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Failure Investigation of Motorcycle Connecting Rod

[1]Sri Nugroho, [2]*Yusuf Umardaani, [3]Yonathan Jalu Bagaskara

[1,2,3]Mechanical Engineering Departement, Faculty of Engineering, Diponegoro University, Jl. Prof Soedarto, SH, Tembalang-Semarang 50275, Indonesia

***Abstract* - Connecting rod is an important component, where the connecting rod is used as a link between the piston and the crankshaft to transmit the force from the piston to the crankshaft. In this research, the connecting rod is buckling so that several tests would be carried out to analyze the mechanism and causes of the failure. The tests carried out were visual observation, chemical composition testing, metallographic testing, hardness testing and FEM simulations. The results of visual observations showed that the failure of the connecting rod was buckling at the bottom of the small end. The chemical composition test shows that the material used is AISI 4130 steel which is a low alloy steel. The microstructure that is formed is the ferrite and pearlite phases on the failed part and martensite on the part far from the failed part, because the oil in the engine runs out so there is no lubricant and coolant so that the temperature rises and causes the connecting rod decrease in hardness value, the hardness test results show if the material has an average hardness of 500 HV on the part far from failure and 350 HV on the part that fails, this proves that the main cause of failure of the connecting rod is a decrease in the hardness value. The FEM simulation results show that the total deformation due to the engine motion mechanism is in the part that has failed, this also supports why the connecting rod failure.**

***Keywords*:** AISI 4130, buckling, connecting rod, failure, hardness.

I. INTRODUCTION

One of the most crucial parts of an internal combustion engine is the piston rod. The piston rod serves as a connector between the piston and the crankshaft in internal combustion engines. The piston's large end is fastened to the crankpin of the crankshaft, while the smaller end is fastened to the piston using a gudgeon pin. The piston rod's job is to translate the piston's reciprocating motion into the crankshaft's rotational action. When piston rods are utilized, fatigue from the constant pressure from the combustion process frequently leads to failure. This usually happens as a result of the installation position being less exact, which can be brought on by improper use or pushing it above its limit[1].

Investigating the failure of the connecting rod (piston rod), which serves as a link between the piston and crankshaft, was done in this study. The connecting rod buckled and cracked. In this instance, it was removed from a motorcycle with a 97cc cylinder size. The purpose of this study is to determine how a motorbike connecting rod can break at the point where the small and large ends link, namely in the vicinity of the small end. An increase in temperature that the connecting rod receives could lead to failure. These parts will undergo a number of tests in order to examine the failure mechanism and its root causes. Visual analysis, among other analytical techniques, chemical composition test, metallographic test, hardness test and numerical simulation.

1.1 Connecting Rod

One of the most crucial parts of internal combustion engines is the connecting rod. The big end, rod, and little end make up the connecting rod. Piston movement is transferred to the crankshaft by means of the connecting rod[2].

Figure 1: Connecting Rod

1.2 Connecting Rod Material

The mechanical parameters of AISI 4130 steel, a low Chromium-Molybdenum alloy steel, are shown in Table 1 below after quench and tempering [3].

Table 1: Mechanical properties connecting rod

Mechanical Properties	*Metric*
Hardness, Vickers	350 - 500
Tensile Strength, Ultimate	1145 MPa
Tensile Strength, Yield	1110 MPa
Modulus Elasticity	205 GPa

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The heat treatment of AISI 4130 steel consists of normalizing, quenching, and tempering. The hardness of the steel after normalizing is 150-230 HV and it has a ferrite + pearlite phase, as shown in Figure 2. The hardness of the steel after quenching + tempering is 350-500 HV and it has a tempered martensite phase, as shown in Figure 3.

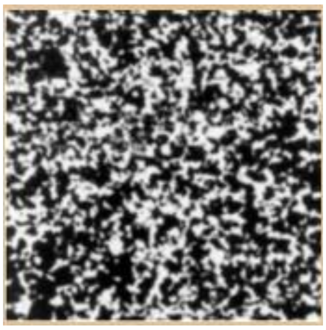

Figure 2: AISI 4130 phase following normalization: ferrite + pearlite [4]

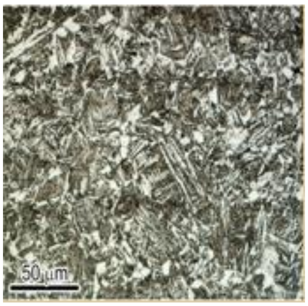

Figure 3: Martinsite phase upon quench and tempering (AISI 4130) [6]

II. METHOD

The connecting rod was analyzed in this study using a number of test procedures. Following a review of the literature, preliminary observations, and initial hypotheses, test specimens are prepared, and testing—metallographic, hardness, and chemical composition tests—is conducted. Next, a simulation is run to ascertain the load applied to the connecting rod until a failure akin to this one occurs.

2.1 Metallographic Test

Testing with metallography is done to observe the microstructure that has formed in the material of the test object. One test object is used for this test, and it is used on both the failed and the non-failed parts at two distinct times. Using an optical microscope, metallographic testing was done at Diponegoro University's Mechanical Engineering Materials Laboratory. Prior to conducting metallographic testing, a number of test item preparatory stages are performed. These steps include the following: Figure 4 shows the components for cutting; Figure 5 shows mountings being made; grinding and polishing; etching; and Figure 6 shows microstructure measurements made with the Olympus BX41M.

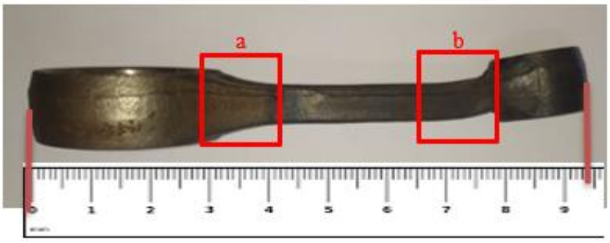

Figure 4: Test specimens from two locations: (a) a distance away from the failure area, and (b) the test specimen itself

Figure 5: Specimens that have been mounted.

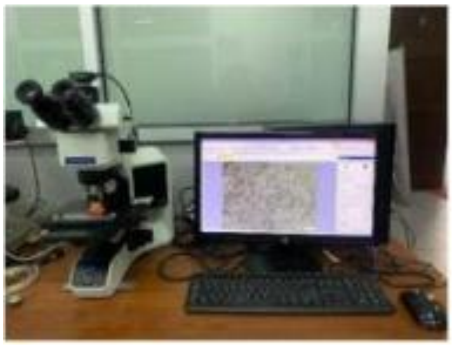

Figure 6: Olympus BX41M Microscope

2.2 Hardness Test

The Vickers Microhardness Tester was used to measure the hardness of connecting rods. The purpose of this test is to ascertain the component's hardness value in order to ascertain whether the connecting rod's hardness has changed or remains consistent with standards. As shown in Figure 4, the test specimens utilized are identical to those used for microstructure testing.

2.3 Chemical Composition Test

The objective of the following test is to ascertain whether chemical components are present in the connecting rod in line with the standard material used to make connecting rods. This test is called the chemical composition test. A device called an optical emission spectrometer is used to perform this test. Refer to Figure 7 below for further details.

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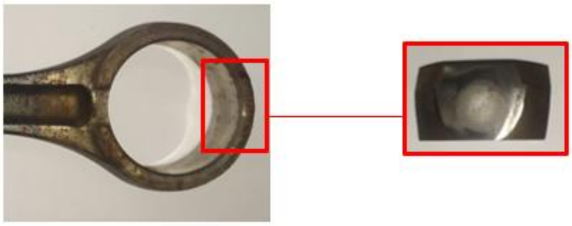

Figure 7: Specimens taken for chemical composition testing

2.4 Simulation

Following testing, the simulation procedure is carried out using Ansys software, with the connecting rod first being remodeled. Figure 8 below illustrates it in more detail.

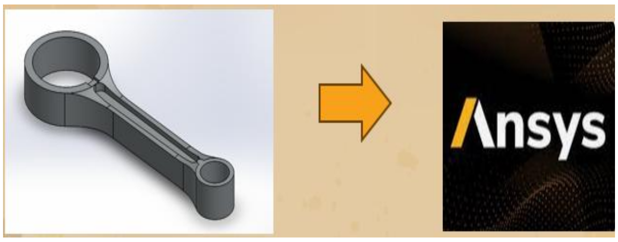

Figure 8: Remodeling and simulation

III. RESULTS AND DISCUSSIONS

Chemical Composition Test Results - The constituents and makeup of the test object material are ascertained through chemical composition testing. The elements present in the material may be identified and the attributes of the inlet valve, including its hardness, strength, ductility, and toughness, can be ascertained based on the test findings. The test findings are displayed in Table 2 below**.**

Table 2: Chemical Composition Test Results

Elements	Chemical Composition (wt%)	
	AISI 4130	Specimen
Fe	97.03 - 98.22	97.2
C	0.28 - 0.33	0.259
Cr	0.80 - 1.1	1.12
Mo	0.15 - 0.25	0.165
Si	0.15 - 0.30	0.254
P	<= 0.035	0.0285
Mn	0.40 - 0.60	0.857
S	<= 0.040	0.0044

Based on the results of spectrometry testing, there is a significant difference in carbon content, where the carbon content in the connecting rod specimen is 0.259% while the carbon content in AISI 4130 is 0.28%and there are no discernible differences in other composition [6].

Steel has alloy elements that total about 2.83%, depending on the alloy. These findings are consistent with the low alloy steel category, which has 2.83% alloy elements, which is slightly less than stainless steel, which has at least 10% Cr. Generally speaking, low alloy steel is a type of iron material that, thanks to the inclusion of alloying elements like nickel, chromium, and molybdenum, exhibits better mechanical qualities than plain carbon steel. Generally speaking, the purpose of these steel alloys is to improve the material's capacity to harden, hence optimizing its mechanical qualities and toughness following heat treatment [7,10].

Based on the chemical composition of spectrometric testing results, steel is categorized as SAE-AISI 4130 steel [8]. This type of steel is commonly used as a material for making connecting rods [4,5].

Metallographic Test Results - Using a micro microscope at a specific magnification, microstructure observations are made on the specimen being evaluated in metallographic testing. Figure 9 below displays the metallography test findings.

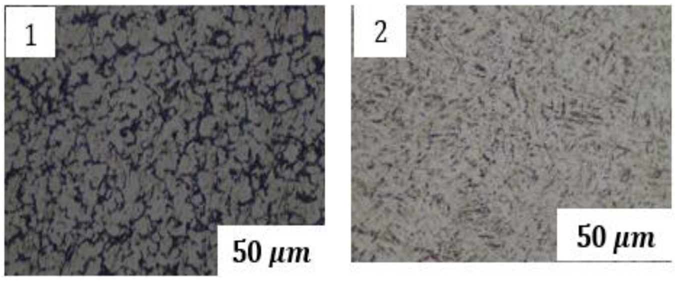

Figure 9: (1) shows the ferrite + pearlite phase, (2) shows the martensite phase

From parts (1) and (2) it can be seen that the phases in figure (1) that are formed in the connecting rod are ferrite and pearlite while in part (2) martensite, which shows that the steel material is not only quenched to produce very high strength, Tempering was also carried out in order to increase the toughness value, but the parts that failed turned into ferrite and pearlite, This is assumed to be caused by the cylinder's interior overheating, which is connected to the connecting rod's small end.

Hardness Test Results - Results of hardness testing carried out using the Micro Hardness Vickers Tester on intake valves that failed and parts that did not. On each specimen, hardness testing using the Vickers method was carried out at five separate points with a loading of 100 gf and an indentation time of 15 seconds. The hardness test results are presented in Table 3 below.

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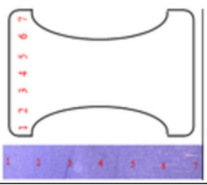
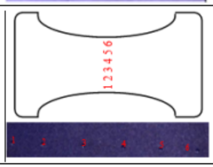
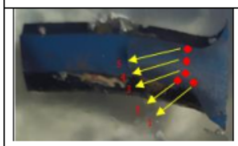
Table 4: Hardness Test Results (Vickers)

Area	Point	Specimen under big end
	1	556
	2	554
	3	517
	4	523
	5	546
	6	553
	7	560
	1	570
	2	540
	3	526
	4	515
	5	541
	6	568

Area	Point	Failure Specimen
	**1**	**488**
	2	**494**
	3	**367**
	4	**304**
	5	**403**

According to the hardness test, the component's hardness value is significantly higher than that of the connecting rod's defective part. This could happen as a result of the engine's performance being affected by overheating brought on by the engine's coolant and lubricant running low.

Result of Simulation - The critical load on the connecting component rod is determined at the start of the simulation, and the results are displayed in Figure 10 below.

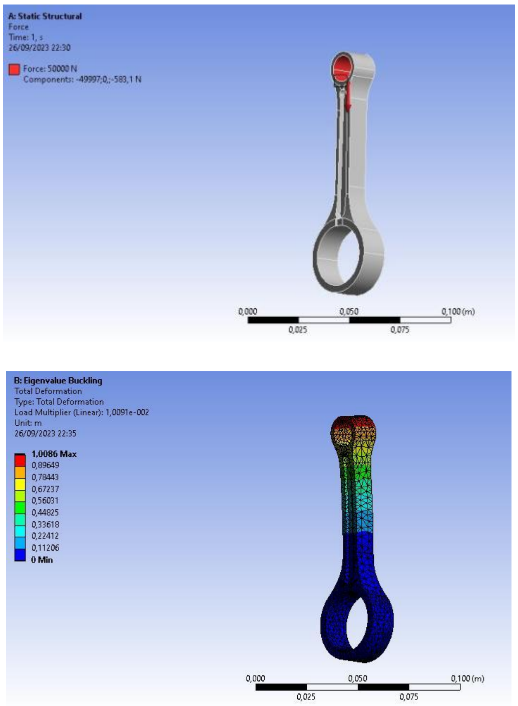


Figure 10: Connecting rod critical load simulation

Figure 10 illustrates that the connecting rod's critical load is 50 kN with a load of 50 kN since the load multiplier value is 1.

The simulation results are shown in Figure 11 below. Next, a bending mode simulation was run using Ansys eigenvalue buckling to obtain the voltage that happens in the connecting rod and also the enormous load received such that a similar failure occurs with actual events.

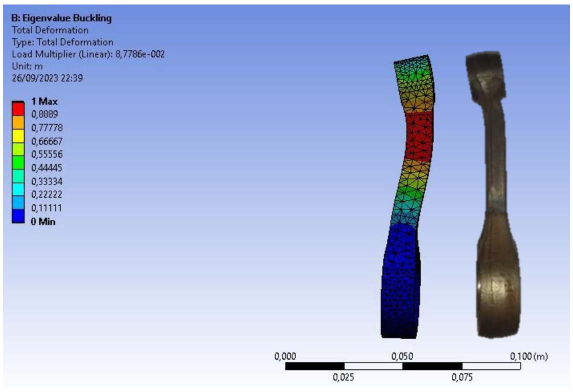


Figure 11: Simulation of connecting rod buckling mode

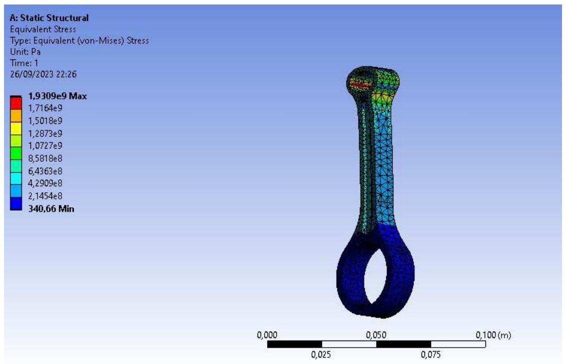


Figure 12: Von Mises connecting rod stress analysis results

According to the results of the buckling mode simulation, the stress at which the connecting rod really failed was 1930 MPa, despite the rod's yield point being 1145 MPa. Additionally, in the simulation, it was discovered that the load multiplier value was 8.7 with a given load of 50 kN, meaning that in the event that the connecting rod fails, for example The connecting rod in the event really received a load of 435 kN.

IV. CONCLUSION

An examination of connecting rod failure on a 97 cc four-stroke motorcycle has been done in this study. The following is an explanation of the research's conclusions based on its findings.

1. According to the test results, the chemical makeup of the connecting rod components is 2.8% low alloy steel, which is consistent with the standard connecting rod

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material, which is AISI 4130 steel. Whereas the specimen that is farthest from failing has a martensite phase, the failed portion of the specimen has a pearlite ferrite phase. The connecting rod's hardness, which should be above 500 HV but is below 370 HV, is what causes the phase to form in the defective part. This occurs when engine oil runs out and the connecting rod reheats as a coolant and lubricant.

2. The bottom of the connecting rod's small end has its smallest area, thus when continuous loading happens, failure will manifest as buckling or fracture in that location. These factors also induce connecting rod failure in combustion engine circuits.

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