

Syahid_2020_IOP_Conf._Ser._
Mater._Sci._Eng._875_012064.p
df
by

FILE	SYAHID_2020_IOP_CONF._SER._MATER._SCI._ENG._875_012064.PDF (964.07K)		
TIME SUBMITTED	09-AUG-2020 02:29PM (UTC+0700)	WORD COUNT	3182
SUBMISSION ID	1367496004	CHARACTER COUNT	16415

PAPER • OPEN ACCESS

Fatigue Strength Improvement of Low Carbon Steel through Carburizing Process with Coconut Shell Charcoal

³
To cite this article: M Syahid *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **875** 012064

View the [article online](#) for updates and enhancements.

Fatigue Strength Improvement of Low Carbon Steel through Carburizing Process with Coconut Shell Charcoal

M Syahid^{1*}, A Hayat¹, S Arief¹, and Rudi¹

¹Department of Mechanical Engineering, Engineering Faculty, Hasanuddin University, Makassar Indonesia

*Email: syahid@unhas.ac.id

Abstract. The fatigue strength of low carbon steel is a limitation that is often considered in machine construction, especially in rotating component parts. Low carbon steel has special properties that are soft, good welding and good machining, as well as relatively inexpensive prices but have low fatigue strength. For this reason, in this study, a carburizing process was carried out with the media of coconut shell charcoal as a source of carbon and shell powder as a catalyst. The addition of carbon using the carburizing method is relatively easy and does not require a large cost because the materials used are abundant in nature. The carburization process was carried out at 950°C for 4 hours. Furthermore, mechanical properties were tested with hardness, tensile testing and fatigue testing. The carburization process with charcoal media is expected to increase hardness, tensile strength and fatigue strength. Fatigue testing is carried out by the reverse bending method with a load varying 70%, 60%, 50% and 45% of the tensile strength of the material. In addition, microstructure examination and fault surface observation are also carried out to analyze the phenomenon of changes in material structure due to carburization. The hardness value of ST37 steel before carburizing is 118 HRB increased to 127 HRB after undergoing carburizing treatment. Tensile test results also experienced an increase in which the initial tensile strength value of ST37 steel by 356.66 MPa increased to 541.15 MPa after the carburizing process. Likewise in fatigue testing, the fatigue limit has increased significantly, where the ST37 steel fatigue limit before the carburizing process is at a stress level of 161 MPa. After experiencing the carburizing process the ST37 steel fatigue limits are at a stress level of 232 MPa.

1. Introduction

Steel is always a top priority in the selection of materials of construction machines because it has good mechanical properties. The hard and ductile nature of steel is a factor that is always taken into consideration in planning machine construction, especially in rotating component parts. For example, steel is often used in cutting tools, chisels, gears or construction machinery. The nature of steel is generally influenced by the content of carbon, other alloying elements and microstructure [1, 2]. The difference in carbon content in steel is one way to classify steel. Based on its carbon content, steel is divided into three types namely high carbon steel, medium carbon steel and low carbon steel. Low carbon steel has special properties that are soft, good welding and good machinery, as well as relatively inexpensive prices but has low fatigue strength [3].

Fatigue failure is a form of failure that occurs in the structure of the material due to dynamic loads that fluctuate below yield strength that occurs in a long time and repeatedly [3, 4]. One example of a form of material failure is a fracture. Generally, the fracture begins with a stress concentration on the crack on the surface of the material. Because the load is fluctuating, the cracks propagate when breakage occurs. Based on the fracture mechanism, the surface condition on the specimen is one of the



factors causing the fatigue strength of the material [5-7]. The surface condition in question is the surface hardness of the material, where the higher the hardness of a surface, the possibility of cracks or defects will decrease. Surface hardness can be increased by carburizing and heat treatment [8].

In high carbon steel and medium carbon steel, the surface hardness can be increased by heat treatment. Whereas in low carbon steel, the hardness of the surface cannot be increased by heat treatment it is because of the low carbon content. The way to increase surface hardness in low carbon steel is by carburizing. Carburizing is a process of adding carbon elements to the surface of steel by diffusion to improve its physical and mechanical properties [8].

The carburizing process is relatively easy and inexpensive because the materials used in the carburizing process are available abundantly in nature. Natural materials that are often used as carburizing media are wood charcoal, coconut shell charcoal, used battery charcoal, mangrove tree charcoal and rice husk charcoal. In this study, we use coconut shell charcoal as an active carbon element and shells (calcium carbonate) as a catalyst. Based on this, the researcher wanted to analyze how "Increasing the Strength of Static Steel 37 through the carburization process with coconut shell charcoal media.

2. Research Method

The material used in this study is ST37 steel in the form of rods. The material is cut to become a tensile test specimen in accordance with ASTM E-8 standard and a fatigue test specimen according to ASTM E-466 standard. Then the specimen is carburized using coconut shell and shell media as a catalyst. The carburizing treatment is carried out by inserting the specimen into the carburizing box then inserting the coconut shell charcoal powder mixed with shell powder (10% of the total weight of the coconut shell charcoal powder) until it covers the entire surface of the specimen and then closes the carburizing box again with the lid. After that the carburizing box is put into a heating furnace at a temperature of 950°C held for 4 hours then the specimen is quenched in seawater media at room temperature. Furnace and carburization boxes can be seen in Figure 1. Furthermore, hardness testing, tensile testing and fatigue testing are performed (Figure 2). Also examined the microstructure and fracture surface using an optical microscope



Figure 1. a) Furnace b) Pack carburizing

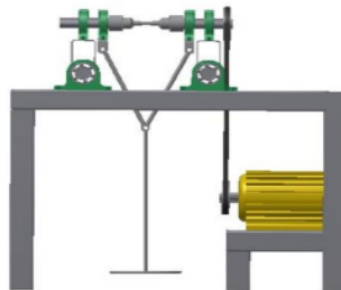


Figure 2. Three Point Bending reverse fatigue machine

3. Result and Discussion

3.1. Effect Carburizing on Hardness Value

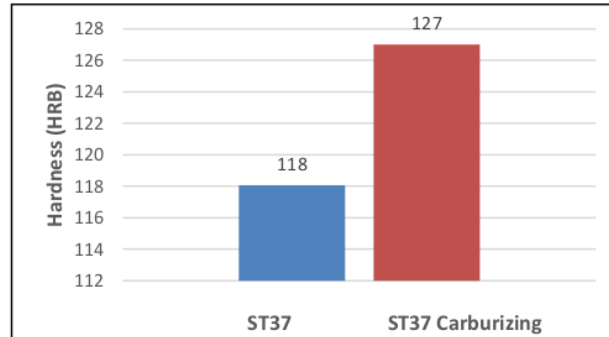


Figure 3. Effect of carburizing on hardness of low carbon steel ST37

Figure 3 shows the value of ST37 hardness before and after the carburizing process. It can be seen that the value of ST37 hardness increases after a carburizing process. This is due to the diffusion of carbon which causes the addition of carbon atoms in the material from the outer side to the inside and continues when the carburizing process is carried out with a temperature of 950°C. It is clear that the hardness of the material is very dependent on the amount of carbon which means more and more carbon content in a material, the harder the material is [2]. In addition, the cooling process also affects the hardness of the ST37 material where a rapid cooling process is carried out in order to obtain a martensitic structure. Seawater is a very fast and evenly distributed cooling medium because seawater contains salinity. The salt will settle around the specimen and tend to prevent/shorten the formation of the vapor layer. This formed precipitate causes the coolant to come into direct contact with the surface of the specimen so that the cooling rate becomes very effective and quickly absorbs heat in high-temperature regions. The effective definition here is that carbon steel is cooled at a rate of cooling that can prevent a softer structure or get a hard, even structure throughout the surface. Thus the effective cooling rate of seawater is at a slower cooling rate in the temperature range of martensitic formation in ST37 material and evenly distributed across the surface. The initial hardness of the ST37 material before the pack carburizing process was an average of 118 HRB and after experiencing the carburizing pack process using coconut shell charcoal media at a temperature of 950°C for 4 hours using seawater as a quenching medium, the hardness value increased to 127 HRB.

3.2. Microstructure Examination

Figure 4 is a photo of the ST37 microstructure before and after the carburizing process. The figure shows that there is a difference in color, which is the color of Figure 4 (b) has a darker color than the color of Figure 4 (a). This is due to the presence of carbon atoms which diffuse into iron at austenite temperature (carburizing temperature). Diffusion of carbon atoms results in the formation of cementite consisting of three (3) Fe atoms binding one (1) atom C. This bond forms new cementite, the growth of cementite mixed with ferrite into pearlite crystals. Rapid cooling of specimens results from the formation of the martensitic phase. The more carbon elements, then the martensitic structure that is formed will also be more and more [2]. This is because the atoms which are separated from the bonds do not have time to be distributed into the bonds to bind the atoms making up the metal and the atoms that are enlarged not to have time to shrink. So here there is a very fast recrystallization process. With a structure like this, it causes a bond that is not strong between atoms with other atoms so that the nature is brittle and hard because the granules are enlarged to fill the material space.

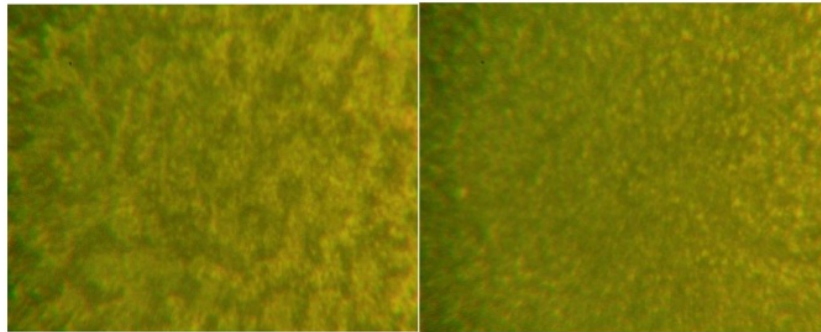


Figure 4. The photographic microstructure of low carbon steel ST37 : (a) Before carburizing; (b) After carburizing

3.3. Effect of Carburization on the Results of the Tensile Test

Figure 4 is a graph of the tensile strength values before and after the pack carburizing process. The results show that the tensile strength value of ST37 material has increased after the carburizing pack process. This is due to an increase in the value of the ST37 hardness after undergoing a carburizing process. The hardness of a material is directly proportional to the tensile strength because the understanding of violence and tensile strength are the same. Equally means material resistance to plastic deformation. It's just that violence is material resistance to plastic deformation locally (surface) while tensile strength is material resistance to plastic deformation that occurs throughout the surface of the material. So that if a part of the material is resistant to plastic deformation, then automatically all parts of the material will be resistant to plastic deformation. The harder material is the higher tensile strength. The average tensile strength value of ST37 is 356.66 N/mm² and after undergoing a carburizing process the tensile strength value becomes 541.15 N/mm². As a study conducted by Zuchry et al with the results that ST37 which undergoes a pack carburizing process at temperatures of 900°C and 950°C for 3 hours, 6 hours and 9 hours has increased the value of tensile strength. However, in general, an increase in the tensile strength of material causes strain to decrease [1].

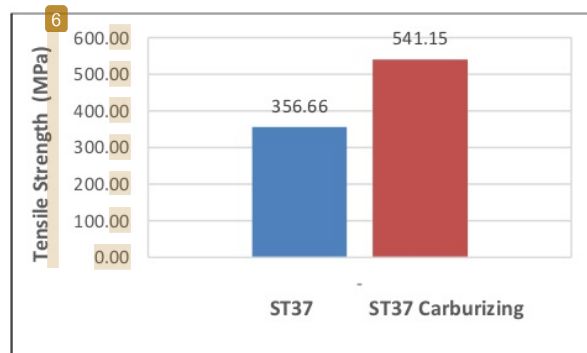


Figure 5. Effect of Carburizing towards low carbon steel ST37 tensile strength

Figure 5 is a ST37 stress-strain chart before and after the carburizing pack process. The results show that tensile stress is inversely proportional to strain. This is because the increased hardness value causes the material to become more brittle after the carburizing process due to the formed martensitic phase.

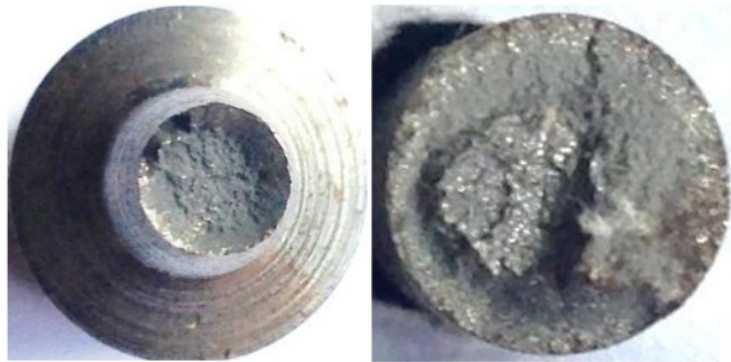


Figure 6. Macro photograph of surface fracture of tensile test specimen ST 37
(a) Without carburizing, (b) Carburizing

Figure 6 is a macro photograph of the fracture surface of the ST37 tensile test material before and after undergoing the carburizing pack process. On the fracture surface of the tensile test specimen (static load), there are two types of fractures namely brittle fracture and ductile fracture. In Figure 6 (a) it is a brittle fracture where the brittle fracture has a characteristic on the fracture that there are no cups and cones. In brittle fracture, necking does not occur so that the specimen is broken immediately if it is given a load above it. In addition, the fracture forms an angle of 90° to the normal axis of the specimen. In Figure 6 (b) it is a ductile fracture, in a ductile fracture there are cups and cones caused by shear stress. The fracture angle forms an angle of 45° to the normal axis of the specimen. Where the tensile load that works raises the maximum stress. If the stress applied to the specimen exceeds the limit, the movement of this dislocation will reach the surface. Dislocation movement until it reaches the surface is called plastic deformation. This plastic deformation which causes length increase in the specimen is fixed. If the amount of stress applied to the specimen reaches the Ultimate point, then the specimen begins to experience local wasting in the middle called the necking [9].

3.4. Effect of Carburization on Fatigue Strength

Figure 7 is a graph of stress vs. the ST37 cycle before and after undergoing the carburizing process. The graph shows that ST37's fatigue strength increases after undergoing a carburizing pack process. ST37 material fatigue strength before the carburizing pack process is at 161 MPa (45% of the ultimate tensile strength). While the fatigue strength of the ST37 material after undergoing the carburizing process is at 232 MPa (65% of the ultimate tensile strength). This is due to differences in the level of violence in the two test samples. As research conducted by [8] with the result that fatigue strength increased after carbon steel AISI 1020 hardened by the carburizing process followed by quenching [8].

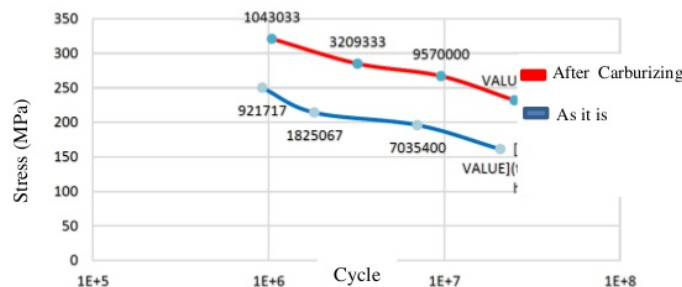


Figure 7. S-N Curve of material ST37 as it is and after carburizing

The higher tensile is fatigue strength. It is because tensile strength and fatigue strength are material resistance to deformation that occurs on the entire surface due to loading. It's just that the loading on the tensile test is a static load while the loading on the fatigue test is a dynamic load. Dynamic loading causes a failure at a voltage much lower than the voltage needed to cause failure at static loading. This is because the fatigue limit stress is half of the ultimate tensile strength value for metals containing ferrous [3].

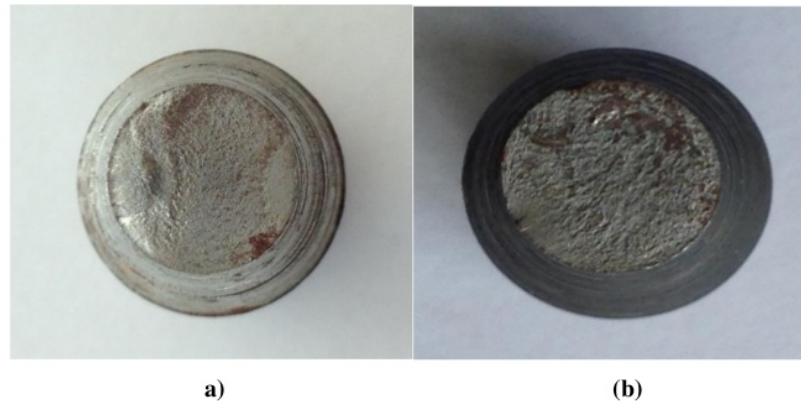


Figure 8. Macro photograph of surface fracture specimen fatigue test of ST37, (a) Without carburizing (b) With carburizing

Figure 8 is a macro photograph of the surface fracture of the ST37 fatigue material test before and after undergoing the carburizing pack process. In this picture, we can clearly see that the initial crack (initiation crack) occurs at the edge which then continues to propagate (propagation crack) due to continuous loading resulting in fracture (static fracture) because the material is no longer able to accept the load. The area between the crack propagation stage and fracture failure quantitatively can show the amount of stress that works. If the area of the propagation crack stage is greater than the area of the fracture failure, It indicates the working stress is low.

4. Conclusion

Based on the results of research and discussion about the effect of the pack carburizing process on the strength of fatigue of ST37 several conclusions can be drawn as follows: 1). The process of pack carburizing material ST37 at a temperature of 950°C for 4 hours, using seawater as a quenching medium can increase surface hardness by 7.6%. The initial hardness of the ST37 material was 118 HRB and increased to 127 HRB after undergoing a carburizing process. 2). The tensile strength is straight-line with hardness, the initial tensile strength of ST37 material is 356.66 N/mm² with a strain value of 8.33% increasing to 541.15 N/mm² with a strain value of 4.17%. 3). The fatigue test also shows an increase in fatigue strength where ST37's fatigue strength is at a stress of 161 MPa (45% of the value of ultimate tensile strength) increased to 232 MPa (65% of the value of ultimate tensile strength).

Acknowledgment

The authors would like to thanks to LBE Project of Engineering Faculty of Hasanuddin University as the funding sponsor for the research.

References

- [1] Zuchry, M. 2011. Effect of Temperature Carburizing and Hold Time on the Tensile Strength of Carbon Steel with Variations Media Cooling.
- [2] Wattimena, W.M.E., Louhenapessy, Jandri. 2014. The Effect of Holding Time and Quenching on the Hardness of Carbon Steel ST 37 in the Carburizing Pack Process Using Nutmeg Shell (*Myristica fragrans*).
- [3] Akuan, Abrianto. 2007. Metal Fatigue. Universitas Jenderal Achmad Yani, Bandung.
- [4] Collins, J.A., 1981, Failure of Material in Mechanical Design, Analysis Prediction and Prevention, John Willey & Son, Inc US.
- [5] Haftirman, "Fatigue Strength of Steel in High Humidity Environment", Transaction of the Japan Society of Mechanical Engineers, Japan, 1995.
- [6] Hisashi Ogawa, An Analysis on the Growth of a Surface Fatigue Crack under Rotary Bending in terms of Fracture Mechanics.
- [7] Iwamoto, K. 1989., On the S-N Curve of Carbon Steel Under Rotary Bending Condition in City Water. Transaction of the Japan Society of Mechanical Engineers, Japan.
- [8] Sriyanto, Nanang Budi. 2014. Effect of Carburizing Pack Process with Coconut-Barium Carbonate Shell Charcoal on AISI 1020 Steel Fatigue Failure.
- [9] Fadllu, Alaya H.M, 2007, The Influence of Metric Thread Notch Depth on Low Carbon Steel Tired Strength, Universitas Negeri Semarang, Semarang.

ORIGINALITY REPORT

%**9**

SIMILARITY INDEX

%**6**

INTERNET SOURCES

%**1**

PUBLICATIONS

%**9**

STUDENT PAPERS

PRIMARY SOURCES

1

iopscience.iop.org

Internet Source

%**2**

2

shura.shu.ac.uk

Internet Source

%**2**

3

dk.upce.cz

Internet Source

%**1**

4

Submitted to Queen's University of Belfast

Student Paper

%**1**

5

Submitted to CSU, San Jose State University

Student Paper

<%**1**

6

Submitted to Universiti Malaysia Pahang

Student Paper

<%**1**

7

Submitted to University of Houston System

Student Paper

<%**1**

8

Submitted to Universiti Putra Malaysia

Student Paper

<%**1**

9

Submitted to Bournemouth University

Student Paper

<%**1**

10

pertambangan.fst.uinjkt.ac.id

Internet Source

<% 1

11

Gupta, A.. "Performance Evaluation of Different Types of Steel for Duck Foot Sweep Application", Biosystems Engineering, 200405

Publication

<% 1

12

Submitted to University of Portsmouth

Student Paper

<% 1

13

Submitted to University of South Australia

Student Paper

<% 1

14

Gennaro Magliulo, Giuseppe Maddaloni, Edoardo Cosenza. "Comparison between non-linear dynamic analysis performed according to EC8 and elastic and non-linear static analyses", Engineering Structures, 2007

Publication

<% 1

EXCLUDE QUOTES ON

EXCLUDE BIBLIOGRAPHY ON

EXCLUDE MATCHES

< 5 WORDS