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Fatigue Analysis Aluminium 6063-TF on the Rotary Bending Testing Machine

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ABSTRACT

Some of the damage that occurs in the structure and construction of engine elements that experience dynamic loading at the time of operation is caused by fatigue (fatigue), which occurs without beginning signs so that it causes great damage and loss. Fatigue strength is the process of local changes in the structure that occur permanently in accordance with the period of time caused by conditions where stress or strain occurs which results in cracks or fractures after being subjected to repetitive loads. Surface roughness factors that affect fatigue are applied in the analysis and application of machining, which are finely grinded and rough machined. Analysis was carried out on 6063-TF aluminum alloy material which is widely used for motor vehicles. To find out the effect of the above, the fatigue strength test is carried out with a Rotary Bending Fatigue Test to obtain a cycle value or fatigue age and certain neighbors so that it can make a semi-log S-N diagram with statistical calculations.

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INTRODUCTION

More than 90% of all damage that occurs in the structure and construction of machines that experience dynamic loading at the time of operation is caused by material fatigue. Dynamic load spreads are generally lower than the fatigue strength or yield stress of materials. Fatigue failures often occur without the initial instructions causing large accidents and financial losses, in practice it can happen that due to errors in the production process or component design can experience premature fatigue (Premature Failure). This can cause all components to be withdrawn, because it is very necessary to conduct analysis and research on the fatigue of a component in order to improve a possible failure of fatigue.

The fatigue strength of a material is influenced by many factors, one of which is the surface roughness that occurs due to machining (machining), the surface roughness of metal is formed from the metal cutting process that occurs due to the relative motion of the work piece (metal) to the cutting tool, so the work piece will have certain surface roughness according to the cutting conditions. In this case, a finely grained work piece has a higher fatigue strength than a coarsely machined work piece, because the surface roughness of the work piece can cause stress concentrations so that local plastic deformation (microscopic) arises more easily. This research is directed at the fatigue strength of 6063-TF aluminum alloy material.

Fatigue is a mechanism of damage that occurs as a result of a large amount of load that is lower than the breaking strength or yield stress of the material. A single load cycle will not damage materials or structures because the load is far below the static damaged load, however if the single load cycle is repeated

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several times the damage will arise due to fatigue.

The definition of fatigue according to ASTM E 206-72 is the process of local structural changes in the material that occur permanently in accordance with the time period caused by conditions where stress or strain occurs which results in cracking or fracture after repeated loadings.

From the definition above it can be seen that the process of fatigue occurs in a period of time or during the operation of a component. Damage can occur suddenly, but the process has been going on since the component's initial operation.

Fatigue occurs only in certain areas, namely areas that experience high work stress or strain, sudden deformation, drastic temperature differences, residual stresses or defects in the material.

As a result of repetitive stresses, fine cracks occur in areas that experience maximum stress. As the loading cycle increases, this fine crack will spread and if the propagation reaches a certain length it will cause the residual section to no longer hold its workload, then the residual cross section will be broken.

The nature of the material to fatigue is usually presented in the form of diagrams called S-N diagrams or Wohler diagrams, this diagram states the relationship between the variable voltage (S) and the number of loading cycles (N). Figure 1 shows the S-N curve for soft steel and aluminum, in the figure it is seen that age will increase with decreasing working voltage.

For some materials, the S - N curve has a horizontal part that is a stress that states that the material will not fail due to fatigue (Fatigue Failure), the price of that voltage is called the fatigue limit. Most nonferrous metals such as Al, Cu and Mg have no fatigue limit so fatigue strength for non-Ferro metals is often taken for a total loading cycle of 108.

Generally the data in the literature is presented in the form of repetitive cycle stresses with σm = 0. To illustrate the S - N curve many ways that can be used Figure 2 shows two commonly used methods. In fig 2. The maximum voltage (σmax) is plotted against log N for the value of a certain voltage, whereas in figure 2b the variable voltage (σa) is plotted against log N for a certain average voltage price.

Fatigue tests conducted on the same number of test specimens at different amplitude voltages can produce different fatigue lives - this data distribution is called scatter, see Figure 1 and 2.

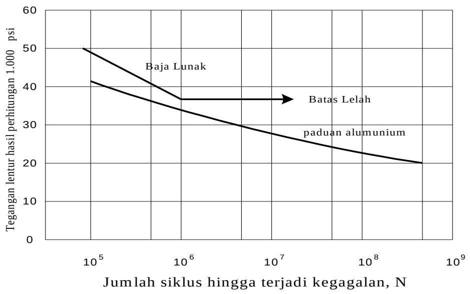

Fig .1. S - N curves for steel and aluminum

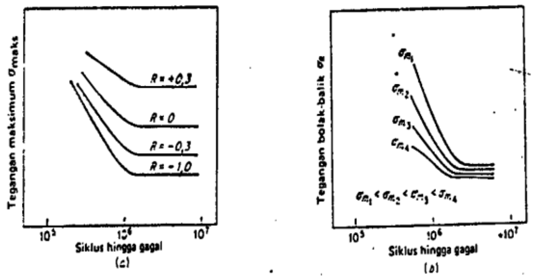

Fig. 2. Method for depicting S-N curves

EXPERIMENTAL METHOD

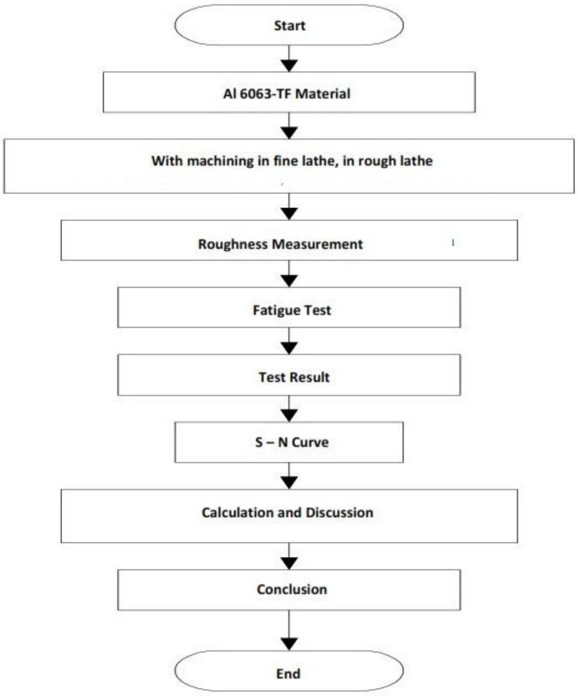

Fig. 3. Flow Chart

Materials

In this research a material of aluminum alloy is used, namely Al 6063-TF, while the composition and mechanical properties of the material can be seen in Table 1.

Table 1. Composition and mechanical properties of Aluminum Alloys.

Chemical Composition (%)		Mechanical Properties	
Si	0.5	Tensile Strenght	245 N/mm^2
Mg	0.5	Yield Strenght	144 N/mm^2
		Shear Strenght	160 (10.5) N/mm^2
		Brinell Hardness	75 N/mm^2
		Elongation	20%

Test Specimens

This study used test specimens with several kinds of surface-finish processes so that different surface conditions of the specimens were obtained, the amount and surface conditions of the specimens are shown in Table 2.

Table 2. Number and surface finish processes

No	Specimen	Amount	Surface Condition
1	Specimen A	6	Fine Lathe
2	Specimen B	6	Coarse Lathe
	Total Samples	12	

In this case, specimens A and B are tested to determine the effect of machined surface conditions on fatigue strength. The results of measurements of average surface roughness of the specimens are as follows:

Specimen A: Ra = 0,065 mm (fine lathe)
Specimen B: Ra = 0,250 mm (coarse lathe)

The shapes and dimensions of the three types of test specimens were made according to ASTM-E 466 standard, as shown in Figure 4.

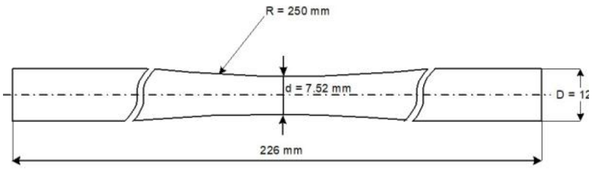

Fig 4. The shape and dimensions of the test specimen

RESULTS AND DISCUSSION

For test specimens A with a smoothly turned surface:

Table 3. Testing Results of test specimens in fine lathe

No *Specimen*	(N/mm^2)	Number of Cycles (N)
1A	200	13.556
2A	200	13.850
3A	200	14.735
4A	100	972.510
5A	100	1.043.238
6A	100	1.281.945

For test specimens B with rough-turning surfaces:

Table 4. Testing Results of test specimens in coarse lathe

No *Specimen*	(N/mm^2)	Number of Cycles(N)
1B	200	11.198
2B	200	11.493
3B	200	11.788
4B	100	943.040
5B	100	1.031.459
6B	100	1.102.472

Table 5. Data of test results of test a specimens with surfaces finely ground for fracture areas

No. *Specimen*	T (N/mm^2)	N (Cycle)
1A	200	13.556
2A	200	13.850
3A	200	14.735
4A	100	972.510
5A	100	1.043.238
6A	100	1.281.945

Table 6. Calculation of fracture area results

With n = 3

			Level 1 : $\sigma_1 = 200$ N/mm^2			Level 2 : $\sigma_2 = 100$ N/mm^2		
I	Zi	Zi^2	Ni x 10^3	Log Ni	Log Ni X Zi	Ni x 10^3	Log Ni	Log Ni x Zi
1	0,615	0,379	13,6	1,133	0,699	972,5	2,988	1,839
2	0,955	0,913	13,8	1,140	1,088	1043	3,018	2,883
3	1,150	1,323	14,7	1,167	1,342	1281	3,108	3,575
Σ	**2,720**	**2,615**		**3,440**	**3,129**		**9,114**	**8,297**

	Level 1: $\sigma_1 = 200$ N/mm^2	Level 2: $\sigma_2 = 100$ N/mm^2
b	0,058	0,209
a	1,094	2,849

Table 7. Result calculation fracture area with substitute to P (10%, 50%, and 90%)

		Level 1: σ_1 =200 N/mm^2		Level 2: σ_2 =100 N/mm^2	
P %	arc sin $\sqrt{P}$	Log N	Nx10^3 L	Log N	N x 10^{3}L
0,1	0,316	1,113	12,958	2,915	821,498
0,5	0,707	1,135	13,655	2,996	991,254
0,9	0,949	1,149	14,104	3,047	1113,277

Table 8. Data from B test specimens with rough lathed surface for fracture areas

No. *Specimen*	T (N/mm^2)	N (siklus)
1B	200	11.198
2B	200	11.493
3B	200	11.788
4B	100	943.040
5B	100	1.031.450
6B	100	1.102.472

Table 9. Calculation of fracture area results

n = 3

			Level 1: σ_1 =200 N/mm^2			Level 2: σ_2 =100 N/mm^2		
I	Zi	Zi^2	Ni x 10^3	Log Ni	Log Ni x Zi	Ni x 10^3	Log Ni	Log Ni x Zi
1	0,615	0,379	11,19	1,049	0,646	943	2,975	1,831
2	0,955	0,913	11,49	1,060	1,013	1031	3,013	2,879
3	1,150	1,323	11,78	1,071	1,232	1102	3,042	3,499
Σ	**2,720**	**2,615**		**3,180**	**2,891**		**9,030**	**8,209**

	Level 1: σ_1 =200 N/mm^2	Level 2: σ_2 =100 N/mm^2
b	0,041	0,125
a	1,023	2,897

Table 10. Result calculation fracture area with substitute to P (10%, 50%, and 90%)

		Level 1: σ_1 =200 N/mm^2		Level 2: σ_2 =100 N/mm^2	
P %	arc sin $\sqrt{P}$	Log N	Nx10^3 L	Log N	N x 10^{3}L
0,1	0,316	1,036	10,864	2,936	863,089
0,5	0,707	1,052	11,270	2,9845	965,979
0,9	0,947	1,062	11,529	3,015	1035,613

CONCLUSIONS

From the test results it can be concluded as follows:

1. Finely-grained test specimens have a fatigue life at voltage (σ1) = 200 N / mm2 with probability (P) = 50% fatigue life equal to (N) = 13,654 x 103 cycles, while at voltage (σ2) = 100 N / mm2 with a 50% probability of fatigue life equal to (N) = 991,254 x 103 cycles longer than the voltage (σ1) = 200 N / mm2.
2. The coarse-grained test specimen has a fatigue life at voltage (σ1) = 200 N / mm2 with probability (P) = 50% fatigue life equal to (N) = 11,270 x 103 cycles, while at voltage (σ2) = 100 N / mm2 with a 50% probability of fatigue life equal to (N) = 965,979 x 103 cycles longer than the voltage (σ1) = 200 N / mm2.
3. Fine-grained test specimens have a longer fatigue life compared to coarse-grained test specimens due to differences in stress concentration (rough-grained surface test specimens > finely-grained surface test specimens).

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