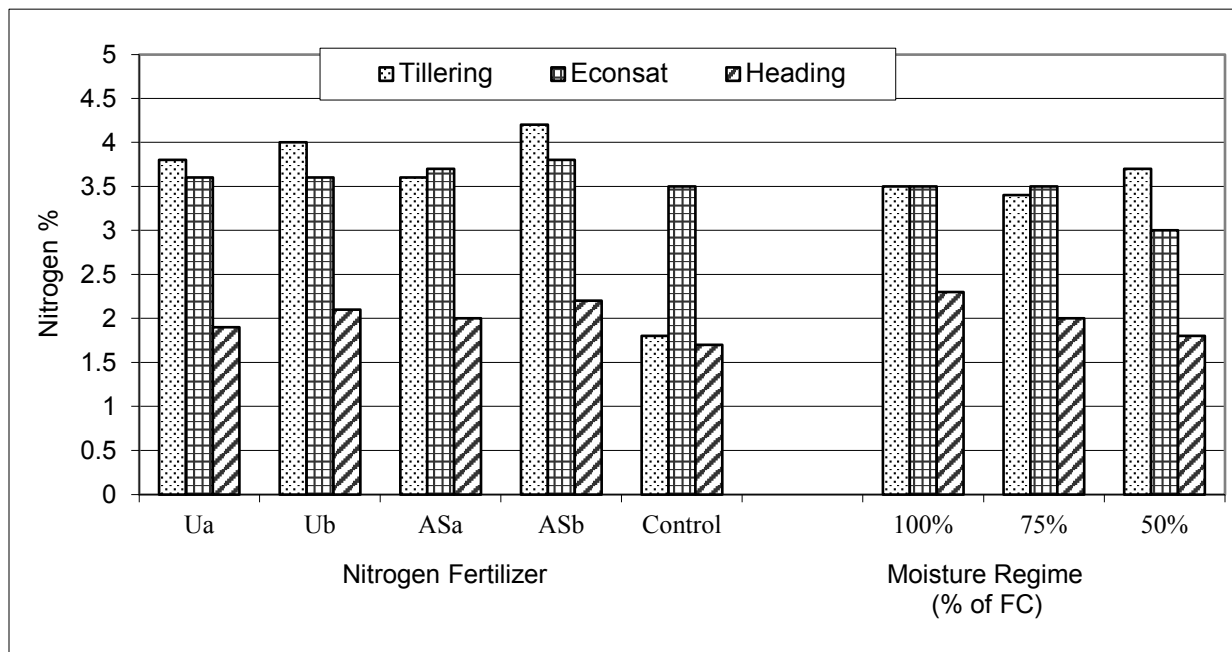


Figure 3. Effect of soil moisture regime and nitrogen fertilization on nitrogen percentage at different growth stages.

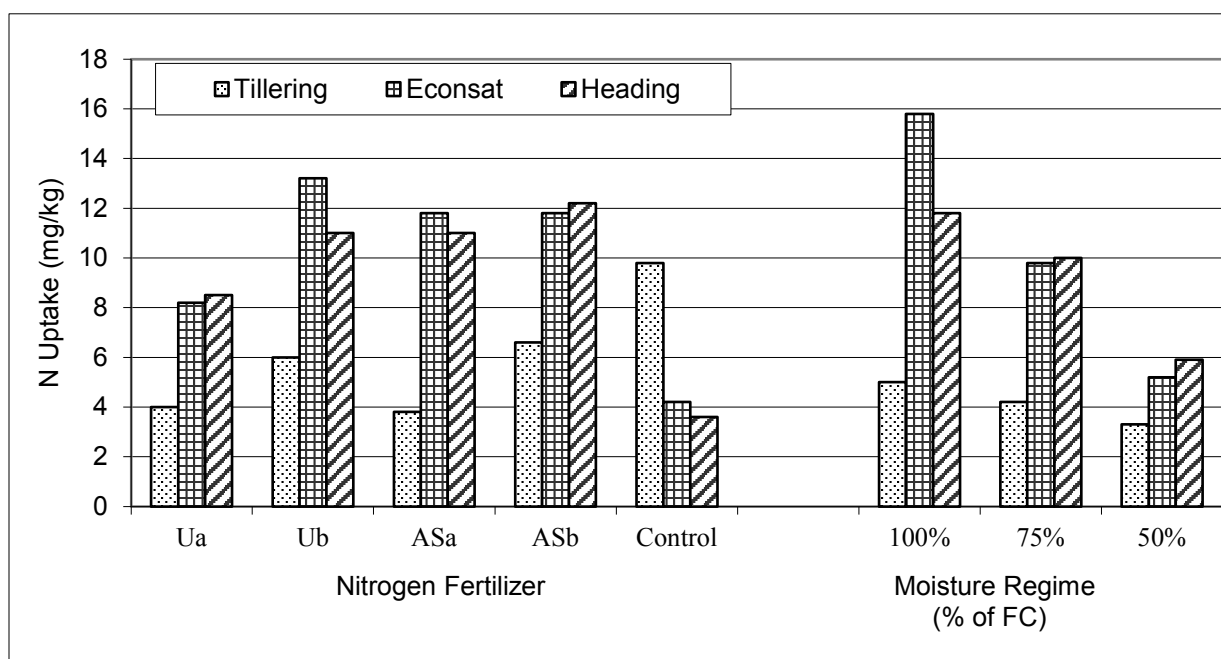


Figure 4. Effect of soil moisture regime and nitrogen fertilization on nitrogen uptake at different growth stages.

2- Harvesting Stage:

2-1- Grain Yield:

The data in Table (3) and Figure (5) show that raising soil moisture level from 50% to 75% of the soil field capacity increased grain yield with nearly two folds. On the other hand maintaining soil moisture around the field capacity showed a decrease in grains yield compared by 75% FC but it is 'still higher than the 50% F.C. Relative value of 100% and 75% FC over the 50% FC treatment were 159.9% and 206.3% respectively.

Application of N fertilizer increased grains yield compared with the unfertilized plants. In addition, application N as ammonium sulphate showed an increase over when urea was used with about 13.7%. Applying N as two equal doses was more effective than when applied as one dose. The relative increase due to splitting the amount of applied N was 147.5% and 132.6% when urea and ammonium sulphate.

were used respectively. The highest grains yield was obtained by applying nitrogen as two doses of ammonium sulphate when soil moisture was maintained around 75% of the soil field capacity.

2.2 Straw Yield:

Straw yield increased progressively by increasing soil moisture level from 50% FC up to 100% FC. The relative values of straw yield over the 50% FC were 141.8% and 195.5% for the 75% and 100% field capacity treatments respectively. N application generally increased ' straw yield when compared with the control. This trend was more pronounced when nitrogen was added as ammonium sulphate. Splitting the amount of added nitrogen as two equal doses was superior than when added as one dose. The relative values over the control were 122.4 and 115.9% when urea was added as two doses or one dose respectively. For ammonium sulphate, the corresponding relatively values were 136.5% and 115.6%. The highest yield of straw was obtained by applying ammonium sulphate or urea as two doses and maintaining soil moisture around the field capacity.

Table 3. Effect of soil moisture regime and nitrogen fertilization on yield of grains and straw.

Yield	Moisture regime as % of F C (M)	Nitrogen fertilizer and splitting {N} 60 Kg N/Faddan					
		Ua	Ub	AS a	AS b	Control	Mean
Grains yield	100%	4.08	5.75	4.08	6.44	3.95	4.86
	75%	4.74	7.18	7.30	8.17	3.97	6.27
	50%	2.75	4.11	2.61	3.93	1.82	3.04
	Mean	3.85	5.68	4.66	6.18	3.24	
	LSD _{0.05}	M=.947 N=n.s. MxN= 2.118					
Straw yild	100%	25.73	27.33	22.77	27.23	23.99	25.41
	75%	16.81	17.60	19.41	24.35	14.06	18.44
	50%	13.27	14.00	13.49	14.15	10.10	13.00
	Mean	18.60	19.60	18.55	21.91	16.50	
	LSD _{0.05}	M=2.427 N=n.s. MxN=n.s.					
Grains /straw	100%	0.15	0.21	0.12	0.23	0.16	0.18
	75%	0.28	0.40	0.37	0.33	0.28	0.33
	50%	0.20	0.29	0.19	0.27	0.18	0.22
	Mean	0.21	0.24	0.24	0.27	0.20	
	LSD _{0.05}						

Control = Without N fertilization, U= urea, AS= ammonium sulphate, a= one dose, b= two doses

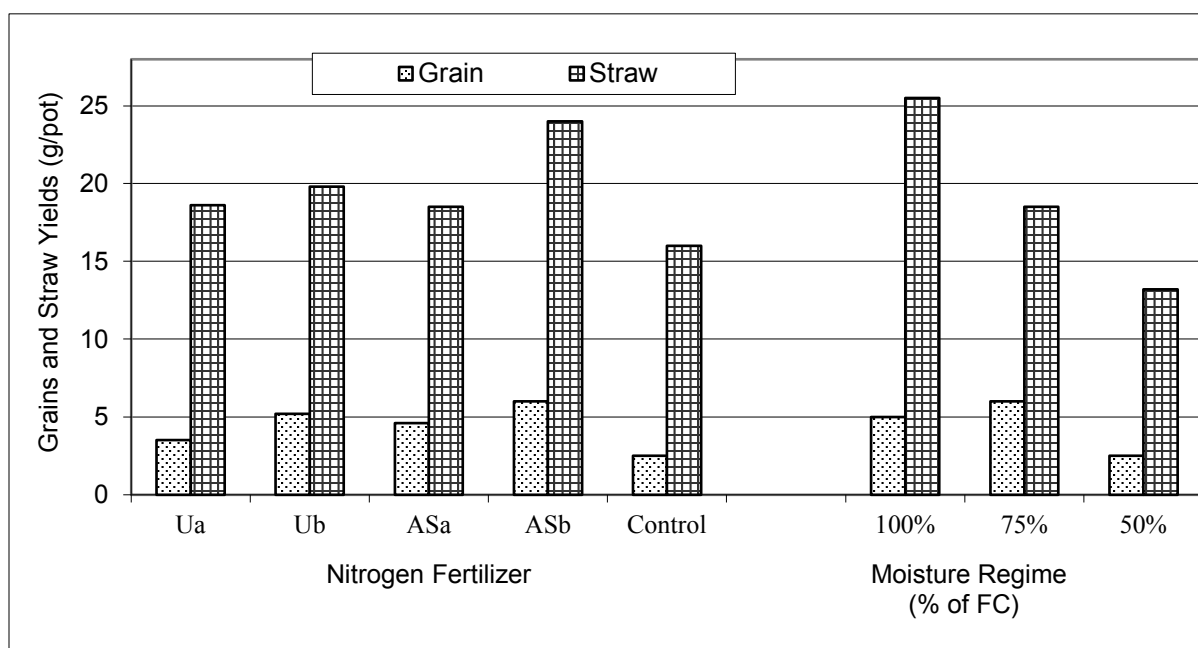


Figure 5. Effect of soil moisture regime and nitrogen fertilization on grain and straw yields of barley.

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Oral cancer knowledge and awareness among dental students at Sirte University

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Abstract

Oral cancer is a multifactorial disease that belongs to a larger group of cancers commonly referred to as head and neck cancers. The alarming increase in incidence rate of oral cancer globally has made it a major public health issue, in which prevention and early diagnosis are the best ways to reverse this situation. A dental practitioner's ability to recognize signs and symptoms of the malignancy in its early stage is crucial. **Aim:** To assess the knowledge and attitude of undergraduate dental students about oral cancer. **Material and Methods:** A cross-sectional study was conducted on third- and fourth-year students of the Faculty of Dentistry-Sirte University in Libya. A total 64 of students participated in the survey. This study is based on a questionnaire contains 40 questions about risk factors, clinical aspects, prevention and attitudes towards oral cancer. Data were collected and analyzed with SPSS18 using independent t-test. Significance level was considered as $p < 0.05$. **Results:** The vast majority of students identified smoking tobacco use and alcohol as the major risk factors for oral cancer. Squamous cell carcinoma was listed as the most common cancer by 91.8% of students, and the tongue and floor of the mouth are the most likely sites. Non-healing ulcer was recognized as the common clinical change pertaining to oral cancer. While the majority showed willingness to advise their patients on risk factors. More than 92.2% of students admitted that they need further information regarding oral cancer. **Conclusions:** The findings of the present study suggest that there is a need to reinforce the undergraduate dental curriculum with regards to oral cancer education, particularly in its prevention and early detection.

Keywords: Dental students - awareness - oral cancer-Sirte University.

1. Introduction

Oral Cancer (OC) is the cancer that affects the lips, the floor of the mouth, the lining of the cheeks, the gums, the tongue, or the palate ⁽¹⁾. The incidence of oral cancer is notably rising, especially in developing countries ^(2, 3). It is the sixth most common cancer in the world and accounts for approximately 2% of cancer-related deaths worldwide ⁽⁴⁾, with an estimated 657,000 new cases of

oral and pharyngeal cancer and more than 330,000 deaths each year ⁽⁵⁾.

The etiology of OC has been linked tightly to excessive consumption of alcohol, tobacco products and chewing betel. A combination of these factors significantly increases the risk of developing oral cancer ⁽⁶⁻⁸⁾. Other risk factors have been suggested including human immunodeficiency virus (HIV), human papillomavirus (HPV), candida infections, unhealthy diet, and regular use of alcohol containing mouthwashes ⁽⁹⁾. Men are more likely to develop oral cancer than women. Moreover, it predominantly affects people older than 40 years and more prevalent in low socioeconomic groups ^(10, 11).

More than 90% of oral cancers are squamous cell carcinomas (SCCs), Twenty percent of SCCs are originated from or associated with previous premalignant lesions including leukoplakia, erythroplakia, and submucous fibrosis. With a prevalence of 2.6%, leukoplakia occurs in patients aged over 50; while the prevalence of erythroplakia is lower, ranging from 0.02% to 0.1% ⁽³⁾.

An aspect that attracts attention is that the number of patients arriving at oral diagnosis services with advanced disease is very alarming, and since oral cancer is generally asymptomatic at early stages, patients usually fail to identify the problem and do not seek professional help early enough ⁽¹²⁾. Thus, treatment becomes more difficult, sometimes leading to patient disfigurement, psychological trauma and dysfunction, affecting prognosis and quality of life. Therefore, despite the significant progress in the treatment of SCC, the five-year survival rate has not been considerably raised since 50 years ago ⁽³⁾. Variables such as comorbidities, nutritional or immune status, tumor site, and oncogene expressions are reported, but the disease stage at diagnosis remains the most important prognostic indicator for oral cancer.

The causes of late diagnosis include unpreparedness of dental professionals without specific training to diagnose cancer at early stages and misinformation of the population about health care ^(2,13). The early diagnosis is essential to achieve the best results, it reduces rates of morbidity, mortality and mutilation, increases the quality of life and lowers treatment costs. To achieve this, it is important that health professionals, especially dentists, perform oral cancer examinations as part of their clinical practice and be especially aware of not only the pathogenesis of the disease, but also the first clinical signs ^(14, 15).

It is expected that dentists, on top of having an extensive understanding of the etiology of oral and clinical aspects of cancer, feel able to make a prompt diagnosis of this condition. Nevertheless, some studies have suggested that these professionals are not able to adequately detect oral cancer in its early stages due to their ineffective attitudes and lack of knowledge ⁽¹⁶⁻²¹⁾. Additionally, information regarding the performance of dental students on this issue tends to be limited and unsatisfactory ^(2, 3, 13, 21-23).

The above issues as well as the importance of this subject derived us to study dental student's knowledge about oral cancerous lesions, because well understanding of this issue during education could affect their inclination to examine their patients aiming at finding mouth cancer signs in future. Therefore, the primary objective of this study was to assess the knowledge of dental students regarding the risk factors, clinical aspects and their attitudes about oral cancer and to assess their awareness of the prevention and early detection of oral cancer.

2. Material and Methodology

A cross-sectional study was conducted on third- and fourth-year students of the Faculty of Dentistry-Sirte University in Libya. For the purpose of this research, a questionnaire was taken from the study of **Carter and Ogden**⁽³⁾ and modified. A total 64 of students participated in the survey, each student gave a verbal consent for use of the data for research purposes. Oral cancer awareness, knowledge about risk factors, signs and symptoms of oral cancer, attitude and practices towards oral cancer were assessed using 40 questions. The questionnaire was distributed, after lecture hours, to a total of students, the objectives of the study were explained to the students before administration of the questionnaire. The students were informed that no incentives would be provided for participation in the study and that their personal data would not be disclosed. Participants were given enough time to complete the questionnaire.

Statistical Analysis:

Data were analyzed using descriptive statistics (frequency, percentage, mean and standard deviations) using chi-squared test in the SPSS version 18. Any difference and/or relationship found were considered significant at $P < 0.05$.

3. Results

Questionnaires were distributed in a total of 64 students, out of which 21.9% (n=14) were males and 78.1% (n= 50) were females. All questionnaires were returned and response rate was found to be 100% as students who participated were instructed to answer all the questions. As the objective of the study was to assess the participants' knowledge, the responses 'No' and 'do not know' were combined into one response, 'No', during the statistics analysis.

Regarding knowledge on risk factors of oral cancer, students of both years gave a great number of different answers. The distribution of various risk factors is shown in (Table 1). There was no statistically significant difference in identification of smoking, tobacco use and alcohol as a risk factors for oral cancer between both groups of students (96.8% ,95.3% ,90.6% respectively of total student body altogether). However, the students of the fourth year showed statistically significant difference (third year 17.8% and fourth year 77.8%, ($p = 0.000$) in identification of sun exposure in the case of lip cancer as a risk factors.

With reference to the diagnostic knowledge, the majority (91.8%) knew that squamous carcinoma is the most common form of oral cancer. When asked to state the most common site in the mouth for oral cancer, 82.1% third year students reported that the tongue is the most common site for oral cancer, followed by the floor of the mouth 42.8%. By comparison, fourth year students reported that the floor of the mouth is the most common site for oral cancer 72.2%, followed by the tongue 36.1%. However, only 68.6% of the students were aware that oral cancer is most often diagnosed at an advanced stage. No statistical correlation was noted according to academic year ($p > 0.5$).

In response to the information related the clinical presentation of oral cancer, the commonly identified cancerous change in oral mucosa was non-healing ulcer (90.6%) was the most frequent change identified, followed by red patch (87.5%) and white patch (82.8%). No statistically significant between the students 'knowledge about clinical signs of oral cancer, other oral mucosal changes associated with oral cancer are shown in (Table 2).

Practices and opinions of dental students regarding oral cancer screening and prevention are illustrated in (Table 3). About 57.8% reported that they would advise their patients on risk factors for oral cancer in the future and 87.5% of the respondents routinely recorded their patients' tobacco and alcohol consumption habits during history taking, with no significant differences according to the academic year.(20.3%) of the students reported performing routine oral examination during routine visits, 8.3% of students of fourth year and 3.1%, of students of third year reported that they had the opportunity to examine patients with oral lesions.

Regarding the knowledge on prevention and early detection of oral cancer 67.9% of the third year students and 47.2% of the fourth year students, respectively, felt that they did not have sufficient knowledge (Table 3). Majority of the respondents (92.2%) wanted to have additional knowledge and information on different aspects of oral cancer such as patient counselling, clinical presentation of oral cancer, its management and treatment. With lectures and seminars being the most popular forms of further information shown in (Figure1).

For referring patients and who should treat patients suspected with oral cancer lesions, it was noted that oral maxillofacial surgery department (26.6%) was the most preferred by both third and fourth year students, followed by oral medicine department(23.4%) (Figure 2).

Table 1: Knowledge of the Risk Factors among Students According to the Academic year (Yes answer)

Variable	Third year n=28 Students N (%)	Fourth year n=36 Students N (%)	Total N (%)	Mean	P-value
Tobacco	26 (92.8%)	35 (97.2%)	61(95.3%)	1.2	.421
Smoking	27(96.4%)	35(97.2%)	62(96.8%)	1.2	.859
Alcohol	26(92.9%)	33(91.7%)	58(90.6%)	1.1	.861
Immunosuppression	24 (71.4%)	21 (58.3%)	45(70.3%)	1.2	.572
older age	21 (75%)	29 (80.6%)	50(78.1%)	1.3	.751
viral infection	22 (78.6%)	25 (69.4%)	47(73.4%)	1.5	.877
Sun exposure	5 (17.8%)	28 (77.8%)	33(51.6%)	1.8	.000
family history of cancer	20 (75.4%)	25(69.1%)	45(70.3%)	1.4	.572
low consumption of fruits	16 (57.1%)	20 (55.6%)	36(56.2%)	1.5	.568
Poor oral hygiene	15(53.6%)	18(50%)	33(51.6%)	1.4	.877
Obesity	10(35.7%)	12(33.3%)	22(34.4%)	1.2	.198

Independent t Test.95% Confidence Interval of the Difference.

Table 2: Rate of students' answers to the questions concerning main clinical aspects of oral Cancer:

	Thirdyear n=28 Students N (%)	Fourthyear n=36 students N (%)	Total Mean	P-value
Non-healing ulcer	25(89.3%)	35(97.2%)	60(93.8%)	1.2.199
White lesion	23(82.1%)	30(83.3%)	53(82.8%)	1.1.902
Red lesion	24(85.7%)	32(88.8%)	56(87.5%)	1.1.903
Speckled	20 (71.4%)	28(77.7%)	48(75%)	1.2 .568
Swelling	24(85.7%)	35(97.2%)	59(92.2%)	1.2.199
Numbness	20(71.4%)	26(72.2%)	46(71.9%)	1.3.567
Bleeding	12(42.8%)	24(66.6%)	36(56.2%)	1.4.443

95% Confidence Interval of the Difference.Independent t Test

Table 3:Practices and Opinions of the Students Regarding Oral Cancer Screening

3 rd year students N (%)	4 th year students N (%)	Total N (%)	P-value
Practices:			
I will advise my patients about OC risk factors	24(85.7%)	30(83.3%)	54(84.4%)NS
I always ask my patients if they use tobacco or alcohol	23(82.1%)	33(91.7%)	56(87.5%)NS
My patients sufficiently know signs and symptoms of OC	13 (46.4%)	16 (44.4%)	29(45.3%)NS
I examine patients' oral mucosa routinely	5 (17.9%)	8 (22.2%)	13 (20.3%) NS
I always screen the oral mucosa of high risk patients group	13 (46.4%)	22(61.1%)	35 (54.7%) NS
I had had the opportunity to examine patients with oral lesions	2 (7.1%)	3 (8.3%)	5(7.8%)NS
Opinions:			
I have sufficient knowledge about prevention and detection of OC	9 (32.1%)	19 (52.8%)	28(43.8%) NS
knowledge level about clinical appearance of oral cancer:			
a. Very well informed	1(3.6%)	3 (8.3%)	4(6.3%)
NS			

b. Well informed	4 (14.3%)	11(30.6%)	15(23.4%)	NS
c. Adequately informed	10 (35.7%)	9 (25%)	19(29.7%)	NS
d. Poorly informed	13 (46.4%)	13 (36.1%)	26 (40.6%)	NS
I would you like more information oral cancer	26 (92.9%)	34 (91.7%)	60 (92.2%)	NS

OC = oral cancer, NS = Not significant

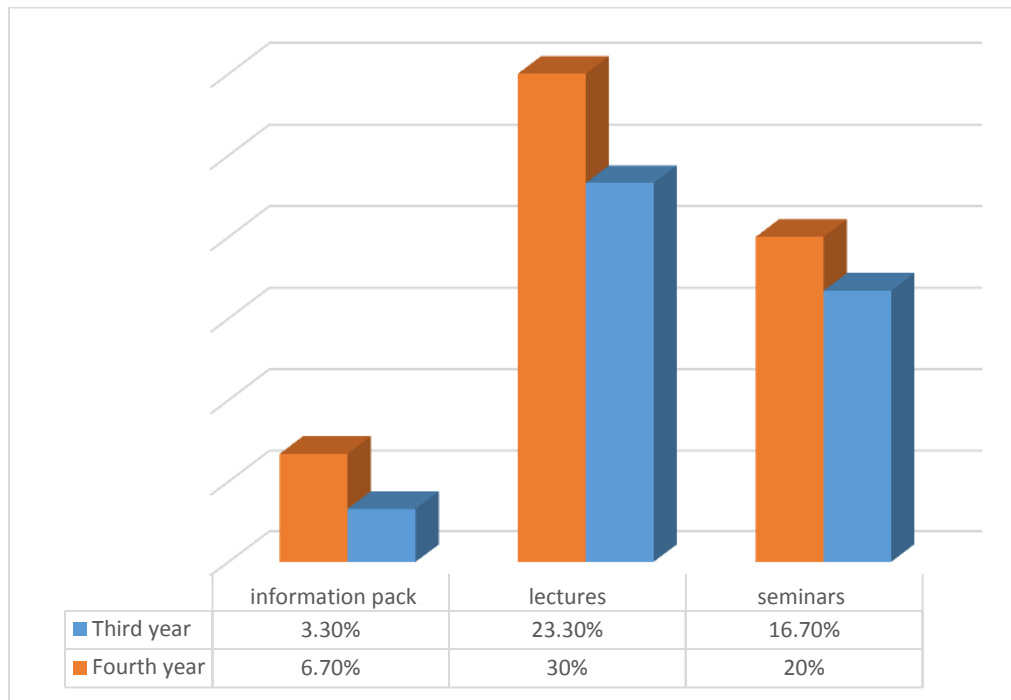


Fig.(1) : Source of Information Requested by Students According to the Academic Year

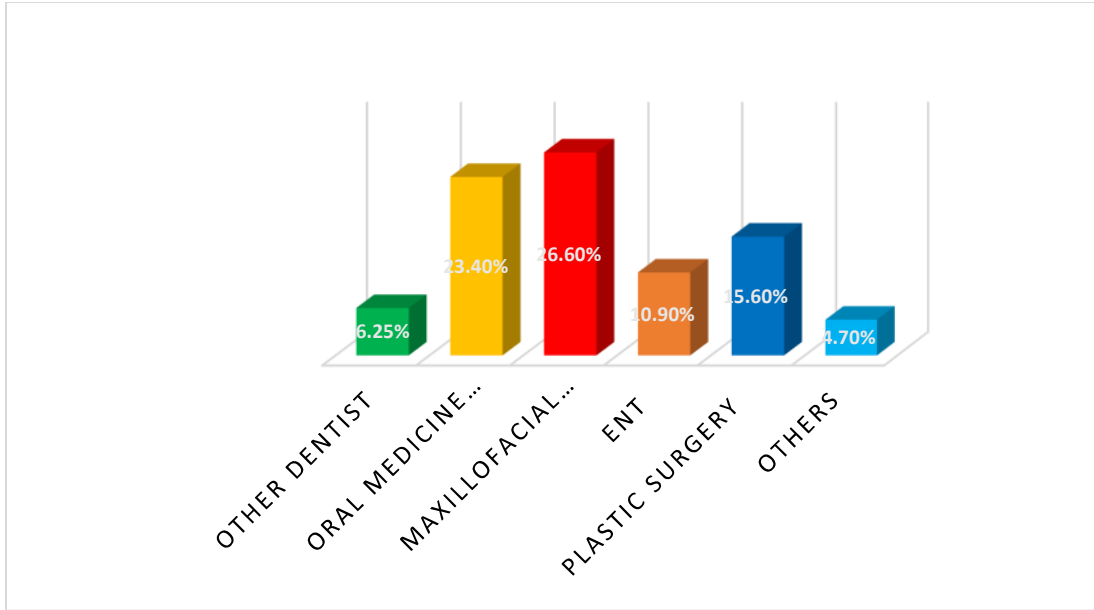


Fig.(2):Point of Referral Selected by Dental Students

4. Discussion

The early diagnosis of oral cancer is crucial to achieve the best results since it reduces rates of morbidity and mortality and increases the quality of life ⁽¹⁴⁾. Nevertheless, some studies have suggested that these professionals are not able to adequately detect oral cancer in its early stages due to their ineffective attitudes and lack of knowledge ⁽²¹⁾.

In addition, information regarding the performance of dental students on this issue tends to be limited and unsatisfactory ^(2, 3, and 21). Thus, the aim of this study is to investigate the knowledge of dental students regarding the risk factors, clinical aspects, and their attitudes about oral cancer.

The majority of participants were female, accounting for 78.1%, with mean age of 22.7 years. The results found here are similar to those reported by **Lima et al.** ⁽²⁴⁾,

Martins et al. ⁽²⁵⁾ and the most individuals included in the sample were non-smokers, which is an important feature when considering preventive attitudes on oral cancer, because it is much easier for a nonsmoker professional to establish guidance measures to combat smoking among patients ^(25,26).

Although the vast majority of students identified smoking, tobacco use and alcohol as the main risk factors, similar to previous studies done in Yemen ⁽²⁷⁾, Kuwait ⁽²⁸⁾, Saudi Arabia ⁽²⁰⁾ and Iran ⁽¹³⁾ a considerable proportion of students were not aware that, sun exposure, HPV, low consumption of fruits, prior oral cancer lesions, obesity, and other lifestyle factors are also potential risk factors. Most of oral cancer cases occur in patients 40 years or older, with most patients at the time of diagnosis being at their sixties, about 78% of students indicated older age as a potential risk factor for development of oral malignancy. These results highlight the need to revise the current curriculum

with emphasis on oral cancer risk factors. As expected, fourth year dental students showed better knowledge regarding some items of risk factors, probably due to curricular factors making them more exposed to topics related to oral cancer, which is in accordance with previous reports .

Regarding the most common mouth cancer type, location and stage of diagnosis,(91.8%) identified squamous cell carcinoma as the most common type of oral cancer, and they identified tongue and floor of the mouth as the most common sites of oral cancer, these findings are consistent with previous studies among dental students elsewhere^(3,28-30) . Slightly more than two thirds of the students knew that oral cancers are most often diagnosed in the advanced stage in contrast to half of the students in most of the other surveys^(30, 31). A review of Hospital Cancer Registry (HCR) reveals that 60% of individuals come to services with advanced disease, when the chances for cure are greatly reduced and treatment is expensive ⁽²⁵⁾. These data may reflect the lack of professional knowledge in early detection of oral cancer as well as limited access to health units and services provided to the population, especially in the dental field ⁽²⁵⁾. Early recognition of the most common clinical presentations of oral cancer is of utmost importance in the diagnosis of oral cancer, regarding clinical manifestations of oral cancers, 93.8% of students believed that ulcers that lasted for more than 2 weeks and had irregular margins were the signs of oral cancers. In previous study ⁽³²⁾, ulcers lasting for more than two weeks were reported to be due to oral cancers with the highest frequency, these results have been confirmed by studies in UK ⁽¹³⁾,and Nigeria ⁽³³⁾.However, red lesion was identified by a higher percentage of students (87.5. %) in comparison to white lesion (82.8%), although both lesions have malignant potential. The significance of red lesion, white lesion and mixed lesion (red and white lesions) needs to be emphasized in future teaching of both medical and dental students.

As oral cancer can be prevented by controlling risk factors such as smoking, use of tobacco and consumption of alcohol, it is necessary that dentists educate their patients on the importance of quitting these behaviors. It is encouraging that majority of students (84.4%) in our study indicated a willingness to deliver advise to their patients in the future regarding risk factors of oral cancer. In our study, a surprisingly high number of students responded that they rarely have an opportunity to see patients with potentially malignant lesions(7.8%).This is consistent with previous studies of dental and medical students where confidence about oral cancer knowledge was attributed to a lack of training ^(3, 31). Emphasis on hands-on training for oral cancer examinations is critical for improving dental students' skills and confidence in this area.

In line with other studies^(3,13), only a few students either felt very well or well informed regarding clinical appearance of oral cancer, and around56.3% of students felt they did not have sufficient knowledge regarding prevention and early detection of oral cancer. In the present study, more than 92.2% of students admitted that they need further information regarding oral cancer, which is very similar to the results of previous studies ^(3, 13, and 30). The most wanted types of information reported by our students were lectures and seminars.

Maxillofacial surgery and Oral Medicine were the most commonly selected proposed points of referral for patients with a suspected oral cancer, which confirmed results of previous studies from Iran⁽³⁾, UK⁽¹³⁾, Yemen⁽²⁷⁾ and Kuwait⁽²⁸⁾. **Hollows et al.** in his study, concluded that majority of the medical and dental practitioners refer suspected patients to oral maxillofacial surgery department within a week, as delays in referral to appropriate department can significantly affect the prognosis of the disease⁽³²⁾.

Some limitations of the study included small the sample size. A survey with a larger sample size and more universities across the country will give more insight into the actual requirement of awareness on the subject of oral cancer and improvements that are required in our teaching strategies nationwide.

5. Conclusions

The role of dental practitioners in early detection and prevention of oral cancer is very important. A dentist is often the first to see suspicious but asymptomatic oral lesions, Therefore dental students should get sufficient knowledge during their undergraduate education about clinical appearance, risk factors and prevention of the oral cancer. Smoking, tobacco use and alcohol consumption are the main risk factors for oral and oropharyngeal cancers and dental practitioners should be included in risk advising and screening programs. This study highlights the need to improve dental students' knowledge about the appearance of oral cancer, and appropriate early diagnostics of patients with such oral lesions as well as strengthening the curriculum in practical and theoretical classes.

RECOMMENDATIONS:

Our study highlights that students prefer interactive methods of teaching over the traditional lectures, hence, our teaching methodologies should be modified accordingly.

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Level of Awareness of Maintaining Dental Records Among Dental Practitioners in Sirte, Libya: Are we Ready for Forensic Odontology?

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Abstract

Objective: To determine the quality of maintained dental records and analyze the knowledge and use of them in any of forensic or medico-legal purposes by Sirte's dental practitioners. **Materials and Methods:** A cross-sectional survey was conducted in a sample of 70 dental practitioners in Sirte and data were collected through a structured questionnaire. The data so gathered were subjected for descriptive analysis.

Results: 80 % of surveyed dentists maintained records but only 10% of them kept the complete dental record. When asked about duration of maintained records, 61% of them kept for less than three years. About 56% of sample used paper prepared form as method to maintain dental records and only 20% used computer software. 91% of practitioners did not think that mandatory to legally maintain the dental records, when asked about whether the legal rights of owning the dental records in Sirte is it medico-legally important, 98% response was yes. The significance of dental records for forensic needs was evaluated, only 18% dental practitioners were asked to produce any records in forensic court of law. Only 3% asked to produce dental file for forensic purposes. 55% of practitioners did not know how to estimate the age of individual. About 94% of sample did not have any training in forensic dentistry. All the surveyed dentists' response was yes, when asked about the importance of forensic dentistry in Libya.

Conclusion: The present study showed Non-maintenance or poor quality of dental records maintained. Our study revealed that the dentists in Sirte are not prepared for any kind of forensic and medico-legal need if it arises due to the poor knowledge, attitude and lack of practice of forensic odontology.

Keywords: *Dental record, Forensic odontology, Sirte's dental practitioners.*

1. Introduction

Dental record is the official detailed document that records all history of the illness, clinical notes, diagnosis, treatment performed that occur in the dental office, including instructions for home care and consent to treatment.

The primary purpose of keeping dental records is fundamental for good quality patient care and means of communication between the treating dentist and any other doctor who will care for that patient. Dental records also have an important role in teaching and research. Since dental remains are usually the last to get destroyed among body parts after death, so dental record may be useful for personal identification in cases of mass disasters, decomposed unidentified bodies and assisting at the scene of crime (Lawney, 1998).

Forensic odontology is branch of forensic science with a broad field of activities. It involves the application of the art and science of dentistry in the identification of carbonized human remains through the comparison of antemortem data - with the postmortem data.

The significance of forensic odontology can be attributed to the ability of the dental tissues to withstand environmental assaults and still retain some of its original structure. This makes teeth an excellent and an accurate source for DNA material (Pretty and Sweet, 2001).

Maintenance of dental records is legally mandatory in most of the European and American countries (ADA, 2004).

Unfortunately, the law of maintenance of dental records are not very clear in Libya and most of the dentists maintaining a poor quality or no dental record at all. Because of that we conducted this survey to determine the level of awareness of Sirte's dental practitioners for importance of dental records and to reinforce them for strict fulfillment of clinical protocols that will provide not only elements for adequate clinical diagnosis and planning, but also for forensic purposes in processes of human identification.

Significance of the Study: This will be considered the first study done in Libya regarding to the quality of oral health record-keeping in clinics as well as the level of knowledge, attitude and practice of medico-legal and forensic odontology.

2. Material and Methodology

A cross-sectional study was conducted among seventy practicing dentists who were selected randomly from different government and private clinics of Sirte city, Libya. The nature and purpose of the survey was explained, and consent was obtained. Each practicing dentist was received his or her questionnaire and data was collected in a personalized manner. A 11-item structured questionnaire was developed to assess the mode of dental records maintenance among dental practitioners. Questionnaire is shown in tables 1.

Statistical analysis was performed using the Statistical Package for Social Science (SPSS) computer software (SPSS 17.0, SPSS Inc., Chicago, USA).

The questionnaire was pre-tested to assess its reliability, which was found to be satisfactory. Test of reliability comprised of question-question reliability, which was assessed by the percentage of agreement (90%). There was no need for any test of significance here as this was a descriptive study.

3. Results

Gender ? A. Male B. Female

Thirty-seven percentage of our sample was male, while female recorded as sixty-three percentage of surveyed practitioners.

How many years of experience in dental field?

A. 0 – 3 years. B. 3 – 10 years. C. more than 10 years.

Dentists with experience three to ten years recorded as fifty-one percentage, while thirty-five percentages of them have more than ten years practice dentistry.

Do you maintain dental records?

Eighty percent of surveyed dental practitioners maintained dental records. Twenty percentage of study sample did not keep dental records in their clinic at all.

Which of the following dental record are maintained?

Surprisingly, complete dental record maintained only by ten percent of surveyed practitioners.

How long time of maintenance of dental records?

When asked about duration of maintained dental records by dentists, sixty-one percent of them kept for less than three years.

What were methods used to maintain dental record?

About fifty-six of sample used paper prepared form as method to maintain these records and only twenty percent of dentists used computer software to keep their patient's records.

Is keeping records legally bound?

Ninety-one percentage of surveyed practitioners response was no, when asked about whether in Sirte is it mandatory to legally maintain the dental records.

Is dental file medico legal importance?

When asked about whether the legal rights of owning the dental records in Sirte is it medicolegally important, 98% response was yes.

Even been asked to produce dental file for medico legal cases?

The significance of dental records for forensic needs was evaluated, only eighteen percent dental practitioners were asked to produce any records in forensic court of law.

Even been asked to produce dental file for forensic purposes?

Very low percent of dentists about three when asked to produce dental file for forensic purposes.

Can you determine the dental age of patient by examining the teeth?

Fifty-five percentages of practitioners did not know how to estimate the age of individual by examining the teeth.

Have you had any training in forensic dentistry?

Majority of sample about ninety-four percentages did not have any training in forensic dentistry.

Are you aware of the importance of forensic dentistry in Libya?

Hundred percent of surveyed dentists response was yes.

4. Discussion

The maintenance of complete dental records professionally which including the personal data, relevant medical, dental history, photograph, radiograph, dental cast, clinical finding, diagnosis and treatment plan became the most important factor needed to protect the dental practitioners against any medicolegal, commercial and legal litigation (Charangowda , 2010).

There are many significant applications of forensic odontology including human remains identification following mass disaster situations that may arise from natural or manmade circumstances through dental records. In addition to that, assist in the identification of suspect in criminal investigations and in medicolegal cases. Furthermore, testify as an expert witness in the court to present forensic dental evidence. With growing field of medicine, the awareness and attitude of dental practitioners toward forensic odontology is essential.

Many victims with severe burn situations and/or following severe disintegration were unidentified. Because visual recognition of facial features and fingerprints is often impossible due to extensive destruction of soft tissue. The identification of these victims could have been made possible if there were adequate forensic odontologists who use the hard (calcified) tissue such as human teeth and bones of jaw for human identification (Valenzuela *et al.*, 2000).

In number of developed countries, the significant applications of forensic odontology have gained importance. While in developing countries like Libya, the practice of forensic odontology is yet very low.

The requirement of the dental records is not always maintained for a forensic purpose only, but also consider as future reference for the practitioners when needed. The level of awareness of the public regarding legal cases involving healthcare has been dramatically increased. This warrants for any dental practitioner to have a thorough knowledge of dental record issues (Charangowda , 2010).

The results of our study did not find any significant relations between gender or duration of experience with quality of dental record maintenance. This survey was conducted among the dentists to assess their knowledge about importance of keeping dental records and the result of this assessment showed that the majority of the dental practitioners were aware of the importance of keeping dental records. Surprisingly, only ten percentages of practitioners maintain complete records and sixty-one percent kept dental records for less than three years. This was in the comparison with the duration of record maintenance as stated by the law, which is range from seven to ten years (Neville *et al.*, 2004).

This survey also showed the awareness of mandatory to legally maintain dental records, majority of dentists answered that it is not mandatory to keep records. Regarding the forensic odontology, the results show that the awareness of forensic dentistry among the dentists is not adequate.

One of the essential factors in the identification of a person is age. Human age estimation is a procedure adopted by forensic scientists and anthropologists (Balwant Rai, 2006; Singh *et al.*, 2004). About Fifty-five percent dental practitioners did not know how to estimate the dental age of individual by examining the teeth. This may be attributed to the lack of basic knowledge about dental age.

The result of our study was in agreement with another study done by Osborn *et al.* (2000) to assessed the quality of keeping of dental record where used questionnaire to survey a random sample of 750 dental practitioners from Minnesota state. Kept of dental record was based to the guidelines of ADA. They concluded that the dentists maintained inadequate dental record components.

Helminen *et al.* (1998) designed a study on the sample consisted from Finnish dental practitioners who were born in 1966-1971. Dental record maintained according to the instructions of Finnish health legislation and the study done to evaluated the quality of maintenance of dental record. The results of the analysis showed that the dental practitioner with age younger than 37 years and female dentists tended to record complete dental record. In addition to that dental record of each patient was available in 90% of documents.

Borrman *et al.* (1995) carried out study to investigate the maintenance of dental records of cases in forensic medicine department in Göteborg between 1983 and 1992. Dental record maintained according to the National Board of Health and Welfare. The outcomes of the study showed that the complete dental records were in sixty-eight percentage of sample, incomplete record were in twenty-seven percentage and no record at all in five percentage.

However the outcomes of our survey suggest that the dental practitioners in Sirte, Libya, either don't have dental records or have the ones which are inadequate. This indicates that these dentists are not at all prepared for any kind of medico legal and forensic needs. This result also sends an alarm for raise the level of awareness for keeping good quality dental records.

The overall quality of record-maintaining was poor, and this result was in agreement with the findings suggested by worldwide studies (Osborn *et al.*, 2000; Helminen *et al.*, 1998; Borrman *et al.*, 1995; Delattre and Stimson, 1999; Morgan, 2001).

From the results of these studies, the inadequacies and inaccuracies of guidelines and systems of many existing dental record, which do not prompt the dental practitioners to keep good quality of recording, a new form of record guidelines should be made available to encourage the dentists for what should be routinely recorded.

A proper system document on maintaining dental in dental practice should be designed (Ireland *et al.*, 2001). To achieve the improvement in keeping the standard of maintaining record, proper education is to be given among undergraduates (Pessian and Beckett, 2004) and postgraduates and also increase the level of awareness in dental practitioners (Cole and McMichael, 2009).

There are many responsibilities of dental practitioners which include production, retention, and release of accurate dental records. Practicing dentists can become valuable members of the dental identification process which considered as large part of the science of forensic odontology (Samadi *et al.*, 2009).

5. Conclusions

The present study showed Non-maintenance or poor quality of dental records maintained. Our study revealed that the dentists in Sirte are not prepared for any kind of forensic and medico-legal need if it arises due to the poor knowledge, attitude and lack of practice of forensic odontology. However, the study was done in Sirte city, the story is not much different in other cities and it can reflect the existing picture of the whole Libya.

Recommendations:

From the results of our study, further researches with larger sample size are required to determine the level of awareness of significant implications of dental records. The result of inadequate maintenance of dental record components should be targeted to encourage the dental practitioners to better utilize the significant implications of dental records.

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Table 1: Questionnaire used in the study.

Questionnaire used in the study:
Gender A. Male. B. Female.
How many years of experience in dental field? A. 0 - 3 years. B. 3 - 10 years. C. more than 10 years.
Do you maintain dental records? Yes/No
Which of the following dental record maintained? A. Personal data. B. Medical and Dental history. C. Study Models. D. Photographs. E. Radiographs. F Clinical notes. G. Diagnosis. H. Treatment plan.
How long time of maintenance of dental records?
Record maintenance by A. Prepared form. B. software. C. Both.
Is keeping records legally bound? Yes/No
Is dental file medico legal importance? Yes/No
Even been asked to produce dental file for medico legal cases? Yes/No
Even been asked to produce dental file for forensic purposes? Yes/No
Can you determine the dental age of subject by examining the teeth? Yes/No
Have you had any training in forensic dentistry? Yes/No
Are you aware of the importance of forensic dentistry in Libya? Yes/No

A review of the relationship between chronic periodontitis, obesity and diabetes mellitus

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Abstract

The increasing incidence of chronic periodontitis (CP), obesity and diabetes mellitus (DM) worldwide imposes a rethinking of the interrelation and their pathogenesis. The current review discusses the pathogenesis of diabetes mellitus, obesity and chronic periodontitis with emphasis on the relationship between them.

Keywords: *Chronic periodontitis, obesity and diabetes mellitus*

1. Introduction

The human organism is a unity that is composed by an infinite number of biologic processes so strongly linked that abnormalities in any part of the body and/or its processes may have deep effects in many other body areas[1], for example as in this review, the three highly prevalent diseases: chronic periodontitis, obesity and diabetes mellitus.

2. Chronic periodontitis

Periodontal disease is an entity of localized infections that involve tooth supporting tissues, the structures that make up the periodontium (i.e., gingiva, periodontal ligament, root cementum, and alveolar bone). The designation periodontal disease includes both reversible (gingivitis) and irreversible (periodontitis) processes. In periodontitis, there is destruction of the connective tissue of the tooth attachment apparatus accompanied by apical migration of the apparatus and eventual tooth loss. The first clinical manifestation of periodontal disease is the appearance of periodontal pockets, which offer a favorable niche for bacterial colonization.[2]

According to the WHO the prevalence of severe chronic periodontitis varies worldwide from 10 to 15% in adult populations whereas complete edentulism (no natural teeth) varies from 10 to 35% among countries depending on national income [3]. The most common forms of periodontal diseases are plaque-induced gingivitis and chronic periodontitis. Gingivitis is defined as an inflammation of

the gingiva induced by bacteria located at the gingival margin. The host response to similar plaque levels varies significantly among patients with gingivitis and bacteria associated with disease progression are also present in health. Gingivitis is reversible upon removal of the etiologic biofilm but when untreated it progresses to chronic periodontitis in certain individuals. Several lines of evidence demonstrated that in some individuals gingivitis never progresses to chronic periodontitis, regardless of periodontal care.[4,5]

Periodontitis is essentially a biofilm induced disease, initiated and progressed by different bacterial species, present in the dental plaque. The periodontopathic bacteria are basically gram-negative in nature and they are present in the depths of periodontal pockets, placed at low oxygen tension. The putative pathogenic bacteria express noxious toxins instrumental for the periodontal destruction.[6] When bacterial biofilms on the teeth are not disrupted on a regular basis, the emergences of Gram-negative anaerobic bacterial species activate several host processes that will interfere in the extent and severity of the disease.[1]

The most frequently recognized periodontal pathogens belong to three microaerophilic species (*Actinobacillus actinomycetemcomitans*, *Campylobacter rectus*, and *Eikenella corrodens*) and seven anaerobic species (*Porphyromonas gingivalis*, *Bacteroides forsythus*, *Treponema denticola*, *Prevotella intermedia*, *Fusobacterium nucleatum*, *Eubacterium*, and *spirochetes*).[7]

Currently, the consensus regarding pathogenesis of periodontitis has undergone an immense change. According to this concept, periodontitis is not only the result of adverse microbial activity but as an interaction among various other factors like genetics, systemic health, immunity, environmental factors like tobacco and stress. The above mentioned factors play an important role in the modification of host response to the disease process. Thus, sometimes the periodontal disease may exhibit varied expression [6]. Various pro-inflammatory mediators like interleukin (IL)- 1 α and IL-1 β , IL-6, tumor necrosis factor (TNF)- α , prostaglandin E2 (PGE2), matrix metalloproteinases are expressed in periodontitis, as a result of activation of the host immune-inflammatory mechanisms. Cytokines are liberated by periodontal tissues like fibroblasts, endothelial cells, macrophages, osteoclasts, epithelial cells, neutrophils, monocytes, lymphocytes, and mast cells. Immune cells like neutrophils, monocytes also let out cytokines in inflammatory conditions. This host tissue expressed a large number of factors that may be detrimental to the host tissue itself, amplifying the destructive disease process [8]. The periodontopathogenic flora produce toxins and significant challenge is offered by lipopolysaccharide (LPS), a component of the gram-negative bacterial cell wall. LPS is a potent endotoxin which exacerbates the host inflammatory response. Subjects with periodontitis are reported to present endotoxin activity in the serum [9]. As discussed previously the bacteria are housed in the periodontal pocket. These bacteria, attended with their noxious products can gain a ready access through the ulcerated lining of the periodontal pocket, into the systemic circulation. Studies have identified many systemic biomarkers, exposing the link of periodontitis with systemic conditions and cardiovascular disease [10,11]. Thus, it can be enunciated that periodontitis is a “low

grade infection” capable of developing a “low grade systemic inflammation” with an ability to influence the general systemic health.

Chronic periodontitis being a low-grade infection is characterized by infiltration of the inflammatory cells within the periodontal tissues, which act as a source of production for resistin. Lipopolysaccharides produced by periodontal pathogens are shown to induce the resistin gene in macrophages via cascade involving the production of proinflammatory mediators [12]. Pro-inflammatory mediators (PGE2, TNF- α , IL-1, and IL-6) produced during the periodontal pathogenesis in addition to local tissue destruction also exert certain systemic effects [13].

Many conditions can predispose and/or facilitate the occurrence of periodontal diseases (PD) such as smoking[14], genetic influences[15], and obesity [16, 17]. The prevalence of obesity is increasing worldwide. This epidemic is also associated with an increased occurrence of obesity-related diseases like hypertension, cardiovascular disease, metabolic syndrome and diabetes mellitus that are also linked to periodontal diseases[16, 17].

3. Diabetes mellitus

Diabetes mellitus is a chronic, non-communicable disease and also one of the major global public health issues [18]. In 2014, it was estimated that 422 million adults were living with diabetes mellitus worldwide. The global prevalence of diabetes in the adult population has nearly doubled since 1980, rising from 4.7% to 8.5% [19]. Diabetes mellitus is a group of metabolic disorders that leads to hyperglycaemia and is classified into four general categories: type 1 diabetes mellitus (T1DM), type 2 diabetes mellitus (T2DM), gestational diabetes and other specific types of diabetes [20]. Diabetes mellitus is characterized by frequent episodes of hyperglycemia [21], which initiates chemical and molecular pathways associated with diabetes complications [22].

T1DM is a polygenic autoimmune disease that is characterized by the destruction of insulin-secreting pancreatic beta cells[23]. T2DM is a metabolic disorder that is characterized by hyperglycemia and altered lipid metabolism, which is caused by the inability of islet beta-cells of Langerhans to secrete adequate insulin in response to varying degrees of insulin resistance caused by over-nutrition, inactivity or obesity. Metabolic defects that contribute to the development of T2DM include an inability of islet b cells to compensate for high glucose levels that are associated with excess food intake, increased glucagon secretion and reduced incretin response, impaired expansion of subcutaneous adipose tissue, hypoadiponectinaemia, inflammation of adipose tissue, increased endogenous glucose production and the development of peripheral insulin resistance[24]. Chronic increased caloric intake is the primary pathogenic event that drives the development of type 2 diabetes in genetically and epigenetically susceptible individuals.[25,26].

In both types of diabetes mellitus hyperglycemia is directly related to pancreatic dysfunction and ultimately leads to macro- and microvascular complications including atherosclerosis, ischemic heart disease, nephropathy, retinopathy, neuropathy and periodontal disease. Uncontrolled

hyperglycemia is central to development of angiopathy through several biochemical and molecular mechanisms manifested in both intra- and extracellular compartments. The four major pathways through which hyperglycemia alters cellular physiology and extracellular matrix structure are the polyol pathway, the hexosamine pathway, activation of protein kinase c (PKC), and advanced glycation end product (AGE) formation. The first three pathways generally alter cellular function by acting directly on intracellular pathways while AGE directly impact the extracellular matrix quality and indirectly the normal cell function through specific receptors for AGE.[27]

4. Obesity

Obesity is a chronic disease[28].The prevalence of obesity is increasing worldwide and is becoming one of the most important health hazards [29], as obesity is highly associated with increased overall morbidity and mortality [30]. Obesity is defined with a body mass index (BMI; body weight in kilogram divided by the square of the height in meters (kg/m²)) of at least 30.0 kg/m² [31], whereas overweight is defined with a BMI of 25–29.9 kg/m². Normal weight is characterized by a BMI ranging between 19 to 24.9 kg/m² [32]. In 2002 WHO reported that over 200 million men and 300 million women were obese[33].Adipose tissue contains usually 5-10 % macrophages, but the adipose tissue of obese patients shows up to 60 % macrophage infiltration. Adipocytes secrete bioactive molecules called adipokines, that can modify or trigger inflammation and fat metabolism locally or systemically as signaling molecules to liver, muscle and endothelium. Therefore, the adipose tissue can be considered as an important metabolically active endocrine organ [32] This explains how obesity acts as a risk factor for several chronic diseases: Hypertension, type 2 diabetes, dyslipidemia, and coronary heart disease are so closely related to obesity that obesity itself is often considered to be a systemic disease. This disease also affects dental health [34]. Accordingly obese persons require attention of physicians and dentists [30].

5. Chronic periodontitis and diabetes mellitus

Chronic periodontitis has been identified as the sixth complication of diabetes alongside retinopathy, nephropathy, neuropathy, macrovascular disease and poor wound healing[35].where individuals with diabetes have a higher prevalence of periodontitis [36–38] and diabetes mellitus can increase the severity of periodontitis [39–41] and the severity of the periodontitis is always greater than individuals without diabetes [36,42].This is due to the following mechanisms: the function of immune cells, including neutrophils, monocytes, and macrophages, is altered in diabetes [43].Neutrophil adherence, chemotaxis, and phagocytosis are often impaired, which may inhibit bacterial killing in the periodontal pocket and significantly increase periodontal destruction[44,45].Although the function of neutrophils is often diminished in diabetes, the monocyte/macrophage cell line may exhibit upregulation in response to bacterial antigens. The

hyperresponsiveness of monocytes/ macrophages results in significantly increased production of proinflammatory cytokines and mediators[46-48]. Peripheral blood monocytes from diabetic subjects produce elevated levels of tumor necrosis factor-alpha in response to antigens from *Porphyromonas gingival* is compared to monocytes from non-diabetic control subjects[46]. also in diabetic patient there is inhibition of osteoblastic cell proliferation and collagen production that result in reduced bone formation and diminished mechanical properties of the newly formed bone[49-52]. Because the periodontal pocket is a site of persistent bacterial wounding, an intact wound-healing response is critical to maintain tissue health. High glucose levels in the gingival crevicular fluid may directly hinder the wound-healing capacity of fibroblasts in the periodontium by inhibiting attachment and spreading of these cells that are critical to wound healing and normal tissue turnover [53]. In individuals with sustained hyperglycemia, proteins become irreversibly glycosylated to form advanced glycation end products (AGEs) [54]. These stable carbohydrate-containing proteins have multiple effects on cell-to-cell and cell-to-matrix interactions and are commonly thought to be a major link between the various diabetic complications. The formation of AGEs also occurs in the periodontium, and higher levels of periodontal AGE accumulation are found in those with diabetes than in non-diabetic subjects[55]. AGEs often form on collagen, increasing collagen cross-linking and resulting in the formation of highly stable collagen macromolecules. These molecules accumulate in tissues due to their resistance to normal enzymatic degradation and tissue turnover [54]. Changes in collagen synthesis, maturation, and homeostatic turnover are common in diabetes. These changes can contribute to the pathogenesis of periodontal diseases and to alterations in wound healing because collagen is the major structural protein in the periodontium. Human gingival fibroblasts produce decreased amounts of collagen and glycosaminoglycans in high-glucose environments[56]. There is additional evidence emerging that decreases in matrix-producing cells critical to maintaining the periodontium, including fibroblasts and osteoblasts, occur due to an increased rate of apoptosis in a hyperglycemic state in response to *Porphyromonas gingivalis* infection [57-59]. The structural changes that characterize diabetic angiopathy include abnormal growth and impaired regeneration of vessels. The changes seen in the microvasculature of the retina, glomerulus, and other end organs in people with diabetic complications also occur in the periodontium[60].

periodontitis may be a risk factor for worsening glycemic control among patients with diabetes. Periodontitis may initiate or propagate insulin resistance in a manner similar to that of obesity, by enhancing activation of the overall systemic immune response initiated by cytokines[61,62].

A bidirectional relationship has been established between diabetes and periodontitis, where in one can influence the other [63]. Chronic subclinical inflammation has been shown to decrease the insulin sensitivity. Levels of resistin are found to be increased in periodontitis, and resistin plays an important role in inducing insulin resistance, thus increasing the risk for type II diabetes [64].

Periodontitis is also associated with an increased risk for diabetic complications. 82% of diabetic patients with periodontitis experienced one or more major cardiovascular, cerebrovascular or

peripheral vascular events[65]. Another study examined the effect of periodontal disease on mortality in more than 600 subjects with type 2 diabetes. After accounting for other known risk factors, the death rate from ischemic heart disease was 2.3 times higher in people with severe periodontitis than in patients without periodontitis or with only mild periodontitis, while the death rate from diabetic nephropathy was 8.5 times higher in those with severe periodontitis[66].

Periodontal treatment can adversely affect on glycemic control in diabetics where Periodontal treatment that reduces periodontal inflammation may help to restore insulin sensitivity, thereby improving glycemic control[38,62]. Studies of patients with both diabetes and periodontitis have shown that nonsurgical periodontal therapy with adjunctive local delivery of minocycline reduced circulating levels of TNF- α . The reduction in serum levels of TNF- α was closely related with, a significant decrease in mean HbA1c values (from 8% to 7.1%)[67].

6. Chronic periodontitis and diabetes mellitus

Obesity is a possible risk factor for periodontitis [68]. One study identified obesity even as the second strongest risk factor for periodontitis preceded only by smoking [69]. The first report on the relationship between obesity and periodontal disease appeared in 1977. Perlstein and co-workers found greater alveolar bone resorption in obese than in non-obese rats. Under healthy oral conditions, obesity itself did not promote periodontal damage, but in the presence of bacterial plaque accumulation periodontal inflammation was more severe in obese than in non obese animals. [70] In another study the researchers found that an increased prevalence odds ratio for obesity among subjects with periodontal disease and in clinical practice, a higher prevalence of periodontal disease should be expected among obese adults. [71].

Maintaining good oral health is also fundamental for obese individuals. Dental practitioners should educate their obese patients about the risk of periodontal disease and reinforce the importance of proper oral hygiene.[72]

A recent systematic review including a meta-analysis concluded that obese and overweight/obese individuals together are 1.8 times and 2.3 times more likely to suffer from periodontitis independent of traditional risk factors in comparison with normal-weight control individuals, respectively[73].

Obesity has been shown to be associated with adverse post-surgical outcomes such as infectious complications and compromised healing[74, 75]. The hypothesis of altered immune response and wound healing associated with obesity raises the question of a possible modifying effect of obesity on periodontal therapy clinical response .

The biological mechanism by which obesity predisposes to periodontitis is not fully understood[68]. Compared to individuals with normal weight individuals with obesity have higher levels of circulating tumor necrosis factor- α and interleukin-6 (IL-6), which are also secreted from adipose tissue and are involved in the pathophysiology of both obesity and periodontitis. Not surprisingly, serum levels of these cytokines decrease with loss of weight [76].

Adipocytokines are bioactive mediators released from the adipose tissues including adipocytes and other cells present within fat tissues. These include several novel and highly active molecules released abundantly by adipocytes like leptin, resistin, adiponectin, and visfatin, as well as some

more classical cytokines released possibly by inflammatory cells infiltrating fat, like TNF- α , IL-6 and IL-1 [77].

Adiponectin is a product of adipocytes and its levels decrease in obese subjects. Adiponectin has several beneficial effects like anti inflammatory, vasoprotective and antidiabetic effects. These protective effects occur due to suppression of tumor necrosis factor- α , interleukin-6 and along with induction of interleukin-1 receptor antagonist. Iwayama et al showed that adiponectin has potent beneficial function to maintain the homeostasis of periodontal health, improve periodontal lesion and contribute wound healing and periodontal regeneration [78].

Resistin belongs to secretory protein family called as resistin like molecules, which is characterized by a highly conserved cysteine rich C- terminal. Resistin has been named since it is believed to convey the resistance to insulin. Resistin may not originate directly from adipocytes but may originate from inflammatory cells infiltrating the fat tissue. Release of resistin appears to be stimulated by inflammation, LPS, IL-6, hyperglycemia, growth and gonadal hormones. While released within the fat tissue, resistin acts on adipocytes leading to insulin resistance. Levels of resistin increase with increasing obesity which is a major contributing factor for the development of type 2 diabetes mellitus, and periodontitis. Two studies showed the positive association of periodontal disease with gingival crevicular fluid resistin levels [13,79].

There are three mechanisms for the role of oral bacteria in the development of obesity as suggested by Goodson et al. First, oral bacteria may increase metabolic efficiency, as suggested by infectobesity proponents. The second hypothesis is that oral bacteria could increase weight gain by increasing appetite. The third hypothesis is that oral bacteria redirect energy metabolism by facilitating insulin resistance through increasing levels of TNF- α . Using any of these mechanisms, even a small excess in caloric consumption with no change in diet or exercise could result in unacceptable weight gain. Periodontal disease may contribute to the development of obesity and the role of the oral microbiota in obesity has been gaining more attention. [80] Obesity is also associated with increased counts and proportions of certain periodontal pathogens, including *Tannerella forsythia* and *Selenomonas noxia* [81].

7. Obesity and type 2 diabetes

Type 2 DM (formerly known as non-insulin dependent DM) is the most common form of DM characterized by hyperglycemia, insulin resistance, and relative insulin deficiency[82]. Type 2 DM results from interaction between genetic, environmental and behavioral risk factors[83,84]. Type 2 DM is due primarily to lifestyle factors and genetics[85]. A number of lifestyle factors are known to be important to the development of type 2 DM. These are physical inactivity, sedentary lifestyle, cigarette smoking and generous consumption of alcohol[86]. Obesity has been found to contribute to approximately 55% of cases of type 2 DM[87].

Type 2 DM is characterized by insulin insensitivity as a result of insulin resistance, declining insulin production, and eventual pancreatic beta-cell failure[88,89].

A strong relationship between obesity and the onset of diabetes has been reported in a number of studies. Research has shown that people carrying more weight particularly around the tummy are more insulin resistant [90-93] and may struggle to achieve good diabetes control.[94-96]

Pathogenesis of obesity appears to play a central role in the dysregulation of cellular mechanism that accounts for insulin resistance, which is the state of reduced responsiveness of liver, muscle and adipose tissue to insulin in type 2 diabetes. The stored fat is required for survival during nutritionally deprived states, however during state of prolonged abundance of food, excessive fat storage results in obesity.[97,98] This excessive storage of fat that creates obesity eventually leads to the release of elevated levels of fatty acids (FFAs) from enhanced lipolysis. The release of these FFAs then induces lipotoxicity, as lipids and their metabolites create oxidant stress to the endoplasmic reticulum and mitochondria. This affects adipose as well as non-adipose tissues resulting in insulin-receptor dysfunction. The consequence is an insulin-resistant state which then creates hyperglycemia with compensated hepatic gluconeogenesis.[99-101] Insulin resistance is a key factor for type 2 diabetes. FFAs also decrease utilization of insulin-stimulated muscle glucose, contributing further to hyperglycemia. Lipotoxicity from excessive FFAs also decreases secretion of pancreatic β -cell insulin, which eventually results in β -cell exhaustion. Moreover, excess adipocytes release inflammatory adipokines [TNF- α , IL-6, complement C3, leptin and macrophage migration inhibitory factor (MIF)], which, along with free fatty acids, provide the pathophysiologic basis for comorbid conditions associated with obesity such as insulin resistance and type 2 diabetes. Along with fatty-acid lipotoxicity, visceral adipokines also contribute to the adipokine inflammatory injury that leads to pancreatic β -cell dysfunction, which, in turn, decreases insulin synthesis and secretion.[102,103] Adipocytes also stimulate fat-associated macrophages that also secrete monocyte chemoattractant protein 1 (MCP-1), macrophage migration inhibiting factor (MMIF), and resistin, all of which decrease insulin sensitivity (i.e. enhance insulin resistance).[104,105]

8. Conclusions

Chronic periodontitis, obesity and diabetes mellitus are important chronic health problems and are closely associated. Obesity is associated with an increased prevalence of periodontitis and diabetes mellitus. Diabetes mellitus associated with an increased prevalence of chronic periodontitis and chronic periodontitis is considered as a risk factor for diabetes mellitus and obesity.

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Some remarks on Rational Barycentric Interpolation

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Abstract

Linear barycentric rational interpolant are a specific type of rational interpolants, defined by weight independent of function. These interpolants have recently been a valuable alternative to more classical methods of interpolation. Rational interpolation gives a much better approximation than polynomial, but it is difficult to avoid poles and unattainable points.

In this paper , discuss the use of rational interpolation development, then we try to introduce another barycentric rational interpolant that provides a good result.

Keywords: Polynomial interpolation, rational interpolation, barycentric interpolation.

1. Introduction

The Polynomial interpolation is the dominant for approximation and has some clear advantages. For instance, any continuous function on a given interval $[a, b]$ can be approximated by polynomials (Weierstrass). But there are some disadvantages, as a high polynomial degree is generally needed for accuracy, which in some cases leads to divergence. The rational interpolation is a promising alternative which can lead to better results in some cases. The presence of undesired poles and unattainable points near or inside of the interpolation interval can render it useless in such cases [7]. Barycentric rational interpolation as presented by Berrut and Mittelmann possesses many advantages over the classical rational interpolation. They showed that every rational interpolant may be written in the barycentric form. Floater and Horman also constructed the rational interpolant by blending polynomial interpolants and defined an explicit formula for weights [10]. The barycentric

form of rational interpolants has many advantages over the polynomial one. In particular, it allows for an easier detection of unattainable points and of poles in the interval of interpolation.

Let $\{x_j\}_{j=0}^n$ be $n + 1$ interpolation points in $[a, b]$, where $a \leq x_0 < x_1 < \dots < x_n \leq b$.

The interpolation of the Lagrange polynomial can be defined by the formula[7]

$$p_n(x) = \sum_{j=0}^n f(x_j) L_j(x), \quad L_j(x) = \prod_{\substack{k=0 \\ k \neq j}}^n \frac{x - x_k}{x_j - x_k} \quad (1a)$$

Where

$$L_j(x_k) = \begin{cases} 1 & \text{if } j = k \\ 0 & \text{if } j \neq k. \end{cases}$$

The formula of Lagrange interpolation is useful for theoretical purposes, but in practice it is not appropriate [7].

Let

$$L(x) = \prod_{k=0}^n (x - x_k) \rightarrow L'(x_j) = \prod_{\substack{k=0 \\ k \neq j}}^n (x_j - x_k).$$

Hence

$$L_j(x) = \frac{L(x)}{L'(x_j)(x - x_j)}.$$

If the weight is defined by

$$w_j = \frac{1}{\prod_{k=0}^n (x_j - x_k)} = \frac{1}{L'(x_j)}$$

then $L_j(x)$ can be written as

$$L_j(x) = L(x) \frac{w_j}{(x - x_j)}.$$

The modified formula for Lagrange is therefore defined as:

$$p_n(x) = L(x) \sum_{j=0}^n f_j \frac{w_j}{(x - x_j)} \quad (1b)$$

If we interpolate $f_j = 1$ for all j is the unique polynomial $p_n(x) = 1$, which has zero degree. Hence, this implies that

$$1 = \sum_{j=0}^n L_j(x) = L(x) \sum_{j=0}^n \frac{w_j}{(x - x_j)}$$

So

$$L(x) = \frac{1}{\sum_{j=0}^n \frac{w_j}{(x - x_j)}}.$$

Therefore

$$p(x) = \frac{\sum_{j=0}^n f_j \frac{w_j}{x - x_j}}{\sum_{j=0}^n \frac{w_j}{x - x_j}}, \quad (2)$$

This is known as the barycentric formula. It is a polynomial if the weights w_j are nonzero and defined in a such a way that

$$\sum_{j=0}^n L_j = L(x) \sum_{j=0}^n \frac{w_j}{(x - x_j)} = 1.$$

In 2004, Berrut and Trefethen discussed the formula. Since then for interpolation, the formula has been commonly known and used [7].

2. Classical Rational Interpolation

Let $\{x_j\}_{j=0}^N$ be distinct points and $f(x)$ a given function. Let the polynomials $p(x)$ of degree $\leq m$ and $q(x)$ of degree $\leq n$, be the numerator and the denominator, respectively, where

$$r_{mn} = \frac{p(x)}{q(x)} = \frac{\sum_{k=0}^m a_k x^k}{\sum_{k=0}^n b_k x^k} \dots \dots \dots (3)$$

The rational interpolation interpolation problem is to find $r(x)$ which satisfies the following condition [7]

$$r(x_j) = \frac{p(x_j)}{q(x_j)} = f(x_j), \quad j = 0, \dots, m + n \dots \dots (4)$$

If r exists, the solution is unique and can be written as a barycentric formula. The condition for (4) to be satisfied is

$$q(x_j)f(x_j) - p(x_j) = 0 \dots \dots \dots (5)$$

Which is

$$a_0 x_j + \dots + a_m x_j^m - f_j (a_0 x_j + \dots + a_m x_j^m) = 0$$

This is equivalent to a system of homogeneous equations, with $(m + 1)$ unknown coefficients in $p(x)$ and $(n + 1)$ in $q(x)$ [8].

The system has at least one nonzero solution, where $N = n + m$, and $n \leq m$ without loss of generality, we have $m \geq \frac{N}{2}$.

It is well known that a polynomial interpolation of degree $\leq n$ exists and is unique. In classical rational interpolation, the condition $n + m = N$ is analogous to the condition $f q - p = 0$ for finite f and $f = \infty$ for $q = 0$. However, the rational interpolation does not always have a solution because of two major obstacles [3, 5]:

- In some cases the interpolation condition $r(x_j) = f(x_j)$ may not be achieved because of the occurrence of unattainable points. That is, there is a point x_j where the given function value f_j may not be obtained. This point x_j is called unattainable and occurs if x_j is a zero of the denominator $q_n(x)$ and the numerator $p_m(x)$.
- Rational interpolant may have poles in the interval of interpolation, which are zeros of $q_n(x)$ that are not common to $p_m(x)$. These poles cause a problem if they are inside the interval of interpolation. Rational interpolation is useless if the function to be approximated is not singular at the same points.

Example 1.1: Let $x = 1$ and $x = 3$ are unattainable points: The corresponding solution $m = n = 2$ is

$$R(x) = \frac{2x^2 - 8x + 6}{x^2 - 4x + 3} = \frac{2(x-1)(x-3)}{(x-1)(x-3)} = 2.$$

The points $x = 1$ and $x = 3$ are unattainable points: $R_{2,2}$ is $\frac{0}{0}$ at $x = 1$ and $x = 3$ and has the common factor $(x - 1)(x - 3)$, but $f = 2$. After cancellation $(x - x_j)$, $r(x_j)$ may be not equal to $f(x_j)$.

Example 1.2: Let $x_0 = -1$, $x_1 = 1$, $x_2 = 2$ and $f_0 = 2$, $f_1 = 3$, $f_2 = 3$. if we take $n=m=1$, then $R(x) = \frac{3x+3}{x+1} = 3$. The denominator is equal to zero at $x_0 = -1$ and so $R(x_0) = 3 \neq 2 = f_0$.

Therefore, the interpolation problem has no solution for the prescribed degree. But for $n=0$ and $m=2$, then $R(x) = \frac{36}{14-3x+x^2}$.

Remark: Consider unattainable point x_j for a non—trivial solution $\frac{p}{q} \in R_{n,m}$, where $p = q = 0$ after the cancellation of $x - x_j$ in $\frac{p}{q}$, we have $\frac{p_j}{q_j} \neq f_j$ [16].

3. Barycentric Rational Interpolation`

If the weights w_j are nonzero and defined in such way that $L(x) = \sum_{j=0}^n \frac{w_j}{x - x_j}$ is not equal to 1, then the formula (2) is rational. To show that the rational interpolates the function, the following lemma is proved:

Lemma: Let f_j be the value of the function at x_j , where $j=0, \dots, n$ with $x_j \neq x_k$ for $k \neq j$. Then if $u_k \neq 0$, the rational function

$$r(x) = \frac{\sum_{j=0}^n f_j \frac{u_j}{x - x_j}}{\sum_{j=0}^n \frac{u_j}{x - x_j}}, \quad (6)$$

Interpolates f_k at x_k and $\lim_{x \rightarrow x_l} r(x) = f_l$.

Conversely, any rational interpolant function $r \in r_{nn}$ of f_j can be written in barycentric form using some weights [3].

Proof: Multiplying (6) by $\frac{L(x)}{L(x)}$

$$\begin{aligned} r(x) &= \frac{\sum_{j=0}^n f_j \frac{u_j}{x - x_j}}{\sum_{j=0}^n \frac{u_j}{x - x_j}} \frac{\prod_{k=0}^n (x - x_k)}{\prod_{k=0}^n (x - x_k)} \\ &= \frac{\sum_{j=0}^n w_j f_j \prod_{k=0}^n (x - x_k)}{\sum_{j=0}^n w_j \prod_{k=0}^n (x - x_k)}. \end{aligned}$$

By taking the limit $\lim_{x \rightarrow x_l} r(x)$, we have

$$r(x_l) = \frac{\sum_{j=0}^n w_j f_j \prod_{k=0}^n (x_l - x_k)}{\sum_{j=0}^n w_j \prod_{k=0}^n (x_l - x_k)} = f_j.$$

The interpolation condition are satisfied as long as the interpolation points are distinct and w_j are not equal to zero.

From the Lagrange formula

$$p(x) = \sum_{j=0}^n f_j L_j(x),$$

The numerator p and the denominator q could be written as

$$r(x) = \frac{p(x)}{q(x)} = \frac{L(x) \sum_{j=0}^n \frac{p(x_j)}{(x - x_j)L'(x_j)}}{L(x) \sum_{j=0}^n \frac{q(x_j)}{(x - x_j)L'(x_j)}}$$

Let $r(x_j) = \frac{p(x_j)}{q(x_j)} = f_j$, where $r(x_j) q(x_j) = f(x_j)$. Then we have

$$r(x) = \frac{\sum_{j=0}^n f_j \frac{q(x_j)}{(x - x_j)L'(x_j)}}{\sum_{j=0}^n \frac{q(x_j)w_j}{(x - x_j)L'(x_j)}}$$

By defining the weights $u_j = \frac{q(x_j)}{L'(x_j)} = w_j q_j$, we arrive at

$$r(x) = \frac{\sum_{j=0}^n f_j \frac{u_j}{x - x_j}}{\sum_{j=0}^n \frac{u_j}{x - x_j}},$$

If $q(x) = 1$, then $q_j = 1$ for $j=0, \dots, n$ and so (6) reduces to the barycentric form of the interpolating polynomial of degree n .

Berrut in [5] showed that if we use $w_j = (-1)^j$, then the interpolant has no poles in R , where

$$r(x) = \frac{\sum_{j=0}^n f_j \frac{(-1)^j}{x - x_j}}{\sum_{j=0}^n \frac{(-1)^j}{x - x_j}}, \dots \dots \dots (8)$$

The advantages of rational interpolation over polynomials interpolation at equally spaced points investigated by many studies such in [3, 5, 7]. If we interpolate Runge's function, then the oscillation vanishes. Rational interpolation using Chebyshev points may yield worse results than using equally spaced points.

It is clear that barycentric rational interpolation allows one to choose the points and the weights.

The rational interpolation can be written in barycentric form, where $u_j = w_j q_j$ is the weight corresponding to the points x_j . Hence, the barycentric form has the advantage that the barycentric weights give information about possible unattainable points. The problem is how to choose the w_j to avoid poles and produce a good approximation.

It is hard to approximate functions with poles, but in general points they do not lead to a good approximation. For example, the weights of $w_j = \frac{1}{\prod_{k=0}^n (x_j - x_k)}$ avoid poles. However, the determination of the weight u_j is more complicated, which can be distinguished in specific ways:

Choosing the degree: This can be done by fixing the exact degree of the numerator and denominator of (6). By choosing the numerator of degree $\leq m$ and the denominator of degree $\leq n$, with $n + m + 1 = N$, such as

$$r(x) = \frac{\sum_{j=0}^n f_j \frac{u_j}{x - x_j}}{\sum_{j=0}^n \frac{u_j}{x - x_j}} = \frac{\sum_0^m a_j x^j}{\sum_0^n b_j x^j}$$

The a_j , b_j and u_j are unknown. The method has been studied in [3, 14, 16, 22].

Choosing the poles: This can be found by solving

$$\sum_{j=0}^n \frac{u_j}{x - x_j}.$$

If some of the poles are known, it is possible to attach them to the barycentric rational interpolant. These methods have been treated in [4].

In [3, 14, 16, 22], they have used a different basis to present q_n and p_{N-n} and derive a homogeneous system of linear equations in barycentric form. Schneider and Werner in [16] presented the rational interpolant in barycentric form with $n + 1$ weights. They expressed q_n and p_{N-n} by using Lagrange basis:

$$p(x) = \sum_{j=0}^n u_j f_j \prod_{k=0}^n (x - x_k),$$

$$q(x) = \sum_{j=0}^n u_j \prod_{k=0}^n (x - x_k),$$

They suggested computing the weights by expressing the denominator $q(x)$ in a Newton basis

$$q(x) = \sum_{j=0}^n w_j \prod_{k=0}^{j-1} (x - x_k),$$

Then, by an algorithm of Werner in [19] unknown weights u_j are found by computing $q(x)$ at $x = x_j$, which is

$$u_j = \frac{q(x_j)}{\prod_{k=0, k \neq j}^n (x_j - x_k)},$$

The solution presented in [16] depends on the coefficients w_j , $0 \leq j \leq n$, $n \leq m - N - n$ and solving the homogeneous linear system.

$$f[x_0, \dots, x_{m+1}]w_0 + \dots + f[x_n, \dots, x_{m+1}]w_n = 0$$

$$f[x_0, \dots, x_{m+2}]w_0 + \dots + f[x_n, \dots, x_{m+2}]w_n = 0$$

$$\vdots$$

$$f[x_0, \dots, x_N]w_0 + \dots + f[x_n, \dots, x_N]w_n = 0$$

Then the barycentric form q_n , can be expressed as

$$q_n(x) = \prod_{k=0}^n (x - x_k) \sum_{j=0}^n \frac{w_j}{x - x_j} q_j,$$

$$w_j = \frac{1}{\prod_{k=0}^n (x_1 - x_k)}.$$

For the resulting linear system, the matrix of coefficients is a divided difference.

A direct method due to Berrut and Mittelmann for finding the corresponding weights u_j can be found in [3]. Using monomial basis functions, conditions for the weights are derived such that $r_n(x) = \frac{p}{q}$, where the degree of p and q are m and n , respectively. A very similar approach is due to Zhu in [22] and Polezzi in [15] who directly determined function values q_n of a denominator of degree at most n from the same degree condition. Schneider and Werner in [16] proposition stated that:

Proposition: [4, 16] If the rational interpolant r has no poles, then

$$w_j \cdot w_{j+1} < 0, \quad j = 0, \dots, N.$$

This condition is necessary, but is not sufficient. A sufficient is still an open problem, despite some effort has been made.

Example 1.3: Let $x = [-1, 0, 1]$ and $u = [1, -1, 6]$ where $n=2$. The alternating the sign $u_j, j=0, 1, 2$ implies the absence of poles.

Example 1.4: For $x = [1, 1.5, 3]$ and $w = [1, 1, 1]$ where $n=2$, $f_j = 1, 0.7, 1.7$, the function $r_2(x)$ has poles.

Example 1.5: For $x=[1, 1.5, 3]$ and $w=[1, -1, 1]$ where $n=2$, $f_j=1, 0.7, 1.7$, the function $r_2(x)$ does not have the poles.

A sufficient condition is that the u_j are similar enough in sizes for the $\frac{u_j}{x-x_j}$ to decrease in absolute value on both size for each x [5, Lemma2.1].

Proposition: [3, 16] If for some j ,

$$w_j \cdot w_{j+1} > 0, \quad j = 0, \dots, N.$$

Then r has an odd number of poles in $[x_j, x_{j+1}]$.

Remark: We can note that u_j in a rational presentation oscillates in sign, because the equation

$$u_j = w_j q_j,$$

Implies that w_j oscillate in sign but q_j does not.

An implicit form of (6) can be written as

$$\sum_{j=0}^n u_j \frac{r_n(x) - f_j}{x - x_j} = 0$$

4. Floater and Horman interpolant

An attractive rational interpolation method that has no poles is presented in [10] by Floater and Hormann. They constructed an interpolant by blending the polynomial interpolants. Consider $n + 1$ points $x_0 < x_1 < \dots < x_n$ with corresponding values $f_0 < f_1 < \dots < f_n$. Suppose that $0 \leq d \leq n$. For $j = 0, \dots, n - d$, let p_j be the polynomial of degree at most d that interpolates $x_j, \dots, x_{j+d}$. Then interpolant undertaken in [10] is

$$R_n(x) = \frac{\sum_{j=0}^{n-d} \lambda_j(x) p_j(x)}{\sum_{j=0}^{n-d} \lambda_j(x)} \dots \dots \dots (9)$$

$$\lambda_j(x) = \frac{(-1)^j}{(x - x_j) \dots (x - x_{j+d})}$$

The interpolant (9) has no real poles for each d , and has an approximation of order $O(h^{d+1})$ as $h \rightarrow 0$, where h is a maximum of the space between two adjacent points

$$h = \max_{0 \leq j \leq n-1} (x_{j+1} - x_j),$$

for $f(x) \in C^{d+2}[a, b]$.

The formula (9) is expensive to evaluate, but if we multiply the numerator and denominator by $L(x)$ we see that (9) is a rational function of degree at most n and $n - d$. So (9) can be written in the barycentric form (6). The weights for the barycentric form $r_n(x)$ of (9) are defined explicitly:

$$u_j = \sum (-1)^j \frac{1}{x_j - x_k}.$$

This because the (9) has no poles and so its weights oscillate in sign [10]. The d gives rise to a whole family of interpolants with no poles and high approximation orders. In theory, the approximation error decrease as d increases. In practice, however due to finite precision arithmetic, the numerically computed approximation may not behave accordingly. For moderate d , the interpolant (9) performs very well even for large n .

5. An Improved Floater and Hofmann Interpolant

The Floater and Hormann interpolation formula faces a problem in the cases where $d = n$ or $d = 0$. In this case, the interpolant r will be interpolating polynomials. The idea of the proposed formula is that instead of blending the polynomial interpolants, the rational interpolants will be blended.

Therefore when $d = n$ or 0 the interpolant will be rational interpolations.

For $0 \leq d \leq n$, let r_j be the barycentric rational interpolation that interpolates $x_j, \dots, x_{j+d}$. The interpolant undertaken based on Floater and Hormann is

$$R_n(x) = \frac{\sum_{j=0}^{n-d} \lambda_j(x) r_j(x)}{\sum_{j=0}^{n-d} \lambda_j(x)} \dots \dots \dots (10)$$

$$\lambda_j(x) = \frac{(-1)^j}{(x - x_j) \dots (x - x_{j+d})} \dots \dots \dots (11)$$

The formula (10) has no poles and so its weights oscillate in sign.

Theorem: Let $\{x_j\}_{j=0}^N$ be $N + 1$ distinct points. Then the rational interpolant defined by (10) satisfies the interpolation condition $r(x_k) = f(x_k), k = 0, 1, \dots, N$.

Proof: By multiplying the numerator and denominator by $(-1)^{n-d} (x - x_0) \dots (x - x_n)$, we have

$$r_n(x) = \frac{\sum_{j=0}^{n-d} (-1)^{n-d} (x - x_0) \dots (x - x_n) \lambda_j(x) r_j(x)}{\sum_{j=0}^{n-d} (-1)^{n-d} (x - x_0) \dots (x - x_n) \lambda_j(x)}$$

Letting $\mu_j(x) = (-1)^{n-d} (x - x_0) \dots (x - x_n) \lambda_j(x)$, then

$$\lim_{x \rightarrow x_k} r(x) = \frac{\sum_{j=0}^{n-d} \mu_j(x) r_j(x)}{\sum_{j=0}^{n-d} \mu_j(x)}$$

We know from Lemma 1.5 the rational function satisfies $\lim_{x \rightarrow x_k} r(x_k) = f(x_k)$. Then

$$r(x_k) = \frac{\sum_{j=0}^{n-d} (-1)^{n-d} \mu_j(x_k) f(x_k)}{\sum_{j=0}^{n-d} (-1)^{n-d} \mu_j(x_k)} = f(x_k).$$

Theorem: Let the function $f \in C^{d+2}[a, b]$, the rational $r_n(x)$ is obtained by (10), then when $n - d$ is odd, we have

$$\|f(x) - R_n(x)\| \leq h^{d+1} (1 + \beta)(b - a) \frac{\|f^{d+2}\|}{d + 2},$$

And if $n - d$ is even

$$\|f(x) - R_n(x)\| \leq h^{d+1}(1 + \beta)(b - a) \left(\frac{\|f^{d+2}\|}{d + 2} + \frac{\|f^{d+1}\|}{d + 1} \right),$$

$$h = \max_{0 \leq i \leq n-1} (x_{i+1} - x_i).$$

$$\beta = \max_{1 \leq i \leq n-1} \min \left\{ \frac{x_{i+1} - x_i}{x_i - x_{i-1}}, \frac{x_{i+1} - x_i}{x_{i+2} - x_{i+1}} \right\}$$

Proof: We start as in [11] for x which is an interpolation points, the error will be zero. And for x is not an interpolation points, the error can be presented as:

$$\|f(x) - r_n(x)\| = \left| \frac{\sum_{j=0}^{n-d} \frac{(-1)^j}{(x-x_j) \dots (x-x_{j+d})} (f(x) - r_j(x))}{\sum_{j=0}^{n-d} \frac{(-1)^j}{(x-x_j) \dots (x-x_{j+d})}} \right| \dots\dots\dots (12)$$

Using

$$\left\| f - \frac{p_n}{q_n} \right\| \leq \max_{x \in [a,b]} \left(\frac{|(f q_m)^{n+1}(x)|}{(n+1)!} \right) \max_{x \in [a,b]} \frac{\prod_{k=0}^n |x - x_k|}{|q_m(x)|}.$$

In [10], we have

$$(-1)^{n-d} (x - x_0) \dots (x - x_n) \lambda_i(x), \mu_i(x) =$$

$$\lambda_i(x) = \frac{\mu_i(x)}{(-1)^{n-d} (x - x_0) \dots (x - x_n)}.$$

Then, we can see that, the numerator and the denominator of (12) is multiplied by $(-1)^{n-d} (x - x_0) \dots (x - x_n)$, which is independent of i . From [10], we have

$$\sum_{i=0}^{n-d} \mu_i(x) > 0.$$

Now, from (12), we can see the error $f(x) - r_j(x)$ that related to the formula (8). Therefore, we have the above.

To prove the case when $n - d$ is even, we follow the similar procedure of an odd $n - d$.

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