

Failure Investigation of the Front Coil Spring of a 160 cc Motorcycle

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Abstract - Coil springs in motorcycles are crucial components in the vehicle's suspension system, where they are used in the front or rear to absorb the impact energy experienced by the wheels. In this study, the coil spring experienced a failure in the form of fracture, prompting several tests to analyze the mechanism and causes of this failure. The conducted tests include visual observation, chemical composition testing, metallographic testing, hardness testing, and FEM simulation. The visual observation results indicate that the failure experienced by the coil spring is due to fatigue fracture, as defined by the presence of crack initiation, crack propagation (beachmark), and final rupture. The chemical composition testing reveals that the material used is SAE 9254 Steel, that is a low-alloy steel. The microstructure formed consisted of ferrite and pearlite phases, attributed to the absence of quenching and tempering processes during the coil spring's production. The hardness testing results show an average hardness of 216,6 HV, confirming the absence of quenching and tempering in the coil spring production process. The FEM simulation results show that the stress does not exceed the yield strength of the material.

Keywords: coil spring, fatigue, SAE 9254.

I. INTRODUCTION

Failure analysis is the process of examining a component that has experienced failure or damage caused by various factors that influence the performance of a tool. Failures in machine components can have significant consequences for an industry, especially when the failed component plays a crucial role within that industry. An example of such a component susceptible to failure is the coil spring, where various factors can contribute.

Coil springs are important in various engineering applications, including the automotive industry, manufacturing, and other industrial machinery sectors. In the automotive sector, oil spring is an important component of a vehicle's suspension system, providing support, stability, and cushioning the vehicle as it travels over uneven surfaces [1]. Coil springs consist of various types, including compression, extension, torsion, and volute springs.

Compression springs are one of the most common coil springs designed to withstand compressive forces. Compression springs have elastic properties, meaning that when pressure is applied to the spring, the spring will compress and store energy, and when the pressure is removed, the spring returns to its original shape [2]. Extension springs absorb and store energy while providing resistance to tensile forces. Extension springs have hooks or loops at their ends that attach to opposing components [3]. A torsion spring is a type of spring that works by rotating or winding the spring around its central axis. Torsion springs are usually used in rack-and-pinion steering systems, where the steering wheel moves the rack back and forth to move the front wheels [4]. Volute springs can withstand more significant pressure because of their configuration. When the ends of the spring are exposed to a load, they stiffen at the edges, and when the load pressure increases, the coils move past each other, allowing the spring to compress to a very short shape [5].

Failures in coil springs generally include fatigue, brittle, and ductile fractures. Fatigue fractures are caused by repetitive stress [6]. Fatigue fracture consists of 3 stages crack initiation, crack propagation, and final rupture. Crack initiation occurs because the surface receives the most significant load and is most likely to cause stress concentrations that can cause the initiation of cracks [7]. Crack propagation is the process by which cracks or fractures in a material grow or extend over time when subjected to stress or external forces. Final rupture occurs when crack propagation increases and gradually reduces the cross-sectional area of the part or test specimen, weakening the specimen so that complete fracture can happen with just one load application [8].

Brittle fracture is a type of fracture that occurs in materials without significant plastic deformation (change in shape) before breaking. It usually happens suddenly and without warning. Brittle fractures occur in materials with a martensite structure or materials with a very high carbon composition, so they have brittle properties [9]. Ductile fracture is a fracture phenomenon type is characterized by relatively large plastic deformation. The fracture fibrous (fibrous fracture), which involves shifting crystal planes in a ductile material [10].

II. MATERIAL AND METHOD

Several testing procedures need to be conducted to determine the type and causes of the fractures in this research, including chemical composition analysis, visual observations, metallography testing, Vickers hardness testing, and finite element numerical simulations. The chemical composition analysis uses the Hitachi Flexem 1000 as depicted in Figure 1. The purpose of this testing is to determine the type of material utilized and the chemical makeup of the coil spring.



Figure 1: Hitachi flexem 1000

Visual observations of the fracture were carried out with the help of a macro microscope, as seen in Figure 2. The purpose of this observation was to determine what type of failure occurred in the coil spring.



Figure 2: Macro microscop

Metallography testing uses several processes, namely cutting the specimen, making mountings on the specimen, sanding, polishing, etching, and finally observing the material grains using an optical microscope, as seen in Figure 3 below.



Figure 3: Optical microscope

Vickers hardness testing using a Vickers hardness tester, as seen in Figure 4. The purpose of this test is to find out the hardness value of the coil spring.



Figure 4: Vickers hardness tester

III. RESULT AND DISCUSSION

3.1 Visual Observation

Based on visual observations conducted on the coil spring, it can be determined that the coil spring has experienced a fatigue failure. Figures 5, 6, and 7 illustrate the fractures on the coil spring.

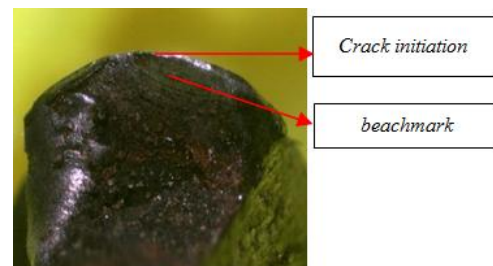


Figure 5: Crack initiation, crack propagation (beachmark)

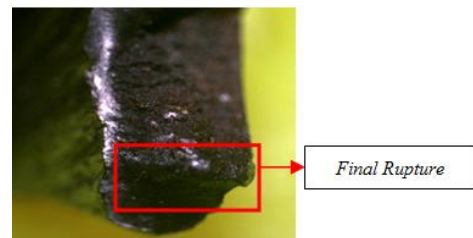


Figure 6: Final rupture



Figure 7: Fracture angle

3.2 Chemical Analysis

In Table 1 there is a comparison between the chemical composition of the specimen and SAE 9254 steel. From the weight percentage of the main elements present in the steel SAE 9254 alloy, it can be seen that the broken spring material complies with the specified chemical composition specifications for this spring.

Table 1: Chemical composition

Material	C	Si	Mn	Cr	Fe
SAE 9254	0,51-0,59	1,3-1,6	0,6-0,8	0,6-0,8	Balance
Specimen	0,56	1,41	0,65	0,68	96,63

3.3 Metallograhy

Microstructure measurements were used in metallographic testing on both specimens using a micro microscope. The results of metallographic testing can be seen in Figure 8 and Figure 9 below.



Figure 8: Results of metallographic testing near the failure coil spring 500X magnification scale

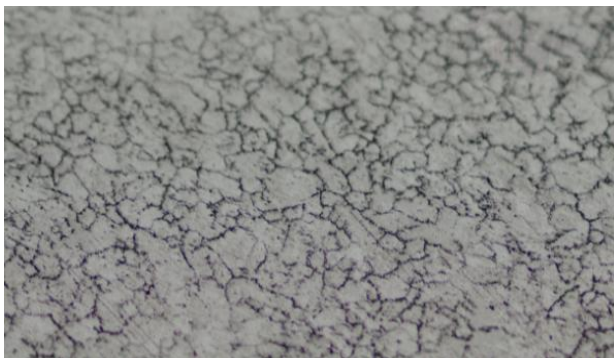


Figure 9: Results of metallographic testing far the failure coil spring 500X magnification scale.

From Figure 8 and Figure 9 above, it can be seen that the phase shape of the coil spring part of the failed specimen and the non-failed part have the same phase, namely pearlite ferrite, which is caused by the absence of quenching and tempering processes in the manufacturing process.

3.4 Hardnest Testing

Hardness testing was carried out on both samples at points in the area that experienced failure and in places far from the failure. The hardness test results can be seen in Table 2.

Table 2: Hardness test results

Test Point	Specimen Variation (HV)	
	Near area fracture	Far area fracture
1	183	218
2	192	235
3	208	228
4	214	242
5	212	234

The graph above shows that the hardness value of the coil spring only ranges from 180 to 234. This can happen because there is no quenching and tempering process in the production process, so the coil spring does not undergo a hardening process.

3.5 Simulation

Simulations were carried out to analyze the stress in the coil spring. The applied force has been calculated and the force on the coil spring is 463,05 N and the torsional moment is 5.731,38 N.mm. The simulation results can be seen in Figure 10.

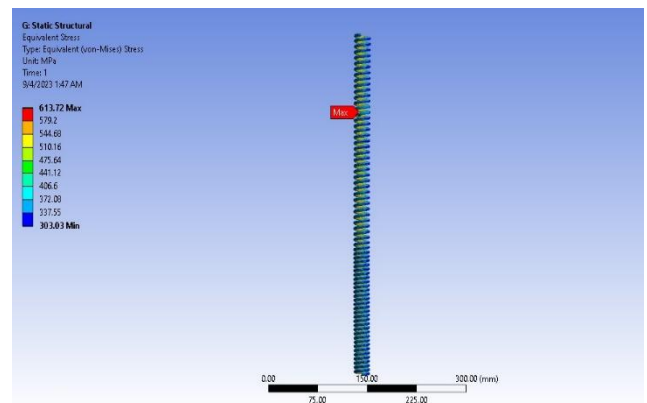


Figure 10: Von-mises stress

IV. CONCLUSION

Based on the analysis and testing that has been carried out; several conclusions can be drawn as follows:

1. The test results show that the chemical composition of the coil spring components is made of low alloy steel with a chromium alloy value of 0,68%. The microstructure formed is the pearlite ferrite phase. The phase formed is caused by the coil spring, most likely not

undergoing a quenching and tempering process. They are characterized by a hardness value ranging from 180 - 250 HV.

2. The failure mechanism for a failed coil spring occurs due to fatigue fracture. Where fatigue fracture is characterized by crack initiation, crack propagation and final rupture.

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Citation of this Article:

Sri Nugroho, Yusuf Umardani, & Dosma Ruben R. Nababan. (2024). Failure Investigation of the Front Coil Spring of a 160 cc Motorcycle. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 8(11), 181-184. Article DOI <https://doi.org/10.47001/IRJIET/2024.811020>
