PAPER • OPEN ACCESS

Increase the Toughness of Material of Construction Using Heat Treatment

To cite this article: H Chandra *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **810** 012015

IOP Conf. Series: Earth and Environmental Science **810** (2021) 012015 doi:10.1088/1755-1315/810/1/012015

Increase the Toughness of Material of Construction Using Heat Treatment

H Chandra[1*], Warizal[2], H Dahlan[1], N Paramitha Eka Utami[1], A Tito[1]

[1]Universitas Sriwijaya, Palembang, Indonesia
[2]Djuanda University, Ciawi, Bogor, Indonesia

*hendrichandra@ft.unsri.ac.id

Abstract. The objective of this research is study on the fatigue strength and fracture behavior of DIN 34CrNiMo6 steel. The specimens were subjected to repeated torsion loading. The type of this steel generally used for turbine rotor, crankshaft, and gear. These components operate in elevation temperature and subjected by fatigue load. The test of fatigue strength were carried out under repeated torsion with variation of angle 1^0, 2^0, 3^0, and 4^0. The test temperature are also varied on 500^0C and 700^0C and than compared to without heating one. The fracture surface were analyzed using scanning electron microscope (SEM) in order to identified the influence of temperature and variation of angles. The results of studies show that either the fatigue strength or fracture surface behavior are significant different. The value of fatigue strength under cyclic torsion which is heated on 700^0C is higher than 500^0C and original ones. Characteristic of surface fracture using scanning electron microscope showed that the increasing of temperature also change pattern of fracture surface significantly. On 700^0C heating the fracture surface is smoother than others. On the specimen without heating plastic deformation area of fracture surface is clearer than others.

1. Introduction

Crack toughness is a quantity that states the ability of a material to resist cracking (Broek.D. 2000). The size and size of the crack resistance is how much energy the material can absorb. Therefore the value of fracture toughness is very important in operating machine material, especially in dynamic loading such as fatigue.

Efforts in improving performance have been done a lot by researchers in order to improve mechanical properties, fracture toughness, machine capability and fatigue resistance. So it has an impact on increasing life span (life tme). Hendri Chandra et al (2018) conducted a machine-capable recall study by carrying out the spheroidization process. In the process it can be done with a relatively short time compared to conventional methods. Improved mechanical properties for aluminum alloy material with heat treatment were also carried out (Nurhabibah PEU and H.Chandra 2017). A low crack resistance value will be vulnerable to damage or damage to a material. Damage does not only occur in general machine construction, but can also occur in agricultural machinery engineering. Kusuma Pratiwi D, et al (2018) investigated by analyzing the damage of a vital component in a plowing device or called molboard plow. This tool often suffers damage in the form of plastic deformation and high friction.

Damage in the form of cracking can be triggered by an area that causes stress concentrations in the form of holes, notches and porisitas and others. Resulting in a crack initiation. With an alternating elastic load that works continuously will cause crack propagation, and eventually broken. Some cases

IOP Conf. Series: Earth and Environmental Science **810** (2021) 012015 doi:10.1088/1755-1315/810/1/012015

of mechanical engineering materials that have failed due to fatigue as occurred in pressure vessels, shafts, gears, piping and others.

A material that has a notch or crack and dynamic load, it will form a zone of plasticity, especially in the area around the crack tip. For plastic loads the plasticity zone is wider than the plastic load or fatigue. This is called small scale yielding. Zone plasticity will increase its violence due to the phenomenon of strain hardening. This hardening strain is caused by a buildup of dislocation so that the toughness goes down. One treatment that is suitable for reducing the buildup of dislocation by heat treatment.

2. Methodology

2.1. Material Preparation

Material used in this research is carbon steel DIN 34CrNiMo6 The chemical composition and the mechanical properties of material are shown on Table 1 and Table 2 below.

Table 1. Chemical composition (% wt)

C	Si	Mn	Cr	Mo	Ni
0,35	0,25	0,50	1,40	0,25	1,60

Table 2. Mechanical properties steel Din 34CrNiMo6

σ_u(kg/ mm^2)	σ_y (kg/ mm^2)	e (%)
90-120	60-90	15

In this study conducted at a stress and cycle using different temperatures that are without heating, 500 0C, 700 0C and using 4 different angles namely 10, 20, 30, 40 in order to get the desired S - n curve.

2.2. Fatigue Test

Testing to observe changes in the value of fracture toughness is done by testing the mode I fatigue by using a fatigue tension-compression machine with a predetermined frequency. From the presentation results obtained crack propagation value and number of cycles at a specified stress level. The quantities obtained are processed to get the fracture toughness value. From some variations of heat treatment can be discussed the best value of the test results. *Moment of Torsion is*:

$$Ip = \pi d^4 / 32 \quad (1)$$

$$Mt = G\, \theta\, Ip \quad (2)$$

Stress of torsion

$$\tau = 16 \times Mt / \pi d^3 \quad (3)$$

$$\text{Cycle (n)} = \text{time} \times f \quad (4)$$

Where:

Mt = moment of torsion (lb-inch)
Ip = inersia (inch^4)
θ = angle (^{0})
D = diameter
τ = stress (MPa)
n = cycle
f = frekuency (50 Hz)

IOP Conf. Series: Earth and Environmental Science **810** (2021) 012015 doi:10.1088/1755-1315/810/1/012015

G = shear modulus (12x 10^6lb / $inch^2$)

3. Result and Discussion

The desired s - n curve. The results of fatigue testing are shown in Tables 3 and 4. This research was conducted at stress and cycle using different temperatures, namely without heating, 500 0C, 700 0 C and using 4 different angles namely 10, 20, 30, 40 in order to obtain s-n curve as shown on Table 3.

Table 3. The result of the fatigue test

Angle	Stress (MPa)	Cycles		
		No heating	500^0C	700^0C
1^0	766,2	432300	573750	738800
2^0	1531,29	339550	501700	594800
3^0	2298,75	264200	376050	489200
4^0	3063,79	193000	303600	390850

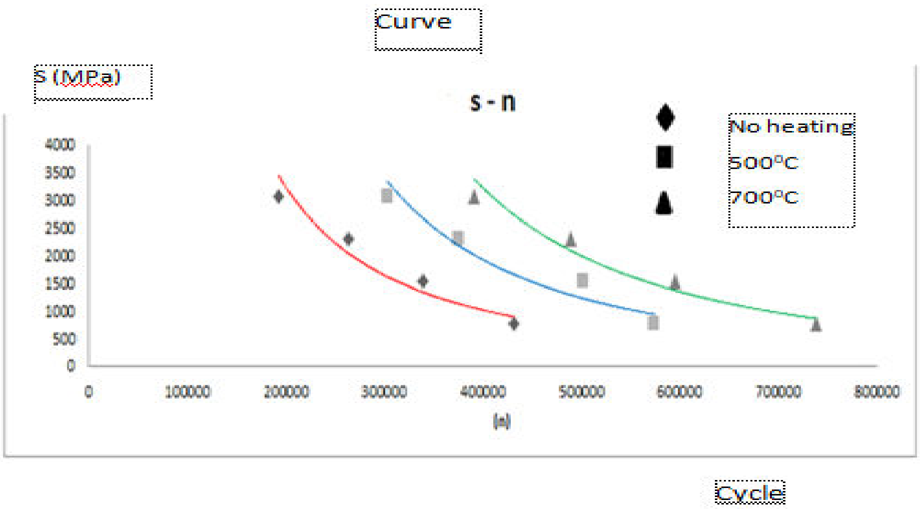

Figure 1. Curve s-n

The pattern of surface fracture of specimens using SEM for the original specimen without heating and two variation heating temperatur (500^0 C and 700^0 C) are shown on Fig 2, 3 and 4.

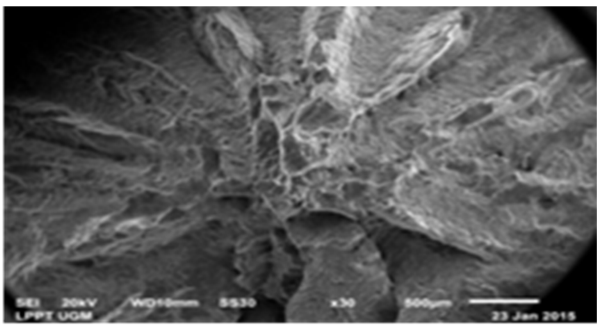

Figure 2. Surface fracture using SEM without heating

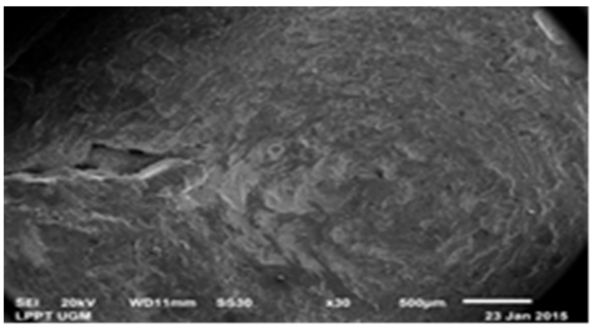

Figure 3. Surface fracture using SEM on temperature 500^0C

IOP Conf. Series: Earth and Environmental Science **810** (2021) 012015 doi:10.1088/1755-1315/810/1/012015

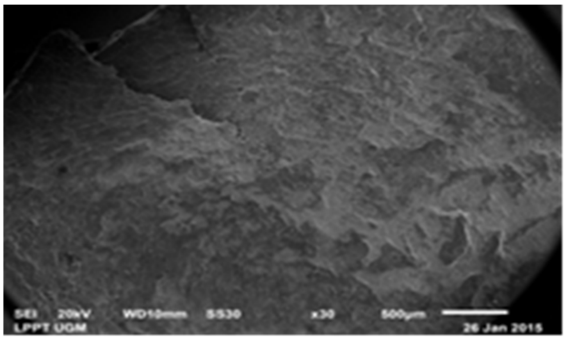

Figure 4. Surface fracture using SEM on temperature 700^{0}C

In the results of fatigue testing using the Repeated Torsion fatigue testing machine on DIN 34CrNiMo6 steel with testing angles of 10, 20, 30, 40 with different conditions ie without heating, heating at 5000C, heating at 7000C can be seen that the number of cycles without heating is smaller heating temperature of 7000C is greater than heating temperature of 500 0C and without heating, so the effect of heat treatment on fatigue resistance in steel DIN 34CrNiMo6 can affect the amount. The surface characteristics of fractures using SEM can be seen that the characteristic shape of the fatigue fracture surface pattern on the heated DIN 34CrNiMo6 steel is finer than before being heated.

4. Conclusion

a. The number of cycles without heating is smaller than that of heating at 500 0C and the cycle with heating temperature 700 0C is greater than heating at 500 0C and without heating.
b. In the SEM test drawing results it can be seen that the characteristic shape of the fatigue fracture surface pattern on the heated DIN 34CrNiMo6 steel is finer than before being heated.

References

[1] ASM Handbook Committee. 1996. *Metals Handbook V olume19, Fatigue and Fracture*. ASM International, Ohio
[2] Cicero S 2012 Estimation of Fracture Toughness by Testing Notched Fracture *J. of material science*
[3] Tanabe Y 2013 Fracture Toughness for Brittle Fracture of Elastic and Plastic Materials *J. of fracture Japan*
[4] Nevalainen M J 1997 the effect of specimen and flaw dimension on fracture mechanics, Int. J. of Fracture 74 2
[5] Chandra H, Pratiwi D K, Zaher M, 2018 High-temperature quality of accelerated spheroidization on SUP9 leaf spring to enhance machinability *Int.J. Helyon* Netherland
[6] Broek D 2000 Elementary of fracture mechanics Martinus Nerjhoup
[7] Diah K P, Chandra H, Nurhabibah P E U, Irawan O, Purba A N 2018 Damage analysis of moldboard plow E3S Web of Conferences, France
[8] Nurhabibah P E U, Chandra H 2017 Mechanical properties analysis of Al-9Zn-5Cu-4Mg cast alloy by T5 heat treatment, Matec web of conference, France