Analysis of the Effect of Stop Drilled Hole Diameter Variation on Fatigue Resistance in Medium Carbon Steel DIN HQ 705

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Abstract. Steel has an important role in the industrial world where many machine component designs use these materials. The mechanical properties possessed by this material are quite capable of various applications in the field in a variety of applications. One application of steel is in the gear and shaft. These gears and shafts use HQ 705 material which is a medium carbon steel with a carbon content of 0.30 - 0.38%. This research was carried out by making a notch on one side of the specimen, then creating an initial crack at the end of the notch with a fatigue machine, to prevent crack propagation, a stop drilled hole was made at the end of the initial crack with variations of 2 mm, 2.5 mm respectively. and 3 mm. Furthermore, this specimen was tested by fatigue test to test the fatigue resistance of each specimen. The results obtained are that specimens with stop drilled holes have longer cycle times compared to specimens without stop drilled holes. With the variation of the stop drilled hole (SDH), the result is that the stop drilled hole with a diameter of 2 mm is easily broken compared to the stop drilled with a diameter of 3 mm. From the fracture surface seen with SEM, it can be seen that the type of crack that occurs in the fracture is an intergranular crack type.

1. Introduction

Fatigue is the main sequence that causes the failure of a material. Nishida's 1985 study showed that about 85%, the cause of material failure was fatigue. Fatigue can be triggered by the concentration of stress on the material, such as: surface roughness, porosity, changes in the dimensions of components, the presence of grooves or other mechanical behavior (Sunardi, et al., 2013). Fatigue begins with the onset of initial cracks due to dislocation movements, followed by growth into a micro crack, then grows into a macro crack, and then cracks propagate until a fatigue occurs. Fatigue can be prevented by inhibiting crack growth by utilizing holes by making holes at the crack ends with a certain diameter called the stop drilled hole method. This method can reduce the stress concentration at the edge of the hole, so that crack propagation is reduced.

2. Methodology

2.1. Material Preparation

Material used in this research is medium carbon steel DIN HQ 705. The chemical composition and the mechanical properties of material are shown on Table 1 and Table 2 below.

Table 1. Chemical composition (% wt)

Simbol	Weight (%)			
	C	Cr	Ni	Mo
HQ 705	0,30 – 0,38	1,30 – 1,70	1,30 – 1,70	0,15 – 0,30

Table 2. Mechanical properties of steel

Symbol	σ_y (N/mm^2)	σ_u (N/mm^2)	e (% min)	RA (% min)	E (J)	BHN
HQ 705	700	900-1100	12	55	45	270 – 330

In this study conducted at a voltage and cycle using different temperatures that are without heating, 5000C, 7000C 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 fatgue 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

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

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

Stress of torsion

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

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

Where:

Mt = Moment of torsion (lb.inch)
Ip = Inersia (inch^4)
θ = angle
D = diameter
τ = stress (kg / mm^2)
N = cycles
f = frekuency (50 Hz)
G = shear modulus (12x 10^{6}lb / inch^2)

3. Result and Discussion

The research was started by giving a notch on one side of the specimen, then making a crack using a fatigue Reapeated Bending test. After the crack was found in the specimen, the specimen was given a stop drilled hole with a variation of 2 mm, 2.5 mm and 3 mm. The next step is the specimen is tested for fatigue to determine the fatigue resistance limit of the specimen using the same test equipment.

Table 3. Testing result without Stop Drilled Hole

Angle (θ)	Stress (MPa)	Cycle (N)
1°	403,1604938	166350
2°	806,3209877	80550
3°	1209,481481	50950

Table 4. Testing result for *Stop Drilled Hole* 2 mm

Angle (θ)	Stress (MPa)	Cycle (N)
1°	510,25	690900
2°	1020,5	331800
3°	1530,75	226500

Table 5. Testing result for *Stop Drilled Hole* 2,5 mm

Angle (θ)	Stress (MPa)	Cycle (N)
1°	543,7003122	774600
2°	1087,400624	380500
3°	1631,100937	242350

Table 6. Testing result for *Stop Drilled Hole* 3 mm

Angle (θ)	Stress (MPa)	Cycle (N)
1°	580,5511111	805850
2°	1161,102222	398250
3°	1741,653333	255950

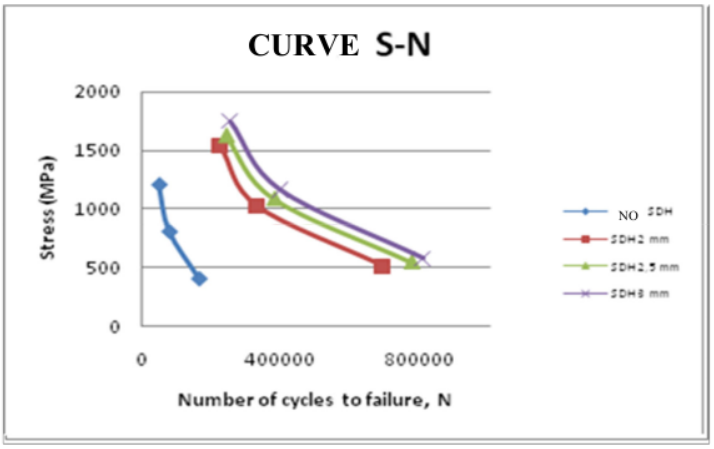


Figure 1. S- N curve

Based on the data obtained, the highest non-stop cycle drilled hole specimens obtained were 166350 cycles. In specimens with stop drilled holes 2 mm, 2.5 mm and 3 mm respectively 690900 cycles, 774600 cycles and 805850 cycles. In these data it can be seen that the cycle differences in specimens without and with stop drilled holes are very far apart. This happens because there is no stop drilled hole to prevent the crack propagation that has been previously made. In addition to the specimen cycle with smaller diameter smaller stop drilled holes compared to large diameter stop drilled holes. A geometric discount in an object, such as a hole or notch, results in an uneven distribution of stress around the disconnect. So, there is a concentration of voltage on the disconnection or stress generator. Therefore, very narrow holes, such as cracks that are perpendicular to the notch, will result in very high stress concentrations (Dieter, 1992). This shows that the size of the stop drilled hole diameter affects fatigue resistance, the smaller a stop drilled hole, the sharper it is to make an initial crack and propagate until finally the final fracture.

Inspection using SEM (Scanning Electron Microscope)

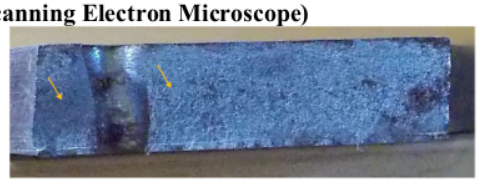
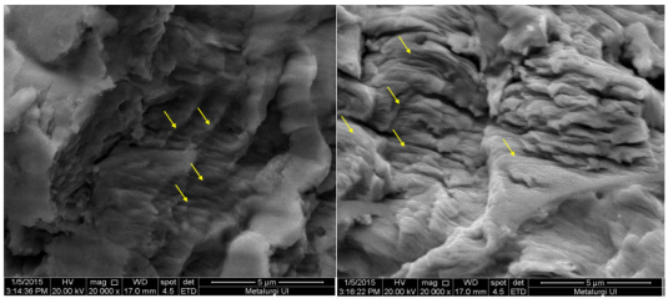


Figure 2. Fracture surface on the specimen with SDH 2.0 mm



(a) (b)

Figure 3. Striation on the specimen with SDH 2.0 mm;
at the hole zone (a), at hole edge (b)

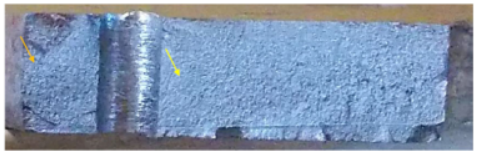
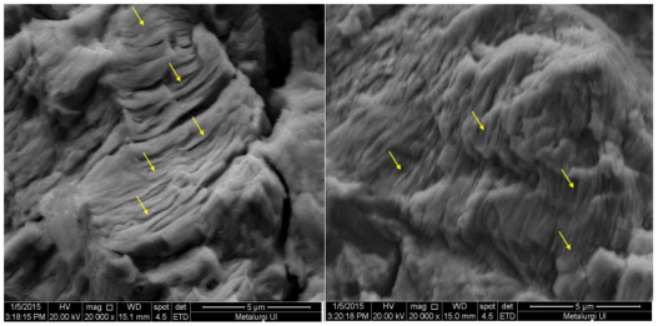


Figure 4. Fracture surface on the specimen with SDH 2.5 mm



(a) (b)

Figure 5. Striation on the specimen Fracture surface on specimen
with SD 2.5 mm; at the hole zone (a), at hole edge (b)

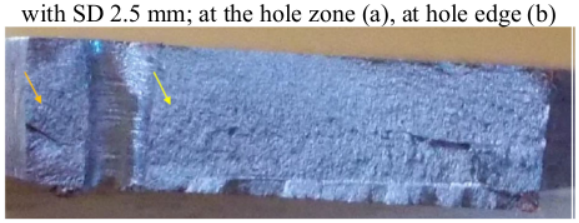
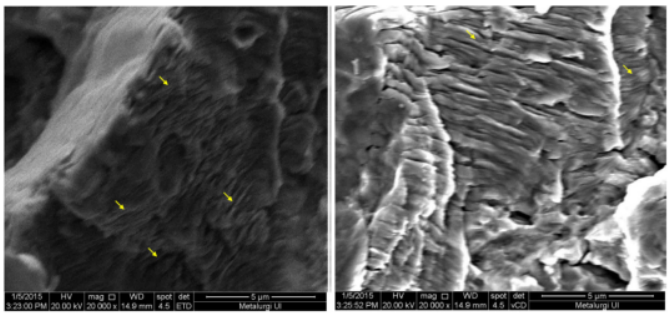


Figure 6. Fracture surface on the specimen with SDH 3.0 mm



(a) (b)

Figure 7. Striation on the specimen Fracture surface on specimen with SDH 3.0 mm; at the hole zone (a), at hole edge(b)

In Figures 5, 6 and 7 above, it can be seen that the striations in the area before the stop drilled hole are very clear compared to the striations in the area after the stop drilled hole that look faint. The position of the striation is different and changes between the area before the stop drilled hole and the area after the stop drilled hole, this is because the stop drilled hole has inhibited the propagation of the previous crack, and the area after the stop drilled hole creates a new initial crack again which causes the directi of its striation. different, besides that the type of crack displayed on the fracture surface is a type of intergranular crack where the crack spreads to the grain boundaries.

4. Conclusion

Specimens that were not given a stop drilled hole (SDH) at the end of the crack fracture faster than specimens that were given a stop drilled hole at the end of the crack. And specimens with smaller diameter stop drilled holes have a smaller cycle than specimens with large diameter stop drilled holes. Striations in the area before the stop drilled hole are clearly visible compared to the striations in the area after the stop drilled hole that are faintly visible. The crack types shown are intergranular crack types.

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