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Research paper

Fatique behavior of steel carbonizing on high humidity environment

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Abstract

Carbonizing is an attempt to improve the mechanical properties of steel carbon is added from the outside by placing the steel in a box, then the carbon is sown by heating above the critical temperature. Because of the heating process, the bonds of the steel atoms will stretch to each other, in the presence of the pressure of barium carbonate, the carbon diffuses into the steel through the distance between the atoms of the steel atoms, and then heated through the environment air, so that the structure of the microstructure consists of a ferrite layer and pearlite with a thicker carbon content on the outer shell. The diffusing carbon increases as the warming temperature is carried out, using a rotating bending fatigue type machine at 887.5 rpm, the steel is tested fatally until it is broken. The fatigue conditions were performed with the S-N curve. The exper-iments were carried out on krupp 1191 heated steels at 8000C, 9000C and 10000C, respective-ly, and then performed a fa-tigue test on RH70%, RH80% and RH90% environments. After the observation that the thicker the carbon layer formed the higher the fatigue strength. However, in a high humidity environment the fatigue strength decreases as the moisture of the test environment increases.

Keywords: *Fatique Strength; Humidity; Carbon Thickness; Carbonization Temperature.*

1. Introduction

The chemical composition, hardness, tensile and microstructure types are mechanical properties[1]–[3] that are always the basic requirements in selecting the steel used for machine components. However, in addition to the type of load and the environment where the steel is operating is something that should be of concern to the designer in designing these components. Engine components will fail if they can be caused by static loads or dynamic loads.

In the design to prevent failure due to fracture should be done in the design phase by using tired criteria [4]–[7]. The first fatigue fracture was found initially in the axle of the locomotive which was initially overcome by enlarging the axle diameter, however after repeated attempts, it also broke[8]. After analyzed by various method hence can be taken conclusion of broken failure which happened is a tired fracture, that mean broken that happened after operated in certain period of time.

Steel is used in various fields of engineering in construction industries, transportation equipment, and machine tools [9]–[11]. The use of such steels is generally reviewed based on the mechanical properties required during the forming process and the properties associated with environmental influences. Viewed from the operating environment, the steel has low resistance to corrosive environments, wear and ultimately fails faster than its optimum lifespan, requiring special treatment to reduce environmental impact, wear and tear. The way it is done, among others, is the addition of Carbon, Manganese, Silicon and others which tend to reduce the rate of environmental corrosion, resistance to wear and also resistant to fatigue treatment.

Hashem and Aly[12] examined the fatigue behavior of carbonized carbon low carbonized with titanium alloy. The coating is carried out by titanium diffusion by powder coating technique on carbon steel surfaces. The specimen is inserted into a tube containing a mixture of ferrotitanium powder, Aluminum oxide powder (Al_2O_3) and Ammonium chloride (NH_4Cl). Furthermore, the results of this coating performed a fatigue test with varying stress levels at 1420 rpm rotation. By obtaining the fracture cycle of the coated specimen (N) and the un-carbonized specimen fracture cycle (N), with varying coating process time produced different coating properties. All types of layers are reduced in fatigue life when compared with uncarbonized specimens.

Ferreira, 1996 [13] examined the corrosive fatigue behavior of carbonized carbonized carbon with chromiumnitrid (CrN). The cylindrical-shaped specimens are carbonized with CrN. The carbonized specimens were subjected to corrosion fatigue testing with cantilever rotary bending test in a 3% saline solution environment. From the test results it is concluded that the increase in corrosion strength depends on the thickness of the chromium nitride (CrN) layer. The TiN layer on carbon steel increases fatigue life and increases resistance to corrosive environments[14]. Increased fatigue life occurs in carbonized specimens.

2. Methods

The material used as a specimen in this research is Steel Krupp 1191, a steel machinery from Germany used for piston, crankshaft, pump shaft, gears, pins and so on. The composition of the chemical elements of the specimens used consisted as in table 1. The specimen size was prepared according to ASTM E-466 [15], for the specimen size fatigue test in Figure 1. The properties of the specimens after undergoing carbonization at 8000C, 9000C and 10000C as Table 2.

Equipment used for fatigue testing is a rotating bending fatigue type machine. The specimen is placed on the end of the shaft which is fastened to the binding chuck, by rotating the chuck, the specimen will be strongly bonded. The specimen is also located in a moisturizing box so that the humidity of the air will be arranged in such a way with the moisture controller. While dial gauge is used to check the centeric or not the specimen, after the centric specimen then the machine is turned on, and at the same time the weight is given or hung on the end of the specimen in accordance with the load that has been calculated theoretically before. To calculate the loading cycle experienced by the specimen to the fracture of the test machine is equipped with counter time.

Table 1: Chemical Composition of Krupp Steel 1191

Number	1	2	3	4	5	6	7	8
Chemical elements	C	Si	Mn	Cr	Mo	Ni	V	W
%	0.43	0,20	0,80	-	-	-	-	

Table 2: Characteristic of 1191steel Krupp

Carbonization Temperature	TKar	8000C	9000C	10000C
Carbon thickness	-	0,60	1,20	2,00
Hardness (HRc)	15,50	14,70	27,00	34,80
Tensile strength	58,20	39,66	46,31	49,97

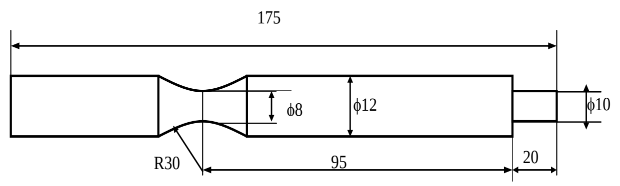

Fig. 1: Size of Speciment (ASTM E-466)

The rotation is derived from a coupled electromotor using a pulley and connected with a belt to the shaft in which the test specimen is mounted. The machine will automatically shut off when the specimen is disconnected because it is connected with the switch off.

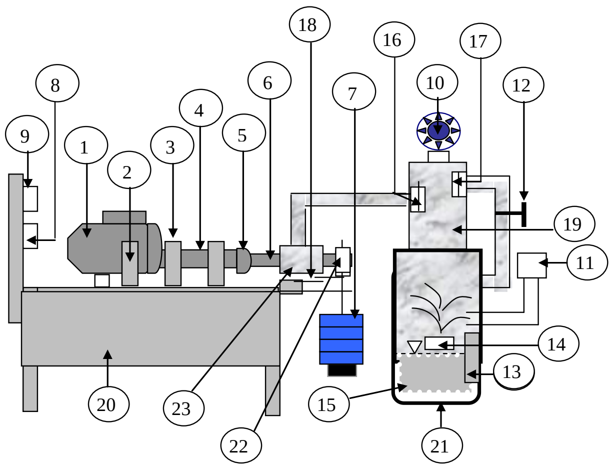

Fig. 2: Fatique Machine Type Rotating Bending.

Description:

1. Electromotor	13. Water Pump
2. Bearing	14. Water spry
3. Pulley	15. Water zinc
4. Shaf	16. Water Steam Blower
5. Nut Specimen Binder	17. Waterproof Steam Blower
6. Specimen	18. Switch off
7. Material loaded	19. Water Vapor Tubes
8. Time Counter	20. Machine Frame
9. Switch Automatic	21. Air Maker Damp
10. Hygrometer	22. Holding Load
11. Water Filling	23. Moisturizing Room

12. Valve Regulator

Other auxiliary test equipment used is a Universal Testing Machine test tool for obtaining tensile strength, yield strength, and elongation specimens, a Rockwell Hardness Tester machine for knowing the hardness of carbonized specimens, whereas carbonized specimens are used by the Brinnel Harness Tester. Against the broken specimen, observation of surface cracking of the specimen by SEM and simultaneously observing the effect of moisture treatment. Research on Krupp 1191 carbon steel was performed on the Rotating Bending Type Fat Drainage Machine (Figure 2) with 887.5 rpm rotation. By preparing 3(three) conditions of carbonization treatment process that is at temperature 8000C, 9000C and 10000C and 3 (three) environmental treatment process that is at humidity RH70%, RH 80% and RH 90%. The test is performed on at least 6 (six) specimens to obtain a test curve line that gives an image of the fatigue strength of the S-N curve.

3. Results and discussion

The result of Baja Krupp 1191 study in high humidity environment can be seen in the relation of S-N curve of figure 3, 4 and 5 below. From this curve can be observed the fatty strength of steel without carbonization (TKar) with the carbonized at 800^{0}C, 900^{0}C and 1000^{0}C and tested fatigue on RH70%, RH80% and RH 90%.

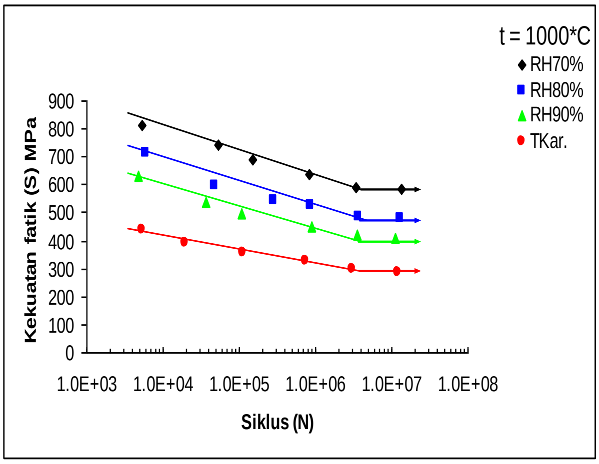

Fig. 3: Relationship of Fatique Strength vs. Cycle Carbonized Steel at Temperature 1000^{0}C.

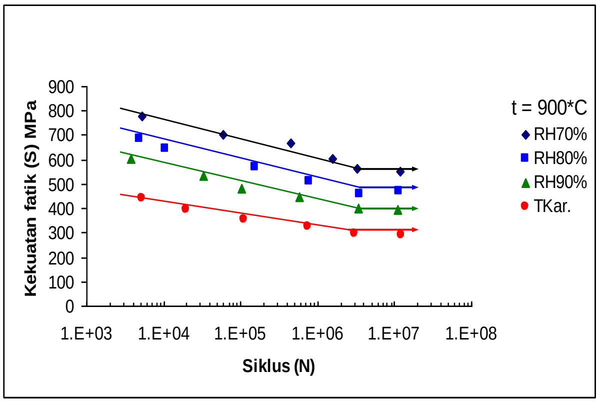

Fig. 4: Relationship of Fatique Strength vs. Cycle Carbonized Steel at Temperature 900^{0}C.

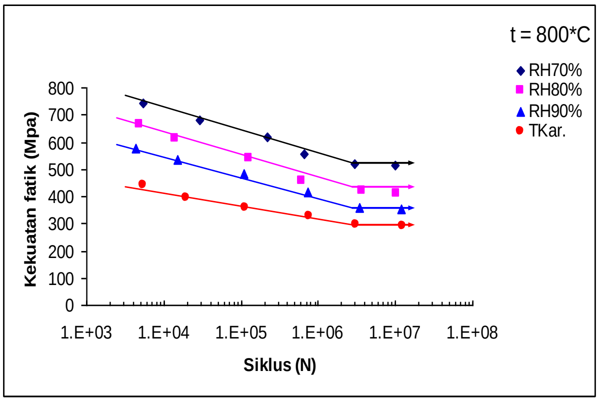

Fig. 5: Relationship of Fatique Strength and Cycle Carbonized Steel at Temperature 800^0C.

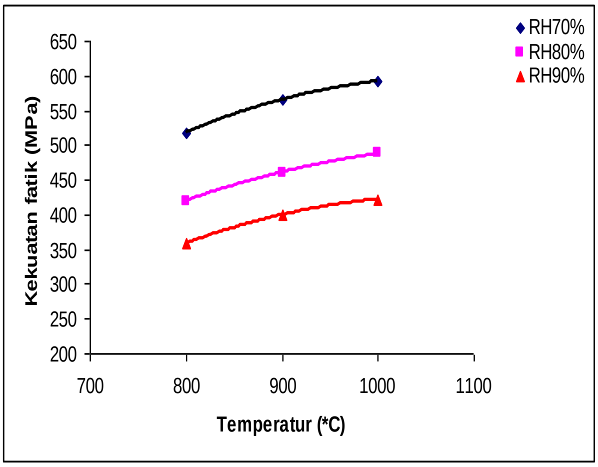

Fig. 6: Relationship of Fatique Strength and Carbonizing Temperature.

Figures 3, 4 and 5 fatigue strength relationships (S) and cycles (N) are shown that with increasing cycle N (n) in each RH70%, RH80% and RH90% environmental moisture, the fatigue strength of steel decreases.

From Figure 6 it can be seen that with rising carbonization temperature, the fatigue strength of steel will increase At RH70% with carbonization temperature of 800^0C, 900^0C, 1000^0C its fatigue strength increase from 518,45 Mpa, 565,58 Mpa to 592,22 Mpa. With RH80% with carbonization temperature at 800^0C, 900^0C, 1000^0C its fatigue strength increased from 420,09Mpa, 461, 07 MPa, 487, 71 Mpa. With RH80% at carbonizing temperature 800^0C, 900^0C. 1000^0C with RH90% its fatigue strength is 358,61Mpa, 399, 60 MPa, 422, 14 Mpa.

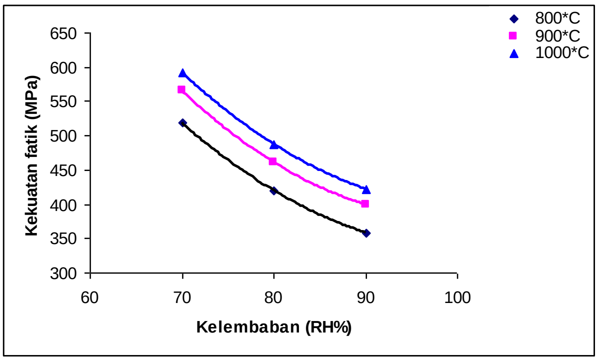

Fig. 7: Power Relation Fatique vs Humidity.

From Figure 7. Fatigue strength relationship with moisture can be explained that the higher the carbonization temperature the more diffuse carbon content, while the energizer's ability to depress the carbon atoms into the steel is limited, consequently the more carbon atoms are on the outer shell and only some of which can penetrate into the inside of the specimen.

The fracture of the steel surface of krupp 1191 can be seen by using Scanning Electron Microscope (SEM) with 500x enlargement as illustrated 8 s/d 10. the fracture surface can be observed by fractografy analysis at the interface of the broken specimen. From the SEM photo observation it shows that the fracture surface (white color) is the fault line due to the repeated loading given by the machine, where the direction of the fault line is circular along the fault surface centered on the axis of the specimen. While the dark color (black) is a grain fracture in which there is a shift or broken between the fellow granules so that regardless of the bonds that resulted fracture occurs suddenly after experiencing such recurring loads.

By comparing the white and the black color, as explained that the white lines occur is caused by the occurrence of fatigue fracture due to intergrain fractures in the tested steel at 800^0C the white color still accumulates along the surface of the crack, but at carbonization temperature 900^0C begins to spread, the white color decreases, while the dark color increases, and so on at the carbonization temperature of 1000^0C. From the crack surface analysis it can be concluded that the higher the temperature of carbonization when tested fatique, the more fracture form in the form of separation between the grains between the atoms are released, is a broken grain that is detached from the bond.

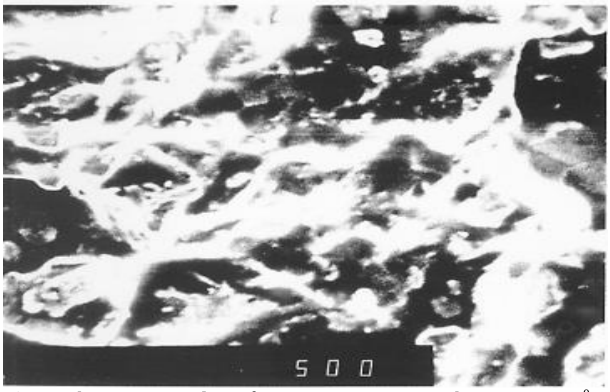

Fig. 8: Photo SEM Fault Surface at Temperature Carbonization 800^0C.

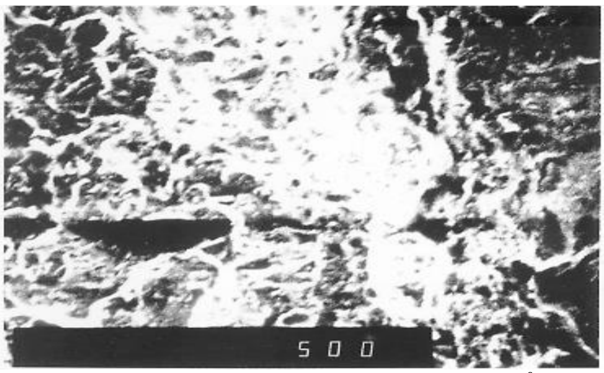

Fig. 9: Fault Surface at Carbonization Temperature 900^0C.

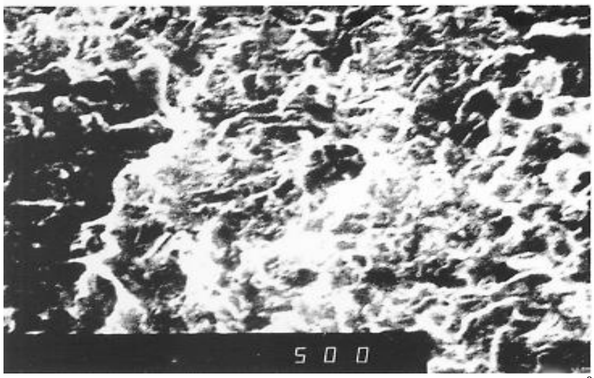

Fig. 10: Photo SEM Fault Surface at Carbonization Temperature 1000^0C.

4. Conclusion

From the research that has been done after looking at the data and pictures shown, then taken the following conclusion:

a) With rising carbonization temperature the fatigue strength of steel will also increase.
b) However, with increasing temperature humidity, the fatigue strength of steel will decrease.
c) The higher the carbonization temperature, the fracture surface the rougher.
d) The higher the ambient humidity temperature the cracked surface is increasingly covered by rust

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