POLITEKNIK MALAYSIA
MUKAH

LEAF VACUUM AND SHREDDER MACHINE

ALEXANDER KALAU ANAK JULIN	20DKM15F1138
MOHD MILZAM BIN MOHAMAD KHAN	20DKM15F1042
MOHD HAMDI BIN HAMCA	20DKM15F1066
AMYLIA JELIMIN ANAK ROBIN	20DKM15F1041
DIANA JOSS	20DKM15F1063

PROJECT SUPERVISOR
MOHAMAD SYAHIDULLAH BIN AHMAD ANUAR

DEPARTMENT OF MECHANICAL ENGINEERING
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NAME	REG. NUMBER
ALEXANDER KALAU ANAK JULIN	20DKM15F1138
MOHD MILZAM BIN MOHAMAD KHAN	20DKM15F1042
MOHD HAMDI BIN HAMCA	20DKM15F1066
AMYLIA JELIMIN ANAK ROBIN	20DKM15F1041
DIANA JOSS	20DKM15F1063

This report is submitted to the Department of Mechanical Engineering in partial fulfilment of the requirements for graduation Diploma in Mechanical Engineering

"We declare that this report is our own work except each piece that we have explained the source"

1. Signature :
   Name : ALEXANDER KALAU ANAK JULIN
   Registration Number : 20DKM15F1138
   Date : 12/10/2017

2. Signature :
   Name : MOHD MILZAM BIN MOHAMAD KHAN
   Registration Number : 20DKM15F1042
   Date : 12/10/17

3. Signature :
   Name : MOHD HAMDI BIN HAMCA
   Registration Number : 20DKM15F1066
   Date : 12/10/2017

4. Signature :
   Name : AMYLIA JELIMIN ANAK ROBIN
   Registration Number : 20DKM15F1041
   Date : 12/10/2017

5. Signature :
   Name : DIANA JOSS
   Registration Number : 20DKM15F1063
   Date : 12/10/2017

PROJECT REPORT VERIFICATION

This report entitled "**Leaf Vacuum and Shredder Machine**" has been submitted and reviewed as to meet the conditions and requirements of project writing.

Reviewed by:

Supervisor 1 : MOHAMAD SYAHIDULLAH BIN AHMAD ANUAR

Signature :

Date :

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ABSTRACT

The project was applied from the observation on how Leaf Vacuum and Shredder Machine were useful in Polytechnic Mukah. There are a lot of trees in Polytechnic Mukah which causes the abundant of dried leaves that litters the ground. One of the conventional method to get rid of the dried leaves in Polytechnic Mukah is usually blow them by blower in one place then raking/swiping then and collect into bags. However, this method takes time and requires major effort. To solve this problem, there is where Leaf Vacuum and Shredder Machine is created. By vacuuming the dried leaves using Leaf Vacuum and Shredder Machine, the work of cleaning up dried leaves easy to implement. This machine also functional to shred the dried leaves until they turns into small pieces of debris. The purpose of shredding the dried leaves that had been vacuum is to reduce the storage of dried leaves. The scopes for this machine are, this machine is for use in small-scare like around Polytechnic Mukah area. The storage space can accommodate about 0.5 x 0.8m size of sack. This machine is only for vacuum and shred the dried leaves and cannot be run in rainy day. In literature review, the products that available in the market is compared to improve the product capability. Methodology research is done to create a planning, selection, flow chart as a guide for fabrication process and design of the machine. A test run is done for data analysis.

ABSTRAK

Projek ini dibuat melalui pemerhatian di mana 'Leaf Vacuum and Shredder Machine" ini amat berguna di Politeknik Mukah. Terdapat banyak pokok di Politeknik Mukah yang menyebabkan banyak daun kering yang berguguran di tanah dan tepi jalan. Anatara salah satu kaedah konvensional untuk membersihkan daun kering di Politeknik Mukah ialah dengan membawanya ke satu tempat dengan mesin "blower" dan menyapu lalu dikumpul ke dalam beg . Walau bagaimanapun, kaedah ini mengambil masa yang panjang. Bagi menyelesaikan masalah ini, "Leaf Vacuum and Shredder" telah dicipta. Dengan vakum daun kering menggunakan "Leaf Vacuum and Shredder", kerja membersihkan daun kering mudah dilakukan. Mesin tersebut juga berfungsi untuk mengisar daun kering sehingga menjadi serpihan yang lebih halus. Tujuan mengisar daun kering selepas divakum adalah untuk mengurangkan tempat penyimpanan daun kering. Mesin ini boleh digunakan di tempat yang berskala kecil sperti di Politeknik Mukah. Tempat penyimpanan dapat menampung kira-kira 0.5 x 0.8m saiz guni. Mesin ini hanya untuk vakum dan mengisar daun kering sahaja dan tidak boleh digunakan semasa hari hujan. Dalam kajian literatur, produk yang terdapat dalam pasaran sekarang ini telah dibandingkan bagi meningkatkan keupayaan mesin yang hendak dicipta. Metodologi dilakukan bagi membuat perancangan, pemilihan, carta aliran sebagai panduan untuk proses fabrikasi dan reka bentuk mesin. Satu ujian telah dilakukan untuk analisis data.

TABLE LIST

FIGURE LIST

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CHAPTER 1

INTRODUCTION

1.1 ABSTRACT

Hardenability is an ability of a material to harden in specific depth by using heat treatment until it form martensite on cooling process to achieve specific hardness.(Taufiq Rokhman)

A machine named Fabrication of End Quench Machine was planned with the concept of Jominy Test (Van Black, 1991). This machine will combine the end quench machine with a furnace above it. Jominy Test is the method used to measure the hardenability of a metal. which is a measure of the capacity of steel to harden in depth. Furnace is a tool used for heating the metal in high temperature.

Specimen use in this machine is a cylindrical shape metal with 100 mm long, 5mm diameter and the distance between water and the end of the specimen is 65mm following the method of ASTM A225.. Then the specimen will transfer to the end quench machine beside the furnace and will be cool with water.

1.2 RESEARCH BACKGROUND

Hardenability is ability of material to be hard until a specific depth by using heat until martensite is form when doing cooling process to reach certain hardness. One of the ways to test the hardenability is through Jominy test (Jominy Test) (Van

Black, 1991), to study the hardenability of a metal. In Jominy test, the sample will be heated at first on a specific temperature (900C) and then will be cool by water which will cool the bottom end of the specimen until all of the metal is cool down.

1.3 PROBLEM STATEMENT

The problem statement to our project is student lack of understanding on the nature of the hardenability of metal. Besides, hardenability of a metal is an important aspect in understanding the properties of materials. After that, the lecturer was not enough equipment to carry out the teaching and process due to equipment constrains. Finally, to do the teaching about hardenability both the lecturer and the student require a machine to test the hardenability of materials.

1.4 OBJECTIVES

For our project, there are several things that we need to achieve while doing this project.

1. Able to design the End Quench Machine.
2. To fabricate the End Quench Machine.
3. To study about the End Quench Machine.

1.5 SCOPE

There are a few scopes that we had set on this project.

1. This model is use as teaching and learning tools for lecturer and student.
2. Limited used by higher education institution that need teaching aids related to hardenability tests.
3. Used by Material Science student during practical sessions.

1.6 CONCLUSION

By the end of the project, we are able to learn how a certain temperature and instant cooling could change the hardness properties of a material. This project only undergoes heating and cooling process which heating is done by our furnace and cooled by our End Quench Machine. During the process in making the End Quench Machine, we are able to come up with some ideas on the fabrication of our machine which led us to our latest design. We are able to fabricate the machine design to make the End Quench Machine much easier to access for the students to use inside the laboratory. The reason on building this machine is for the student from Mechanical Engineering Department to learn and used this machine in Material Science subject.

CHAPTER 2

LITERATURE REVIEW

2.1 CHAPTER INTRODUCTION

Literature review is a research that is done about the result of past experiment that was done by the past researchers before and also looking for the information that will be used when doing this project. Literature reviews also help us to know this project more. Besides that, it can help us to design the project better by referring to the past review on the researchers. We are also able to identify the problem that will be face when doing the project.

From the start, we had faces many problem and difficulties as we go through the process of making our project. From what we observe, we have identified some problems which are found as the past experiment that we have studied about. Most of the problems came from the design of the project and how we could make the furnace hot enough to make sure our project run smooth. By referring to the last experiment, we have come up with some new design and ways to ensure that the project that we will build is safe and easy for the lecturer and student to do teaching and learning sessions without any problem.

Literature reviews help us to solve problem that had already occur at the past and make us prepare for any possibility problem that will come when we build our project. It also helps us in designing the suitable design for us to make our End Quench Machine to be able to operate inside the Material Science laboratory.

2.2 PAST RESEARCH

One of the past researchers, Taufiq Rokhman, states that a hardenability of a metal is one of the main conditions when choosing material of a machine. Hardness of a metal can be modified by using heat treatment. A hardenability is ability of a material to be harden until is reaches a specific depth using heat treatment. This process will change the mechanical properties of a material.

He also said that not all material can be hardens by using that process and to prove the statement is by doing the hardenability test. One of the hardenability test is the Jominy Test (Jominy Test) (Van Black, 1991). In Jominy test, the specimen will be heated in specific temperature and be cooled by using water which will cool the bottom end of the specimen first. This cooling process will be carried out until the specimen is cold entirely.

2.3 END QUENCH MACHINE

The development of Induction Furnaces starts as far back as Michael Faraday, who discovered the principle of electromagnetic induction. However it was not until the late 1870's when De Ferranti, in Europe began experiments on Induction furnaces. In 1890,Edward Allen Colby patented an induction furnace for melting metals. The first practical usage was in Gysinnge, Sweden,by Kjellin in 1900 and was similar to the Colby furnace with the primary closest to the core. The first steel made in an induction furnace in the United States was in 1907 in a Colby furnace near Philadelphia. The first induction furnace for three –phase application was built in Germany in 1906 by Rochling-Rodenhauser. Original designs were for single phase and even two phases were used on the three phase furnace.

The two basic designs of induction furnaces, the core type or channel furnace and the coreless, are certainly not new to the industry. The channel furnace is useful for small foundries with special requirements for large castings, especially if off-shift melting is practiced. It is widely used for duplexing operations and installations where production requirements demand a safe cushion of readily available molten metal. The coreless induction furnace is used when a quick melt of one alloy is desirable, or it is necessary to vary alloys frequently. The coreless furnace may be completely emptied and restarted easily, makes it perfect for one-shift operations. Induction furnaces have increased in capacity to where modern high-power-density induction furnaces are competing successfully with cupola melting. There are fewer chemical reactions to manage in induction furnaces than in cupola furnaces, making it easier to achieve melt composition. However, induction melting is more sensitive to quality of charge materials when compared to cupola or electric arc furnace, limiting the types of scrap that can be melted. The inherent induction stirring provides excellent metal homogeneity. Induction melting produces a fraction of the fumes that result from melting in an electric arc furnace (heavy metal fumes and particulate emissions) or cupola (wide range of undesirable gaseous and particulate emissions as a result of the less restrictive charge materials).

A new generation of industrial induction melting furnaces has been developed during the last 25 years. The development of flexible, constant power-tracking, medium-frequency induction power supplies has resulted in the widespread use of the batch melting methods in modern foundries. These power units incorporate heavyduty silicon-controlled rectifiers that are able to generate both the frequency and the amperage needed for batch melting and are able to achieve electrical efficiency levels exceeding 97%, a substantial improvement over the 85% efficiency typical of induction power supplies of the 1970s. The new designs allow maximum utilization of furnace power throughout the melting cycle with good control of stirring .Some of the largest commercial units are capable of melting at nearly 60 tons per hour and small furnaces with very high power densities of 700 to 1,000 kWh/ton can now melt a cold charge in 30 to 35 minutes.

2.4 FURNACE

The development of Induction Furnaces starts as far back as Michael Faraday, who discovered the principle of electromagnetic induction. However it was not until the late 1870's when De Ferranti, in Europe began experiments on Induction furnaces. In 1890,Edward Allen Colby patented an induction furnace for melting metals. The first practical usage was in Gysinnge, Sweden,by Kjellin in 1900 and was similar to the Colby furnace with the primary closest to the core. The first steel made in an induction furnace in the United States was in 1907 in a Colby furnace near Philadelphia. The first induction furnace for three –phase application was built in Germany in 1906 by Rochling-Rodenhauser. Original designs were for single phase and even two phases were used on the three phase furnace.

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2.5 CONCLUSION

At the end of this chapter, we are able to learn more about the hardenability of a material by doing research on the topic. We are also able to identify the weakness and the strength of the project when doing the literature review. Besides, we are able to learn how to find information by doing literature review. It helps us a lot in doing this project. Literature review can help us by reviewing the last researches by other researcher which provide us information about the End Quench Machine. They also inform us about how to do the test and which temperature is suitable for this test.

CHAPTER 3

METHODOLOGY

3.1 CHAPTER INTRODUCTION

This chapter explained about method or steps that will be used when doing this project. There are a few aspect that were bring forward such as the methodology and progress of the project including technique and ways to get the result from the experiment, suitable design, project and specification.

By referring to the literature review before, we are able to prepare some steps and suitable equipment that we need to make sure the building process is running smooth. We are also able to avoid possibility error that can occur during the process.

3.2 DESIGN REVIEW

Design review is a plan act that shows how the research been done (Sabitha, 2006). It also used as guide for researchers for collecting, analysing and getting result process for the research that had been done. Design review also becoming the model to help researchers to find about the changes on the research. Review is made by accessing the internet to find information about the End Quench test machine.

Design review is as shown in Figure 3.1

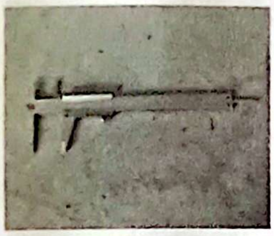
Review design is to identify the information that is needed to produce this experiment. For example, material use to build the machine.

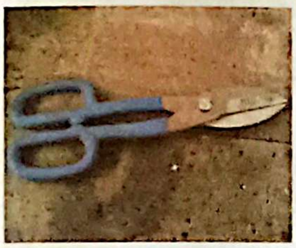
Figure 3.2 : End Quench Machine

Figure 3.3 : Design process of Fabrication of End Quench Machine.

3.4 PROJECT TOOLS

Table 3.1 : Tools needed to use while working.

Tools	Function
Measuring tape 	To measure work piece dimension.
Vernier Calliper 	To measure the inner and outer diameter of pipe.
Safety Google 	To protect eye when doing welding and cutting work.
Hand Grinder 	To grind and cut metal and pipe.
Spirit Level	To make sure the straightness of work piece.

	
Grinder Cutting Disk 	To cut metal and steel.
Metal Siccor 	To cut and shape aluminium plate.
Hand Drill 	To drill hole on work piece.

3.4FUNCTION ANALYSIS

Function analysis is important to make sure that our machine work as we planned. We can learn more about its function and could help us manage our machine better to avoid any error or mistake while operating the machine.

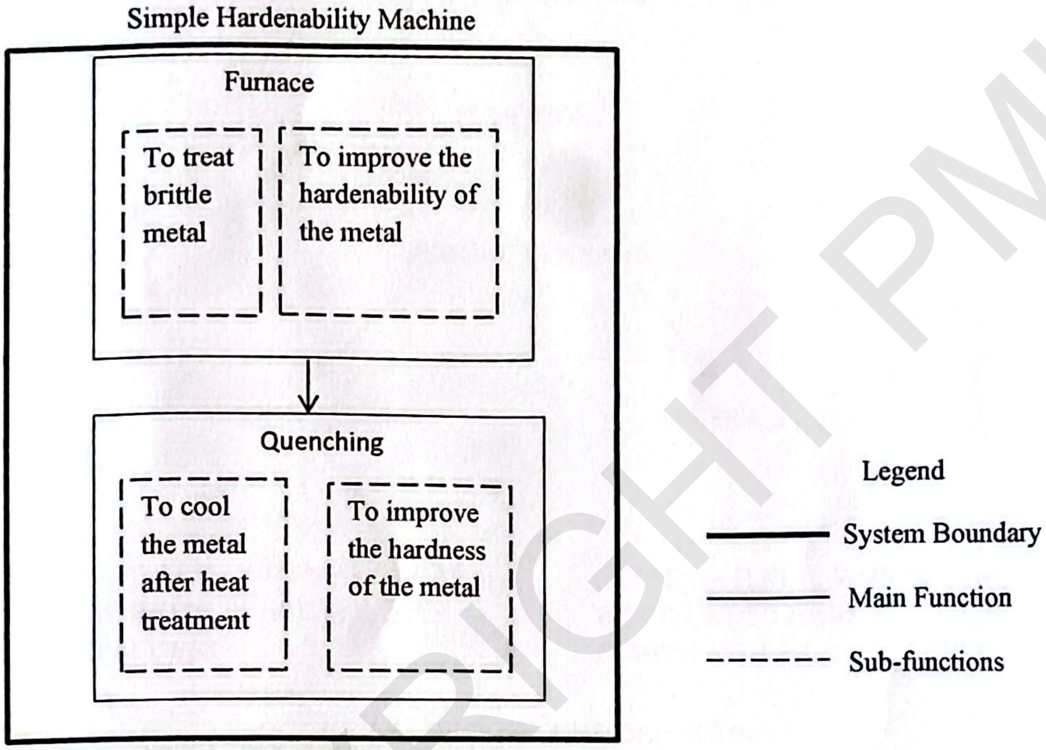


FIGURE 3.4 : FUNCTION ANALYSIS

3.5DESIGN CONSIDERATION

Design considerations are section where we started to come up with some designs which are suitable with our machine and our surrounding.

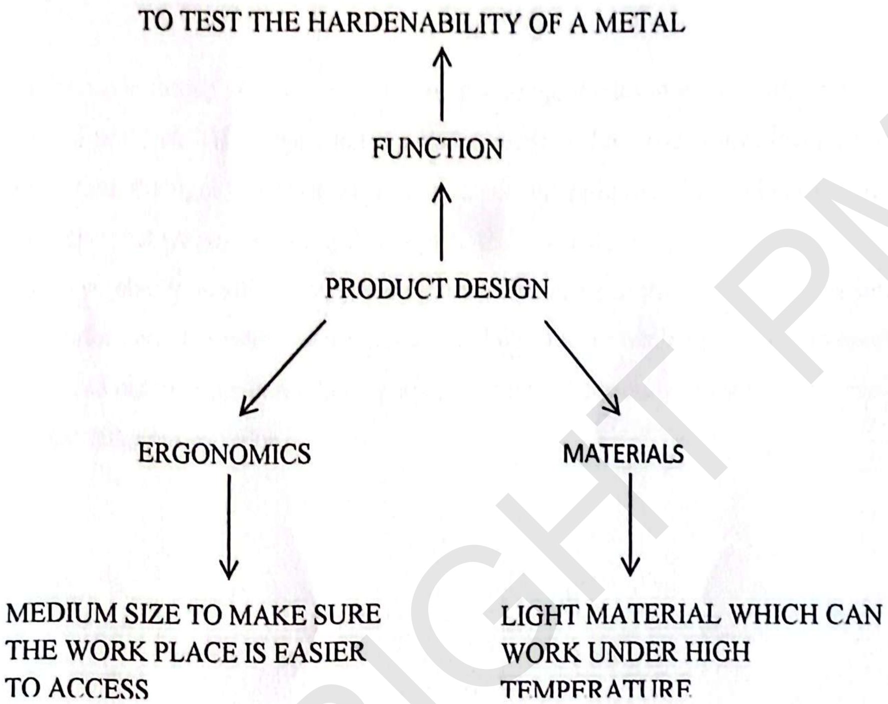


FIGURE 3.5 : DESIGN CONSIDERATION

3.6PRODUCT SPECIFICATION

TABLE 3.2 : PRODUCT SPECIFICATION

Metric	Value
Number of butanols tank needed	1 tank
Amount of wheels used	3 pairs
Number of person needed to operate	1 person
Amount of specimen that can be test per time	1 piece only

3.7 CONCLUSION

After going through this chapter, we are able to build our project smoothly with small amount of problem. This chapter helps us to know more about our project from the aspect of it function, the right way to operate the machine, the right tools to build our project, the suitable size that we can design, and way to collect our data.

We also able to identify the right design which can reach the needs of ergonomics in the laboratory and the safety of the lecturer and the student while operating the machine. the safe and ergonomics in the laboratory are important for our project to avoid accident when operating our machine.

CHAPTER 4

DATA ANALYSIS

4.1 CHAPTER INTRODUCTION

Hardenability is the capacity of a material to be hardened by heat treatment (quenching). Hardenability of steels can be measured using the end-quench test. The end-quench test testifies the incidence of the composition of the alloy and heat treatment procedures for manufacturing purposes. We will test the machine in the Metallurgy Laboratory in order for us to obtain the result from heating and cooling the specimen. After we go through both of the process, we will proceed the experiment by testing the hardness of the specimen using the Rockwell C Hardness test machine,

4.2 EXPERIMENT

Experiment need to carry out in order for us to study about the hardenability of a metal in the Metallurgy Laboratory. By doing this experiment, we can find out the difference in hardness at different position on the specimen.

4.2.1 EXPERIMENT PLAN

4140 steel was used and heated to 850°C, 900°C and 950°C. At 900°C and 950°C the heat times are as follows a half hour, two hours, and four hours. At 850°C two bars the heat times are a half hour, and four hours. Through the heating and quenching process the desired result is to see a change in hardness data but the expectation is to see higher Rockwell C numbers towards the quenched end of each jominy bar and lower values towards the other end. There should also be a difference of rate of chance of the hardness values in the bars heated to 850°C and the bars heated to 950°C. The austenitic grain size should be smaller for the 850°C bars and larger in the 950°C bars.

4.2.2 PROCEDURE

1. Prepare a specimen solid bar following the ASTM E112 standard.
2. Heat the furnace for 30 minutes.
3. Insert the specimen.
4. Close the furnace and let it heat for 1 hour.
5. After 1 hour, check the specimen and to see if it has turn red or orange in colour.
6. Once the specimen has turned red or orange in colour, remove the specimen from the furnace and transfer it into the End Quench Machine.
7. Open the water pipe until the water reach the distance needed.
8. Wait until the specimen is fully cool to room temperature.
9. After the specimen is fully cool, test the hardness of the specimen in the Rockwell Hardness Test Machine.
10. Obtain the result from the machine.

4.3 DATA AND ANALYSIS

TABLE 4.1 : DATA AND ANALYSIS

POSITION	SIDE 1	SIDE 2	AVERAGE
1.5875	58	58	57
7.9375	68	57	62.5
4.7625	52	52	52
6.35	54	52	53
7.9375	55	52	53.5
9.525	62	52	57
11.1125	68	52	60
12.7	63	52	57.5
14.2875	62	49	55.5
15.875	61	56	58.5
17.4625	57	56	56.5
19.05	54	55	54.5
20.6375	48	48	48
564.515	49	57	53

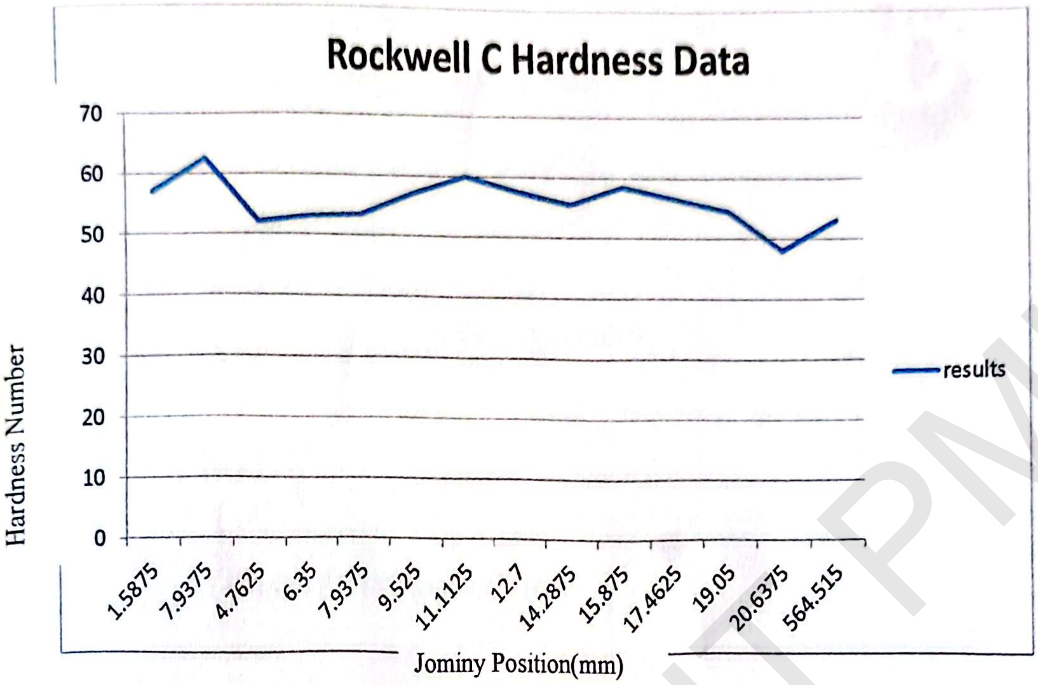


FIGURE 4.1 : ROCKWELL C HARDESS DATA GRAPH

4.4 CONCLUSION

At the end of the chapter, we are able to obtain the data that we needed to prove the hardenability of a material. Each point have different amount of hardness as we get from the test. It is because of the cooling rate when the specimen is cooled by using the water. What we can conclude here is, the faster the cooling rate, the harder the properties of the material.

CHAPTER 5

CONCLUSION

5.1 CHAPTER INTRODUCTION

In this chapter the conclusions derived from the findings of this study on the hardenability test machine are described. The conclusions are based from the purpose, research, designing, fabrication and data analysis of this study. The implications of these findings and recommendation will also be explained. Recommendations were based on the conclusions and purpose of the study.

5.2 DISCUSSION

Hardenability is a measure of the capacity of a steel to be hardened in depth when quenched from its austenitizing temperature. Hardenability of a steel should not be confused with the hardness of a steel. The Hardness of a steel refers to its ability to resist deformation when a load is applied, whereas hardenability refers to its ability to be hardened to a particular depth under a particular set of conditions. Information gained from this test is necessary in selecting the proper combination of alloy steel and heat treatment to minimize thermal stresses and distortion when manufacturing components of various sizes.

First, a sample specimen cylinder either 100mm in length and 25mm in diameter, or alternatively, 102mm by 25.4mm is obtained. Second, the steel sample is normalized to eliminate differences in microstructure due to previous forging, and then it is austenitised. This is usually at a temperature of 800 to 900°C. Next, the specimen is rapidly transferred to the test machine, where it is held vertically and sprayed with a controlled flow of water onto one end of the sample. This cools the specimen from one end, simulating the effect of quenching a larger steel component in water. Because the cooling rate decreases as one moves further from the quenched end, you can measure the effects of a wide range of cooling rates from vary rapid at the quenched end to air cooled at the far end.

Next, the specimen is ground flat along its length to a depth of .38mm (15 thousandths of an inch) to remove decarburized material. The hardness is measured at intervals along its length beginning at the quenched end. For alloyed steels an interval of 1.5mm is commonly used where as with carbon steels an interval of .75mm is typically employed. And finally the Rockwell or Vickers hardness values are plotted versus distance from the quenched end

The test data illustrates the effect of alloying and microstructure on the hardenability of steels. Commonly used elements that affect the hardenability of steel are carbon, boron, Chromium, Manganese, Molybdenum, Silicon, and Nickel.

Carbon is primarily a hardening agent in steel, although to a small degree it also increases hardenability by slowing the formation of pearlite and ferrite. But this affect is too small to be used as a control factor for hardenability.

Boron can be an effective alloy for improving hardenability at levels as low as .0005%. Boron is most effective in steels of 0.25% Carbon or less. Boron combines readily with both Nitrogen and Oxygen and in so doing its effect on hardenability is sacrificed. Therefore Boron must remain in solution in order to be affective. Aluminum and Titanium are commonly added as "gettering" agents to react with the Oxygen and Nitrogen in preference to the Boron.

Slowing the phase transformation of austenite to ferrite and pearlite increases the hardenability of steels. Chromium, Molybdenum, Manganese, Silicon, Nickel and Vanadium all effect the hardenability of steels in this manner. Chromium, Molybdenum and Manganese being used most often.

5.3 RECOMMENDATION

For heat treatment, hardenability is a very useful and important property of steel. It determines the rate at which the given steel should be quenched. This also tells about the maximum hardness that can be achieved on the surface of steel of larger cross section bars, subjected to drastic quenching. A steel of high hardenability will show a uniform, high hardness along the whole length of the bar. This is because the cooling rate, even at the far end of the bar, is greater than the CCR; and the whole bar transforms to martensite. A steel of medium hardenability gives quite different results. Steels with high hardenability are needed for large high strength components, such as large extruder screws for injection moulding of polymers, pistons for rock breakers, mine shaft supports, aircraft undercarriages. High hardenability allows slower quenches to be used (e.g. oil quench), which reduces the distortion and residual stress from thermal gradients. Steels with low hardenability may be used for smaller components, such as chisels and shears, or for surface hardened components such as gears. High hardness occurs where high volume fractions of martensite develop. Lower hardness indicates transformation to bainite or ferrite/pearlite microstructures.

5.4 CONCLUSION

In this study we have review the important of end quench machine in metallurgy and change in hardenability of different steels due to change in alloying elements in steels using the end quench machine. The data obtained from the test can be used to determine whether particular steel can be sufficiently hardened in different quenching media for the section diameter.

APPENDIX

Appendix 1 : Past Review

Figure 1 and 2 shows the past review on End Quench Machine.

Keywords aging, aluminum alloys, heat treatment, Jominy, quenching

1. Literature Review

In this section, a brief review of the available literature on the use of the Jominy end quench test will be described. The previous use of the Jominy end quench test for nonferrous alloys will be discussed, and the specific use of the Jominy end quench test for aluminum alloys will be shown.

2. Jominy End Quench

In the original classic work by Jominy and Boegehold,[1] they described a cylindrical specimen 100 mm long by 25 mm in diameter. The specimen was austenitized and then removed from the furnace and placed in a fixture, where the specimen was exposed at one end to a specified vertical stream of water. The resulting cooling is one dimensional and is invariant on the composition of the steel. But the resulting hardenability of the steel, as measured by hardness, is dependent on the composition and grain size of the steel. The simple design of the specimen, and the relative ease of the test procedure, has made this test the preferred method to measure the hardenability of steel. The popularity and repeatability of the test has resulted in the test procedure being adopted in ASTM,[2] SAE,[3] and other agencies' test methods. A schematic of the method is shown in Fig. 1.

Jominy[4] also described a test specimen with a slightly different configuration that was designed for shallow hardening steels. It provided for much faster cooling rates. This specimen was called the "type L specimen" and had a conical section removed from the quenched end to a depth of approximately 25 mm. The quenching conditions were changed slightly, requiring a free unimpeded water rise of 100 mm. Because of difficulties in machining and the sensitivity to small dimensional changes, this geometry was never adopted as a standard test method.

Hergat[5] described precautions that should be taken to achieve a 1 HRC precision when conducting the test. These improvements include making sure that the machined flats on the specimen are parallel and that the operator error induced during hardness testing is reduced by the use of semiautomatic hardness machines. It is also necessary to ensure that the specimen is in a fixture that ensures accurate positioning and firmly holds the specimen. It was found that the Vickers hardness test provided much better repeatability. Brown[6] also found that Vickers hardness measurements provided much better repeatability and allowed for more data to be taken because the indentations could be spaced much closer together, improving the signal-to-noise ratio. It was found that the precision of the test was also improved by the use of a calibrated positioning device that held the specimen firmly in place. One of the advantages cited for the use of Vickers hardness is that the measurements can be readily rechecked by measuring the diagonals again or by placing an additional indention alongside the disputed reading. He found that the repeatability of the standard Rockwell-type test was typically 2 HRC. Using a 15 kg load, he found that the variability of the hardness measured by Vickers was roughly half that of the Rockwell test. In his concluding comments, he indicated that accurately determined hardenability curves often show that the test introduces the scatter rather than does the steel.

The nature of the hardness distribution at specific distances in the Jominy end quench test was investigated by Sheikh.[7] Three different steels were examined, with the intent of understanding the scatter that occurs when testing. Probability plots were created from the hardness data on the three steels and interpreted. It was determined that the hardness scatter at each location on the Jominy end quench is normally distributed and therefore would be bounded by a 3-sigma around the mean. The expected probability distribution can be used to predict and establish upper and lower control limits for heat treatment.

Kura and Long[8,9] measured cooling rates as a function of austenitizing temperature, quenchant temperature, composition, and plate thickness. They described higher quench rates at the quenched end of the test bar than that of Jominy. This is probably due to the age of the instrumentation. Several cooling curves

J.W. Newkirk and D.S. MacKenzie, University of Missouri - Rolla, Rolla, MO 65409.

Figure 1

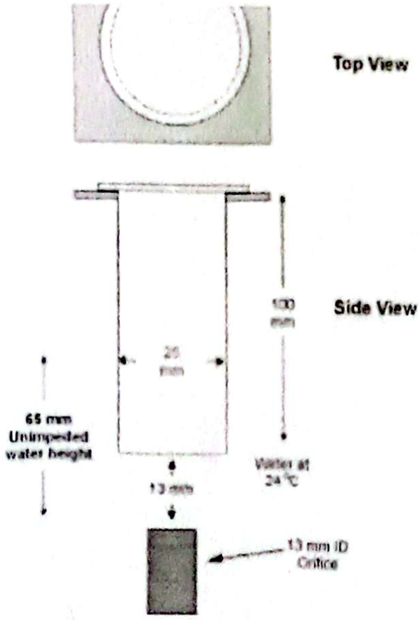


Fig. 1 Schematic of the Jominy end quench

are provided. Plates from 12.5 to 100 mm thick were examined. The severity of quench using Grossman quench factors was estimated for water and oil and correlated to plate thickness for the Jominy end quench test conditions. It was determined that the hardness within the cross section of a plate closely approximates that measured by the Jominy end quench test at equivalent cooling rates. This is applicable regardless of the quenchant or thickness of the plate, since it is a function of cooling rate.

3. Jominy End Quench of Nonferrous Alloys

There has been some published work on the use of the Jominy end quench test for nonferrous alloys. Toda[10] measured the critical cooling rates for Cu-Cr, Cu-Be, and Cu-Co$_2$Si using the Jominy end quench method. The cooling rates of these tests were determined using a pen-recording oscilloscope. It was determined that the critical cooling rate for the alloys investigated was the cooling rate that caused a decrease in properties. It was defined as the cooling rate necessary to obtain a supersaturated solid solution at room temperature. Both as-quenched and aged hardnesses were taken. In a study sponsored by Rolls rate for specific applications. He showed schematically how the microstructure of various titanium alloys varied as a function of cooling rate.

4. Jominy End Quench—Aluminum Alloys

There has been limited published work on the use of the Jominy end quench test for aluminum alloys. Loring *et al.*[12] authored the first published paper on the use of the Jominy end quench test for studying aluminum alloys using a modified L-type Jominy specimen. The cooling curves at various distances up to 25 mm were measured. Different types of aluminum (14S, 24S, 61S, R-301, and 75S) were tested. Hardnesses were measured at 3 mm intervals using the Rockwell B, F, and Vickers (5 kg) scales. Further, it was seen that higher quench rates yielded decreasing hardness in the as-quenched condition. Low cooling rates produced relatively small changes in the hardness. Only 75ST exhibited a sensitivity to quench rate after aging.

In the work by 'tHart *et al.*,[13] the Jominy end quench test was applied to extruded rods of 2024 and 7075. The bars were aged to the 2024-T4, 2024-T6, and 7075-T73 conditions. The Jominy bars were evaluated by transmission electron microscopy (TEM) and corrosion testing to examine the relationship between quench rate, corrosion properties, and microstructure. The cooling rate of Jominy specimens fabricated from 2024 and 7075 were measured. Vickers hardnesses were taken at 5 mm intervals. It was found that 7075 was strongly quench sensitive and that hardness increases were only found in the first 60 mm of the bar. It was found that the quench rate and tempering operation influenced the widths of the precipitate free zone (PFZ). With only two data points, it was shown that faster cooling rates made for thinner PFZ.

The authors also evaluated 7010 and P/M 7091 aluminum alloys heat treated to the T6 and T73 tempers.[14] Corrosion properties and microstructure were determined as a function of cooling rate. It was found that 7010 was quite quench-insensitive compared to 7075. It was found that the alloys were insensitive to SCC and EXCO. No effect related to quench rate was found. It was also observed that the PFZs in 7091 and 7075 were more dependent on quench rate than that of 7010.

Using an apparatus similar to a Jominy end quench, Hecker[15] evaluated aging cycles as a function of time for an Al-Mg-Si alloy. It was shown that silicon has a marked effect on the age hardening of Al-Zn-Mg-Cu aluminum alloys.

Alternative methods of end quenching, similar in principal to the Jominy end quench, have been tried. Bomas[16] determined the time-temperature-property diagram of an Al-Zn-Mg alloy. This was accomplished using a rectangular specimen 15 × 140 × 300 mm, with the 15 × 140 mm face of the specimen exposed to the quenchant stream. This enables the specimen to be exposed to one-dimensional heat transfer, in the same fashion as the Jominy end quench test. Tensile specimens were laid out perpendicular to the axis of the quench medium and enabled to be taken as a function of cooling rate during quench. Arthur *et al.*,[17] used an apparatus similar to Bomas to develop

Figure 2

Appendix 2 : Furnace building process

Figure 1

Figure 2

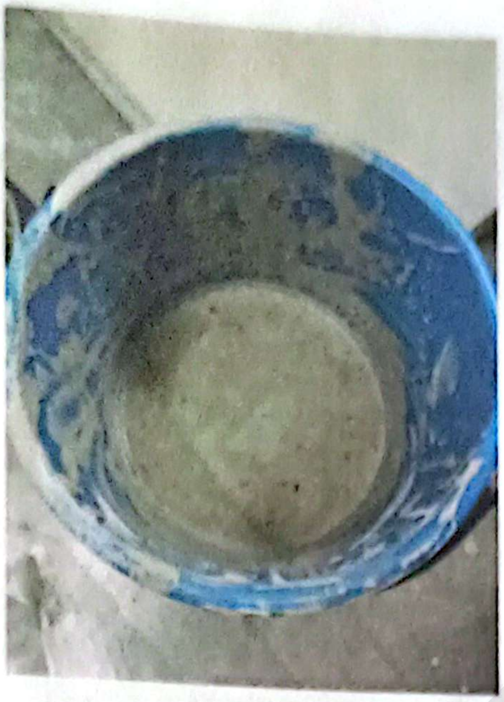


Figure 3

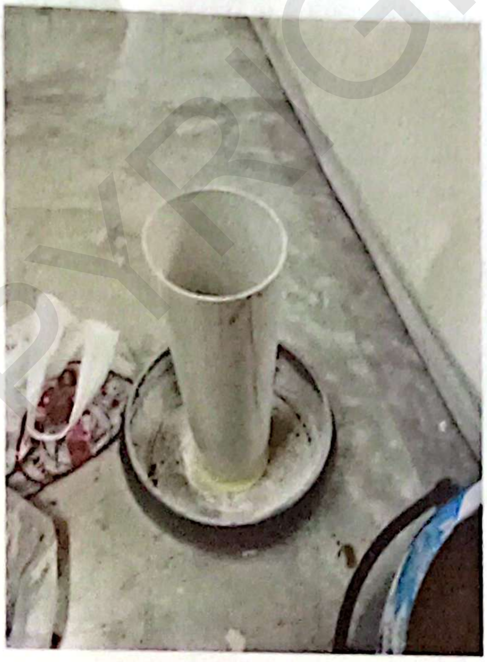


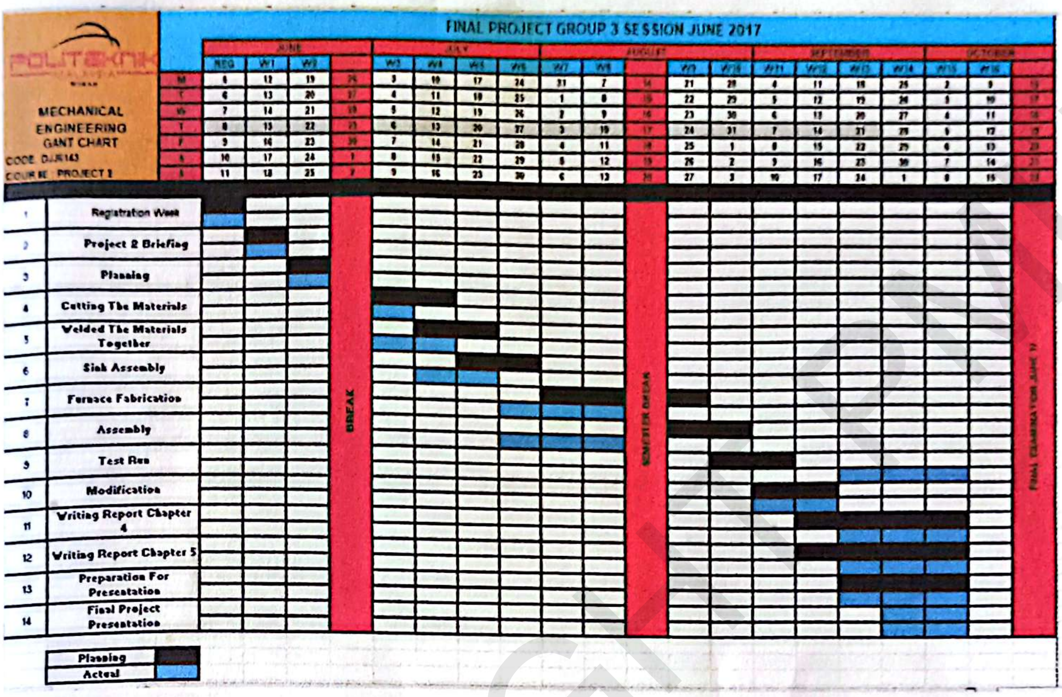
Figure 4

Figure 5

Appendix 3 : Final design of product.

Figure 1 shows final design of product.

Appendix 4 : Gantt Chart



REFERENCES

J.W. Newkirk and D.S. MacKenzie (Submitted 2 December 1999; in revised form 22 March 2000)

Andrew Ruble Department of Materials Science & Engineering University of Washington Seattle, WA 98195

Jominy End Quenching of 4140 Steel:The Effect of Time and Temperature on Austenitic Grain Growth by WORCESTER POLYTECHNIC INSTITUTE

Bhaskar Chandra Kandpal, Agnay Chutani, Amit Gulia, Harsimran, Chandan Sadanna Department of Mechanical Engineering, ITM University, Gurgaon, India.

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