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DEVELOPING OF QUALITY IMPROVEMENT MODEL ON ISO 9001:2015 PLATFORM USING TAGUCHI METHOD

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RAZVPO MODELA UNAPREĐENJA KVALITETA NA PLATFORMI ISO 9001:2015 PRIMENOM TAGUCHI METODA

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DEDICATION

To my parents, my wife, my sons, daughters, brothers, sisters and all families. Also all faculty staff and my friends.

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I wish to express my gratitude to Prof. Dr. Vidosav Majstorovic for his kind support, encouragement and valuable guidance throughout the research, showing the trust and giving me an opportunity to present my work at various meetings, which assisted me to envisage my good ad motivated me. Also I wish to express my gratitude to Prof. Dr. Aleksandar Sedmak for his meticulous suggestion during the discussions at various meeting and encouragement throughout the research and endless support. In addition, my full thanks to Prof. Dr. Srđan Tadić, for his advice and guidance that helped me to complete my research.

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DEVELOPING OF QUALITY IMPROVEMENT MODEL ON ISO 9001:2015 PLATFORM USING TAGUCHI METHOD

ABSTRACT

Improving the quality of products and services is a generally accepted trend around the world. The ISO 9000 series is a universal framework for quality management and its new model ISO 9001: 2015 is particularly characteristic in this respect. Continuous improvement model based on PDCA cycle concept has applied to this model, and the basis of this application is the support of quality engineering techniques for optimizing the process. Taguchi is a technique of quality engineering for complex process optimization (with multiple input and output parameters) applied in research under this thesis.

The thesis including of quantities analysis about the number of ISO certificates have issued in the entire world with more details in European countries. In addition, it includes the qualitative analysis for the relation between number of certification, gross national income per capita, and inhabitants in the European countries.

Research status, quality improvement approaches history in the World - Quality Improvement in Industry; Crossroads of QMS / IMS / TQM and Taguchi methods.

Taguchi technique of quality engineering used to optimise asset of parameters, which give the desired result. In this thesis, Taguchi approach applied on friction stir welding operation, which is one of modern welding method. Three of most significant parameters in FSW (rotation speed, welding traverse speed, and tilt angle) used to find out optimum set for the three responses (average absorbed energy, energy for crack initiation, and energy for crack propagation). Experiment designs by Taguchi design of experiment and, and optimization of results by apply Taguchi technique. The analysis of variance (ANOVA) done to find the contribution of each parameter on the responses.

The dissertation consists of the following sections:

1. Introduction.

2. Quality management system.

3. Improving the quality in the industry.

4. Application of the Taguchi method for improving quality in manufacturing.

5. Application of Taguchi method for optimizing friction-welding parameters - experiment, results, discussion.

6. Integration of ISO 9001: 2015 and Taguchi method.

7. Concluding considerations.

8. Future research

9. References

Keywords: QMS, Taguchi, Improvement

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РАЗВОЈ МОДЕЛА ПОБОЉШАЊА КВАЛИТЕТА НА ПЛАТФОРМА ИСО 9001: 2015 УПОТРЕБА МЕТОДА ТАГУЦХИ

АБСТРАЦТ

усавршити квалитета производа и услуга је опште прихваћени тренд широм света. Серија ISO 9000 представља универзални оквир за управљање квалитетом а његов нови модел ISO 9001:2015 је посебно карактеристичан у том погледу.

Модел континуалних унапређења заснован на концепту PDCA циклуса је примењен на овај модел а основу те примене чини подршка техника инжењерства квалитета за оптимизацију процеса. Taguchi метод је техника инжењерства квалитета за комплексну оптимизацију процеса (са више улазних и излазних параметара) примењена у истраживањима у оквиру ове тезе.

Теза укључујући анализу количине о броју ИСО сертификата издала је у целого свету са више детаља у европским земљама. Поред тога, она укључује квалитативну анализу односа броја сертификације, бруто националног дохотка по глави становника и становника у европским земљама.

Стање истраживања у свету - унапређење квалитета у индистрији; прилази QMS / IMS / TQM и Taguchi метод

Тагуцхи техника квалитетног инжењеринга који се користи за оптимизацију вредности параметара, који дају жељени резултат. У овој тези, Тагуцхи приступ се примјењује на операције заваривања фрикцијом, што је један од савремених метода заваривања. Три најважнијег параметра у ФСВ-у (брзина ротације, брзина заваривања и угао нагиба) користе се за утврђивање оптималног подешавања за три реакције (просечна апсорбована енергија, енергија за покретање пукотина и енергија за ширење пукотина). Дизајн експеримента од стране Тагуцхи дизајна експеримента и оптимизација резултата применом Тагуцхи технике. Анализа варијансе (ANOVA) учињена да би се пронашао допринос сваког параметра на одговорима.

Дисертација се састоји од следећих поглавља:

1. Увод.
2. Систем менаџмента квалитетом .
3. Унапређење квалитета у индустрији.
4. Примена Taguchi метода за унапређење квалитета у области производње.
5. Примена Taguchi метода за оптимизацију параметара заваривања трењем – експеримент, резултати, дискусија.
6. Интеграција ИСО 9001:2015 и Taguchi метода.
7. Закључна разматрања.
8. Будућа истраживања
9. Литератур

Кључне речи: QMS, Taguchi, усавршити

UDC број: 005.6: 006.83(043.3)

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CHAPTER 1

1 INTRIDUCTION

In our present era, quality and continuous improvement become a vital important theme is represented through the ways which uses by various organizations to be able to build a competitive strategy based on quality products and services in the circumstances of the increasing pace of competition [1]. By producing high quality products and services at low prices, organization can increase the satisfaction and confidence of its existing customers and adding new of them, and increase its participate in the market share from domestic and global trade [2]. For this target, all organizations around the world, hardly working to build their quality system to get the desired results through applying the suitable quality systems and tools. The ISO 9000 series is a universal framework for quality management and its new model ISO 9001: 2015 is particularly characteristic in this respect. Continuous improvement model based on PDCA cycle concept has applied to this model, and the basis of this application is the support of quality engineering techniques for optimizing the process. Taguchi is a technique of quality engineering for complex process optimization (with multiple input and output parameters) applied in research under this thesis.

Taguchi method provide a powerful and efficient method to achieve the goal of increasing quality without any additional cost [3]. With its main foundation or tools, design of experiment, quality loss function, and robust design, farther than the offline quality control philosophy.

In the research that will carry out within this thesis, the basic starting hypotheses are:

(a) the ISO 9001: 2015 model represents a good framework for defining a model of continuous improvement of the process, because it in a new way, in relation to the previous QMS models, defines and processes, making the application of quality engineering techniques an imperative,

(b) the manufacturing and technological processes in the industry are generally complex - with multiple inputs and outputs, so the Taguchi method is a convenient way, due to its characteristics, for their optimization, which ensures the essential application of the QMS model, and

(c) It is possible to develop a part of the knowledge base for the application of the QMS model in practice.

In this thesis, we development of a new model for improving the quality of the process by the intrusion of two approaches ISO 9001: 2015 and Taguchi method.

In chapter one, introduces the basic information about the International Organization for Standardization and ISO standards for business standardization, as standardize management system (SMS). It starts main information about the basic conceptions and principles about the international standardization which including date and place of foundation, the member's types and numbers and their powers and responsibilities. Then, names the main models of ISO SMS with brief definition. Flowed by survey for the number of certifications that issued by the ISO SMS around the world.

The second part of this chapter is about the ISO 9001, which stared by basic conceptions, principles, and the history of devolvement for ISO 9001 with focus on last two versions ISO 9001:2008 and ISO 9001:2015 as a comparing between them from clauses. In the last part of chapter two, is about ISO 9001 state of the art. And it includes quantities and qualitative data collection and analysis for the number of certification issued by ISO SMS in the world and European countries. Date and statist stoical analysis show how the number of certification was fats diffusion and the forecasting statistical analysis shows that the number will continues growing in the next years. Qualitative analysis about the ISO certifications number and the economic ((state gross domestic product)) (GDP)) for some European countries.

Chapter three, correlated with quality and continuous improvement using different approaches. In begging, starts with brief information for the quality gurus including places and time for each of them and their important contributions in quality imp journey. The second part of this chapter, displays some of continuous improvement approaches. These approaches are:

- Total Quality Management (TQM),
- Quality Management System (ISO 9001:2015) and,
- Integrated Management System.

In the last section of this chapter, is about the relation between cost and quality and cost of poor quality which including in brief, the history and relation changing by the time, between quantities, cost, and quality of product and how we can reduce cost of the product and improve its quality in the same time. And at the end of this chapter, show in brief, the knowledge modeling of quality improvement.

Chapter four, the Taguchi approach which, discuses with more detail about the Taguchi method philosophy and how to apply it. It starts with Foundation of Taguchi's method (System design, parameters design and, Tolerance design). Then, The Taguchi philosophy and the non-visible costs (hidden costs) of quality, Quality loss-function (Taguchi loss function, and Robustness. The second part of this chapter is how to apply this approach starting from determining the goal and determine the parameters and their levels. Then building the suitable orthogonal arrays and run the experiments. Find out the results and chose the optimum set of parameters.

Chapter five, case study, which was an experiment. In this experiment, a modern welding method (Friction Stir Welding) used to join an aluminum alloy (AA 5083) plates. The design of experiment and analysis done by using Taguchi method. And the results were to find the optimum set of parameters (welding speed, rotation speed, and tilt angle) to find the desired responses of Average Absorbed Energy, Energy for crack initiation, and Energy for crack propagation.

Chapter six was about the relation between quality management system (ISO 9001:2015) and the Taguchi approach and how can be integrated them. then, development of a new model for improving the quality of the process by the intrusion of two approaches ISO 9001: 2015 and Taguchi method. In chapter, seven conclusions and future research are given, and at the end the list of references.

CHAPTER 2

2 QUALITY MANAGEMENT SYSTEM

2.1 Quality management system background

The International organization for standardization has founded in 1946 in Geneva, Switzerland and it has seated there ever since. Now days, there is 162 member countries from all over the plant which represented the national standards bodies all around the world [4]. These members have divided into three member categories [5, 6]:

- Full members (or member bodies) influence ISO standards development and strategy by participating and voting in ISO technical and policy meetings. Full members sell and adopt ISO International Standards nationally (there are one hundred twenty member bodies).

- Correspondent members observe the development of ISO standards and strategy by attending ISO technical and policy meetings as observers. Correspondent members can sell and adopt ISO International Standards nationally (there are thirty-nine Correspondent members).

- Subscriber members keep up to date on ISO's work but cannot participate in it. They do not sell or adopt ISO International Standards nationally (there are only three subscriber members).

Process for developing the ISO standard takes many people (technical experts nominated by the international organization for standardization's members).working together. The experts form a technical committee that is responsible for a specific subject area and they begin the process with the development of a draft that meets a specific market need. Then it shared for commenting and further discussion. The voting process is the key to consensus between members who has right for vote (only full members). If that is achieved then the draft is on its way to becoming an ISO standard.

If agreement do not reached then the draft will modified further, and voted on again. From first proposal to final publication, developing a standard usually takes about three years [7].

2.2 Most popular ISO standards known in the world

Since it has founded, ISO has issued a numerous of standards in various aspects and fields, but some of them have well known in all world. The most known and popular for the ISO standards are [4]:

- ISO 9001 Quality management. Certification under this standard contributes to improvement of the quality of delivery in the global supply chain, fulfilling the requirements and increasing customer satisfaction.

- ISO 14001 Environmental management. In this standard, the requirement for an environment management system specifies, and exerts global significance due to organization to operate in an environmentally sustainable manner.

- ISO/IEC 27001. This model of standard provides the requirements about the informational security management system.

- ISO 22000 Food safety management. Inspire confidence in your food products with this family of standards.

- ISO 50001 Energy management. Make energy savings and help make your organization more efficient with this standard.

- ISO 13485 Medical devices. Manage quality throughout the life cycle of a medical device.

- ISO 45001 Occupational health and safety. Reduce workplace risks and create safer working environments.

However, ISO 9001 (Quality management system) has considered as the engine of development of business standardization process since, its first model issued in the year 1987[4]. It has gotten more than 70% from the total number of certificates which issued by ISO the in the past years. The pie chart 1 illustrates the percentage of number of certificates issued by the ISO in the last six years (2010 - 2015). The pie chart in figure 2.1 shows the percentages of the number of certification issued in five years for the each ISO model. Table 2.1 illustrates the number of certification issued by ISO 90001, ISO 14001, ISO 27001, ISO50001, ISO 22000, ISO 1348 and ISO 16949 for the period 2010 t0 2015.

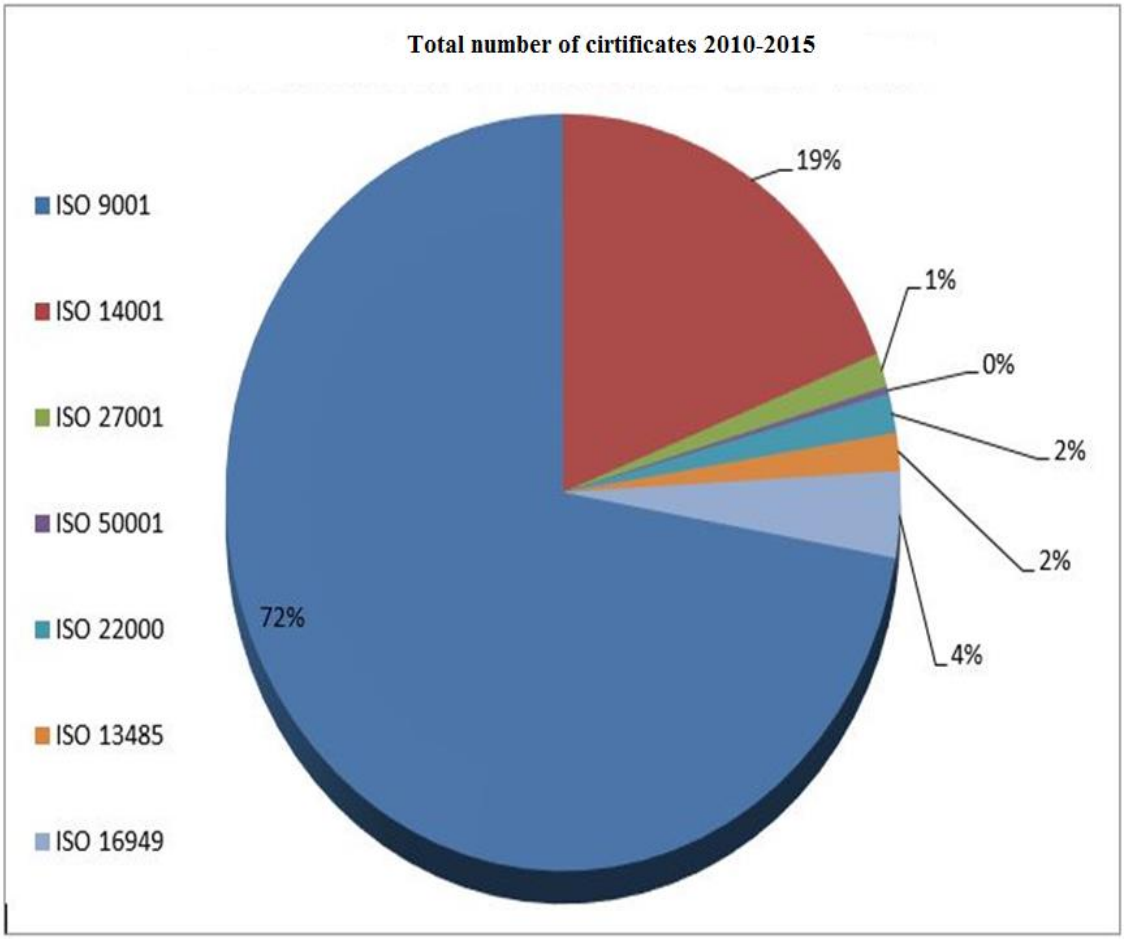

Figure 2-1 Percentages of the number of certificates issued in period 2010-2015 for the most popular ISO models.

Table 2-1. The total number of certificates for most popular models of ISO in the last six years (2010-2015).

SMS model	Number of certificates	SMS model	Number of certificates
ISO 9001	6197027	ISO 2200	145175
ISO 14001	1634218	ISO 13485	139190
ISO 27001	124746	ISO 16949	316146
ISO 50001	26271	TOTAL	8582773

2.3 Quality management system standard (ISO 9000) series.

The ISO 9000 family standards, which founded to address a various aspects of quality management and to improve the level of management quality of management for organizations throughout the globe. Moreover, to provide guidance and tools a variances companies and organizations who want to ensure that their products and services consistently meet customer's requirements, and that quality is consistently improved. The ISO community produced a many of ISO's best-known standards. The most famous and known one is ISO 9001 standard series. The ISO 9001:2015 which is the last version of the ISO 9001 series (published in October 2015) to replace the previous version (ISO 9001: 2008) which was the fourth version of ISO 9001 issued. The first issued version was ISO 9001:1987 (in the year 2007), followed by the version ISO 9001:1994 (issued in the year 1994) and, the third, ISO 9001:2000 (issued in the year 2000).

In addition, from the sector - specific applications side, ISO 9001 has a range of standards for quality management systems, which based on ISO 9001 and adapted to specific sectors and industries. These standards include, ISO/TS 16949 for automotive production, ISO/TS 29001 for petroleum, petrochemical and natural gas industries, ISO 13485 for medical devices, ISO/IEC 90003 for software engineering, ISO 17582 for electoral organizations, and ISO 18091 for local government [8].

2.4 Quality management system ISO 9001:2015

Since September 2015, the fifth edition from the ISO 9001 series standard (ISO 9001:2015) has published for cancels and replaces the previous edition from the ISO 9001series (ISO 9001: 2008) standard version.

The new version of QMS ISO 9001:2015 has issued officially on September 15, 2015 and it has a completely new structure through revolutionary and radical changes on its clauses compared with the preview issued version. It defines common requirements for all management systems and it is mandatory for all new standards and also, for the revision of the existing management system standards [4]. Moreover, it is necessary, for any organization wishes to maintain its certification to ISO 9001, to upgrade its quality management system to the new edition of the standard and seek certification to it. In three-year transition period from the date of publication (September 2015), the organization, must move to the 2015 version. This means that, after the end of September 2018, a certificate to ISO 9001:2008 will no longer be valid, and the main changing in terms [7] are:

- Terms, product in ISO 9001:2008 version turn into products and services.
- Exclusions turn into applications,
- Documentation becomes records documented information,
- Work environment change to environment for the operation of processes,
- Purchased product replaced by externally provided products and services, and
- The term supplier as external provider.

2.4.1 Basic concepts of quality management

Quality management system (QMS) has several concepts, which can consider as [9, 10, 11]:

- A Quality Management System in its basic concept is quite simple. It seeks to recognize the external quality related requirements specified in Licenses to Trade, guidelines, specified customer requirements, and the chosen management system standard(s).
- Ensure that all requirements have documented within the management system in the appropriate location in terms of defined specific system requirements.
- Confirm that employees receive applicable training in the quality system requirements
- Outline performance processes, where applicable, to the quality system requirements
- Produce records or evidence that system requirements have met.
- Measure, monitor and report the extent of compliance with these performance procedures.
- Continually monitor and analyze changes to the requirements and confirm that all changes reflected in the changes to the specific requirements when necessary.
- Execute the auditing and analyzing the system processes and correct them when necessary.
- Include processes that will help continually improve the quality management system.

2.4.2 ISO 9001:2015 – QMS principles

ISO 9001:2015 bases on a seven principles, which are, discusses in brief and as shown in the figure 2.2 [12, 13, 14, 15]:

1- Customer requirements and, it is the primary focus of quality management is to meet customer requirements and to strive to exceed customer expectations. All these are to get increase of customer value, satisfaction and loyalty.

2- Leadership. Leaders establish unity of purpose and direction of the organization by establish a vision and direction for the organization, defending the goals, evaluate organizational, built the trust and recognize employee contributions[12].

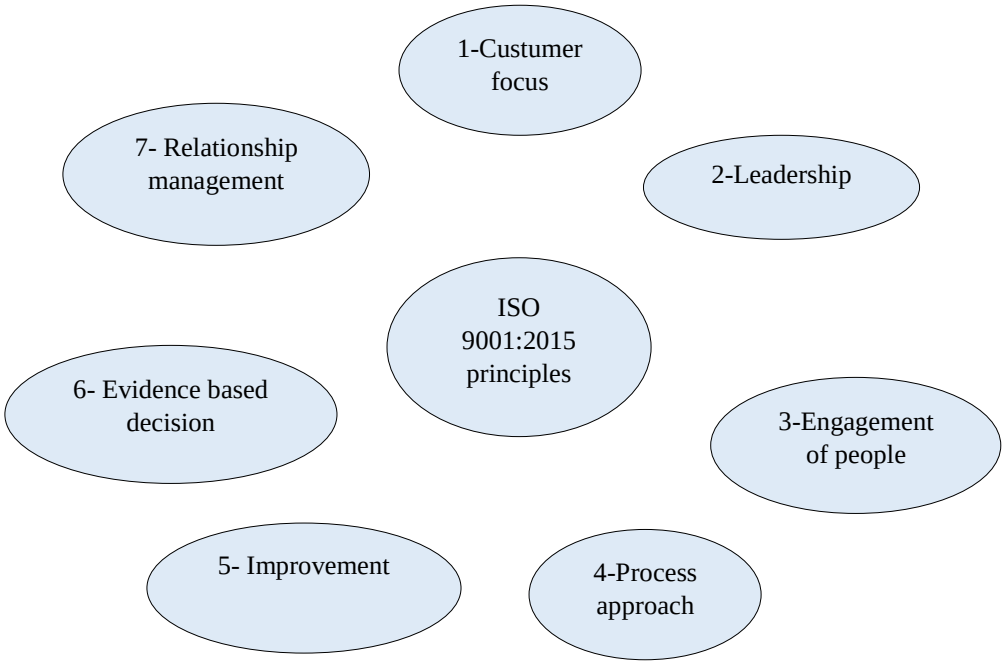

Figure 2-2. The seven ISO 9001:2015 principles.

3- Engagement of people. of course, to get the highest level of success, we must looking to the people as most important factor in all level of the organization and by the full engagement of them we can establish sustained success. The management of the organization must find such ways that encourage employees to make important decisions as that will make them accept as their own, to create the better feeling of responsibility and the obligation to implement them [14].

4- Process approach. The process is the chain of activities that in a recurrent flow creates value and, results of products and services are depending on the improving of processes [14].

5- Improvement. It is for an improvement in decision-making processes.

6- Evidence-based decision-making with main benefits ,an improvement in decision making processes ,assessment of process performance and ability to achieve objectives , operational effectiveness and efficiency, increased ability to review, challenge and change opinions and decisions, there is an increased ability to demonstrate the effectiveness of past decisions.

7- Relationship management. The main benefit are enhanced performance of the organization and, an increased capability to create value for interested parties by sharing resources and competence and managing quality related risks.

2.4.3 ISO 9001-2015 clauses

The strategy of the International Standards Organization looks to create a common approach to all management system standards and, it will apply to all certification standards, and the ISO 9001 Quality standard is one of them. Part of this approach includes a common high-level clause structure [16]. As we mentioned in the preview section 1.2.1 that, new version of QMS ISO 9001:2015, which was the last version officially, issued from the ISO 9001 series has a significant and essential changes compared with the preview issued version. Moreover, the preceding version of ISO 9001, was ISO 9001:2008 so, comparing between these versions (ISO 9001:2008 and ISO 9001:2015) are needed for the knowledge about the extent of changes between them.

For instance, instead of the only eight chapters of old version (ISO 9001: 2008), in the newest version (ISO 9001: 2015) it has more two chapters (ten chapters) with completely different headings. In the first three clause, there were not any changed and, main changing accrued on the clauses from the fourth to the tenth. In addition, the new essential requirements of the QMS, compared to the previous model, are the context of the organization, the extended process model, measures relating to risk and

opportunities, knowledge in order to achieve quality, innovation, procurement management (ISPs), recorded information. Number of terms also has expanded compared to the previous model.

In the table 2-2 there are a simple compering between the ISO 9001: 2015 and the preview version ISO 9001: 2008 from the side of the clauses for the two versions. The number of clauses becomes ten clauses in version 2015 instead of eight clauses in the in preview version 2008.

Table 2-2. The clauses of the ISO 9001: 2015 compared with preview version ISO 9001: 2008 clauses.

ISO 9001 : 2008	ISO 9001 : 2015
1. Introduction	Introduction
2. Scope	Scope
3. Normative reference	Normative reference
4. Terms and definitions	Terms and definitions
5. Quality management system	Context of the organization
6. Management responsibility	Leadership
7. Resource management	Planning
8. Product realization	Support
9. Measurement, analysis and	Operation
10. ----------	Performance evaluation
11. ----------	Improvement

Clauses of ISO 900:2015 in brief are [17, 18];

0. Introduction.
1. Scope.
2. Normative reference.
3. Terms and definitions [16]. The ISO 9001 defines the terms, which used related

to the Terms related to person or people, terms related to organization, terms related to activity, terms related to process, terms related to system, terms related to requirement, terms related to result, and many other terms.

4. Context of the organization. The current rule ISO 9001:2015 proposes, as starting point of the QMS implantation, the definition of the context of the organization. The organization needs to determine internal (values, culture, and development of the organization...) and external issues (legal framework, social, technological,

competitive...) that may be relevant to the achievement of the objectives of the QMS itself, which might affect the objectives and strategies of their own organization. Therefore,

5. It is necessary to understanding organization and its context, understanding needs and expectations of interested parties, determining the scope of Quality Management System and, Quality Management System and its processes.

6. Leadership. This clause deals with policy and, Organizational roles, responsibilities and authorities.

7. Planning. Looking for the actions to address risks and opportunities, Quality objectives, planning to achieve them, and planning changes.

8. Support. The resources, competence, awareness, communication and, documented information are the goal of this clause.

9. Operation. Its works with the fields operational planning and control, requirements for products and services, design and development of products and services, control of externally provided processes, products and services, production and service provision , release of products and services, and Control of nonconforming outputs.

10. Performance evaluation. It refers to monitoring, measurement, analysis and evaluation, internal audit and, management review.

11. Improvement. The main goal of this clause is continual improvement.

2.4.4 Benefits of quality management system.

Organization may get many benefits by introducing and using the quality management system as [18].

- Supply a product and/or a service as the requested requirements by the user to increase the confidence and customer satisfaction parallel they obey with the current legal requirements,

- Be able to aware and locate of the sources risks and opportunities that related with this activity

- And, be able to demonstrate the approval and accepted of the product and/or service, obtaining the internationally recognized certifications.

2.5 QMS certification around the world –stat of the art

2.5.1 QMS certification around the world diffusion

ISO is a worldwide federation of national standards bodies was established in 1946 in Geneva, Austria, and has been seated there ever since [4] and by the time, a number of members increases form both developed and developing countries [4,6]. More than 19000 international standards have published since 1947 covering all aspects of technology and business [5]. Developing of the ISO standards are carrying out through by a hierarchy of technical committees and subcommittees (currently more than 700) and their associated working groups (currently more than 2200) [9]. ISO 90001, ISO 14001, and ISO 27001 are among ISOs most well-known and recognized quality management standards applied all around the world, and recently, they constitute the conceptual framework for business process standardization [5]. Since 1987, when the first certification of ISO has issued there is enormous diffusion of certificates through the entire world every year. For example, in the year 2015 the following number consist of ISO 9001: 2008 (1 029 746), and ISO 9001: 2015 (4190) [20]. According to the vast prevalence, many studies have done to find out the reasons of this spread and determine the impact of ISO practices on organization performance. Generally, there are a various reasons, which push an enterprise to certify, both internal and external [21]. Some studies keep exogenous reason first to motivate a company for seeking the certification (benefits, ability to preserve or improve the share of the market. In addition, it has asserted that for exporting companies, the certification is requirement for them to have direct access to other markets supporting [22]. Other studies prove that endogenous reasons are the significant to push a company for seeking certification [22]. Studies about the impact of ISO certificates on organizational performance are varied even the

majority of them prove a positive relationship between implementations of ISO and organizational improvement [23]. The diffusion of ISO certifications started mostly in Europe companies, and then they pressed their supplier from other parts of world to seek ISO certification [24]. The effect of quality on business performance has based on manufacturing and market, by improvement of internal process quality results in better operational performance. The improvement of products or services quality will influence customer and improve business performance [23].

However, the variation of reasons for seeking certification and the impact of ISO practices on organization performance, the diffusion of number of certification vastly grows (ISO surveys number of certification issued) and there are no indicators for reach Saturation level by the statistical analysis result as shown in forecasting analysis for the number of certificates in the next few year. ISO 9001(Quality management system) gets the highest number of certification for the past time in Europe and al the world with an enormous difference with the other models of the ISO, and by the statistical analysis result ,ISO9001 will continue grow with the same way in the next few years (up to the year 2022).

2.5.2 QMS certification around the world –state of the art - Quantitative analysis

Since 1978, when the first model of ISO 90001 issuing, it has been considered as the engine of development of business standardization process [4]. A great deal of attention has been given to the issue of quality management certification and the reasons for the steady increase in the number of certificates and their relationship to some environmental and economic factors and the size of companies, institutions, the reasons and, others. Also, to look for the reasons of the desire of different institutions and companies to be accredited by the ISO. ISO certificates are widely distributed in organizations with 10 or more users, while significantly decreasing among smaller organizations [25]. by success of implementing ISO 9001 quality management systems will increase operational and business performance if it is well planned and implemented when the philosophical quality[26]. In general, the concepts of quality management have applied more in large companies than in small companies, that is,

large firms achieve better quality performance compared to smaller firms. [27]. There is an interesting relationship between ISO 9001 motivations and the corresponding benefits especially, when companies achieve ISO 9001 certification based on internal motivations [28]. Companies, which got on ISO 9001 certification for internal reasons have perceived higher benefits than those, which have become certification based on external motivations, but it was easier to quantify increased profits and sales deriving from ISO 9001 certification for the companies that got certification for external reasons [23]. Various organizations earned this certification for their business operations because as increasingly more of their suppliers became ISO 9001-compliant, they also requested the organization to attain the certification as well. One of the main results for many companies in implementing this approach is improved sales; many companies experienced that without having attained the ISO 9001 certification they could not have won a significant number of new contracts [29].

ISO survey 2015 illustrates the story of ISO 9001 certifications for all its models from the year 1992. Table 2-3 shows the development of the number of certification issued by IMS for over the plant in the period from 1993 to 2015. Table 2-3 presents the percentage for number of certificates for ISO 90001 in this period in seven divided areas. And from this table, it is noticeable that the number of certifications for Europe is strikingly higher than the other areas in the all years with a percentage from 42.5% to 81%. In the last period the East Asia and Pacific has been growth for the number of certificates obtained and become a fierce competitor for Europe, and the difference of number of certification dropped to the less than 2% in 2015 comparing with more than 70% in the year 1993. However, Europe peaks the top of the number of certificates issued in all the period. On the other side, Africa reaches the bottom by the lowest number in all period except the first four years. Not away from Africa comes the Middle East the flows by Central and South Asia, North America and Central and South America respectively. The figure 2.3 summaries the development of the number of certifications issued in the seven deferent areas for 24 years.

Table 2-3. The number of ISO 9001 certificates in the word 1992-2015.

Year	AF	C&S-A	NA	Europe	E-A &P	C&S-AS	ME	Total
1993	1009	140	2613	37779	4767	74	189	46571
1994	1177	475	4915	55400	7719	330	348	70364
1995	1563	1220	10374	92611	19766	1038	776	127348
1996	2255	1713	16980	109961	27885	1712	2194	162700
1997	2555	2989	25144	143674	42824	2963	3149	223298
1998	3342	5221	33550	166255	54671	3556	5251	271846
1999	4928	8972	45166	190247	81950	5508	6870	343641
2000	4769	10805	48296	219173	109217	6411	9003	407674
2001	3903	14409	50894	269648	155597	6348	9550	510349
2002	4529	13679	53806	292878	177767	9383	9724	561766
2003	3769	9303	40185	242455	185846	9162	7199	497919
2004	4865	17016	49962	320748	240938	13856	12747	660132
2005	6763	22498	59663	377172	266100	27966	13681	773843
2006	7441	29382	61436	414208	320320	44923	19195	896905
2007	7446	39354	47600	431479	354056	50379	21172	951486
2008	8534	37458	47896	455303	366491	44171	20469	980322
2009	8435	35549	41947	500286	408498	44432	24604	1063751
2010	7667	49260	36632	530039	396492	37596	18839	1076525
2011	8164	51685	37530	459367	402453	33577	17069	1009845
2012	9674	51459	38586	469739	396398	32373	19050	1017279
2013	9816	52466	48579	458814	387543	44847	20812	1022877
2014	10143	50165	41459	453628	414801	44790	21335	1036321
2015	12154	49509	46938	439477	422519	40822	22761	1034180

*AF-Africa, C&S-A Central and south America, NA-North America, E- A &P- East Asia and Pacific, C&S-AS- Central and South Asia, and ME Middle East.

The total number of ISO 90001 certifications which issued among the period 1993-2015 was 14746942, Europe peaked the highest number by 7130341certificates, flowed by East Asia and Pacific With 5244618 certificates and together (Europe and, East Asia and Pacific) reached about 84% from the total number of certificates in all the world in this period of time. Africa stayed at the bottom by only 134901 in the figure 2.4, the pie chart shows the distribution for the total number of ISO 90001 certifications in the period 1993-2015 between the seven areas.

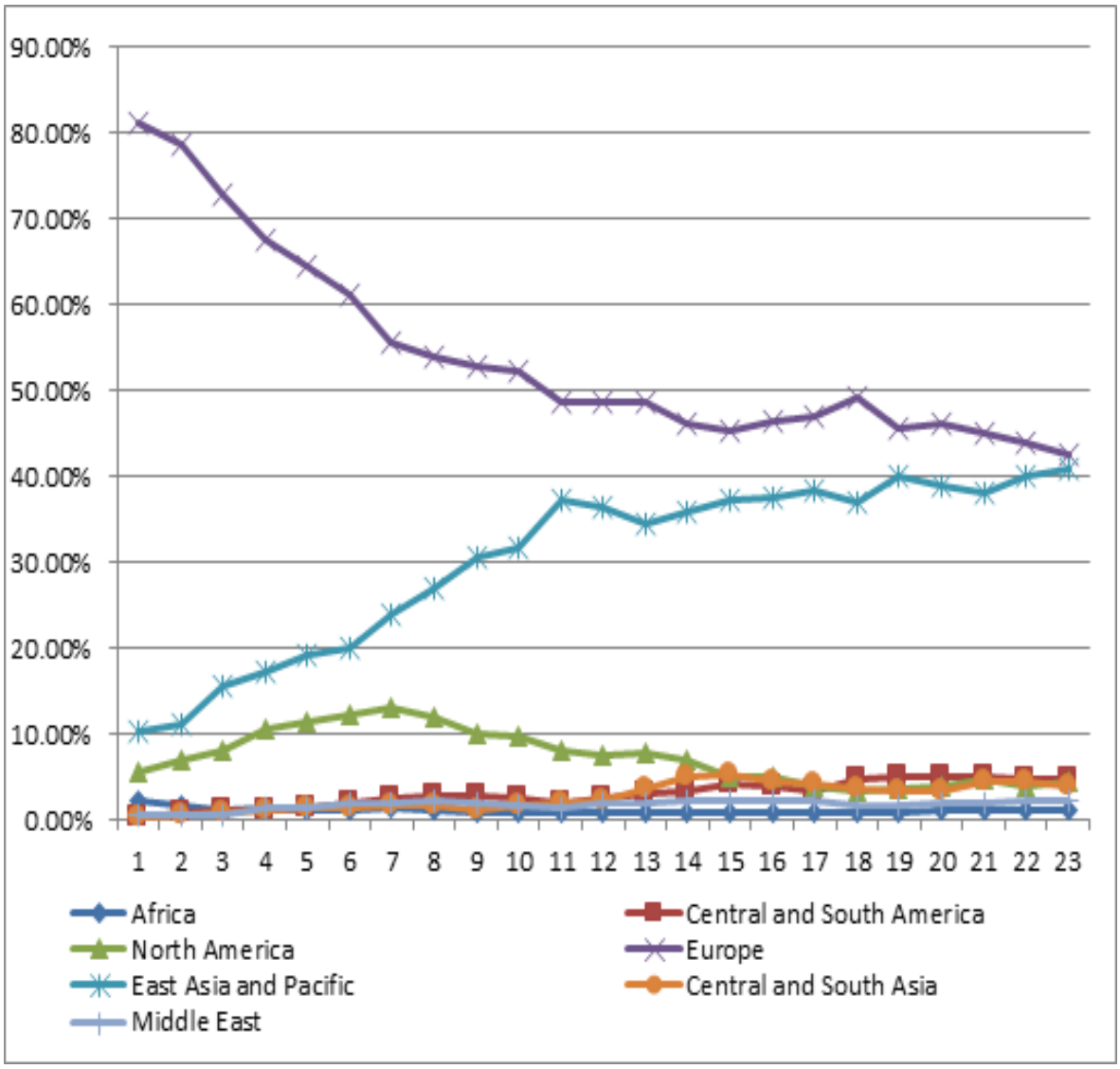

Figure 2-3. The number of certificates in 1993-2015

As countries, China (from Asia) leads the diffusing of the ISO 90001 certificates, flows by Italy (from Europe). Germany, Japan, the UK, India, the USA, Spain, France, and Romania had gotten the highest number of certificates. In 2015, China got 28.3 percent by 292559 certificates from the total of issued certificates Italy comes in the second by 13% and 132870 certificates from the total. Then, Spain, Germany, the UK, India, the USA, France, and Romania comes at the last, with 10th order, by 20524 certificates.

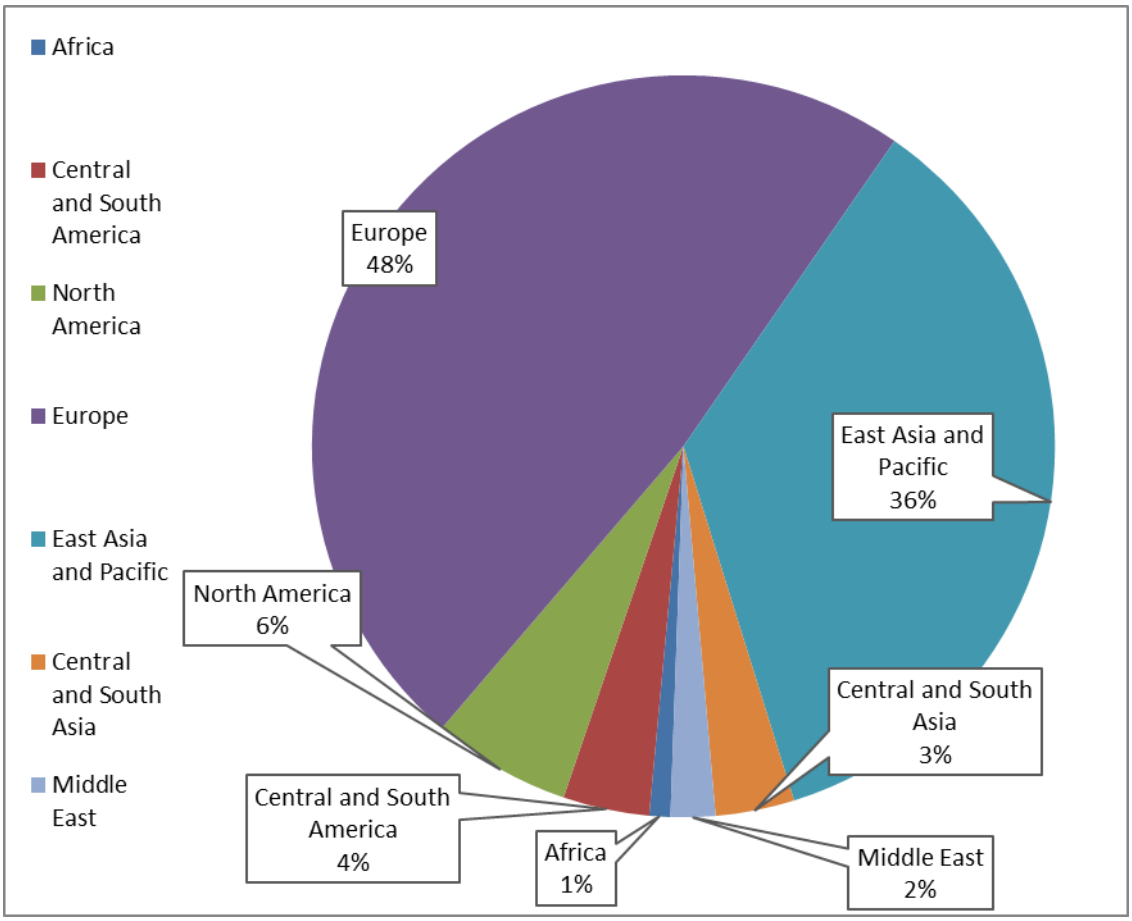

Figure 2-4. The distribution for the total number of ISO 90001 certifications in the period 1993-2015 between the seven areas

These named ten countries obtained more than 69%. The table 2-4 and the figure 2-5 shows the top ten countries in 2015.

2.5.3 QMS Certification diffusion in European countries Quantitative analysis.

The preview section shown that the European continent gets the highest number of ISO 90001 certifications compared with other continents. The table 2-4 represents full information about the number of cortication for all European countries in period 1992-2015.

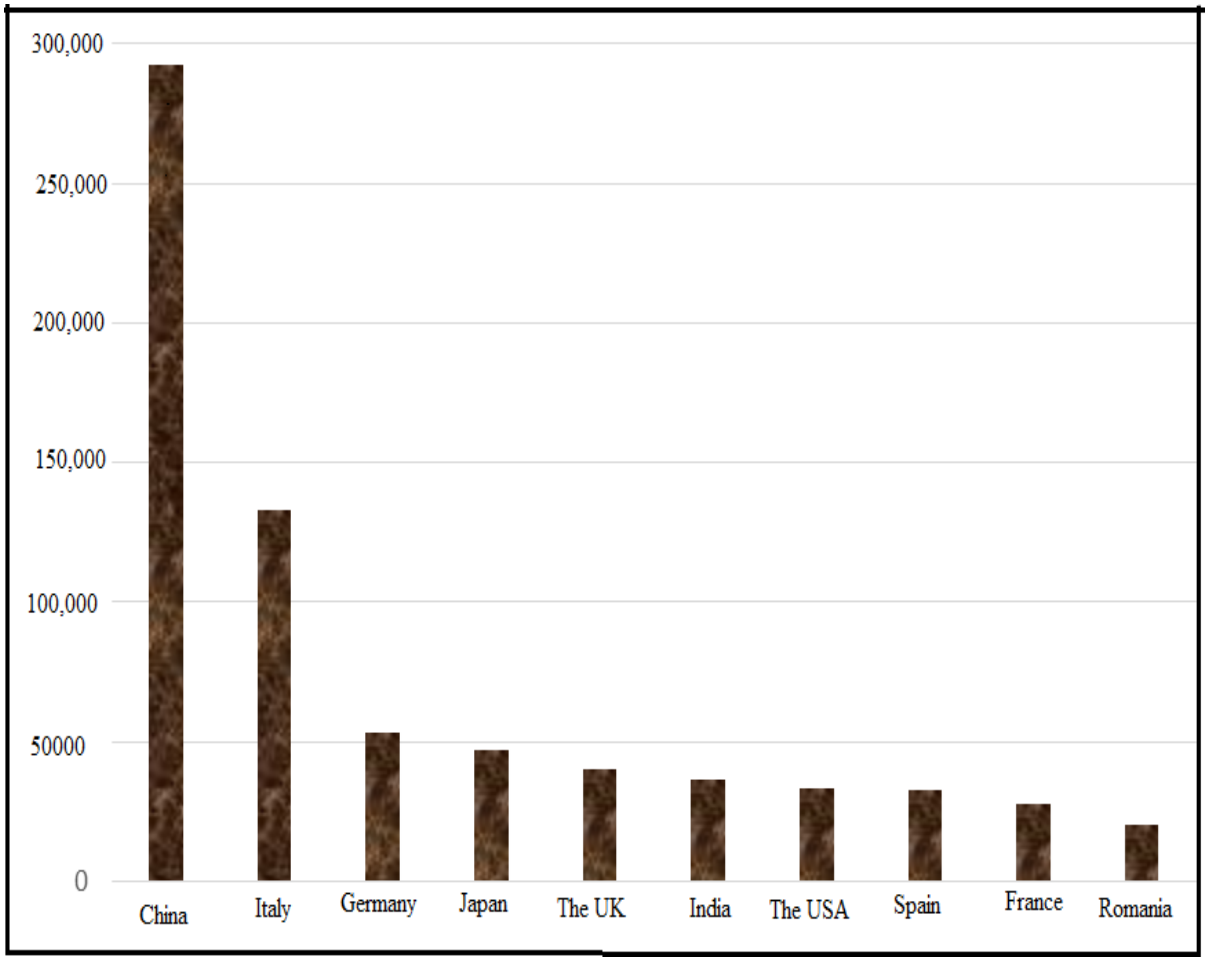

Figure 2-5. The top 10 countries for ISO certification number in 2015

The UK leads the Europe by the highest number of ISO 90001 certifies in the first interval 1993-1995 by 117516 certifications which repents 63.25% from total certifications in this period for all European countries. Germany and France follow the UK in second and third places. About fifteen countries, does not get any certification in this period.

In the second period 1996-99, the UK peaks also the highest number with 38.14% from the total certifications in this period flows by Germany with 87840 certifications and 14.4%. Italy comes in third place by 58619 and 9.6%. Only four countries stays without any ISO 90001 certificated.

In the interval 2000-03, the UK also gets the highest number by 236910 certifications and 23.15%. Italy in the second and becomes so closed to the first, Germany still in the third place flows by Spain, France, and Netherlands respectively.

In the period 2004-07, the UK loses her place to drop to the third position and Italy peaks the top with 403671 certifications and 26% from the total. Spain comes in the second and Germany the fourth position.

At the interval 2008-11, the first countries stays same Italy, Germany, Spain, the UK and France are coming in the order first to fifth respectively. The last interval 2012-15 stays in the same for the first five orders.

It clear that there are neuromas of variation between the European countries about the number of ISO 90001 certification, in every year the first three counties get on more than the half of the certification issued, in the first period the UK itself gets on more than a half of certification in Europe.

Table 2-4. The numbers of certificates (in 1000) in European countries 1993-2015

Year / Country	1992-95	1996-99	2000-03	2004-07	2008-11	2012-15	Total
Albania	0	0	6	68	414	766	1254
Andorra	0	1	16	45	115	114	291
Armenia	0	4	35	194	242	86	561
Austria	1767	11117	14729	14636	17848	17880	77977
Azerbaijan	0	1	5	642	526	926	2100
Belarus	0	46	353	3295	4085	6862	14641
Belgium	3050	11584	16322	17968	15747	14950	79621
B H	0	46	199	1453	3783	3669	9150
Bulgaria	3	351	2199	11665	21894	22585	58697
Croatia	24	591	1887	5988	9088	10555	28133
Cyprus	13	299	1289	2226	2619	1820	8266
Czech Republic	245	4055	20536	46793	53059	47235	171923
Denmark	2838	7451	7256	5903	6618	7861	37927
Estonia	2	108	919	2129	3045	3974	10177
Finland	1592	5951	7254	7488	8630	10485	41400
France	10481	50221	73032	87799	105,83	115,75	443115
Georgia	0	2	29	184	370	353	938
Germany	15240	87840	133,53	158,12	195,60	216,34	806678
Gibraltar (UK)	0	0	54	180	118	114	466

Table 2.4 Continued.

Greece	384	2844	9293	15712	20271	23721	72225
Hungary	390	6706	28038	51152	32217	27116	145619
Iceland	19	193	110	76	104	262	764
Ireland	3642	10544	11007	7962	8607	9109	50871
Italy	7686	58619	203,81	403,67	534,53	544,77	175,308
Kosovo	0	0	0	0	0	9	9
Latvia	0	55	327	2012	2804	3829	9027
Liechtenstein	33	204	326	326	385	312	1586
Lithuania	2	163	979	2584	4301	4727	12756
Luxembourg	79	354	502	597	756	824	3112
Malta	16	178	809	1223	1688	1874	5788
Moldova, Republic	0	30	53	150	431	504	1168
Monaco	8	70	124	151	133	162	648
Montenegro	0	0	0	169	548	434	1151
Netherlands	9504	39556	46896	53406	48142	43642	241146
Norway	1462	5394	5818	5948	7175	8513	34310
Poland	147	2709	11004	32770	46851	40887	134368
Portugal	655	3429	10648	21687	20405	29195	86019
Romania	48	1010	7217	30339	57147	75972	171733
Russian Federation	35	824	5323	26624	144776	44549	222131
San Marino, Rep of	0	63	60	95	143	189	550
Serbia	0	0	103	3538	9842	10265	23748
Slovakia	75	1674	4041	9093	14633	18453	47969
Slovenia	158	1642	3307	7993	6992	6741	26833
Spain	2398	21875	90851	211081	241217	170787	738209
Sweden	2078	11995	16156	19503	21311	18773	89816
Switzerland	3579	21904	35864	46023	45773	46995	200138
FY RM	0	0	47	759	1189	1604	3599
Turkey	605	5169	12416	41090	47048	32293	138621
Ukraine	13	182	1621	6267	9504	4715	22302
United Kingdom	117516	232458	236910	172922	167579	165290	1092675
Total	185787	609512	1023307	1541702	1946139	1818848	7125295

The graph in the figure 2-6 shows the top six countries in Europe (Italy, the UK, Spain, Netherlands, Germany and France).

At the staring period, overall, the UK gets so larger number of ISO 9001 certification compared with the other five countries where any of them, gets less than 10% from the UK number. At the second period, as the UK rises and reach double value of firs period, the other five countries also increase.

By the end of third period, Italy surges and become much closed from the UK. The four remained countries fluctuate in this period.

In the fourth and fifth periods (2004-11), Italy surges flows by Spain, the UK falls and other three countries (Netherlands, Germany and France) stay in a period of stability.

Finally, at the last period (2012-15), Italy peaks the highest number with a neuromas variation compared with the other competitors. The number of certification of Spain dips and for the UK, Netherlands and Germany stay in a period of stability.

2.5.4 QMS certification in the European countries, qualitative analysis.

As the ISO certification has continued diffusion since it issued, there are several a lot of views and analyses on their relationship to the economic aspect and overall growth. A number of views and analyses on their relationship to the economic aspect and overall growth. They work for prove if there is a relationship between the continuous growth of number of certificates issued and various economic indexes. There is seems to be some evidence to support that there is a positive relationship between ISO 9000 certification and countries' economic development. By using the index, factor Gross National Income per capita (GNIpc) although exceptions can also be found in this regard with some a positive relationship between the number of certified companies and the number of companies that do carry out innovation activities in some countries. In addition, on average, the EU countries ISO 9000 growth trajectories (per capita and as a percentage of certified companies) were robust and consistent during the 11 years here considered, that range from 1992 to 2004. [25].

Here in this study, we did some of the qualitative analysis for some of European countries (figure 2-6), which have the highest numbers of certificates, and it has carried out by using three parameters, which were:

(i) Parameter1, which represents the number of certificates per 1,000 inhabitants of the countries,

(ii) Parameter 2, which represents the number of certificates that "take part" in the 100 000 Euros of GDP making, and

(iii) Parameter 3, which a result of number of inhabitants divided by the value of (number of certificates *GDP).

The table 2.5 shows the collected data and calculation of each parameter.

a) For parameter 1, Italy comes as the first in order with the highest a rank, flowed by Czech Republic as the second then, Romania, and Spain.

b) Parameter 2, Romania had the highest rank, then, Bulgaria, Italy, and so on.

c) In the last parameter 3, Italy was on the top of the list, Germany got the second, and the UK got the third place parameter 3.

According to results obtained also for the top twenty four European countries for the number of certificates had issued (table2-5) and the three parameters there seems to be an apparent weak relationship between the number of ISO 9001 certificates per 1000 inhabitants (NC/NI)and the levels of economic development reached in different countries. Italy, Spain Germany and the UK which high value of number of certification per 100000 inhabitant have also a high gross domestic product per number of certificates but also other county have same result. As result of parameter 3, there seems to be an apparent positive relationship between it and the numbers of ISO 9001 certificates per 1000 inhabitants. Countries which have value numbers of ISO 9001 certificates per 1000 inhabitants (Italy, Spain, Germany), get smallest values for this parameter and the posit is write (Serbia, Croatia, and Denmark) which get high value for parameter three they, have small ISO 9001 certificates per 1000 inhabitants vales.

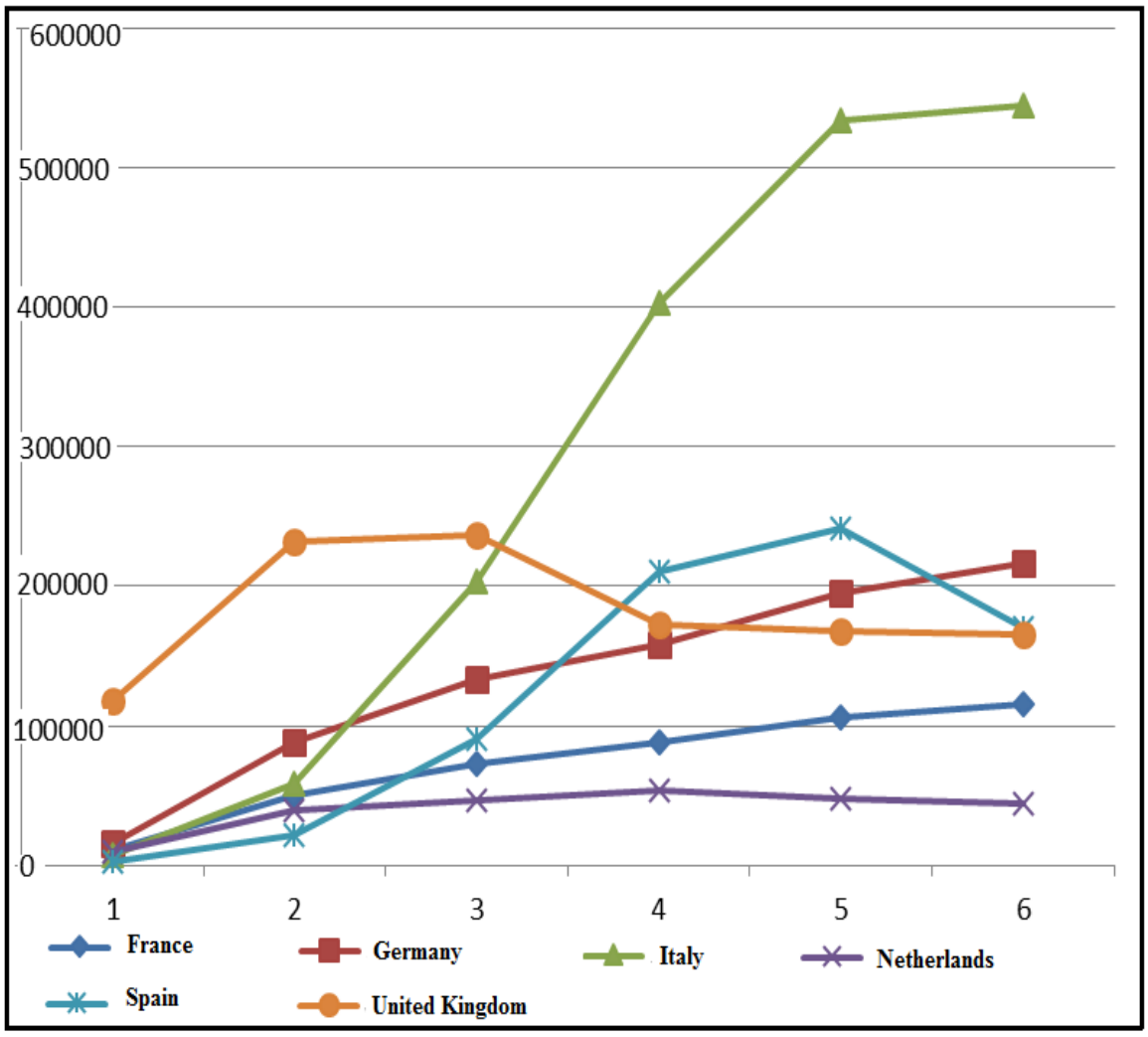

Figure 2-6. The number of certification in the top six countries in the Europe.

Table 2-5. The data and results for the three parameters.

	Country	NC	NI	GDP	NC/NI	GDP/NC	NCG
1	Italy	202551	61.07	2147.952	3.31669	10.6045	0.14037
2	Spain	52687	47.07	1406.855	1.1194185	26.702128	0.63498
3	Germany	73762	82.65	3859.47	0.8924378	52.324327	0.29033
4	UK	62111	63.49	2945.146	0.9782918	47.417462	0.34708
5	France	40556	64.64	2846.889	0.627401	70.196494	0,5599
6	Russian	13575	142.0	1857.461	0.0955986	136.82954	5.63157
7	Romania	30714	21.64	199.95	1.4193051	6.5100606	3.5237
8	Czech	20466	10.74	205.658	1.9055036	10.048764	2.55179
9	Switzer	16067	81.58	712.05	1.9706061	44.292735	0.71267
10	Netherland	14027	16.80	866.354	0.8348181	61.763314	1.38266
11	Turkey	13421	76.67	806.108	0.1750538	60.063185	7.08666
12	Poland	13554	38.22	546.644	0.354626	40.330825	5.15852
13	Hungary	10101	9.933	137.104	1.0168956	13.57331	7.17255

Table 2-5 Continued.

14	Sweden	9728	9.63	570.137	1.0100443	58.607833	1.73653
15	Greece	7887	11.13	238.023	0.708727	30.179156	5.92792
16	Portugal	9853	10.61	230.012	0.9286256	23.344362	4.68176
17	Bulgaria	8100	71.68	55.837	1.1300226	6.8934568	15.8486
18	Austria	6197	8.53	437.123	0.726799	70.537841	3.14762
19	Slovakia	7090	5.45	99.971	1.2999266	14.100282	7.69497
20	Belgium	5524	11.14	534.672	0.4956741	96.790731	3.77326
21	Finland	4425	5.44	271.165	0.8128966	61.280226	4.53660
22	Denmark	2971	5.64	340.806	0.5267559	114.71087	5.57036
23	Croatia	4006	4.27	57.159	0.9377244	14.268347	18.6569
24	Serbia	3964	9.47	43.866	0.4186567	11.066095	54.4520

*NC-number of certification, NI-number of inhabitant by million, GDP- Gross domestic product by billion, NCG- NI/ (NC*GDP), NC/NI (parameter1), (GDP/NC) (parameter 2, and NCG (parameter 3.

According to results obtained also for the top twenty four European countries for the number of certificates had issued (table2-5) and the three parameters there seems to be an apparent weak relationship between the number of ISO 9001 certificates per 1000 inhabitants (NC/NI)and the levels of economic development reached in different countries. Italy, Spain Germany and the UK which high value of number of certification per 100000 inhabitant have also a high gross domestic product per number of certificates but also other county have same result. As result of parameter 3, there seems to be an apparent positive relationship between it and the numbers of ISO 9001 certificates per 1000 inhabitants. Countries which have value numbers of ISO 9001 certificates per 1000 inhabitants (Italy, Spain, Germany), get smallest values for this parameter and the posit is write (Serbia, Croatia, and Denmark) which get high value for parameter three they, have small ISO 9001 certificates per 1000 inhabitants vales.

CHAPTER 3

3 QUALITY IMPROVEMENT IN INDUSTRY

3.1 Introduction

Since the prehistoric beginnings of human material culture, until now days, productivity or the production size has been main target in industry field. In our present era, People (the customers) all over the world expect quality products and services as a right and not an option. From historically side, in the precedent era, a size of production or productivity concept had the Priority to the product quality concept. The quality of product get lowest important comparing to production size. This fact may be the main reason for the Juran when he argued that in the twentieth century is production size century, and the twentieth century will be the quality century [30, 31].

3.2 Quality era emerged

At the end of the eighth century and the beginning the twentieth century, when the industrial revolution started in the Europe and North America, the quantity (production size) was the main goal or the target of the companies and factories. The production quantity and scale accompanied by the circulation of shoddy goods and products [5]. In that period of time, they was treated with quality concept as an object luxurious , and only few of people concerned about it therefore, it was rarely used in the production and services sectors. Then the quality concept has received a considerable attention from the companies' management and, modern quality has emerged at the middle of the twenty a century when the typical production and mass production started in the Europe and the USA. Mass production system necessitates using huge number of workers who have variation skill and knowledge to produce a different parts product and almost they need assembly in the factory or may be in other place. To work with these problems, a scientific approaches have started and successfully implemented by Frederick Taylor (Taylor, 1914; Locke, 1982), and quality

gurus era started and the movement of quality systems (TQM, QMS, SIX sigma,….el, is a result of the philosophies of quality gurus or leaders who use a scientific approach of the quality. In brief, we introduce the famous quality gurus who were at the first debates in the twenty centuries and what their Contributions in quality improvement journey [30].

3.2.1 Quality gurus

There are many concepts or definitions for meaning of word guru like a "respected teacher", "spiritual leader", "good person", a wise person who in his field who has more than made a great contribution and innovation, but also he presents a large-scale revolution. People, who have established themselves and profiled philosophical trends in quality, are the gurus of quality [31]. In brief, there are the fumes quality gurus who have the major contributed on the quality development:

Walter Andrew Shewhart - (The Father of Statistical Quality Control). He graduated from the University of Illinois with bachelor's and master's degrees, and he received a doctorate in physics from the University of California at Berkeley in 1917 Most of Stewart's professional career was spent as an engineer at Western Electric from 1918 to 1924, and at Bell Telephone Laboratories [32].

- Statistical quality control (SQC)
- Statistical process control (SPC)
- Process Capability
- Control charts

Ford is moving assembly line combined with Stewart's statistical methods of quality control contributed mightily to the creation of Detroit "The Arsenal of Democracy" as during World War 2 and the subsequent rise and dominance of the US manufacturing in the three decades immediately following the war [30, 33].
By the late 1800s, a new form of production emerged first in Europe and then in the US: mass production. A key element of mass production was the "scientific" approach to

work including differentiation of labor by skill level advocated and successfully implemented by Frederick Taylor (Taylor, 1914; Locke, 1982) [30].

Joseph Moses Juran - (1904-2008) - in 1924 he get his B.S. in Electrical Engineering after, in 1936 a J.D. in Law at Loyola University. During his career, he published many international handbooks, training books, training courses which translated into 16 languages [34]. The Juran Trilogy was the most important contributed of Joseph Moses Juran in the quality. The Juran Trilogy is an improvement cycle that meant to reduce the cost of poor quality by planning quality into the product/process [35]. The figure 3-1 shows the Juran Trilogy. The three stages cycle of Juran quality improvement are:

1. Quality Planning. In this stage the more important issue, is defined the customers and what his needs to be satisfied. Then, define the requirements to produce the product.
2. Quality Control. In quality control stage, we need to measure the actual performance, and find the gap between your performance and your goal. There are many tools may use in control Pareto Analysis, flow diagrams,, and control charts, to name a few[35].
3. Quality Improvement. There are four different "strategies" to improvement that could be applied during this phase, which are,

- Repair: Reactive; fix what is broken.
- Refinement: Proactive; continually improve a process that is not broken (like the continual pursuit of perfection in Lean!)
- Renovation: Improvement through innovation or technological advancement
- Reinvention: Most demanding approach; start over with a clean slate.

Kaoru Ishikawa (1915 – 1989). Was a Japanese professor, in 1939, Kaoru Ishikawa had obtained his Master's degree (MSc.) in applied chemistry from the University of Tokyo, in 1960; he obtained his doctorate from the University of Tokyo.

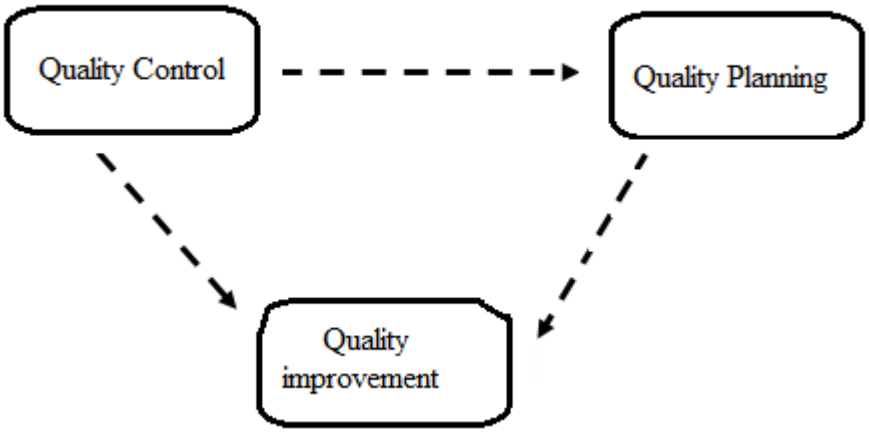

Figure 3-1The Juran Trilogy

He was advisor and motivator with respect to the innovative developments within the field of quality management. The best contributed of Kaoru Ishikawa in field quality management is Cause & Effect Diagram or Ishikawa Diagram. A Cause-and Effect Diagram is a tool that shows systematic relationship between a result or a symptom or an effect and its possible causes. It is an effective tool to automatically generation ideas about causes for problems and present these in a structured form. Figure 3.1 shows the Ishikawa Diagram [36].

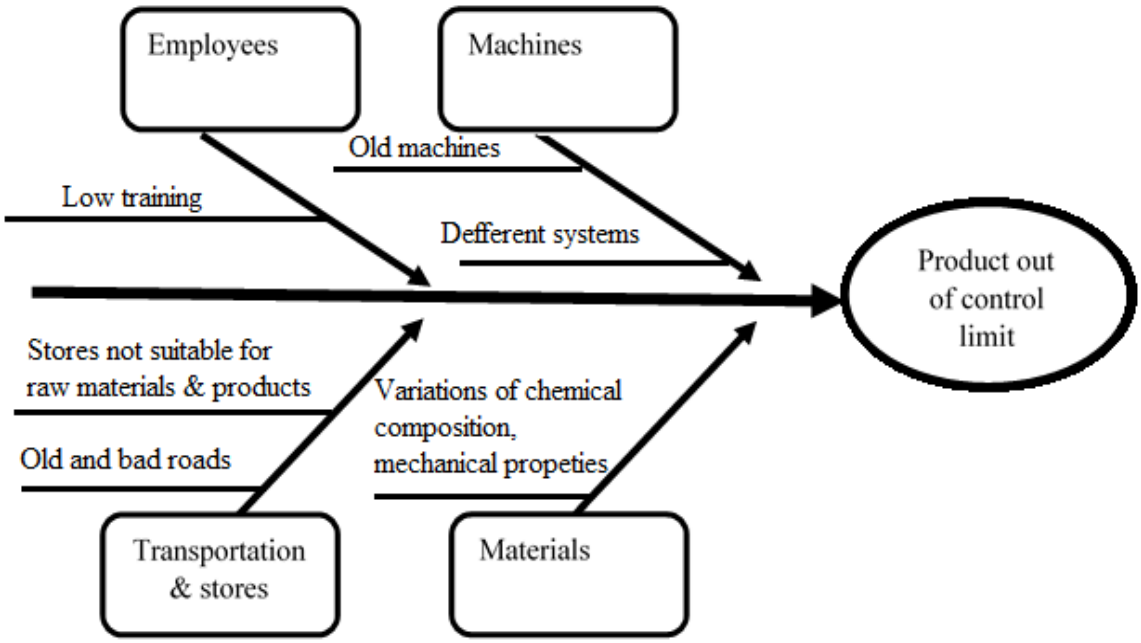

Figure 3-2. The Ishikawa Diagram.

Walter Edwards Deming (1900 –1993). Is widely acknowledged as the leading management thinker in the field of quality. He achieved a BSc in 1921, and the master degree at University of Colorado. In 1928, he obtained the doctorate in mathematical physics at Yale University in 1928. Deming then concentrated on lecturing and writing in mathematics, physics and statistics for the next 10 years [37]. The most important contributed for him was (Deming's 14 Points on Quality Management), a core concept on implementing total quality management, is a set of management practices to help companies increase their quality and productivity [38].

Philip B. Crosby -Zero Defects and Quality is Free (1926-2001). Philip B. Crosby known for his notable concept "Zero defects" and a globally known quality leader. Crosby severed as a director of quality and corporate vice president of ITT Corporation for fourteen years. Before this, Crosby worked as a junior technician in a quality department and led several different positions in various organizations until he became the director of quality. His concept, "Zero Defects' was originated during 1960s while he is working with Martin Marietta Corporation in the United States. In 1979, he founded Philip Crosby Associates Inc. (PCA), which in the next 10 years grew into a public traded organization. Crosby's book Quality is Free has sold over two million copies and became a best seller in the field of management. Quality without tears is another best seller. Prevention is the basic ideology of the Crosby's approach. His philosophies towards quality has best understood by the following concepts.

Shigeo Shingo (1909-1990. Japan). Shigeo Shingo (Japan, 1909-1990.). Shigeo Shingo is credited with starting the Zero Quality Control (ZQC) as quality system. In beginning, He was a leading proponent of statistical process control in Japanese manufacturing in the 1950s. After, he became frustrated with the statistical approach When he realized the impossibility of this approach to reach the goal of reduce product defects to zero [39] with a basic idea is to stop the process whenever a defect occurs, define the cause and prevent the recurring source of the defect. In 1961, he incorporated his knowledge of quality control to develop the mistake proofing or 'Poka-Yoke' devices had the effect of reducing defects to zero. By 1970, he developed perhaps the most revolutionary concept in manufacturing called "Single Minute Exchange of Dies" [40]

Dr. Genichi Taguchi (1924 2012). In next chapter three and, five more details for the Taguchi approach.

All of those gurus and other, with their system philosophies, concepts, and practices, have leaded the revolution for improve quality of products and services in the all area in our world. All of these Gurus had major contributions to the TQM Movement although more recognized by practitioners than the academia and surprisingly not making many citations of each other work. To go even beyond, we could say that the movement started in the US more as Quality Control (in the 1950´s) went back to Japan and come back to the US. Then, strengthened as a management philosophy: Total Quality Management (TQM) in this chapter will discuss some of well-known models of quality improvement approaches in industrial field (TQM, QMS and, IMS).

3.3 Total quality management (TQM)

Total quality management (TQM) is a set of opinions and ideas for improving the quality of products or services, which widely called “management philosophy”. Its main aims are to satisfy customers and survive in the market [31]. this concept (TQM) was a result of quality guru’s contribution and their significant roles which changing the concept of quality from a mere technical system to a broader body of knowledge known as total quality with management implications in production [31. Historically, TQM was first emerged by the contributions of quality gurus. A total quality management a management approach that originated in the 1950's and has steadily become more popular in the all world area since the early 1980's [41]. A total quality management revealed its name itself “Total”, “Quality” and “Management”. It indicated assurance of quality in all functional domains of an organization [42]. In other word, for an organization to be truly effective in implementing TQM, each component (employee, unit, departments, and so on…) must work together in harmony, recognizing that the all of them, and every activity affects, and is in turn, affected, by others (an effect and impact relationship) [43]. Its leads to essential underlying or philosophy idea behind the total quality management label refers to build a system in an organization which keep all its functions working as integrated at all field of productions and services in

other words, it is a management strategy that aims to include quality in all processes of the enterprise... In other words, it's an approach that seeking to incorporate all organizational objectives as marketing, finance, design, engineering, and production, customer service and so on to emphasis on providing customer needs to get their satisfaction and achieve the objectives of the Organization [44, ,45,46]. This approach can be applied successfully in all organization fields, production processes, services, education, etc. where, everyone in the organization must be contributed in the continuous improvement of activities in all levels and departments of the organization to get the advantages of the implementing the Total Quality Management approach in enterprises. [47].

TQM was first emerged by the contributions of quality gurus, such as Deming and Juran in Japan after Second World War. Then Crosby, Feigenbaum, Ishikawa, and others had developed this powerful management technique for improving business quality within the organizations. During the period 1980s to 1990s, many national and international quality awards (QAs) have established to provide guidelines for implementing TQM based on the suggestions and theories of TQM gurus. Guru means a "respected teacher", "spiritual leader", "good person", a wise person who in his field has not only made a great contribution and innovation, but also a large-scale revolution. People, who have established themselves and profiled philosophical trends in quality, are the gurus of quality [25]. The gurus extensively made substantial contribution to quality management by their theories in improving quality. TQM techniques and tools could be innovated by these theories [47]. The total quality management has evaluated through four stages or generations of phases passed through four phases of evolution [47].

First generation models:, started by the gurus or pioneers in quality improvement where they introduced or provided the basic building blocks which make a huge contribution on improvement for a systematic method to focus on total quality management and their contributed in brief are [48,49];

W.E.Deming, 1950 with his fourteen Principles in Quality, seven deadly sins and diseases / PDCA. AV. Feigenbaun 1961 who contributed by the concept: Make it right at the first time (One Basic TQM). Koaru. Ishikawa 1979 when he stablished Statistical Approach in Quality Control and Fishbone. Philip B Crosby 1979 with his (Top Management in Quality), 14 steps for quality improvement. Joseph --- M. Juran 1988 Cost of the quality, SPC Quality, and Juran's quality triangle. After this stage, the Second-generation models started when many quality awards started to spread in the all world, such as Japanese Deming prize, American Malcolm Baldrige National Quality Award (MBNQA), and European (European Foundation for Quality Management, .and so on. The third generation models: are business excellence (BE) models. The most developed is EFQM that evolved into BE model in 2011. The main characteristics are excellence achieved by producing the top quality products and/or services – excellent quality. The satisfaction of all interest groups of an organization is continuously followed through measured and improve business style and corporate culture of the organization are entirely oriented towards continuous quality improvement, led by top management. In addition, the learning organization, creativity and innovations are basic paradigms; progression towards BE is assessed using RADAR method and based on self-assessment. The last generation with the main characteristic features; where it considers that the application of digital manufacturing (digital models of product and quality), radical (discontinuous) improvements, and zero defect manufacturing is the base for superiority.

3.3.1 TQM concepts and principles

Since the 1980s (when the begging of the modern era), the continuous improvement has been a main principle of the quality movement. From both theoretically and practically, in the organizations, it has accepted generally that the foundation of the TQM philosophy is the principle of continuous improvement [24, 49]. In addition, the key principles of TQM are as following [49]:

Customer Focus. Both internal and external customers have the main concern to the organization Moreover, the customer including anyone who may affect by the

product, service or process which delivered by the organization. There are internal and external customers. The internal customer including all departments or divisions in the organization that received the processed product. The external customer, he may be the end user as well as intermediate processors. The external customers including anyone who may not buys the product but he has a connection. Management Commitment with plan do check act circle where [49]:

- Plan, the first stage and includes; the drive and direct activities.
- Do, after planning and its activities are deploy, support, and participate).
- Check, after we do the work, making the review must do) and,
- Act in this stage do the (recognize, communicate, and revise).

The implementation of the PDCA cycle has found more effective than adopting "the right first time" strategy [50]. Of course, the development is a target for any organization to stay in the Competition and for this; it must build its management system based on continuous improvement. The PDCA cycle has observed more effective in both doing a job and managing a programmer [50].The benefit and aim by implementation of PDCA cycle is tackling and fixing the problem practically. The figure 3.2shows PDCA cycle purpose and aim and the figure 3.3shows one of TQM model. Employee Empowerment. The system should has a good program or agenda in the areas of (training, suggestion scheme measurement and recognition and excellence teams).

Decision should be making based on facts as, Failure Mode Effects Analysis (FMEA), Statistical Process Control (SPC), Design of Experiment (DOE), and so on. Continuous improvement which the main principle of the organization and its leads the organization to has systematic measurement and focus on Cost of Non-Quality (CONQ) , excellence teams, cross-functional process management, attain, maintain, and improve standards [50].

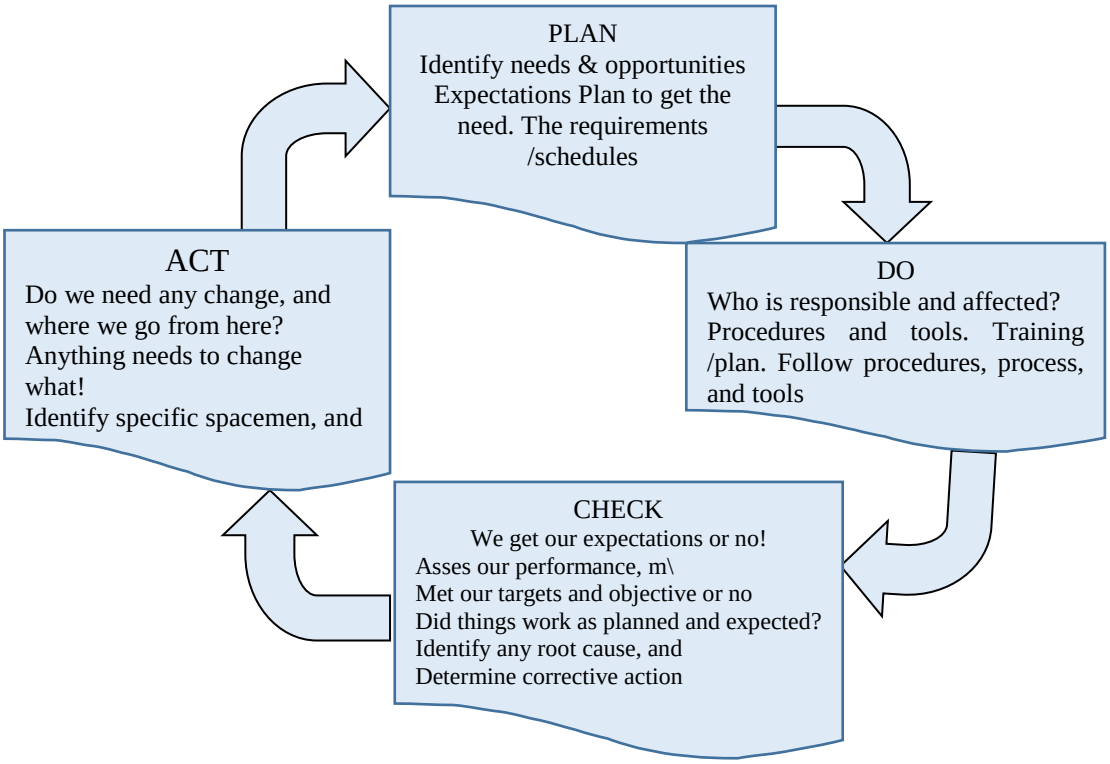

Figure 3-3. The Plan Do Check Act cycle [51]

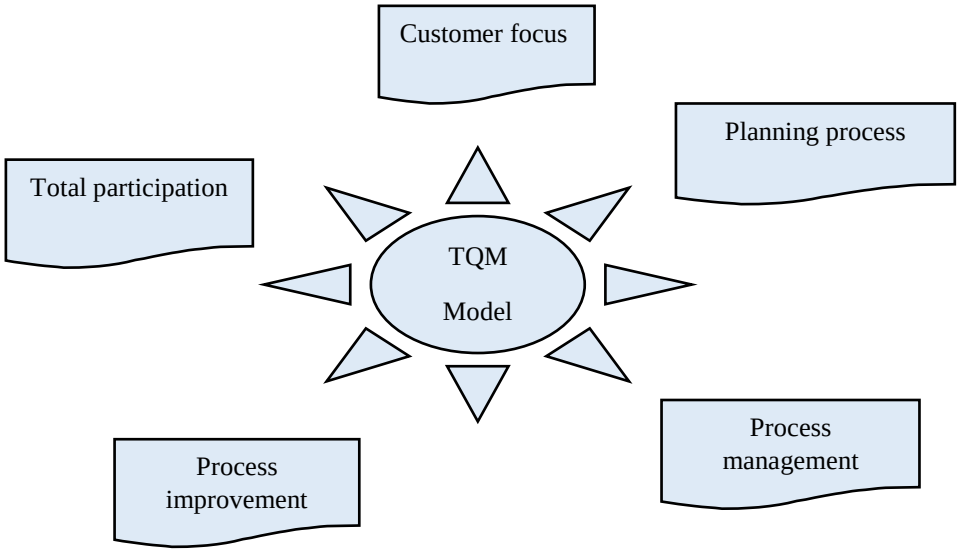

Figure 3-4. TQM model.

3.3.1 Benefits of adaption the TQM in organization

The main reasons that keep TQM so important for any organizations are Continuous improvement, reduce waste, doing it right in the very first attempt, and take quantitative measures to analyses deviations from quality. In manufacturing industry for continuous production, TQM has widespread and become more and more popular for many reasons as [51, 52]:

1- Competition in the market companies who adopt TQM, not only produce quality products, but also are able to enhance their reputation for adopting the same.

2- For the costumer. Costumers are the essential target for the organization and it most work to maintain on the existing customer and to add a new customer. The organizing must know the remaining on the current costumer cheaper than find new one.

3- Revenue. Where TQM plays a vital role in increasing revenue by minimizing the input and maximizing output [51, 52].

3.4 ISO 9001: 2015 and continuous improvement

This Standard correlated with quality and continuous improvement. It describes the requirements for organizations to help them promote continual improvements and achieve the main goal (customer satisfaction).

Despite the many previous versions of ISO (every seven years), the latest version included significant changes unlike earlier versions as mentioned in chapter two. Through the statistics mentioned in chapter two, which showed the huge spread and the continuous pursuit by the various bodies to obtain the certificate of ISO [53, 54]. This huge diffusion refer to this standard represent highly significant to all sizes of organizations, in all sectors, and all around the globe. The last version of these series was published in September of 2015 was, ISO 9001:2015.This standard already follows the terminology and the high-level structure provided by Annex SL [55]. As a key tool to allow for the growing internationalization of business and the need for common quality management system standards. Its success lead to the birth (or at least the

significant growth) of professions like “Quality Manager”, “Quality Auditor” and “Quality Consultant” and the standards were more targeted on middle managers [56].

3.4.1 Plan do check act (PDCA) cycle and ISO 9001:2015 requirements.

The continual improvement is the essential goal or main target, which the Quality Management System (The ISO 9001 standard) strove to reach. Plan-Do-Check-Act (also called “PDCA”) is a cycle that originated by Walter Shewhart and made popular by Edward Deming – two of the gurus of fathers of modern quality control as mansion in preview section. By using the PDCA cycle approach, which concept for implementing change, when followed and repeated, it will lead to repeated improvements in the process that was applied by this concept, the figure 3-4 shows the Plan-Do-Check-Act concept.

The PDCA cycle is a loop, which never ends, and we use it both formally and informally. It is a continual improvement process. Actually, the PDCA cycle includes to all elements and requirements of a quality management system. The principle of the PDCA cycle can be maintained throughput all of our daily business aspects. Its objective is to maintain the continual improvement [52]. As the PDCA cycle is not one of the ISO 9001:2015 Standard requirements but the standard definitely promotes the approach of the PDCA (Plan-Do-Check-Act) cycle. Moreover, it is an efficient tool for achieving its requirements, especially the requirement for Continual Improvement [57].

In brief, we can show how the PDCA cycle of improvement works within the QMS with the ISO 9001’s clauses [58].

Plan – Planning is one of the biggest parts of the QMS and starts with understanding the context of the organization and the needs of parties interested in the QMS ISO 9001 standard clauses 4.1 and 4.2, (the scope of the QMS definition), and the QMS ISO 9001 standard processes, in clauses 4.3 & 4.4. This followed by the commitment of leadership in the company to drive the organization to a customer focus by defining the organizational roles and responsibilities and by establishing a quality

policy to give the overall QMS a focus in clauses 5.1, 5.2 & 5.3. The next level of planning is to identify and address risks and opportunities of the QMS, including setting and planning for quality objectives and changes to support continual improvement in clauses 6.1, 6.2 and 6.3. The final level of planning is to identify and implement the support structure to allow you to carry out your plans. This includes resources in clause 7.1, identifying competence in clause 7.2, and awareness in clause 7.3. The communication deals by the clause 7.4. The set the processes for creation and control of documented information deals in clause 7.5 [57, 58].

Do – after finishing the plan stage, it is necessary to start the second stage (DO). At the DO stage, is carrying out what we have planned at the first stage. At this stage (DO) must Controls need to identify by the QMS operations. product or service requirements need to identified, designs developed, controls placed on externally provided processes, products and services The process of producing the product or service needs to be carried out with control of product and service release, any non-conforming products or services need to be. In short, the activities of creating and providing products or services to the customer's addressed needs to done [57, 58].

Check – There are several requirements in the standard to check the processes of the Quality Management system to ensure they are functioning properly as they have planned. There is a need to monitor, measure, analyze and evaluate the products or services to ensure they meet requirements, the processes used are adequate and effective, and customer satisfaction is being met (9.1). Internal Audit (9.2) of the processes is the key way to assess the effectiveness of the system. Further is the Management Review process (9.3), which reviews and assesses all of the monitored data to make changes and plans to address the issues [57, 58].

Act – Action in this case involves the actions needed to address any issues found in the check step. Improvement (10.1 & 10.3) is the overall heading for these action steps (10.1) with the activities of addressing nonconformity and Corrective Actions (10.2) to eliminate the causes of actual or potential nonconformities as the first step in acting to improve the system [57, 58].

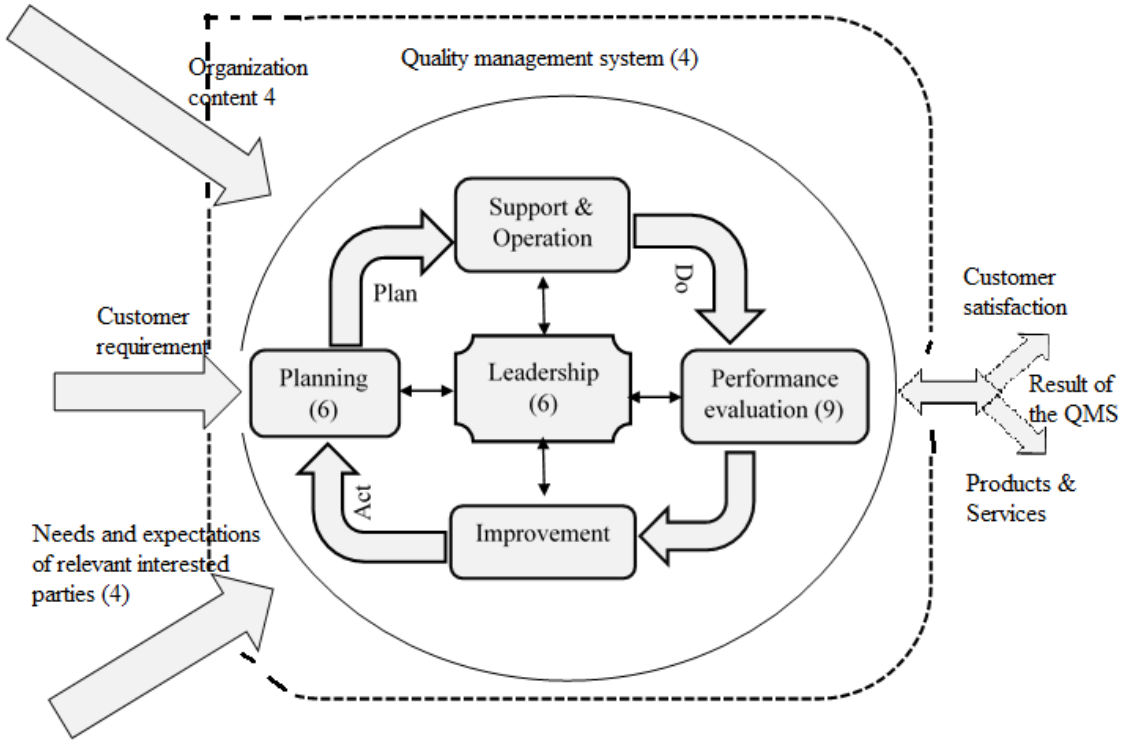

Figure 3-5. The diagram shows how clauses 4 to 10 of ISO 9001 be grouped in relation to PDCA [59].

The figure 3.5 shows how Clauses 4 to 10 of ISO 9001 can grouped in relation to PDCA. The inputs are the needs and expectations of relevant interested parties (customers or market requirements) (4), and Intended outcomes (products and/service which keep the customers satisfaction). Inside circle, there is the process approach of PDCA cycle with the quality management system ISO 9001 standard clauses [59].

3.5 Integrated management system and continuous improvement.

At the beginning of the 21st century, management standardization has been experiencing intense development, while technical standardization has moved to the back -ground. Globalization, the development and application of IT technology, the global economic and severe conditions in business have only contributed to this development. Today, the most current standards to be apply are ISO9000, 14000,

17000, 18000, 20000, 22000, 27000, 31000 and others. In today's conditions, linking individual standardized management systems into one integrated management system (IMS) is the ultimate task. IMS, as a method for effective and efficient management of the organization, can work on different qualitative levels, and at different levels of maturity. Researching models of maturity of the organization, process maturity, and level of excellence and using analogy with these models [60, 61]. Now days, where our enterprise environments become so complex, and this leads the organizations to have ensure delivers what customers need in an effective, efficient, and compliant way. And to get this goal, enormous of advanced organizations have more interested for this side and work hardly to find out optimum solution for the management to implement it as a system.

To enhance the efficiency of the system and tool many practices, researchers, and authors have shown the importance of integrating or mixing of different of these systems and tools to get the highest value of benefit. Sure, organization have diverse quality management systems is a necessary but, creating an integrated management system will robust the managerial structure too. With such a certification in place, you would assured of a good growth pattern [62]. The Integrated Management System (IMS) is one of integrating model or type of integration. It is a new concept of organization management; it emerged in the twentieth century [63]. It is a set of related processes which, share information for different management systems about human, financial and infrastructural resources in order to achieve present objectives, while focusing on the requirements of all stakeholders [63]. An IMS certification is a quality system that improves the process, service quality in the company, and thus leads to increased efficiency within the system. And it is achieved purely with reduction in wastages and by better usage of resources and streamlining the current practices in the company [62] an integrated management system integrates all or some of an organization’s systems and processes in to one complete framework, enabling an organization to work as a single unit with unified objectives.

The companies by building an integrating system (by mixing two or more of management systems) strive to get several advantages such as improve quality, reduce

risks and improve internal and external efficiency. In other words, by integrates some or all management systems of an organization's systems and processes in to one complete framework, enabling an organization to work as a single unit with unified objectives. Organizations often focus on management systems individually, often in silos and sometimes even in conflict. A quality team is concerned with the QMS; often an EHS manager handles both Environmental and Health and Safety issues and so on [64]. An integrated management system (IMS) is a way or approach, which used to combine all internal management systems practices of a business into one system to obtain easier management and operations. Managing all the aspects of a Management System can be difficult. Of course understanding and meeting customer requirements, getting top management involvement, verifying product/service design and fulfilment processes, and achieving continual improvement are wide range of diverse elements to manage.

With an integrated management system, you work together, with each function aligned behind a single goal: improving the performance of the entire organization. With such standards, companies perform better and grow constantly. Company, has a coordinated effort, which is greater than the sum of its parts and it is only more efficient but it is also more effective. An integrated system provides a clear, uniform image of your entire organization, how they affect each other, and the associated risks. Efficiency gained from less duplication, and it becomes easier to adopt new systems in future [65]. Karapetrovic and Willborn developed the first model of integration based on a systemic approach with only two management systems. Later it updated and becomes including four management system as shown in the figure 3.6 [66]. where we can observe a central core management system sharing different requirements while specific ones are located in parallel functional modules resulting a new system, thus constituting an integrated management system in which the components are interrelated but without sacrificing their individual identity and without invading other management systems.

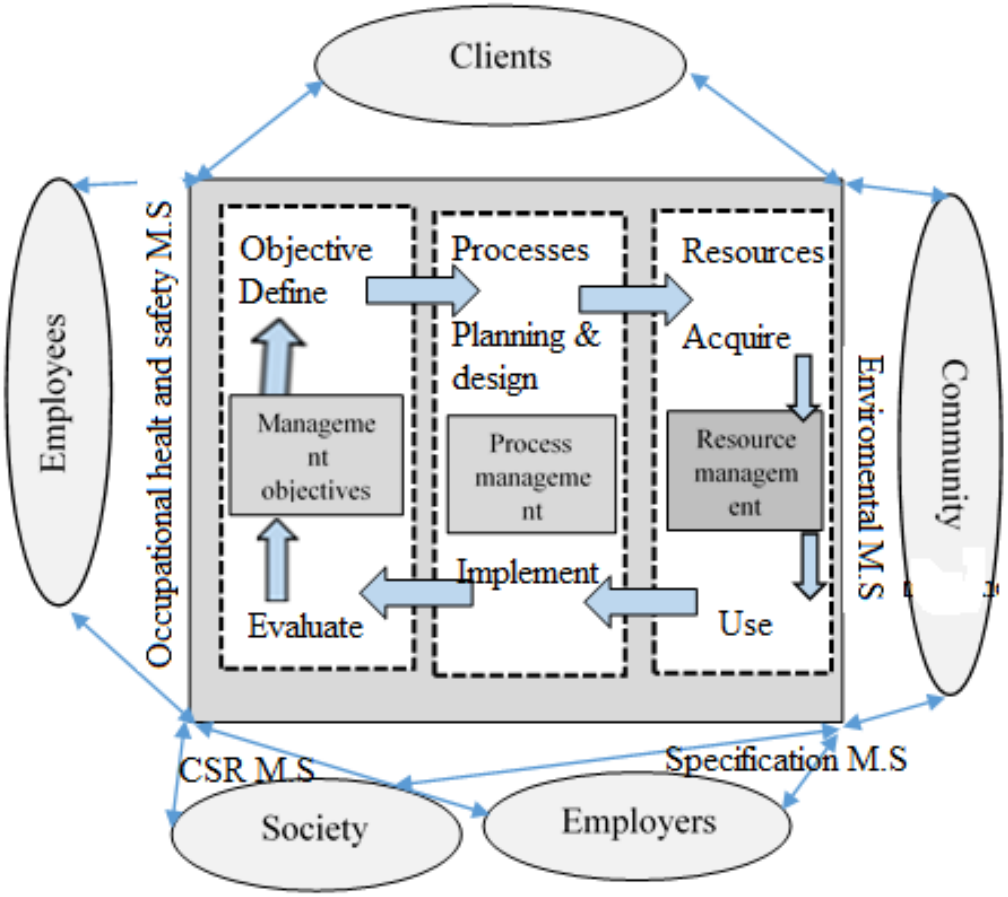

Figure 3-6. The systems model for IMS [67]

An Integrated Management System has many advantages for the organization through the benefits, which can the organization obtained by, adopted such integrated management model such as [65, 67]:

- Increased efficiency and effectiveness so, better productivity and higher profitability (focus on Core activities is eliminated- thus increased operational efficiency).
- Cost reductions while minimizing (documentation is simplified and reduced and the disruption caused by several external audits).
- It shows your commitment to increased performance, employee and customer satisfaction, and continuous improvement.
- Balance conflicting objectives e.g. between occupational health and environment and facilitates the focus on the most important aspects in a company.

- Integrating the management systems facilitates the focus on the most important aspects in a company, harmonize, and optimize practices.
- Create consistency and Improve communication.
- Separate systems tend to put focus on each area instead of the common area.

Quality Management System (QMS), Environmental Management System (EMS), and Occupational Health & Safety (OHSAS), management systems often combined and managed as in IMS. Where these model of management system have the major partly of number of certifications which issued by the International Organization for Standardization over the world in the past period time as ISO 2014 survey (data in preview chapter one) [63].

An integrated management System is relevant to any organization, regardless of their market. Integrating several management systems into a unified system (who share documentation, policies, procedures and processes) makes sense. Ideally, you would have an Integrated Management System that addresses all of your objectives at once, like an executive committee meeting. However, it can be difficult to meet the needs of the various management systems operating within a single business.

3.6 Cost of quality and cost of poor quality

In quality improvement journey, level of quality and its costs has considered as essential issue for any organization provides products or services. For years, management assumed that it was more expensive to provide high-quality products and services to customers, and used this excuse to keep the organization's output from reaching its full potential. This belief is due to fact that improved quality will greatly increase the cost of product or service and by expensive product or services; company may loss its customers. That is because improve the quality by the using approaches in that time leads to lose an additional of materials and loss the time. This leads the practices and rechargers to strive for developing new approaches which optimizing quality and reducing cost. Since early 1950, this attitude has started to change when the companies realized that in international markets quality products provided an increase

on market's shares. When it turned out to be the most important for cost of quality is, the cost of poor quality and external failures comprises of maximum part of cost of poor quality (COPQ) [68]. The term of Cost of Poor Quality has appeared, since to provide high-quality products is no more expensive than poor quality products cost. Actually, in many cases, it is less expensive. In general, the quality costs a categorized into visible and invisible (or hidden) costs. Where tangible or visible costs are visible cost and refer to the measured kind of cost of quality so, it is possible to calculate the exact expenditures such as scrap, rework, and deficits and so on.

On the other hand, invisible or hidden cost represent that costs of poor quality which hidden from our normal quality measures (are not easy to measure). For examples, unhappy customers leads to loss them, schedule interruptions, unnecessary procedures lose time and resources , equipment failures, extra operations such as touch ups and trimming, distracted engineers, expediting time, Poorly performing product, extra inspection and testing, wasted materials and energy, sorting ,extra inventory, unexplained budget variations, missed shipments, complaint investigation cost[69]. Genichi Taguchi invented methods of approximating these costs are developed by called Quality Loss Function (more detail in chapter three).

A simple definition of the cost of poor quality (COPQ) is all the costs that would disappear if your manufacturing process were perfect. This includes all appraisal, prevention, and failure costs. Anyone running a company knows these costs exist, but what they may not realize is how much of their expenses tied directly to COPQ [71]. Figure 3.7 shows (iceberg) which represent the deferent types of visible and invisible (or hidden) costs. Quality costs can segregate into four major categories as: [72, 73]

- Prevention costs; Prevention costs that incurred to prevent or avoid quality problems. On other word, prevention costs occur in order to minimize the appraisal and failure costs. In addition, it may defend as all the activities to avoid poor quality from occurring in the first place in products and services. All these costs associated with quality planning, designing, implementing and managing the quality system, auditing the system, supplier surveys and process improvements. Prevention

cost increases, the total number of errors will decrease, thereby reducing the total error cost [74].

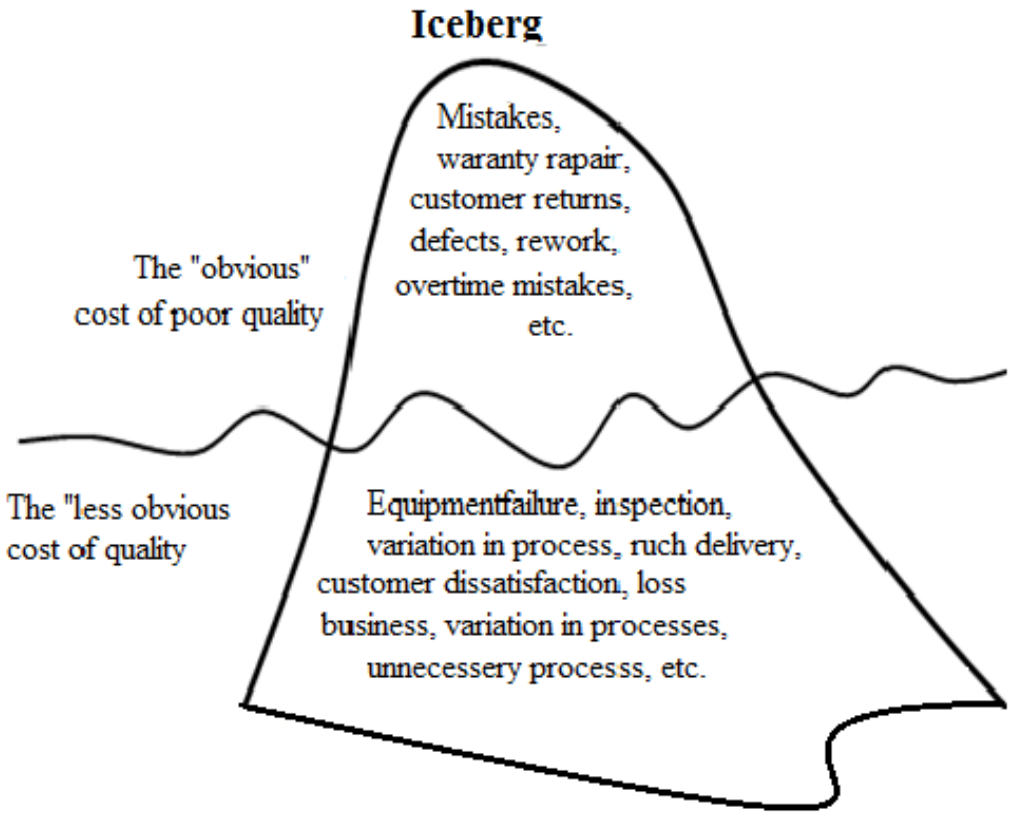

Figure 3-7. The visible and invisible (or hidden) cost [70]

- Appraisal costs; Appraisal costs are associated with measuring and monitoring activities related to quality. It means that this cost comes from quality operations that done and devices and equipment that are used in all stages of manufacturing process of the product. Also, quality equipment maintenance costs, audit quality costs as, the wages of workers who collect the necessary information to measure quality levels and the verification of compliance with specifications. The testing materials costs: receives the raw material an inspection for it and so on.

- Internal failure costs; Internal failure costs are incurred to remedy defects discovered before the product or service is delivered to the customer. These includes

defective product (Loss material and time, wages of worker…,). Re-work or rectification (loss additional or not necessary time. Failure analysis: the activity required to establish the causes of internal product or service failure and, these re-works need another inspection or examination after correction

- External failure costs. External failure costs are all costs come after the goods or services received from customers and it may discovered by some of customers or from the company itself. Defective products, services and processes generate these during customer use. They include warranties, complaints, replacements or recalls, repairs, poor packaging, handling and customer returns.

3.7 Knowledge modeling for quality improvement

Manufacturing sectors in all across the globe in our era are striving and aiming to produce the goods with low cost and highly quality and performance as essential goal. Surely, in the future the competition in manufacturing will be fierce more and next generation manufacturing will manifest. We can further assume that the general pattern of technology s-curve progress also applies here, i.e., when a current technology's contribution to improvement (value) levels off, then technology is ripe for enhancement or replacement by a new technology [75]. Of course, the revolutionary boom in communications systems, which have facilitated the speed of communication, information exchange and research, as well as the emergence of advanced powerful computers and software, has generated an ever-expanding sea of data. As a result, this will lead to greater acceleration and greater competition in the market. The industrialization environment simulates this general trend, with the content of manufacturing-related databases potentially extending far beyond the information scope of current statistics based quality and reliability approaches to include areas such as warrantee data, sales and marketing information, financial data, etc.[76].

To confront this challenge, companies are required to prepare plans, scenarios and alternatives, and to follow and develop methods that suit their potential while also meeting the competitive market needs. We can assume that the general pattern of

technology s-curve progression also applies here, i.e., when an incumbent technology's contribution to improvement (value) levels off, the technology is ripe for augmentation or replacement by a new technology[68], as shown in figure 3.8. Think of each "S" curve as a technology platform (as a model of changes). Movement up an "S" curve is incremental innovation while stepping down on a lower new "S" curve now, can lead to radical innovation, as the new "S" curve surpasses your existing "S" curve. Quality improvement tools and approaches, following some of the timeline for developing. The current traditional analysis approaches to identifying underlying patterns and structures in data may not flow (the tail of the technology s-curve) the returns relative to the growth in available data and this means the needs for development of new generation. .and this enhance the theory that, next generation of technology of quality/reliability will include finding useful patterns and structures in data currently unperceivable using common statistical approaches.[75]. Quality varies continuously according to the progressive evolution of social needs and of scientific and technical progress.

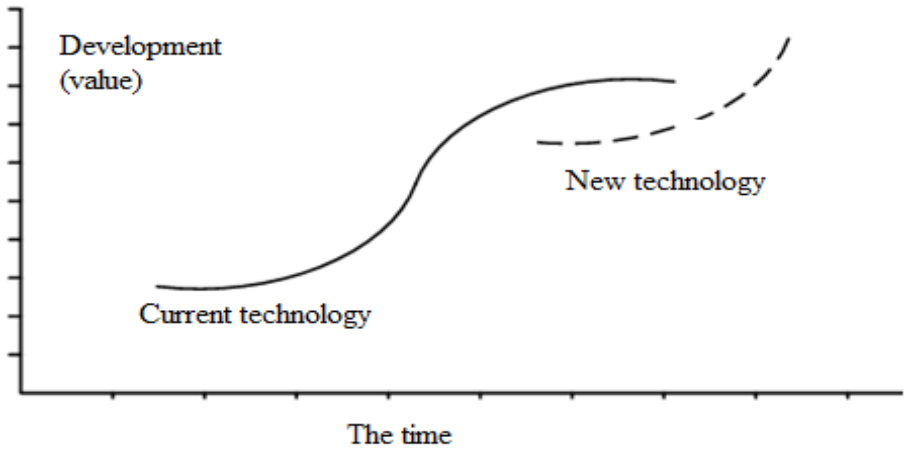

Figure 3-8. The "S" curve as a technology platform

And of course, its systems, approaches, and tools will improve or change by newer. Achieving quality is an endless race (Quality is a moving target). The big change rhythms characteristic for developed society oblige organizations to continuous adapt products, processes, structures, system of values to the new requirements [76].

CHAPTER 4

4 TAGUCHI THEORY AND APPLICATION FOR QUALITY IMPROVEMENT IN MANUFACTURING FIELD

4.1 Introduction

In the quality improvement journey, at the beginning of the year 1980, Dr. Genichi Taguchi presented a new approach for the quality design knows by Taguchi Method, also called the Robust Design method, and greatly improves engineering productivity. Initially it was developed for improving the quality of goods or products manufactured (manufacturing process development), later its application was expanded to many other fields in engineering, such as biotechnology etc. [77]. The Taguchi method considers design of product more important than the manufacturing process in quality control and tries to eliminate variances in production before they can occur [78]. Taguchi defines quality as, "The quality of a product is the (minimum) loss imparted by the product to the society from the time product is shipped" [79].

Cost of quality is a term that has widely used and widely misunderstood. The "cost of quality" is not the price of creating a quality product or service. It is the cost of NOT creating a quality product or service. Every time work is redone, the cost of quality increases viz. reworking of a manufactured item, retesting of an assembly, rebuilding of a tool, correction of a bank statement, reworking of a service, such as the reprocessing of a loan operation or the replacement of a food order in a restaurant. In short, any cost that would have not expended if quality were perfect contributes to the cost of quality. By consciously considering the noise factors (environmental variation during the product's usage, manufacturing variation, and component deterioration) and the cost of failure in the field the Robust Design method helps ensure customer satisfaction. Robust Design focuses on improving the fundamental function of the product or process, thus facilitating flexible designs and concurrent engineering. Indeed, it is the most powerful method available to reduce product cost, improve quality, and simultaneously reduce development interval. Nowadays, the aspect of reduce the cost of

quality by implementing robust design as a tool. The dimensional tolerance plays an important role in acceptance and rejection of a product. Any product that fails to reach the target value is termed as loss in robust design, in contrast to traditional design approach where product with in a tolerance range are accepted as product of good quality.

Significant research has been done on various aspects of quality still the area of Taguchi quality loss function is unexplored in various fields of manufacturing such as dimensional tolerance of a product, relating cost of quality of a product with robust design, etc. Methodology for reduction in cost of quality by implementing robust design will explain in the further section [80].

Taguchi's philosophy can be summed up by these 4 statements:

- We cannot reduce cost without affecting quality.
- We can improve quality without increasing cost.
- We can reduce cost by improving quality.
- We can reduce cost by reducing variation. When we do so, performance and quality will automatically improve.

4.2 Foundations of Taguchi's method

Quality engineering has divided into two gropes [81] on-line quality control and off-line quality control. On-line quality control, traditional statistical methods for quality control applied at the manufacturing stage in an attempt to reduce the manufacturing imperfections in the product. This classical statistical methods based on a random selection of samples at the end of the production process are being abandoned in favour of new automatized systems that are able to monitor every single sample, assuring in this way the control of 100% of the production [82]. The most used of them are Cause and effect diagrams, Control sheets, Histograms, Pareto diagrams, Scatter diagrams, Control charts, Stratification.

Off-line quality control, going to optimize the system (product and process) from design and supporting the on line quality control [81]. Taguchi's idea, that the

process of inspection, screening and salvaging (on-line quality) cannot improve poor quality. Where, an inspection process can only check the characteristics of product's quality (in limit or out of limit) but it cannot increase or improve the quality by itself. Therefore, he believed that quality concepts should be based upon, and developed around, the philosophy of prevention. Through this conviction, Taguchi developed new optimizing methods of the processes of engineering experimentation that based on philosophy of the best way to improve quality is to design and build it into the product (off-line quality). He quoted that, "Cost is more important than quality but quality is the best way to reduce cost." He developed the techniques, which now known as Taguchi methods [83].

Which based on design of experiment design of experiment (DoE). Its main roles are, select the best level of these factors to minimize the variation, and system (product and /or process) optimization. The three phases could recognized in the context of system optimization [81].

- System design encloses the testing of the solution draft with respect to nominal value of the observed quality characteristics. The design of a product and /or process in such a way to provide consistency of its characteristics with in the determined tolerance is the objective of parameter design-phase

- Parameter design. The main objective of Taguchi method aims to produce a robust product against to the noise factors. By DoE Taguchi find out the optimal set of parameters (control factors) with care for the product cost (best design with minimum cost) and the system performance quality could improve . In same time, reducing the variation without any additional cost is chive by parameter design.

- Tolerance design. Its aims to find out or determined the acceptable variability range of dimensional from the nominal, which determined in the parameter design stage.

In practical, the three concepts, orthogonal arrays, robustness, and quality loss function recognized as the main contributions of the Taguchi method to the quality-engineering field [81].

Figure 4.1 administrates the manufacturing process system and the types of factors influences. R represents a system response. Taguchi divides factors those have impact on the process responses in to three groups [81], which are:

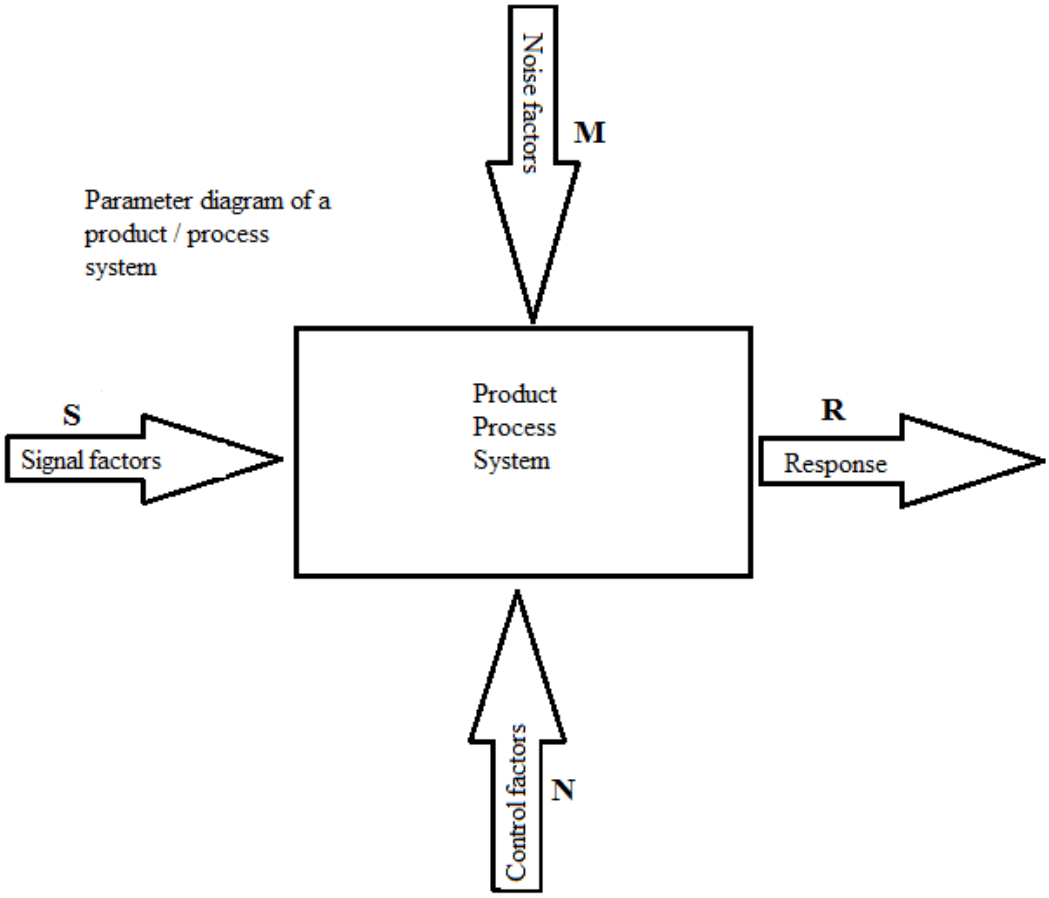

Figure 4-1. The product process system.

- Control factors donated by (N). These factors can be specified and controlled by designers and each of them can take a numbers of values called levels (for example, in milling operations, rotation speed as a control factor may take different level of revolution per minute).

- Signal factors donated by (S). Strength of this group of factors has a direct effect on the response and any changes of value of these factors will make highly and directly changing on the response.
- Noise factors (M). Some factors influence the process performance but either cannot controlled by the process engineers or regulation is too expensive and impractical are called noise factors. Its values or levels change from time to time and from one unit to other [81]. The noise factors cause the specification or response deviate from the target.

4.2.1 Taguchi Philosophy and the non- visible cost (hidden cost) of quality

Dr. Genichi Taguchi's method combines engineering and statistical methods which contribute for achieve rapid improvements in the products and services from the quality and cost side by increasing quality without any additional in the cost. This feature or advantage can obtained through optimizing product design and manufacturing processes. Therefore, when we do so, performance and quality will automatically improve [83] [84].

The fundamental of quality is “the loss imparted to society from the time the product is shipped’’, was the Taguchi approach to quality engineering is this concept of loss. As usual, Quality costs quantified in terms of scarp and rework, warranty or other tangible costs. As we saw, however these constitute only the “tip of the iceberg" What inventory, customer dissatisfaction, and loss to company’s bad reputation, which leads to eventual loss to customers and drop in market share. This leads to try to find some way to avoid or reduce these unvisitable costs [84]. Dr. Taguchi introduced his philosophy about the Quality Loss Function (QLF) for this purpose [85].

4.2.2 Quality loss -function (Taguchi loss function)

In the first half of the twentieth century, it was common in industries field to measure quality of product from the side of percentage of number good parts from the line or factory to the total number of parts that produced. The part accepted as a good

quality when its quality characteristic (diminutions, Wight, volume…) stays in the tolerance limits (upper control limit and lower control limit). The rest parts treat as a rework, reject, or defective. This principle deals with all good products (in specification limit) as same quality but this is not exacting true. In fact, and from customer side, all products that good quality and in tolerance range, are not same. Part or product that has specifications at the end of tolerance limit upper or lower (in area A as shown in figure 4-2 is equally bad as a reject or defective product from the customer side and has lower performance compared with the product those characteristic is at the nominal or target.

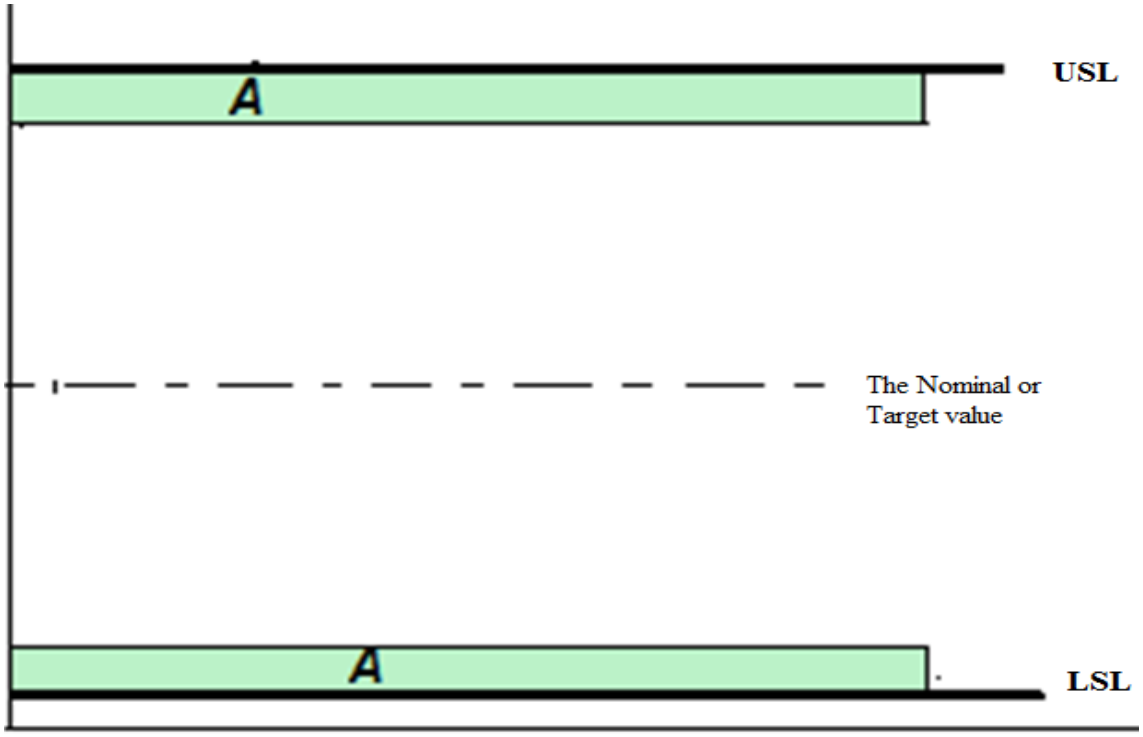

Figure 4-2. The tolerance limits and good or reject product.

In addition, there are a deferent statistical chart for the same specification for the side of the control limits as shown in figure 4-3. Where we find that the product S and the other product Y each of them has a deferent chart shape but the same value of tolerance (UCL, LCL).

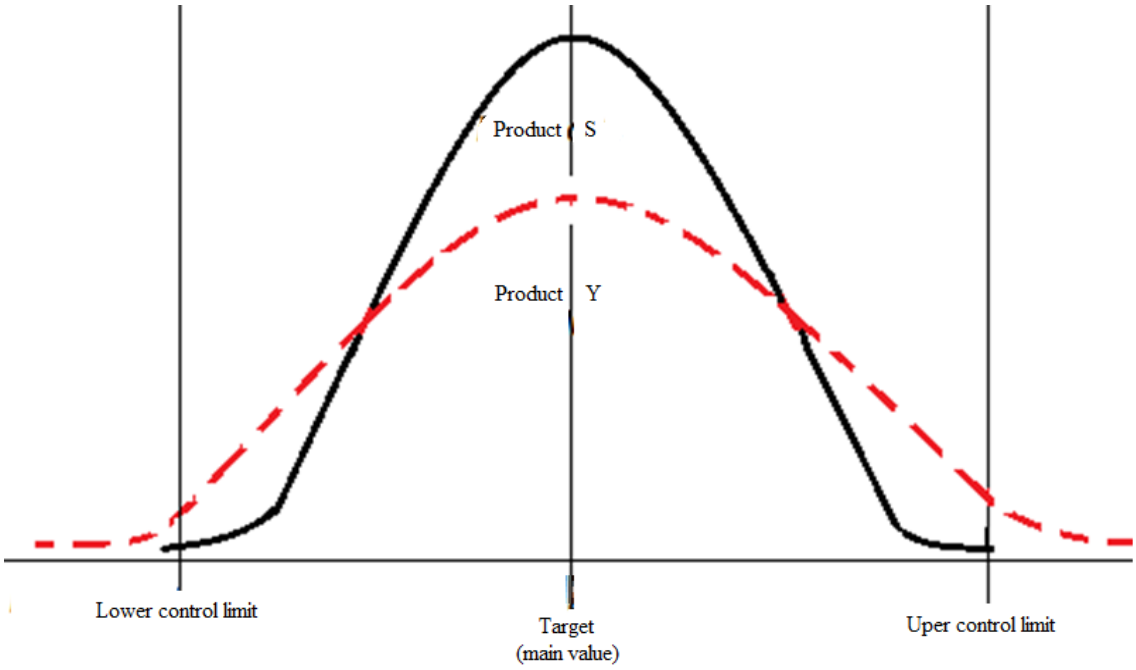

Figure 4-3. The many products have a deferent chart shape but the same value of tolerance (UCL, LCL).

On other word, loss not insures only when there are defects or problems in the goods and services. Or when the products and services fall outside from the limits (maximum and minimum) of quality standards. In the areas between these limits of quality, losses can still incurred. With the loss function approach, losses became broader in category. It defines them as anything that is not efficient and may cost the consumers negatively [86]. In the traditional thinking around specification limits is that the customer is satisfied as long as the variation stays within the specification limits. If the variation exceeds the limits, then the customer immediately feels dissatisfied.

The specification limits divide satisfaction from dissatisfaction. For a simple example, if the minimum or lower limit for the ball diameter is 70mm, the maximum or upper limit is 72mm, and the main target diameter 71mm then a ball diameter of 70 will lead to customer satisfaction, while a ball's diameter of 69.99 will lead to customer dissatisfaction. Also, if the measurement is 70, the customer will be dissatisfied more than a measurement of 70.15mm which more close to the target. And, if the diameter is 69.99mm, the customer will be slightly more dissatisfied than the diameter of 70mm. The loss function also emphasizes the importance of reducing variation.

Variation always leads to waste and poor quality. It can also bring about changes in output and can be a source of defects. When variations are controlled, performance and quality will improve as a consequence [86].

When a critical quality characteristic deviates from the target value, it causes a loss. In other words, variation from target is the antithesis of quality. Quality simply means no variability or very little variation from target performance. An examination of the loss function shows that variability reduction or quality improvement drives cost down. Lowest cost can only achieved at zero variability from target. Continuously pursuing variability reduction from the target value in critical quality characteristics is the key to achieve high quality and reduce cost [79, 87].

This was the foundation for Dr. Genichi Taguchi in the middle of the twentieth century to present the concept of Quality loss-function or knows as (Taguchi loss function) Which is based on the assumption that any deviation from the target value of a characteristic will result in a loss to society.

Taguchi suggests that every process have a target value and that as the product moves away from target value, there's a loss incurred by society figure 4-4. This loss may involve delay, waste, scrap, or rework.

And from his experience in manufacturing practice and the way to keep the customer satisfied with high product or service quality without increasing in the cost, has led him to formulate something that’s not relatively simpler yet worked well. He concluded that quality loss is proportional to the square of the characteristic deviation from its nominal (from the “target“). His expressed that in a mathematical equation model known as the quality loss function or Taguchi loss function as equation 4.1. [88, 89].

$$\mathbf{QL(y)= K(y-m)^2} \text{----------} \mathbf{4.1}$$

Where;

y is the actual value of the quality, **m** is the target, and **k** is aconstant that is afunction of financial importance of the quality characteristic.

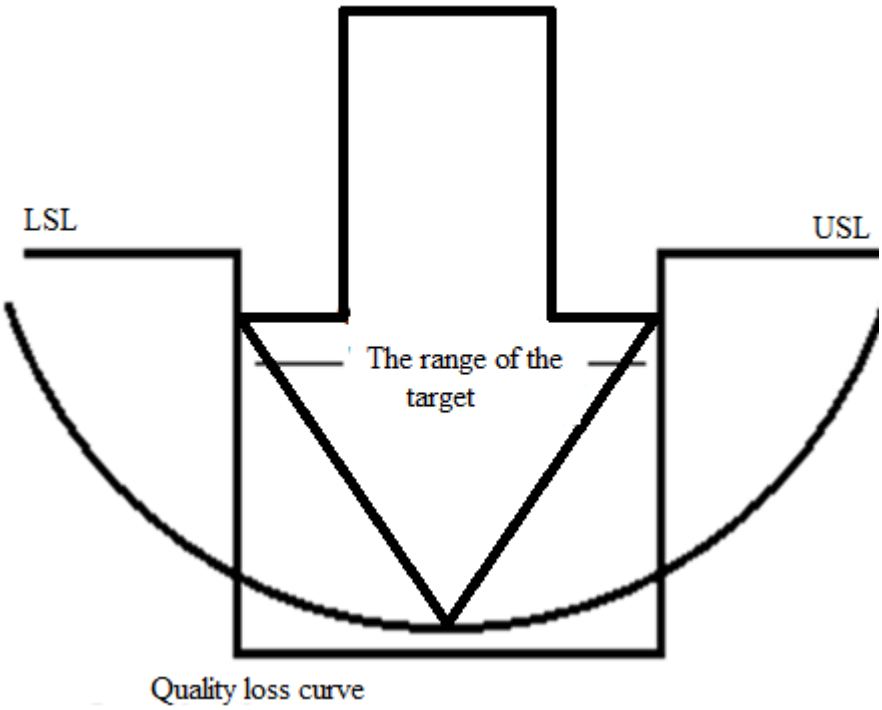

Figure 4-4. The cost lost by deviation from the target.

4.2.3 Robustness

Taguchi's definition of a robust design is "a product whose performance is minimally sensitive to factors causing variability (at the lowest possible cost)" [84]. This definition leads Dr. Taguchi to develop the robust parameter design in order to improve the product or process by making it less sensitive to variation. And to achieve the desirable product quality by design, he recommends a three stage process. (a) Systems design (b) Parameter design and (c) Tolerance design.

The system input variables divided into groups: control factors and noise factors which. Control factors are process or design parameters that you can control such as equipment settings, material used to manufacture the product, or product design features. Noise factors are process or design parameters that are difficult or expensive to control during manufacturing, and they divided into external factors, such as weather conditions and, internal conditions such as, machine deterioration, Labourer skills [84].

To minimize the effect of the noise factors on the product or system, Taguchi introduced a new model to minimize of response variations. By choosing the control factor setting that make the system less sensitive to the effect of those noise factors. In order to mathematically present the robustness, he defined a signal-to-noise (SN)) ratio which presents a ratio between the average response value caused by control factors and variability as consequence of the noise factor effect [81].

Taguchi categorized the SN ratio analysis into three types depending upon the type of response or customer specification desired and nominal response value as the following [81]:

- Large is the better (LTB or L-type). quality characteristics is usually a desired output(say current), for example yield strength of the material, critical current, mass flow rates for filling fluid,…..

S/N Ratio $\mu = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$---------- **4.2**

- Smaller is the better (STB or S-type). Quality characteristics is usually an undesired output (say defects), for example rate of engine fuel consumption, weight of airplane parts.

S/N Ratio $\mu = -10\log_{10}\left(\frac{1}{n}\sum y_i^2\right)$---------- **4.3**

- Nominal-is-Best (NB) quality characteristics is usually a nominal output, say diameters, for examples, ratios of chemical, parts in mechanical fitting have nominal dimension.

S/N Ratio $\mu = 10\log_{10}\left(\frac{y^2}{s^2}-\frac{1}{n}\right)$----------**4.4**

Where, μ is S/N Ratio, y is measurable statistic of response, s^2 is the sample variance of n unit.

4.2.4 Orthogonal arrays (OAs)

Taguchi array or orthogonal array, is orthogonal matrix were developed by Ronald A Fisher at the beginning of the twentieth century and used to control the experimental error. Initially, they used to focus on planning excrements so that the random error in physical experiments has minimum influence in the approval or disapproved of hypothesis [81]. Then, at the middle twentieth century, when Dr. G. Taguchi, has envisaged a new method of conducting the design of experiments which are based on well-defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulates the way of conducting the minimal number of experiments, which could give the full information of all the factors that affect the performance parameters. The crux of orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment. This orthogonal array uses to plan of the experiment where, the dimension of the matrix is the number of the factors and number of their levels.

Dr. Genichi Taguchi founded the general matrix of orthogonal arrays, and it designed as a type of general fractional factorial. This orthogonal array balanced to ensure that all levels of all factors considered equally and allow evaluating each factor independently from others. [81,82,83].

When the factors affecting on the output (responses) determine, their levels also, should vary in the experiment must be determined. The value of level depends on depth understanding of the process [81]. In orthogonal arrays design, it is a typical design that the number of level is the same for each parameters but in some cases not. After determining the number of factors and their level in the experiment, then the orthogonal array can be select. Table 4.1 shows standard table for Taguchi orthogonal array selection.

Table 4-1. The standard table for Taguchi orthogonal array selection.

Orthogonal Array	Number of Rows	Maximum Number of Factors	Maximum Number of Columns at These Levels			
			2	3	4	5
L4	4	3	3	-	-	-
L8	8	7	7	-	-	-
L9	9	4	-	4	-	-
L12	12	11	11	-	-	-
L16	16	15	15	-	-	-
L’16	16	5	-	-	5	-
L18	18	8	1	7	-	-
L25	25	6	-	-	-	6
L27	27	13	1	13	-	-
L32	32	31	31	-	-	-
L’32	32	10	1	-	9	-
L36	36	23	11	12	-	-
L’36	36	16	3	13	-	-
L50	50	12	1	-	-	11
L54	54	26	1	25	-	-
L64	64	63	63	-	-	-
L’64	64	21	-	-	21	-
L81	81	40	-	40	-	-

As mention before, selection of orthogonal array depends on the number of factors and their levels. To define the name of orthogonal array, look at the table and find where the number of factor and number of level is corresponding, the interaction is the orthogonal array. For example, if there were three factors determined each of them has four levels, the suitable orthogonal array to be choosing is L’16 and this mean the number of experiments needed is sixteen runs. And if there were eight factors each of them has three levels then L18 orthogonal array will be choose and eighteen experiment runs will be done. In complete factorial statistical approach design, 3 that is 6561 runs,

and for 13 factors with 3 levels full factorial design needs 13! 3 which equal 1594323 runs (experimental trail), and by using Taguchi array L27, only 27 trails needed.

In some cases, each of factor has not the same number of level, here, we look to the factor who is the highest number of levels when we choose the orthogonal array. For example, if they are factors A, B, C, and D each of them have four levels, and, factors E has two level, then the choosing as five factors with 3 levels and , OR L18 is selected. The third level for factor E is randomly field with the existing two levels in balanced way [79].

In other cases, if the orthogonal array matrix, which selected (from the standard Taguchi table) based on the number of parameters and levels has more parameters than those used in the experimental design, we need only to ignore those additional parameter columns. For example, if a process has seven parameters with 2 levels each, the available design from table; the L12 array so, it should be selected according to the array selector. As can be seen below in the table 4.2, the L12 Array has columns for 11 parameters (P1-P11). The right three columns ignores.

Degree of freedom. In the experiments design by using the orthogonal array mostly, is efficient compared with other statistical designs. The number of degree of freedom (DoF) determines the minimum number of experiments that we need to run. In general, the number of degrees of freedom associated with a factor (control variable) is equal to the number of levels for that factor minus one. For example, if there are five factors (A, B, C, D and E) each of them has four levels except factor, A which has only three levels. Table 4.3 shows the degrees of freedom calculated for this example. And here, we should do at least fifteen experiment runs.

4.1 Taguchi method stages.

The Taguchi method involves several of stages or steps, which started at defining or determining the goal of the experiment and the end of it. Figure 4.5 illustrates the stages of Taguchi design of product. These steps or stages summarize as the flowing points [81].

Table 4-2. The example ignore that additional parameter.

Experiment	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	2	2	2	2	2	2
3	1	1	2	2	2	1	1	1	2	2	2
4	1	2	1	2	2	1	2	2	1	1	2
5	1	2	2	1	2	2	1	2	1	2	1
6	1	2	2	1	2	2	1	2	1	1	1
7	1	2	2	2	1	2	2	1	2	1	1
8	2	1	2	1	2	2	2	1	1	1	2
9	2	1	1	2	2	2	1	2	2	1	1
10	2	2	2	1	1	1	1	2	2	1	2
11	2	2	1	2	1	2	1	1	1	2	2
12	2	2	1	1	2	1	2	1	2	2	1

Table 4-3. The degrees of freedom calculated for this example.

Factors	Degrees of freedom
Overall mean	1
A	3-1=2
B,C,D,E	4x(4-l) = 12
Total	15

- Defined or determine the goal of the experiment and the end of it (what we need to find or know?).
- How many factors we need (control factors and noise factors) which have effected on the product quality characteristic.
- How many levels for each factors and what is the value of these levels that should be use in in the experiment to get the desired result.
- By the number of parameters and number of their level which chosen, we determine the suitable orthogonal array (which matrix size) from the stander Taguchi's table 4-5.

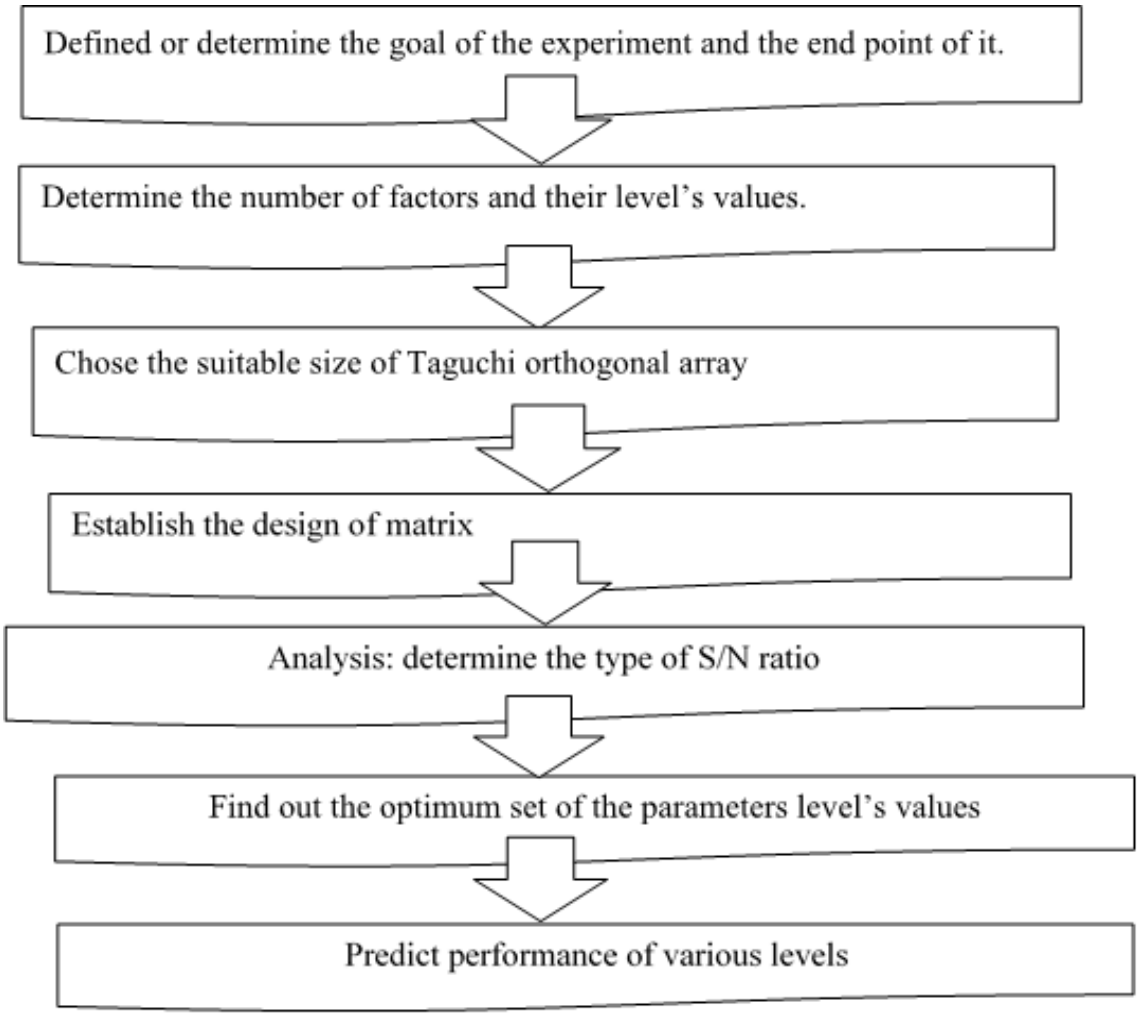

Figure 4-5. The stages of Taguchi design of product [81].

- Establish the matrix. Complete the data of used parameters and their values for the analysis in the matrix depending on Taguchi system or use suitable software.
- Determine the type S/N ratio (LB, SB, and NB) depending on the desired value of response (if we need the highest value, lowest value or we need the nominal value of the response) equations 3.2, 3.3, and3.4.
- Complete data analysis to determine the effect of the different parameters on the performance measure.
- Select the optimum set of the parameters from the output level's values and it is the optimum solution.
- Predict performance of various levels.

4.2 Multi-response process optimization approaches based on Taguchi method

Now days, the manufacturing field, the products become more complexed. Therefore, manufacturing process after material transformation typically deliver product or semi-products characteristics by multiple output quality characteristics. In Taguchi method, design of experiment uses to deal with single response as a function of the process parameters. But this optimum set of parameters which get a response may not lead to optimum other response values.

When we have multi-response process, optimizing the process purely with respect to any single response will, indeed lead to non-optimum values for the remaining responses [81]. Taguchi's robust is a great method to deal with separate response or single-response to get a high robustness and high desired quality characteristic product. But when deal with more responses (multi responses), we need a new advantaged intelligent and integrated approach methods which used the Taguchi's robust as a base for design of experiment, the main equations for single to noise factors and, Taguchi loss function.

CHAPTER 5

5 APPIED TAGUCHI METHOD TO OPTIMIZE THE FRICTION STIR WEDING PARAMETERS (THE EXPERIMENT)

5.1 Introduction

In modern industry, sector quality and cost of product are essential target, in welding field, friction stir welding (FSW) has become a technology of widespread interest because of its numerous advantages, and Taguchi robust design approach, is powerful statistical technique for high quality product with no additional cost. In this study, we use friction steel welding method to weld aluminium alloy sheet (5083). To find out the optimum set of levels of the parameters or factors which in our study are (rotational welding speed, traversing speed, and tool tilt angle) to reach the optimum values for output characteristic or responses which are in our study, (total energy, energy for crack initiation, and energy for crack propagation). The Taguchi approach had used to design of experiment which, according to the three of parameters (Rotational speed welding, traversing speed, and tilt angle). Each of them has four levels we use L16 orthogonal array then, signal to noise ratio analysis to find the optimum set of parameters, and finally by the ANOVA analysis we determine the significant influence between each of these parameters.

5.1.1 Introduction to welding technology

Welding is a fabricated process, in which two or more parts are need to join at their contacting or touching points or surfaces by a suitable application of heat (often melting point) and/or pressure, a filler material is added to facilitate coalescence or without filler. The assembled parts that need to joint by a welding method calls a weldment. Welding primarily used to join the metal or alloys parts by bringing them to melting point. In some type of welding as, Soldering, friction stir welding and Brazing do not involve melting the work piece but rather a lower-melting-point material melts between the work pieces to bond them together. The most famous welding technology types;

- Arc Welding where electric arc between an electrode and the base material to melt metals at the welding point.
- Gas Welding: when a high temperature flame generated by gas combustion melts the work piece and filler material.
- Resistance Welding; heat generates by resistant the high current impairs.
- Energy Beam Welding: Laser beam or electron beam is used to melt the work pieces and thus join them together
- Solid-State Welding this technology is a solid-state joining process, before the stage of melting materials by uses a friction heat produces from rotating tool under an axial forging force to join two contact surfaces as in ultrasonic welding, explosion welding, electromagnetic pulse welding, roll welding, friction welding (including friction-stir welding), etc. [90]

5.1.2 Friction stir welding (FSW)

Friction stir welding (FSW) is a relatively new solid-state joining process. It has invented and patented by Wayne Thomas at TWI Ltd (the UK) in year 1991 [91]. And, from that time it has started Spread fast until became one of the most important welding types in the fabrication and assembly industry, that is because of several of Influential advantages on the quality of product beside, the advantages of this process high reproducibility, short production time and low energy input [92].

The theory of friction stir welding is rising the temperature at the contact area or line of the work pieces until reach the plastic state by rotating a special tool with determine revolution per minute in the interface areas of the base metal. Figure.5-1 shows the main compartment of the (FSW) operation. It's in simple, a non-consumable rotating tool with designed pin (probe) and shoulder is inserted into the edges of the plates to join. The pin traverses along the line of joint with the determined speed (m/s) and the shoulder touches the plates [93].

The friction sir welding operation has a several phases, which starts by: facing the work pieces and clamping them. Then the pin plugged and penetrated into the plats

until the tool shoulder has penetrated into the material at prescribed depth (a few tenths of a millimetre). Axial pressure force which, enabling sufficient pressure keeps the material within the welding zone and produce enough heat by friction and plastic deformation for establishing the appropriate welding conditions [90,91].

Then, the rotating tool with high revolution per minute starts moving with determine speed along the facing contact of the plates (joint line) and generating the heat by the friction between the head (probe, shoulder).

Majority of heat generated (about 95%) in the welding operation is transferred to the work piece and the remained (about 5%) flows in to the tool. The material around the pin becomes soft, and moves it from the front of the pin to the back by the rotation and movement of the pin [94, 95]. where a hard non-consumable rotating tool penetrates the plates to be welded, dwell with nonstop the tool rotating, then the rotating tool moves along the joint line The pin penetrates into the plates until the tool shoulder has penetrated into the

For the tool, it consists from two parts, a probe (pin) and, a shoulder. Figure 5-2 shows deferent shape of tools some are simple designs and others are more complex) [96, 97]. The rotating and moving of the pin create the friction and deformational heating those softeners the work piece material; shoulder contacts area with work piece lets it heating, the zone of softened material expands, and constrains the deformed material [98].

The function of tool in the friction stir welding needs to use a good material specifications for product it like; High resistance for wear, high temper resistance, good toughness, and tool should be stronger than working materials [98, 99]. Therefore, it is clear that there are two important factors of friction stir welding tool design: its material and geometry.

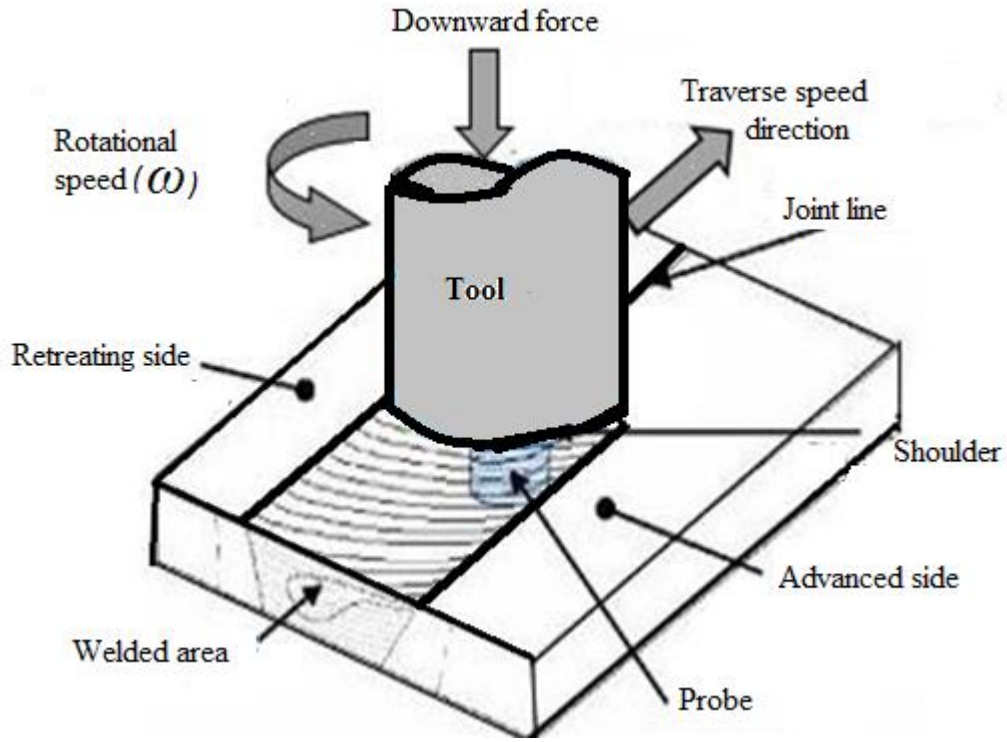

Figure 5-1. Main competent FSW operation [96].

Figure 5-2. Deferent shape of tools some are simple designs and others are more complex [97].

The main advantage of friction stir welding is coming from that; its highest temperature in the FSW process is lower than the melting temperature of the work piece material to be joined, and this gives it a capability of producing high quality joints, where, the temperatures involved are lower than those encountered in the other fusion welding techniques [100, 101]. This advantage gives it the ability to join materials that are difficult to weld by conventional effusion welding, as some kind aluminium magnesium and copper alloys. In addition, non-similar material that was a problem in conventional welding types it can be welding by friction stir welding because, of its solid-state nature.

Moreover, the main advantages for Friction stir welding technology are, [100,101,103].

- It purpose-designed equipment or modified existing machine tool technology. The process is also suitable for automation and is adaptable for robot use.

- In addition, there are many other advantages including, a low of distortion and shrinkage in material even at the long line of welding, better mechanical properties of products such as strength, no hot cracks, no gas.

- Also, the props energy efficient, possibility to weld large thickness of aluminium and copper (up to >75mm thickness in one pass), no welding fume and no UV radiation. Farther than, some tolerance to imperfect weld preparations, there is good dimensional stability,

- Thin oxide layers can be accepted; no grinding, brushing or pickling required in mass production; no loss of alloying elements, and farther there are more advantages.

The main disadvantage of friction stir welding are [103,104]:

1. An exit hole is produce when tool is withdrawn the hole which is made by the blunt probe tool is left unfilled at the time of exit.

2. Heavy duty clamping of parts is required.

3. Forces required is large to get the probe tool are inserted inside the work piece.

4. Slower than many other welding processes.

5. Starting cost of the FSW machine is too high.

6. It is less flexible comparing with manual and arc welding processes

The most important parameters which effect on the on the friction stir welding product quality [105].

1) Tool rotation speed

2) Traverse speed

3) Tool geometry

4) Tilt angle

5) Axial load

6) Plunge depth

7) Backing plate

The quality of a weld joint (product) is depending on these parameters during the welding process, and the Tool rotation speed, Traverse speed and Tool geometry are the main important sources of the heat generation during the welding operation. Therefore, determine the value of these input parameters have an essential effect in deciding quality of welded joint. Various industries of welding follow the conventional experimental procedure i.e. varying one parameter at a time while keeping the other parameter constant. This conventional parametric design of experiment way losses time and more cost [103,106]. Taguchi method presented tools for design the experiment with less number of experiment runs and robustness the product quality with no additional cost.

5.1.3 Taguchi method

We applied the Taguchi method, which discussed in the preview chapter three, in our work here. We used Taguchi orthogonal array L16 (suitable matrix for three parameters with four levels for each of them) and for robustness design S/N large is better LB was used; the analysis to find out the optimum set of parameter levels ANOVA were don.

5.2 The experiment

In this study, friction stir webbing process with three parameters (welding speed, rotation speed, and tilt angle) and four levels for each of them as shown in Table 4, is used to weld aluminium 5083 alloy plate, Taguchi approach is used for design the experiment and analysis the results.

5.2.1 Preparing the material

The base material is alumnus alloy 508 with thickness 5.5 mm, length 1000mm and width 500 mm. The thickness is reduced to 5.5 mm hot rolling operations is prepared at laboratories of University of Belgrade - faculty of technology, by several hot rolling operation steps from the original plate thickness 7,2mm. Then, the plate is cutter into set of strips with a fit size dimensions, length 260mm, width 45mm and 5.5 mm thickness. Figure 5.3 shows the pate strips every of them facing together.

The chemical composition of the aluminium alloy 5083 and its mechanical properties plot in the tables 5.1 and 5.2 respectively.

Table 5-1. Chemical Composition of the Investigated AA 5083.

Mg	Mn.	Cu	Fe	Si
5.13	0.718	0.013	0.337	0.108
Ti	Zr	Zn	Cr	Na
0.0254	0.0202	0.513	0.008	0.0005

Table 5-2. Mechanical Properties of AA5083.

Deformation [%]	Thickness of specimens	Yield strength [MPa]	Ultimate strength [MPa]	Elongation max [%]
16.6	6.02	300.50	369.15	9.79

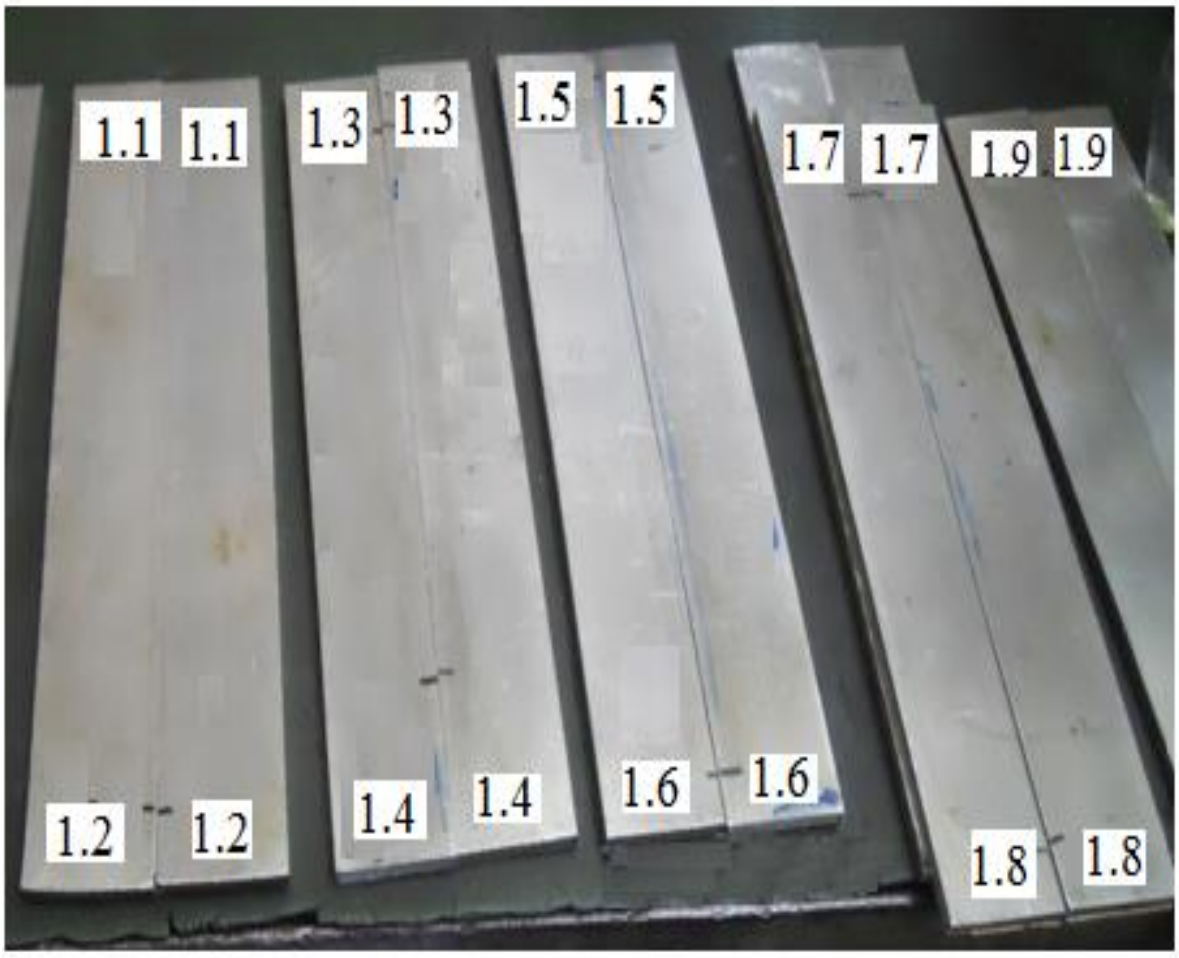

Figure 5-3. Facing the plate strips.

5.2.2 Determine the parameters

In this study, there were three parameters, which have strong effect on the microstructure, mechanical properties, and residual stress profile of friction stir welding

process. That is because, these parameters are the mean sources for the heat generated during the operation [94, 95,106]. For each of these parameters, four levels used for each factor in this study. Table 5.3 illustrates the three parameters and the values of their levels.

Table 5-3. The Parameters and their level values.

Parameters	Levels			
	1	2	3	4
Welding speed (mm/min) S	500	600	700	800
Rotation speed (rpm) R	75	100	125	150
Tilt angle A	10	20	30	40

5.2.3 Design of the experiment

Parameters (Tool rotation speed, welding traverse speed, and tilt angle) were determined and each of them has four levels. Depending on Taguchi method, orthogonal arrays selecting according to these number of parameters 3 and their levels 4, the number of degree of freedom is calculated as: (4-1) + (4-1) + (4-1) +6=15,this means that the minimum experiment runs is 16. In this case, we found that the possible and suitable orthogonal array is L16 that is mean we have to run the experiment 16 times. Table 5.4 represents the orthogonal array L16 with the distribution of the parameters and their level values.

Table 5-4. The orthogonal array L16 with the distribution of the parameters and their level values.

Experiment number	Rotation Speed(rpm)	Welding Speed (mm/min)	Tilted Angle
1	500	75	10
2	500	100	20
3	500	125	30
4	500	150	40
5	600	75	20
6	600	100	10
7	600	125	40
8	600	150	30

Table 5-4 Continued

9	700	75	30
10	700	100	40
11	700	125	10
12	700	150	20
13	800	75	40
14	800	100	30
15	800	125	20
16	800	150	10

5.3 Experiment and result

After the design of the experiment, (preparing and welding the plate strips), 16 experiments were run. The results of the three responses or outputs (Average Absorbed Energy, Energy for crack initiation, and Energy for crack propagation), were measured in laboratory. Table 5.5show the measured values of these responses of the 16 runs.

Table 5-5. The Results of the three parameters in the 16 experiment runs.

Experiment number	Average Absorbed Energy(J)	Energy for crack initiation (Ei)	Energy for crack propagation (Ep)
1	15.50	7.00	8.00
2	19.25	9.30	10.00
3	22.90	11.00	12.00
4	16.20	11.00	4.80
5	18.50	6.8	12.00
6	18.30	12.00	6.80
7	20.20	11.00	9.10
8	20.30	11.00	9.60
9	14.90	8.30	6.60
10	16.10	7.60	8.50
11	18.70	10.00	8.40
12	20.80	10.00	11.00
13	18.50	10.00	8.40
14	19.80	11.00	9.10
15	17.50	9.30	8.20
16	15.40	6.30	9.20

5.3.1 Taguchi analysis

In this study, the Average Absorbed Energy, Energy for crack initiation, and Energy for crack propagation optimization is the target, and it needs to find out the best set of parameter levels. To appreciate the influence of the (rotational welding speed, traversing speed, and tool tilt angle) parameters on the (total energy, energy for crack initiation, and energy for crack propagation) responses the signal to noise ratio (S/N) and means for each parameters need to find out. Here the desired values for each responses (Absorbed Energy, Energy for crack initiation, and Energy for crack propagation) is maximum as possible as so, in the calculation, the equation 3.3 (Higher the Better (HB) or Large is the better (LTB) was used. By using the software (Minitab) using table 6 data, and the experimental results transformed into means and signal to noise ratio(S/N) we get the following results.

The mean response of raw data and signal-to-noise ratio of Absorbed Energy for each parameter at four levels were calculated, as indicated in tables 5-6 and, 5-7.

The output results of the effect of noise ratio (S/N) is as plotted in figures 5-4, and figure 5-5 illustrates the main effects for means, by using software (Minitab). In addition, it is clear that the absolute energy reaches the highest value at the second level of rotational speed, the third level of welding speed, and the third level of tilt angle. Therefore, the set of parameters, which get the maximum value of absolute energy, are (rotational speed at 600rpm, traverse or welding speed at 125 mm/min, and tilt angle at30^0).

By the same processor, we found out the optimum parameter levels set for the energy for crack initiation are (600 rpm, 125 mm/mi, and30^o). For the Energy for crack propagation, only deferent level was in the tilt angle where, plotted that the maximum was at the20^o.

Table 5-6. The response table for Signal to Noise Ratios Larger is better (absolute energy) Taguchi Design.

Taguchi Orthogonal Array Design L16 (4**3) Factors: 3 Runs: 16 Columns of L16 (4**5) Array.			
Level.	Rotational Speed (rpm).	Welding speed. (Mm/min)	Tilt angle (Degree)
1	25.16	24.43	24.50
2	25.71	25.25	25.56
3	24.85	25.90	25.69
4	24.97	25.11	
	24.94		
Delta	0.86	1.48	1.19
Rank	3	1	2

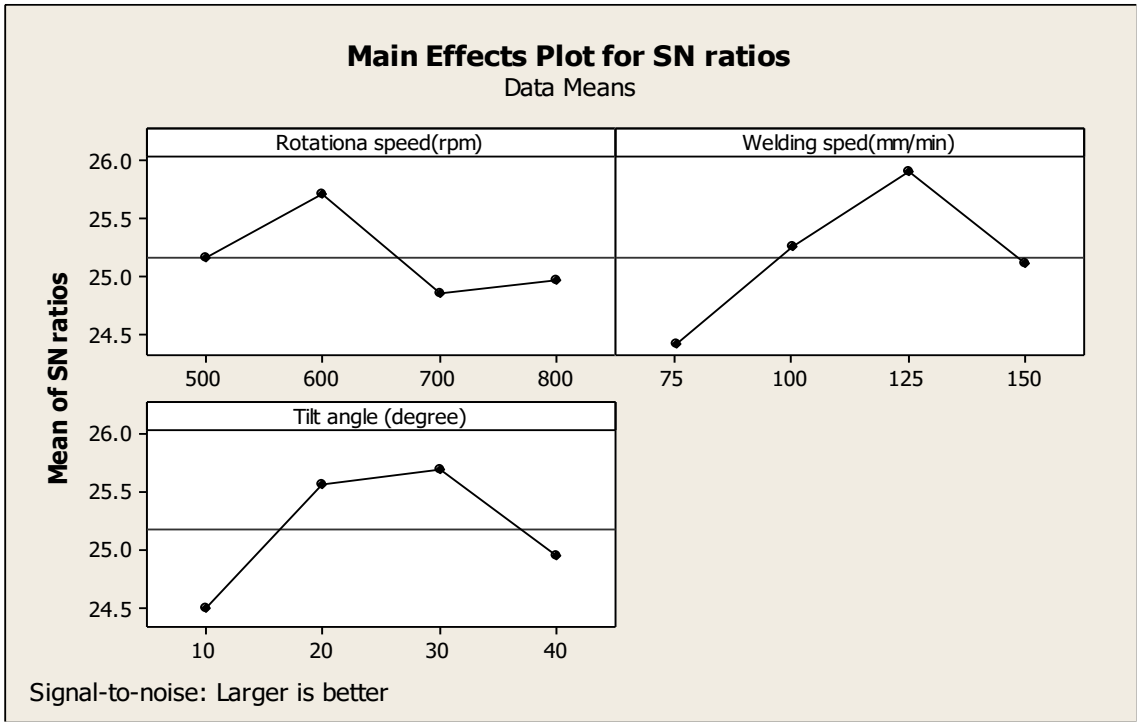

Figure 5-4. The plotted of the S/N ratio effect on the welding speed, rotational speed, and tilt angle for response absolute energy.

Table 5-7. Response table for Means Larger is better (absolute energy) Taguchi Design

Taguchi Orthogonal Array Design L16 (4**3) Factors: 3 Runs: 16 Columns of L16 (4**5) Array.			
Level.	Rotational Speed (rpm).	Welding speed. (Mm/min)	Tilt angle (Degree)
1	18.35	16.74	16.86
2	19.32	18.36	19.01
3	17.63	19.82	19.48
4	17.80	18.18	17.75
Delta	1.70	3.09	2.61
Rank	3	1	2

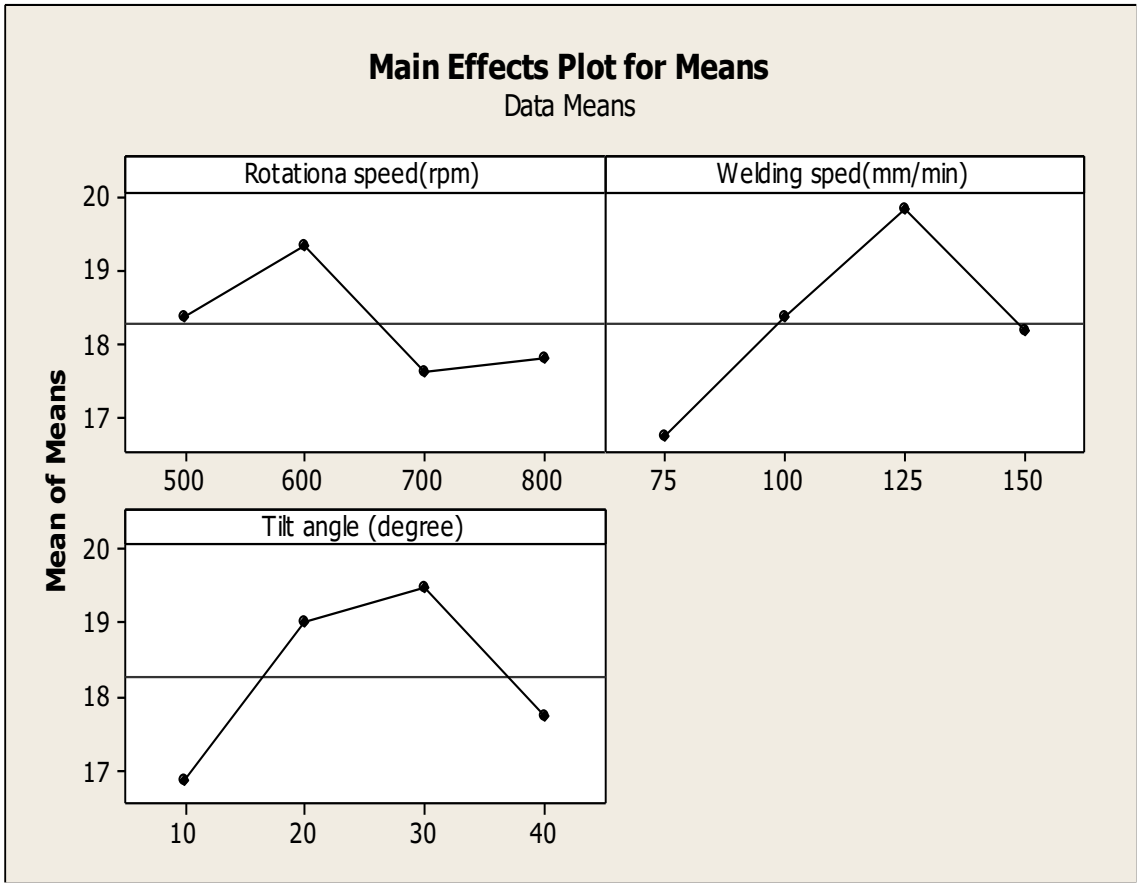

Figure 5-5. The plotted of the mean effect on the welding speed, rotational speed, and tilt angle for response absolute energy.

When, the optimum set of parameter levels condition are determined, the optimum performance of the response under the optimum condition predicted. The optimum value of the response characteristic is estimated as following equation 5-1 [105,106]

$$\Upsilon=\frac{R}{N} + (\varepsilon_{f1av} - \frac{R}{N}) + (\varepsilon_{f2av} - \frac{R}{N}) + (\varepsilon_{f3av} - \frac{R}{N}) - \frac{R}{N} \text{ ---------- (5.1)}$$

Where, Υ is the optimum value of the response characteristic (here the absolute energy).

$\frac{R}{N}$ is the overall mean of absolute energy values in 16 experiments; ε, is the absolute energy; ε_{f1av} is the average absolute energy at the second level of rotational speed (600 rpm); ε_{f2av} is the average absolute energy at the third level of welding speed (125 mm/min);

ε_{f31av} is the average absolute energy at the third level of tool tilt angle30^{o}. By sub substituting data from table 5, and 6 in equation number 4,

$$\Upsilon = 18.275 + (19.325 - 18.275) + (19.825 - 18.275) + (19.475 - 18.275) = 22.075.$$

Now, the optimum design was determined to be rotational speed L2, welding speed L3 and, tilt angle L3. It must note that the above combination of factor levels is among the sixteen combinations tested for the experiment and the average absolute energy was determined by the value 20.8.

And, by comparing between these two value of the response (absolute energy) we find that the two values are much closed together and, there is only about 6.12% deviation between them (predicted 22.075 and, actual 20.80).

Tables 5.8- 5.11 present the output values for the Signal to Noise Ratios and Means for the, energy for crack initiation, and energy for crack propagation. Table 5.12 represents S/N ratios and means for total energy, energy for crack initiation, and energy for crack propagation. Figures 5-6 - 5-9 show the output results of the noise ratio (S/N)

effect and the main for energy for crack initiation, and energy for crack propagation respectfully.

Table 5-8. Response for Signal to Noise Ratios Larger is better (energy for crack initiation).

Taguchi Orthogonal Array Design
L16 (4**3)
Factors: 3
Runs: 16
Columns of L16 (4**5) Array.

Level.	Rotational Speed (rpm)	Welding sped (mm/min)	Tilt angle (degree)
1	19.54	18.02	18.59
2	19.85	19.70	18.86
3	19.04	20.30	20.03
4	18.99	19.40	19.94
Delta	0.85	2.28	1.44
Rank	3	1	2

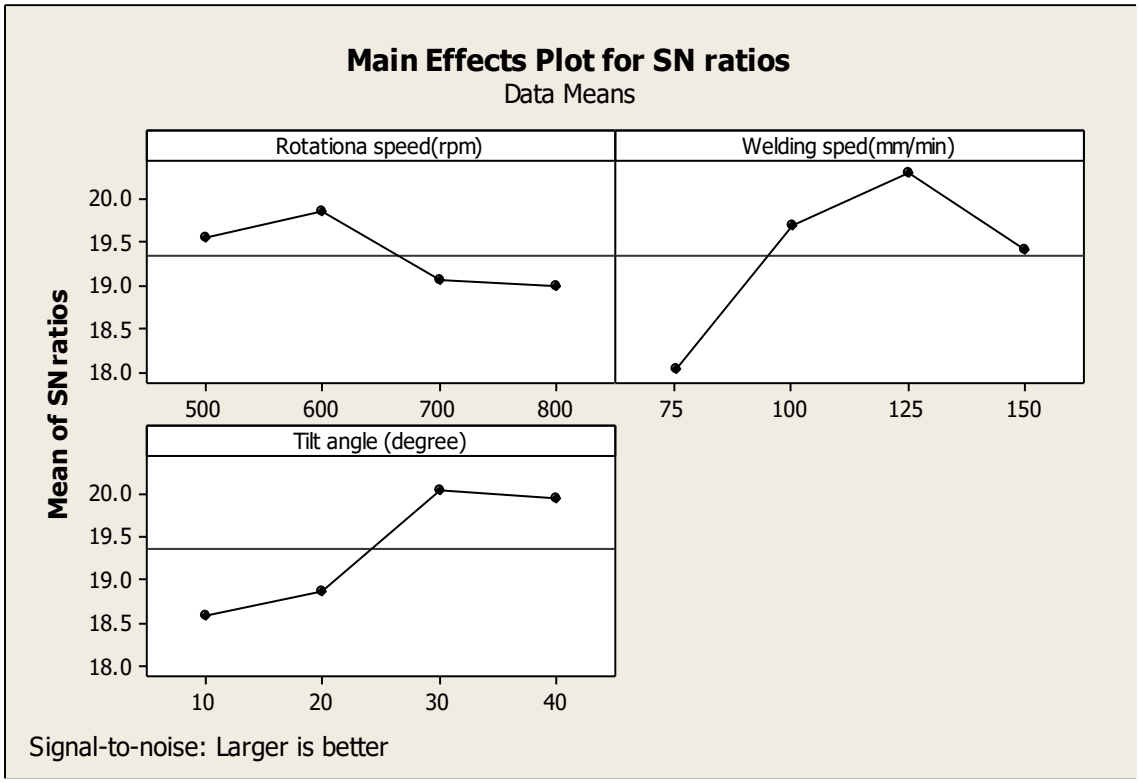

Figure 5-6. The plotted of the mean effect on the welding speed, rotational speed, and tilt angle for response energy for crack initiation.

Table 5-9. Response for Means (energy for crack initiation)

Taguchi Orthogonal Array Design
L16 (4**3)
Factors: 3
Runs: 16
Columns of L16 (4**5) Array.

Level	Rotational speed (rpm)	Welding sped (mm/min)	Tilt angle (degree)
1	9.641	8.058	8.780
2	10.026	9.777	8.857
3	9.028	10.370	10.094
4	9.087	9.579	10.053
Delta	0.998	2.312	1.314
Rank	3	1	2

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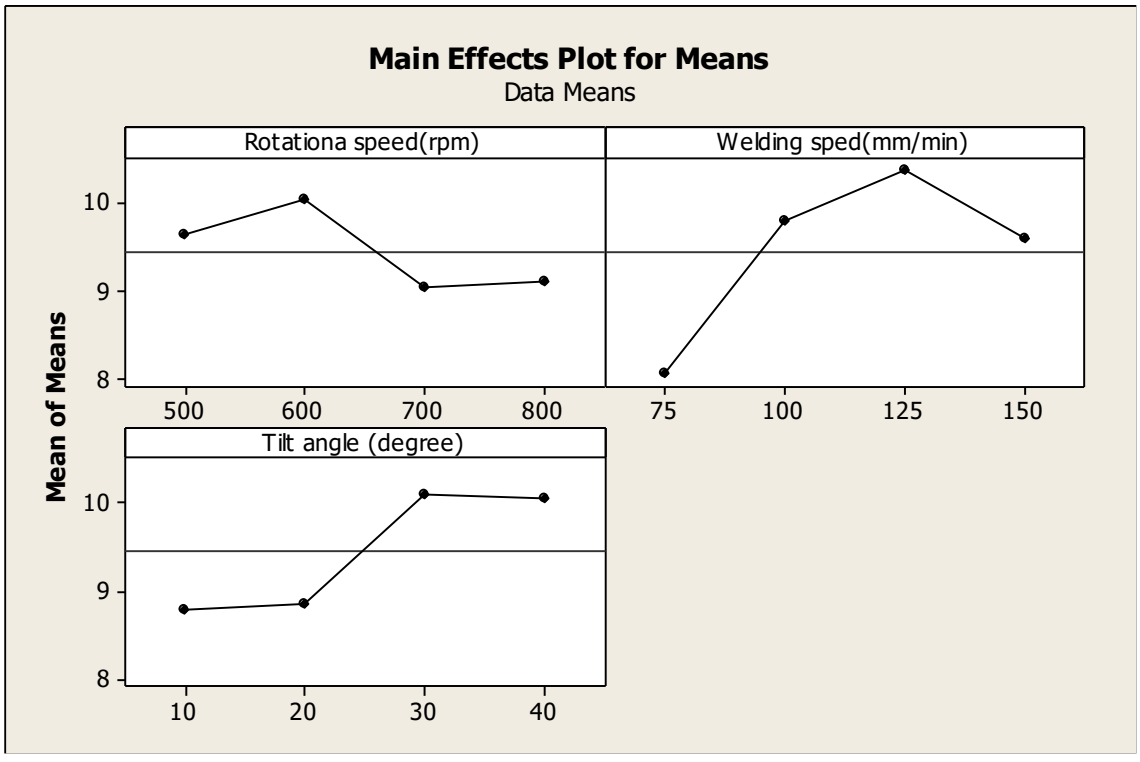

Figure 5-7. The plotted of the mean effect on the welding speed, rotational speed, and tilt angle for response energy for crack initiation.

Table 5-10. Response for Signal to Noise Ratios Larger is better (and energy for crack propagation)

Taguchi Orthogonal Array Design L16 (4**3) Factors: 3 Runs: 16 Columns of L16 (4**5) Array.			
	Rotational	Welding	Tilt angle
Level.	Speed (rpm)	speed (mm/min)	(degree)
1	18.31	18.59	18.10
2	19.20	18.59	20.06
3	18.56	19.40	19.25
4	18.79	18.29	17.46
Delta	0.89	1.12	2.60
Rank	3	2	1

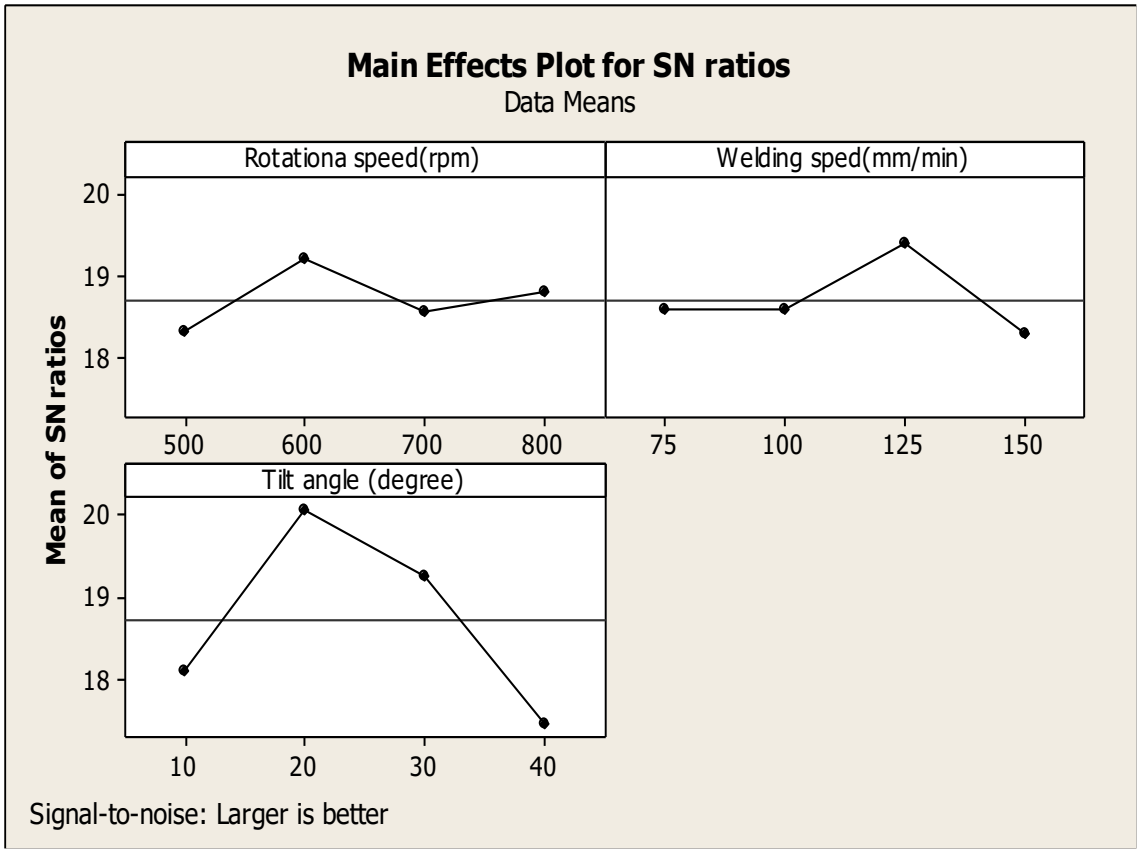

Figure 5-8. The plotted of the mean effect on the welding speed, rotational speed, and tilt angle for response energy for crack propagation.

Table 5-11. Response for means (energy for crack propagation)

Taguchi Orthogonal Array Design L16 (4**3) Factors: 3 Runs: 16 Columns of L16 (4**5) Array.			
Rotational Level.	Welding Speed (rpm)	Tilt angle sped (mm/min)	(degree)
1	8.710	8.679	8.083
2	9.294	8.585	10.154
3	8.597	9.455	9.380
4	8.713	8.595	7.698
Delta	0.697	0.870	2.456
Rank	3	2	1

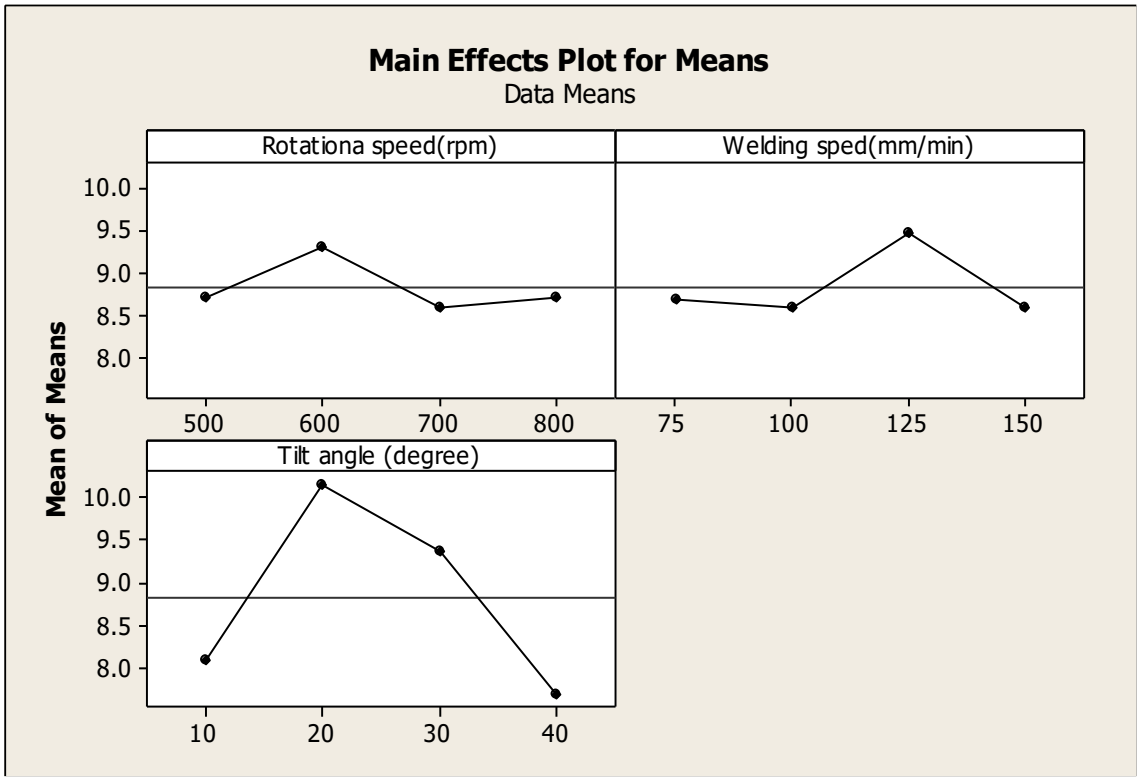

Figure 5-9. The plotted of the mean effect on the welding speed, rotational speed, and tilt angle for response energy of crack propagation.

Table 5-12. . S/N ratios and means for total energy, energy for crack initiation, and energy for crack propagation.

Experiment Run	SNRA1 (E)	MEAN1 (E)	SNRA2 (Ei.)	MEAN2 (Ei.)	SNRA3 (Ep)	MEAN3 (Ep)
1	23.5507	15.05	16.9626	7.049	18.0629	8.001
2	25.6886	19.25	19.3566	9.286	19.9687	9.964
3	27.1967	22.9	20.6524	10.78	21.6701	12.12
4	24.1903	16.2	21.1761	11.45	13.5412	4.754
5	2.53434	18.5	16.7087	6.846	21.3265	11.65
6	25.2490	18.3	21.2366	11.53	16.6092	6.768
7	26.1070	20.2	20.883	11.07	19.2047	9.125
8	26.1499	20.3	20.5551	10.66	19.677	9.635
9	23.4637	14.9	18.3354	8.256	16.4486	6.644
10	24.1365	16.1	17.6288	7.611	18.5771	8.489
11	25.4368	18.7	20.2483	10.29	18.5011	8.415
12	26.3613	20.8	19.9617	9.956	20.7006	10.84
13	25.3434	18.5	20.0692	10.08	18.5083	8.422
14	25.9333	19.8	20.5714	10.68	19.1999	9.12
15	24.8608	17.5	19.4069	9.34	18.2338	8.16
16	23.7504	15.4	15.9176	6.25	19.2284	9.15

5.4 Analysis of variance (ANOVA)

The target from Analysis of variance (ANOVA) test is identifying the process parameters that are statistically significant [107]. In our study, the purpose of the ANOVA test is to investigate the significance of the rotational speed, welding speed, and tilt angle which effect on the absolute energy of friction stir welding operation. Table 5.13 displays the ANOVA result, and figure 5-10 plotted the contribution of the three parameters of rotational speed, welding speed, and tilt angle on the absolute energy at welding operations.

A factor gets a high percentage contribution means that it has a great on the performance at little variation. From the results, which obtained of ANOVA indicate to consider parameter was highly significant affecting on the absolute energy in friction stir welding operation is the welding speed with 45% the second is the Tilt angle with 39%, and in the last, by 16% rotational speed. The pie chart in the figure 5-10 shows the contribution percentage for each parameters comparing to others.

Table 5-13. Analysis of Variance (ANOVA) for absolute energy (E), Using Adjusted SS for tests

Parameters.	DF	Seq. SS	Adj. SS	Adj. MS	F	P	%Parameters contribution
R.S(rpm)	3	7.025	7.025	2.342	0.39	0.762	8.912147
T.S(mm/mi)	3	19.136	19.136	6.397	1.07	0.428	24.27656
Tilt angle(º)	3	17.019	17.019	5.673	0.95	0.472	21.59087
Error	6	35.645	35.645	5.941	-	-	45.22042
Total	15	78.825	-	-	-	-	100

Where, DF-Degrees of freedom, Seq. SS- Sequential sum of squares, Adj. SS- Adjusted sum of square, Adj. MS-Adjusted mean square, F-Fisher ratio, P-probability that exceeds the 95 % confidence level.

5.5 Conclusion

- The parentages of these three parameters (rotational speed, welding speed, and tilt angle) contribution on the absolute energy in friction stir welding operation were determined and we found out that welding or traverse speed has highest effect flowing by tilt angle and, at the end with lowest effect was the rotational speed.
- The result shown that, the set of these three parameters and there levels values was:-
- A-(rotational speed at 600 rpm, welding speed at 125 mm/min and, tilt angle at 30^{o}) for absolute energy and the energy for crack initiation,

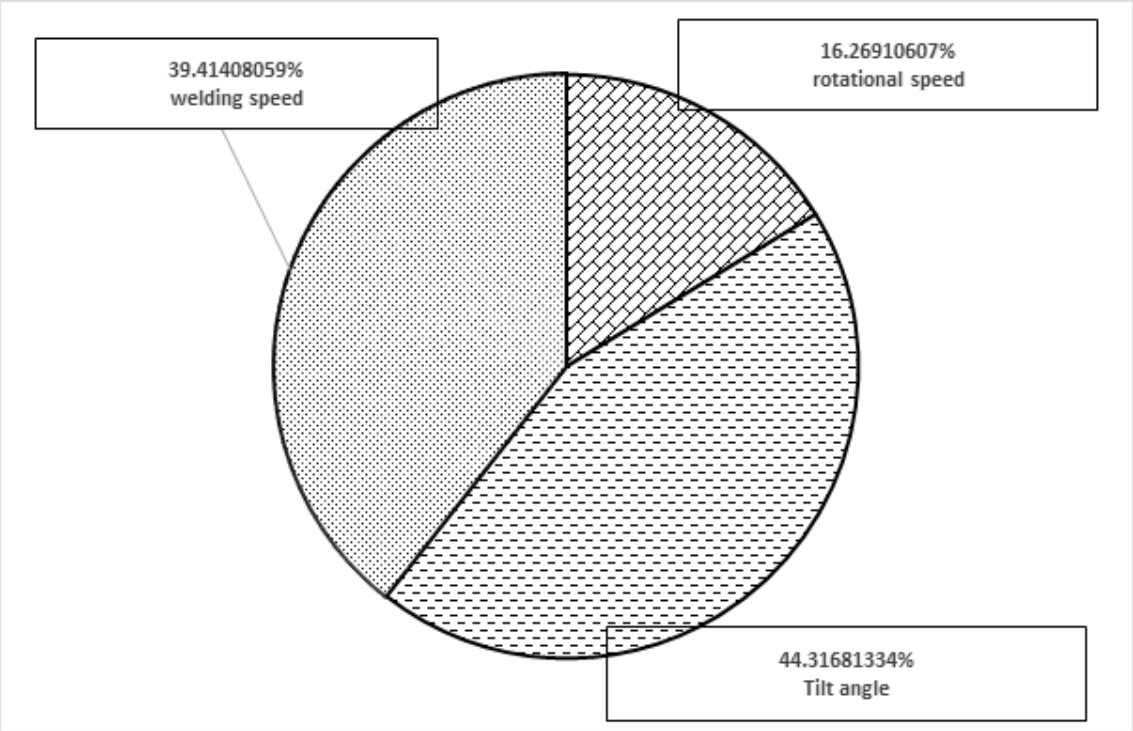

Figure 5-10. The contribution of the three parameters on absolute energy result

- B - And, for the Energy for crack, propagation was only one deferent and that was the tilt angle, which was at, $20°$and optimum set is (rotational speed at 600 rpm, welding speed at 125 mm/min and, tilt angle at $20°$).

CHAPTER 6

6 INTEGRATEDOF QMS (ISO 9001:2015) AND TAGUCHIMODEL

6.1 Introduction

Competitiveness, innovation and performance are the key words that best define the goals of the present business environment. And in the present globalization era, the producers must have a high ability to increase competitiveness for their products and services. The high quality with low cost plays the most essential factor in the competitive to stay in the market. It is necessary for any organization to enable for drive and improve operational efficiency and overall compliance to address these challenges of market. While market globalization has vastly increased the profit potential for profit for manufacturers and other businesses by facilitating communications and market access across the globe, it has also intensified competition and the pressure to produce products faster and at a lower cost less expensively as the result. This leads the companies to search for best quality systems and tools, which obtain the desired target.

All organizations implement different quality systems and tools approaches such as, ISO 9001 quality management system (QMS), lean management and Six Sigma (SS) methodology and so on, to achieve higher quality performance. In the industrial and manufacturing field now days, and in the present operational management environment the authors and researchers have shown the importance of integrating a mix of different but overlapping manufacturing systems and practices for quality improvement which have enormous contributed enhance and achieve competitiveness for companies and maintain market share and striving to increase it. Regarded as a whole, in industrial sector, for the economic environment and obtain outcomes products meet the organizational goals by implementing Taguchi approach with one of the quality management systems, namely the model ISO 9001: 2015, for the development and continuous improvement of enterprises.

A synergetic approach created by analysing and simultaneously using the benefits of Taguchi approach and ISO 9001:2015 plays an important role in the

development and success of a manufacturing processes. ISO 9001:2015 standard encourage organizations to adopt various forms of improvement to stay at the consistently enhancement its overall performance, to better be able to meet customer and other stakeholder requirements, as well as to address their future needs and expectations. On the other hand, Taguchi approach Taguchi is a modern approach that promotes the improvement of the organization, through product and process design optimization, which improve product quality and reduce costs drastically. Taguchi methods employs crucial statistical and analytical approaches that your business can use as a step toward improvement.

6.2 An overview of ISO 9001: 2015

The ISO 9001 family has several different versions, which addresses various aspects of quality management and contains some of ISO's best-known standards. The standards provide guidance and tools for companies and organizations who want to ensure that their products and services consistently meet customer's requirements, and that quality is consistently improved figure 6.1framework of ISO 9001:2015 standards.

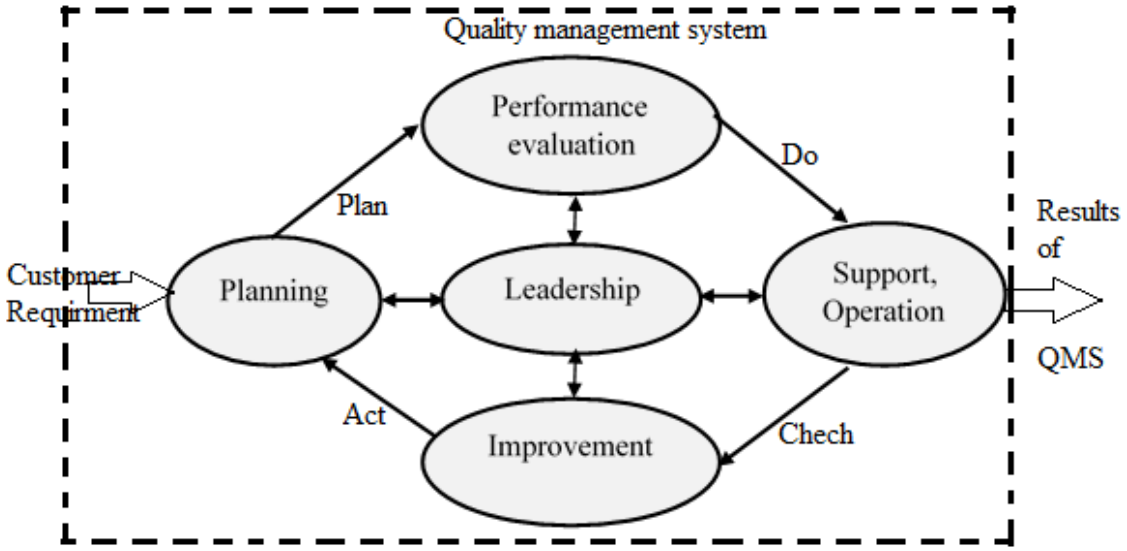

Figure 6-1. Framework of ISO 9001:2015 standards.

ISO is a high esteem and established standard for quality management system and is applicable across nearly every industry. This standard was initiated in 1987 as a theoretical framework, and then developed into process oriented approach models after new issues versions [108].

More details about ISO 9001:2015 in chapter one and two with the data survives and analysis.

6.3 An overview in brief for Taguchi approach

Taguchi method is a new engineering design optimization methodology that improves the quality of existing products and processes and simultaneously reduces their costs rapidly, with minimum engineering resources and development mam-hours (getting high quality without any additional cost). These benefits obtained by employing crucial statistical and analytical approaches that the business could use as a step toward improvement. The main involves of this method are the loss functions, orthogonal array and robustness design. As Taguchi philosophy, the loss not incurred only when these defects and problems in the goods or services, or when the products and services fall outside of quality standard limits (upper and lower specifications). As Taguchi, losses can still incurred inside limits. With the Taguchi loss function approach, losses became broader in category. It defines them as anything that is not efficient and may cost the consumers negatively (more detail in preview chapter two).

As a result of Taguchi approach which is of-line quality philosophy is not expensive with high performance products or services that is because, quality can be improved and get high performance products or services without loss any additional sources or time. And getting a high quality products or services and in low cost means that a company provide to the market what the customer needs (not expensive with high quality from goods or services) which the essential goal for any company where it leads to maintain on the existing customers and attract new customers. As a result, the sells will expand, and it lead to enhance the profit of the company.

The Taguchi method (figure 6-2) achieves this by making the product or process performance “insensitive” to variation in factors such as conditions. Taguchi method makes the product or process robust and therefore it knowns as (ROBUST DESIGN).

Taguchi loss-function and robust design, which lead to get products and service not only at the range of upper and lower limitations but with minimum dispersion from the nominal value (the target). As showed in preview chapter three, equation 3.1 which express the loss due to the performance variation is proportional to the esquire of deviation of the performance characteristic from its nominal value. From this philosophy, the loss function emphasizes the importance of reducing variation that always leads to waste and poor quality. It can also bring about changes in output and can be a source of defects. When variations are controlled, performance and quality will improve consequently.

The Taguchi’s principle contributions to statistics are-

- Robust design, a design that has minimum sensitivity to variations in uncontrollable factors which called, factors noise to signal ratios (N/S), equations 3.2,3.3 and,3.4 in chapter three.

- The philosophy of-line quality control. It helps in the lowering or minimizing of the variation at the design stage which, including, system design, parameter design, and tolerance design of a product or service. And all should be optimized so variations are limited.
- Innovation in the design of experiments. Orthogonal array which leads to massive save of time and sources by the huge drop from the number of experimental which needed to determine the optimum set of parameters comparing with conventional full factorial methods

6.4 Integrated of ISO 9001: 2015 with Taguchi method

The essential goal of any company is striving for growing and reaching highest value from profits. To get this target in our globalized era, where the competition is highly strong, it must has product with high quality with low cost. Therefore, it’s

necessary for any company to stay in the world competition, to give the market a product with high quality and in the same time with low cost. Its leads to study the relation between quality and the cost of product or quality cost. It is easy to produce a product with high quality and high cost but company will lose the customers and fail in competition. In the other word, you cannot just cut down costs across the board because often times, reductions in costs negatively affect quality, which has a direct effect on the customer satisfaction.

If a company or organization goal looks simply to reduce expenses, then the quality of the goods and/or services often becomes lower than before. By the end, with a lower quality leads to loss customer satisfaction, decrease in sales, and repeat business; and further, leading to a decrease in profits. In addition, it is the result if a company or organization goal looks simply to raise the quality of his product where, expensive product leads to loss the customers and shutdown the profit. Therefore, to avoid these, a company or organization must improve its product quality with decreasing of cost or at least, without any additional cost. And to get that, companies in all over the world, implement a different systems for management and use variety of quality tools. To enhance the efficiency of the system and tool many practices, researchers, and authors have shown the importance of integrating or mixing of different of these systems and tools to get the highest value of benefit. In this thesis to integrate the basic concepts and principle of the last version of QMS ISO 9001which is ISO 9001: 2015 with the main concepts of the Taguchi approach to create a high product quality with lower cost.

Taguchi approach method is a methodology for product or service quality improvement, which aims at product and/or service that have high performance quality without any increasing of cost. This method philosophy tends to improve the performance of organization bossiness by making organizations effective and efficient, and keeping customers and employees satisfied. Taguchi method is quality improvement for products / services, which comes by the basic Taguchi phosphides (DOE, Robust design, loss function, off-line quality control) which described in before. And these lead to getting products/ services with high quality and perfect

performance with no additional cost which comes from saving the time and sources of the companies or organization.

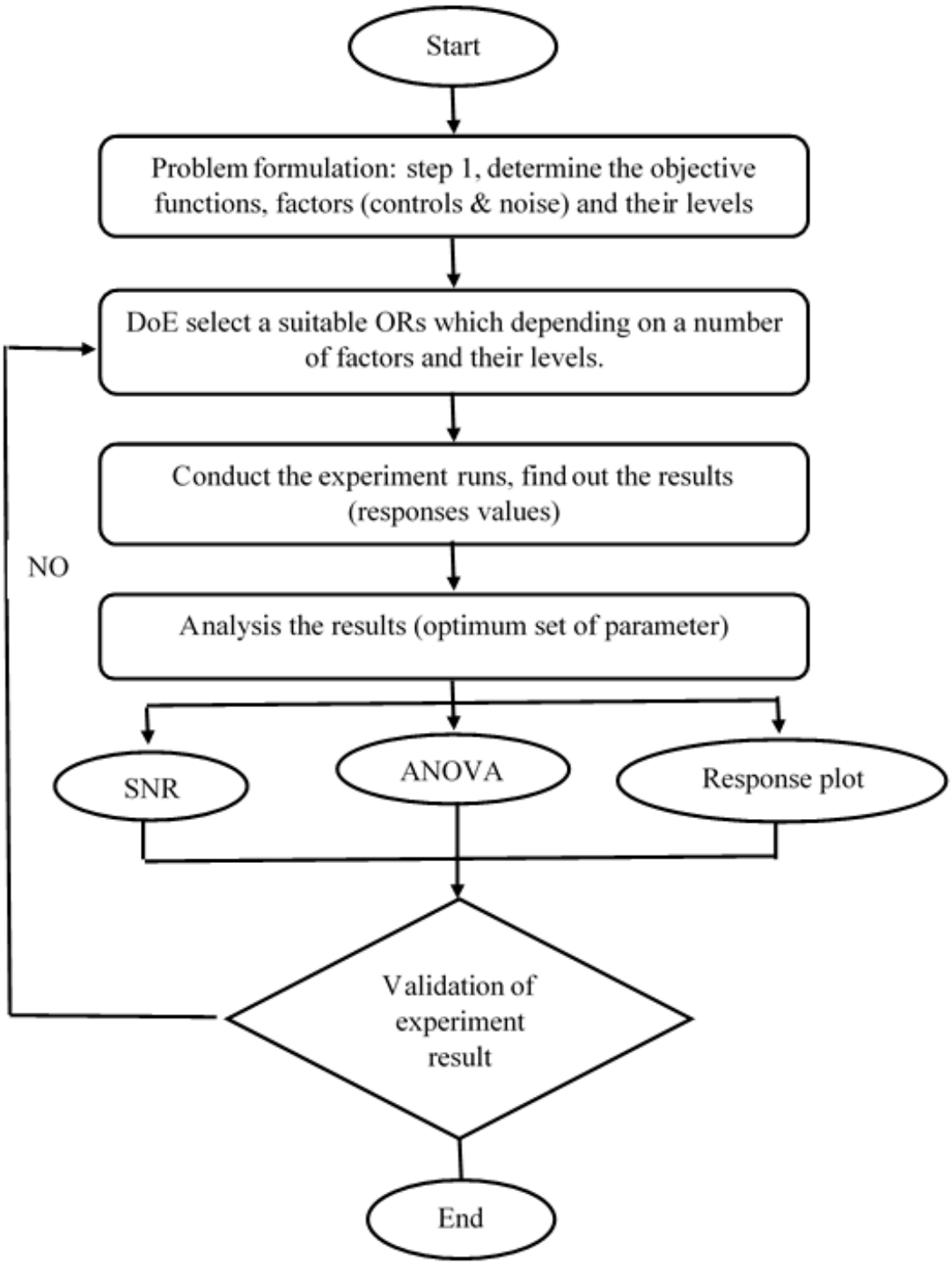

Figure 6-2. Taguchi approach

On other hand, ISO 9001:2015 which is a last version of quality management system ISO 9001 (belongs to ISO 9000 family) and it has a completely new structure through revolutionary and radical changes on its clauses compared with the preview issued version(chapter 1). ISO 9000 addresses various aspects of quality management for organizations who want to ensure that their products and services meet customer's requirements. ISO 9001:2015 which is a quality management system that requires a continual improvement process that based on total control of production operations. The quality management system requires that organizations have a pre-established control system in place, but does not determine how the processes should look like. ISO 9001 is a control regime that requires all processes to document, however it does not always help organizations that have set in place ineffective processes. ISO 9001 uses the Plan-Do-Check-Act (PDCA) model to all process, but also to the entire system to implement change leading to process improvement.

The ISO9001-2015 based QMS based on the same quality management principles. It provides guidance to companies that want to ensure that their products/services consistently meet customers' requirements and that their product/service quality undergoes continual improvements. So, any organization has certificated by ISO 9001- QMS is required to conduct internal audits, to check the health of its QMS and ensure that it can satisfy customer requirements. And it may keep the ISO-based QMS might become too rigid and has been mainly used only to meet requirements.

As we mentioned in preview chapters, about the reasons behind the certificate for different organization, various organizations earned this certification for their business operations because as increasingly more of their suppliers became ISO 9001-compliant, they also requested the organization to attain the certification as well. One of the main results for many companies in implementing this approach is improved sales; many companies experienced that without having attained the ISO 9001 certification they could not have won a significant number of new contracts. Regarding the relationship between ISO 9001 implementation and its subsequent evolution to the adoption of integral quality approaches, many experts argue that in order to achieve more benefits, the organization's first step should be to attain certification.

In Taguchi approach, it refers to a quality philosophy including tools and methods used to enhance quality, performance, and productivity (goods and services) in organizations.

So, integrating Taguchi method with ISO 9001:2015 will help organizations in assuring that there is no retrogression form the quality level of products and/service. because as organizations getting the benefits from implemented Taguchi method (products/services high quality and performance) also, its importance for them building a quality system, which is crucial to continually improve the quality while decreasing nonconformities and that is the goal of ISO 9001:2015. In same time, true value of ISO 9001:2015 can grasp only, if organizations set in place effective processes that lead to get high quality product and/or services and continues improvements in quality within the organization. Organizations can use Taguchi tools to define a problem (customer or market needs, design the experiments (control and noise factors and their levels), analyse the results (loss function and robust design), and improve the processes. Then, imply ISO 9001:2015 to control and continually improve these processes.

In brief, from the preview section and the preview chapters, we can conclude that:-

- QMS ISO 9000 aimed at improving the capability of an organization as a whole to manufacturing products to specified technical specification and quality standards and to the deliver them to the customer on time.
- Taguchi method deals with the product design itself, through product and process design optimization it improve product quality and reduce costs drastically
- Taguchi Method and ISO 9001: 2015 thus complement each other. Taguchi method helps organization to produce a good quality high performance product and or service in additional ISO 9001: 2015 leads organization to continue improvement.

So, integrated of the Taguchi technique and ISO 9001:2015 concepts and methodologies together will lead to improve and enhance of the internal and external customers satisfaction and, boost their confidence for the organization.

CHAPTER 7

7 CONCLUSION.

7.1 Conclusion

This research, an attempt has made to correlate between the ISO 9001: 2015 model and Taguchi engineering technique. ISO 9001: 2015 model, represents a good framework for defining a model of continuous improvement of the process, because it is a new way, in relation to the previous QMS models, defines and processes, making the application of quality engineering techniques an imperative. Taguchi method is a good way to deal with manufacturing and technological processes in the industry. As practical part (experiment), we apply the friction stir welding process to joint aluminium ally parts with result analysis and optimization by Taguchi method. And the main conclusion was:-

1- From an analysis of survey data for the number of certifications, which have issued by ISO in the entire world and in European countries, we can observe that;

The number of certifications has increased by years and by statistical analysis, it will be growth in the same way in the next period.

ISO 9001, QMS leads the spreading of the ISO certifications by more the 70% from the total number of certifications which issued by the International Organization for Standardization.

China has gotten highest number of certifications in all over the world, Followed by Italy as the second. In the same time, Italy came in the first order in European countries with 25 % from the issued certification for European continent.

Forecasting analysis for the path of number of certificates in next year's refers to the number will continue growth, and there is no evidence to reach saturation.

2- The high quality with low cost plays the most essential factor in the competitive and sharing in the market. This compels all companies around the world to

continue the hard work on improving the quality of their goods and services to increase competitiveness for their products and services.

3- Taguchi approach is powerful statistical technique for improving product/process designs and solving production problems. And it's simple, easy, and no any additional cost or losing time. Defining the parameters and their values are need to the experts. Using ANOVA analysis is helpful to evaluate the significant influences between the parameters.

4- Friction stir welding (FSW) is anew welding processes has several of important advantage which contributes for solving of many welding problems appearance in the other previews welding process.

5- The optimization of FSW process parameters for aluminium alloy sheet (5083) welds using the recommendation of Taguchi method for design of experiment is applied. And three parameters (rotational welding speed, traversing speed, and tool tilt angle) each of them has 4 level values, and robust design was done to find out the optimum set for the desired result which was the total energy (maximum value is needed) and the results was:

Optimum sets of parameters and there were (rotational speed at 600 rpm, welding speed at 125 mm/min and, tilt angle atilt angle at30^{o}. From ANOVA analysis, we found that, the welding speed parameter has the highest significant influence on the result comparing other two parameters (rotational speed and tilt angle).

6- QMS ISO 9001: 2015 and Taguchi method are:

QMS ISO 9000 aimed at improving the capability of an organization as a whole to manufacturing products to specified technical specification and quality standards and to the deliver them to the customer on time. Taguchi method deals the product design itself, through product and process design optimization it improve product quality and reduce costs drastically. So, Taguchi Method and ISO 9001: 2015 thus complement each other. Taguchi method helps organization to produce a good quality high performance product and or service in additional ISO 9001: 2015 leads organization to continue improvement.

CHAPTER 8

8 FUTURE RESEARHES

8.1 ISO9001:2015

As mentioned in chapters one, and two, ISO 9001: 2015 has issued since September 2015 with several significant changes compared by the previous version (ISO 2008). Also, by the end of year 2018, ISO 9001:2008, will be no used more and all organizations that have ISO 9001:2008 certificated, must replace it with the ISO 9001:2015 by the end of year 2018. In additional, enormous of organizations already adapted the new version. So a study is needed to investigate the effect of implementation of ISO 9001:2015 on that organizations and how this version make improvement on the organization from all sides such as (Consumer confidence and satisfaction, Increase in market share and Profit growth) and if it get the target comparing with the previews issued which it was used before.

8.2 Taguchi technique.

In this thesis in chapter five, Taguchi is applied to find out the optimum set of three parameters in friction stir welding processes for one response. Particularly in modern industries, manufacturing processes becomes more complex and controlled by multiple inputs (factors) and out puts (responses) and optimize one response will degrade other responses. therefore, a new work using multi responses optimization process which may include more input factors as (plunge depth, axial force, tool geometry) to find out optimum set for multi responses outputs from the mechanical properties such as (yield and ultimate stress, hardness, fatigue, est.). Further researches needed by using an integrated intelligent multi response optimization approaches.

9 REFERNES

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BIOGRAPHY- ABUAJILA M.S RAWENI

Abuajila Raweni, was born in 01/01/1964, in Garapulli, Tripoli-Libya. He finished his primary and secondary schools at his city Garapulli. In the year 1983, he joined Tripoli university faculty of engineering and get the BSc. In mechanical engineering in 1988.

In the period 2001-2003, he studies at university of Belgrade faculty of mechanical engineering, and he get his master there in 2003.

1988-2009, he worked at the Technical Reaches Canter in Tripoli, Libya. He worked in this canter as engineer in field of planning, welding and assembly line, heat treatment, and machines.

From 2009 until 2013 when he came to University of Belgrade to study PhD program, he worked as a teacher at University of Elmergab, Libya. The subjects who teaches in faulty, were engineering management, production engineering and, workshop technology.

In the last three year (2016-2018), he published the flowing papers,

1. Raweni, Abuajila, et al. "Optimization of AA5083 Friction Stir Welding Parameters Using Taguchi Method." *Tehnički vjesnik*25.3 (2018): 861-866.

2. Raweni, Abuajila MS, and Vidosav D. Majstorović. "ISO Certifications Diffusion in European Countries 2007-2014 and Forecasting for 2022-State of the Art." International Journal" Advanced Quality" 44.1 (2016): 53-58.

3. Vidosav D. Majstorović, Abuajila M. S Raweni, Nuri Mohamed Saad Algheriani. Asigurarea Calitatii ‘The Integrated Index of Business Standardization - Research and Development’. Quality Assurance, ISSN 1224-5410 Vol. XXII, Issue 87, July-September 2016 Pages 23-27

4. Vidosav D. Majstorović, Nuri Saad, Abuajila Raweni. “The Integrated Index of Business Standardization -Review For 2015 of World and Europe” (2016 Belgrade).

Прилог 1.

Изјава о ауторству

Потписан - Абуајила м.s Равенс

индекс број Д41 / 2013

Изјављујем

да је докторска дисертација под насловом

"да се позива на докторску дисертацију

Развијајући модел побољшања квалитета на платформи ИСО 9001: 2015 користећи методу Тагуцхи"

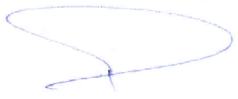
“DEVELOPING OF QUALITY IMPROVEMENT MODEL ON ISO 9001:2015 PLATFORM USING TAGUCHI METHOD”

GN “

- резултат сопственог истраживачког рада,
- да предложена дисертација у целини ни у деловима није била предложена за добијање било које дипломе према студијским програмима других високошколских установа,
- да су резултати коректно наведени и
- да нисам кршио/ла ауторска права и користио интелектуалну својину других лица.

Потпис докторанда

У Београду, 10.09.2018



Прилог 2.

Изјава о истоветности штампане и електронске верзије докторског рада

Име и презиме аутора Абуајила м.s Равені.

Број индекса Д41/2013

Студијски програм Докторске студије

Наслов рада “Развијајући модел побољшања квалитета на платформи ИСО 9001: 2015 користећи методу Тагуцхи"

“DEVELOPING OF QUALITY IMPROVEMENT MODEL ON ISO 9001:2015 PLATFORM USING TAGUCHI METHOD”

Ментор Видосав Мајсторовић

Потписани/а

Изјављујем да је штампана верзија мог докторског рада истоветна електронској верзији коју сам предао/ла за објављивање на порталу **Дигиталног репозиторијума Универзитета у Београду.**

Дозвољавам да се објаве моји лични подаци везани за добијање академског звања доктора наука, као што су име и презиме, година и место рођења и датум одбране рада.

Ови лични подаци могу се објавити на мрежним страницама дигиталне библиотеке, у електронском каталогу и у публикацијама Универзитета у Београду.

У Београду, 10.09.2018 **Потпис докторанда**

Прилог 3.

Изјава о коришћењу

Овлашћујем Универзитетску библиотеку „Светозар Марковић“ да у Дигитални репозиторијум Универзитета у Београду унесе моју докторску дисертацију под насловом:

“Развијајући модел побољшања квалитета на платформи ИСО 9001: 2015 користећи методу Тагуцхи"

“DEVELOPING OF QUALITY IMPROVEMENT MODEL ON ISO 9001:2015 PLATFORM USING TAGUCHI METHOD”

која је моје ауторско дело.

Дисертацију са свим прилозима предао/ла сам у електронском формату погодном за трајно архивирање.

Моју докторску дисертацију похрањену у Дигитални репозиторијум Универзитета у Београду могу да користе сви који поштују одредбе садржане у одабраном типу лиценце Креативне заједнице (Creative Commons) за коју сам се одлучио/ла.

1. Ауторство

2. Ауторство - некомерцијално

3. Ауторство – некомерцијално – без прераде

4. Ауторство – некомерцијално – делити под истим условима

5. Ауторство – без прераде

6. Ауторство – делити под истим условима

(Молимо да заокружите само једну од шест понуђених лиценци, кратак опис лиценци дат је на полеђини листа).

У Београду 10.09.2018 Потпис докторанда