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Failure Analysis of Valve Unit for MAN 9L21/31 Diesel Engine Generator

Wilarso[1,2,*], Che Wan Mohd Noor[1], Ahmad Faisal Ayob[1], Wan Nurdiyana Wan Mansor[1], Muhamad Ali Pahmi[1,2]

[1] Faculty of Ocean Engineering Technology and Informatics, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Malaysia
[2] Sekolah Tinggi Teknologi Muhammadiyah Cileungsi. Jl. Anggrek No. 25, Perum PT. SC, Cileungsi, Cileungsi, Bogor, 16820 Jawa Barat, Indonesia

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ABSTRACT

Damage to the MAN 9L21/31 generator valve system caused issues with the industrial generator. The MAN 9L21/31 generator produces 1,980 kW and has nine in-line cylinders. It is powered by a gasoline engine. The purpose of this research was to harm the MAN 9L21/31 exhaust valve. The engine's cylinder head number 7 has a gutter that displays a temperature rise indication of up to 457 degrees Celsius. The procedure for analyzing valve hardness, chemical makeup, and microstructure. the outcomes of the material hardness test on Sample I-1 Numbers 10, 11, and 12 (523 HV), as well as on Sample I-2 Numbers 1 and 2 (558 HV) (523 HV). The valve face is hardened using electric arc welding using nickel, chromium, and high molybdenum alloy steel. According to microscopy testing, austenitic dendrites represent thermal fatigue corrosion in the region of the stellite microstructure. From the thick side, the microstructure of the bainite-ferrite valve base material can be seen, with fine carbide grains distributed evenly in several regions of thermal fatigue corrosion fracture. Austenitic dendrites, a type of thermal fatigue corrosion, also develop in the stellite microstructure region. More than 86.1%–86.5% Fe is the primary chemical component of the material that makes up the main valve. Hardness is produced by a carbon compound of iron with 0.038% to 0.042% carbon. Despite having a composition of only 1.67%, this Fe-C alloy is still referred to as alloy steel. It has excellent elastic and ductility properties thanks to the additional Si material, which ranges from 3.02% to 3.34%.

1. Introduction

Despite the fact that it is powered by a diesel engine, a normal motor generator set should have a quiet engine sound. Standardized clearance and appropriate lubrication provide great engine performance with minimal noise emanating from mechanical parts rather than the combustion chamber. Excessive noise may occur if any of the mechanical pieces, such as the crank or valve mechanism, are worn out or broken. Several ways for anticipating and pinpointing the cause of engine failure using signals or increased temperatures collected by specialized diagnostic equipment have recently been developed [1,2]. However, diagnostic instruments cannot detect all component

* *Corresponding author.*
E-mail address: wilarso09@gmail.com

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faults, particularly those that do not generate a signal, such as component discolouration or minor cracks that do not cause abnormal vibration symptoms.

Excessive engine noise is audible in one of PT. X's generator sets powered by a MAN 9 L21/31 diesel engine, indicating a problem. The exhaust vent is not functioning properly. The exhaust valve and suction valve on Unit 9 cylinder 7 of a MAN 9 L21/31 diesel engine encountered deposit deposition and failures of approximately 90% of damaged exhaust valves due to heat-related discolouration after operation at 457 degrees Celsius (head discoloration).

The discharge valves were examined, and guttering was observed on each of them. More research is needed to gather scientific knowledge that can be used as maintenance data in other circumstances. The proposed research topic is exhaust valve damage analysis. To determine the root cause of valve damage. The study approach consists of testing the microstructure, chemical content, and hardness of the valve material.

This study was compared to prior investigations on MAN 9L21/31 diesel engine generator sets, where the diesel engine uses high-fuel oil. The purpose of this investigation is to identify the key component causing valve damage in biodiesel-powered diesel engines.

2. Methodology

The primary focus of the research is on the combustion chamber valves of the MAN 9L21/31 generating set engine.

2.1 Work Procedures

Work procedures are a series of stages that must be completed in order for the work to be completed. They also clearly represent the course or flow that must be followed from the start of the work to the completion of it. Figure 1 depicts the process of completing the study framework.

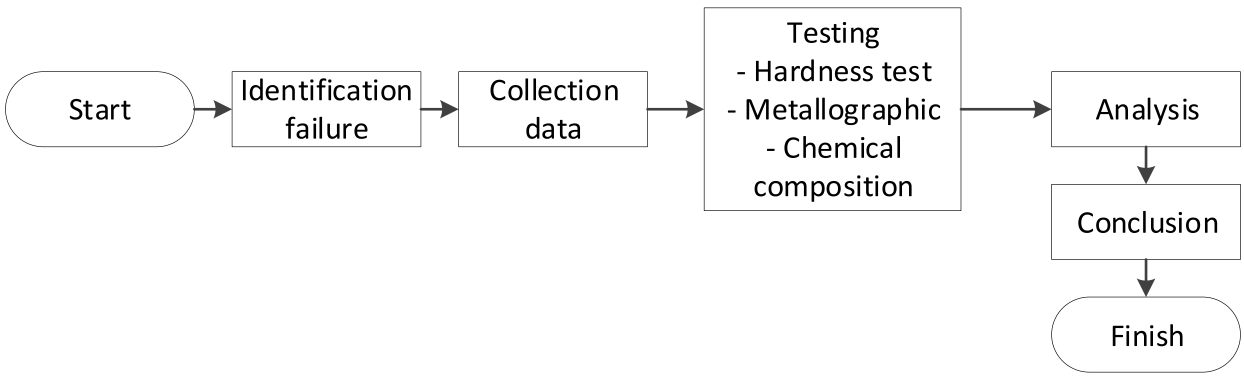

Fig. 1. The method of research

2.2 Hardness Testing

The hardness test is used in valves to determine the material's resistance to plastic deformation, as well as its tensile strength, wear resistance, and abrasiveness. It is also used to test whether the material's mechanical strength has diminished and its resistance to surface penetration in piston rods. The results of this hardness test will be compared against data from the literature to evaluate whether they are in agreement with the standards or not [3,4]. Observations on the toughness test include the following:

i. The surface of the test sample must be consistent with the material's characteristics and must not have been subjected to any analogous treatments, such as case hardening or carburizing.
ii. The diameter of the traces can be examined and quantified using a magnifying optical lens.
iii. The hardness of the valve material was assessed using one valve and samples from four separate areas (samples I-1, I-2, I-3, I-4). The hardness testing instrument use Vickers hardness.

2.3 Macro Examination (Macroscopic Examination)

When we say "macro inspection," we mean closely inspecting an object with our eyes or a low-magnification magnifier (a low magnification) [5]. Its goal is to check the surfaces of fragile metal structures with holes and cracks, as well as specimens damaged during mechanical testing [6-8]. These specimens are then compared to various metals based on how they differ in terms of shape and structure [9]. For macro investigations, magnification factors range from 0.5 to 50. Macro inspection is typically utilized for materials having large and rough crystal structures, such as metal from castings or molds, as well as nonmetals [10]. The goal of this finding is to determine which phases are present in the sample. The microstructure was observed using a stereo lens. Amplification of 100X and 500X is used. Microstructural studies were performed on the sample using a 2% nital etching agent in order to identify the phases created. Before conducting metallographic observations and photographing the microstructure, various stages must be done, including sanding, polishing, and etching.

2.4 Chemical Composition Testing

The goal of chemical composition inspection is to ascertain the valve material so that comparisons between the design material and the actual valve material composition may be made. An Optical Emission Spectrometer is used to determine chemical composition. The steps for chemical testing are as follows:
i. Test cutting.
ii. Carry out grinding or sanding on the test object.
iii. Placing the test sample on the test site and then spraying 99.99% argon gas on the surface, followed by testing [4].

The elements Fe, C, Si, Mn, Cr, Ni, Mo, Cu, Al, V, Ti, S, P, Co, Nb, W, and Pb are used to determine the molecular make-up of this material. In this test, the valve material is used to identify the base material.

3. Results

For damage analysis, visual and macro fractography, metallography, hardness testing, and chemical composition inspections and tests are performed.

3.1 Test Item

The combustion chamber valve of the MAN 9L21/31 diesel engine is being tested. Starting from left to right, the valves that have been in use the longest are followed by the valves that are still new [11].

Figure 2 compares macro pictures of exhaust valves 1 and 2 with damaged gutters to gutters in good condition to validate the investigation of the causes of damage. Intake valves 3 and 4 are in good working order.

Fig. 2. Close-up image of the valve

3.2 Results of the Fractographic Test

Figure 3 depicts a stress fractured test valve with damage or gutters on the valve head. The shape of the fatigue fracture area is included in the material of the valve base, which goes through a forging process to make the core region more structurally homogeneous and avoid fracture. Figure 3(a) and Figure 3(b) show the upper surface of the valve stripped. Figure 3(b) shows that the guttering is caused by high-temperature gas escapes between the valve face and valve cushion. This leak is caused by foreign particles lodged between the valve face and the valve cushion.

Fig. 3. Test valve

Figure 4 shows that the initial fracture is assumed to have been caused by an insufficient combustion process, which resulted in the accumulation of fuel scale or deposit on the component in contact with the engine body, resulting in combustion detonation. Meanwhile, the detonation of combustion shocks and stresses the valve head.

Fig. 4. On the valve seat, carbon

Figure 5 depicts the angle formed by the valve head's base material and the stellite layer, which is a high-stress area where combustion deposits can easily collect.

Fig. 5. Components of the valve are shown in a micrograph

Figure 6 depicts an accumulation of deposits on the valve stem induced by incomplete combustion (traces of deposit buildup or crust that has fallen off).

Microstructure thermal fatigue corrosion occurs where the valve material area and stellite material meet in Figure 7. At the fracture's conclusion, a deposit product with symptoms of a high-temperature corrosion attack has formed. The stellite layer suffers from the same high-temperature corrosion as the valve base material does; however, this time, a combustion explosion is to blame, and the result is the same. The stellite layer is normally 2.1 mm thick and 10 mm wide, but when eroded, it is 17 mm thick.

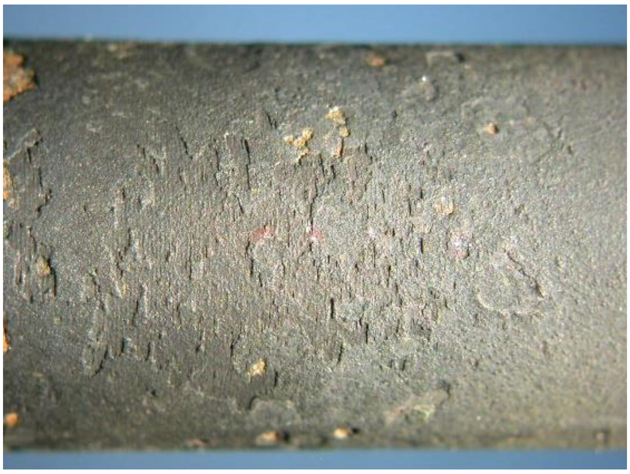

Fig. 6. Valve stem

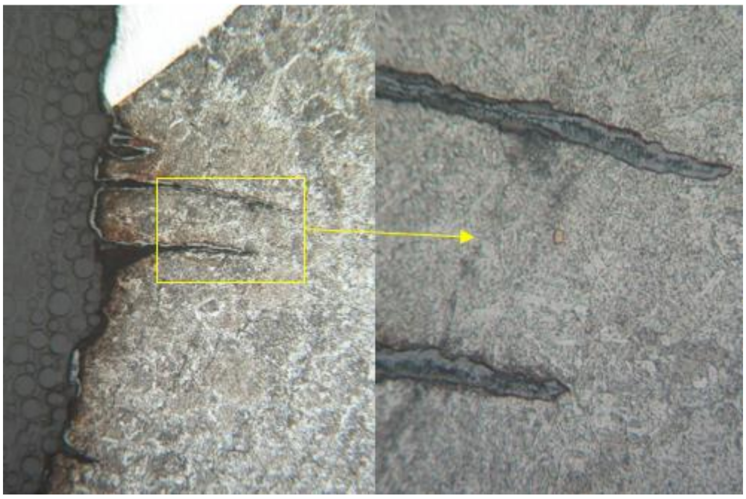

Fig. 7. Valve microstructure

The microstructure of the stellite material in Figure 8 is made up of austenite dendrites, and thermal fatigue corrosion occurs. The valve head material has a bainite microstructure with fine carbide grains that are uniformly dispersed.

Fig. 8. The stellite material's microstructure

Thermal fatigue corrosion cracks are observed from the thick side in Figure 9. The microstructure of the valve base material is bainite-ferrite, with tiny carbide grains dispersed uniformly throughout. Thermal fatigue corrosion appears as austenite dendrites in the stellite microstructure.

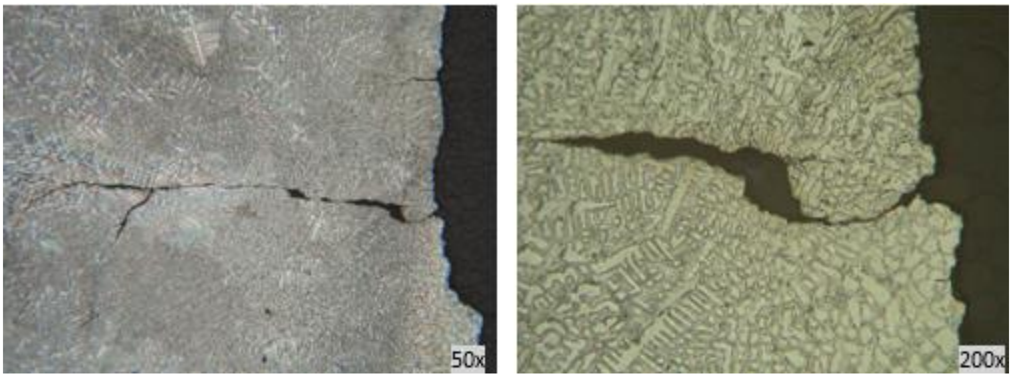

Fig. 9. The basic material for the valve's microstructure

3.3 Vickers Hardness Test Results

Figure 10 shows the position of the hardness test, which used three test samples. Material hardness tests on Samples I-1 Numbers 10 (507 HV), 11 (507 HV), and 12 (523 HV), as well as Samples I-2 Numbers 1 (558 HV) and 2, (523 HV), show this. High voltage arc welding is used to form a hard surface on the surface of the valve from nickel, chromium, and molybdenum alloy steel [12].

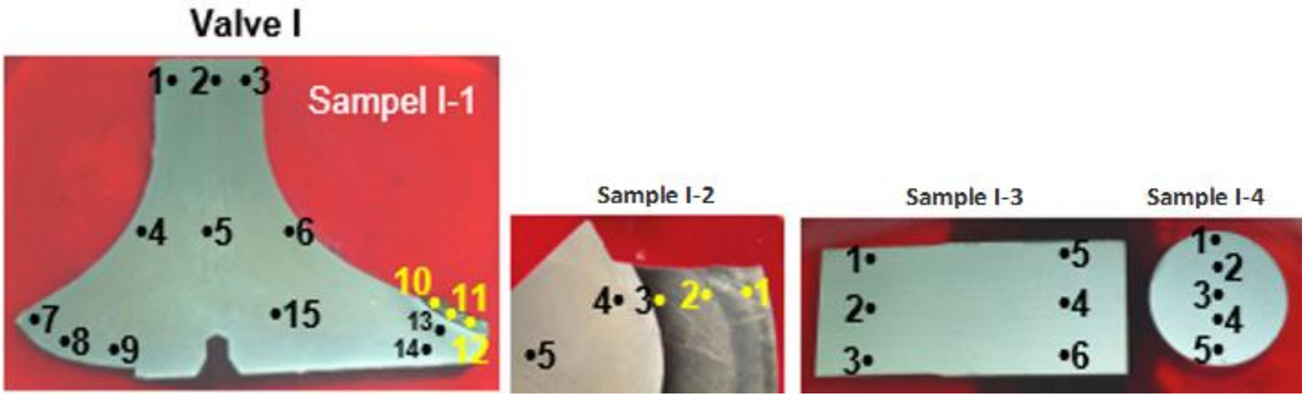

Fig. 10. Measure for hardness position

Table 1 demonstrates that the material's hardness weakens progressively beginning with valve I in this hardness test. This implies that the hardness of the valve will decrease as its useful life grows. Because the material became brittle due to the elevated temperature, samples I-1 numbers 7, 8, and 9 on the valve head exhibit decreased hardness.

Vickers hardness tester data,
Tool's name : Frank Finotest
Test method : Hardness Vickers (HV)
Load (P) : 5 Kgf
Indenter Angle: 136º
Test Time : 15 second

Table 1
Valve hardness test results

Hardness Value, HV No.	Valve 1 Sample I-1	Valve Sample I-2	Valve Sample I- 3	Valve Sample I-4
1	306	558	341	336
2	302	523	336	332
3	303	532	332	326
4	302	313	332	336
5	293	227	332	341
6	229	-	332	-
7	266	-	-	-
8	277	-	-	-
9	274	-	-	-
10	507	-	-	-
11	507	-	-	-
12	523	-	-	-
13	303			
14	262			
15	268			
Min	229	227	332	326
Average	328	431	334	334
Max	523	558	341	341

A hardening agent is an iron carbon alloy containing 0.038% to 0.042% carbon. Despite its low composition of 1.67%, this Fe-C alloy is referred to as alloy steel. Because of the Si-added substance, which is 3.02%-3.34%, it has strong elasticity or ductility. Silicon gives steel sharpness and hardness, and its fiber characteristics make it heat resistant. The silicon addition must be of the appropriate composition because it makes steel brittle [13].

Mn alloy with a friction and pressure resistance range of 0.244% to 0.268%. A Cr alloy with 8.98% to 9.30% Cr provides corrosion resistance. Cr benefits from Si's frictional resistance as well. Simply having too much Cr makes it less ductile. Rust is eradicated, high temperature damage is avoided, and ductility and chemical resistance are all increased by adding Ni in the range of 0.153%-0.170% [14].

Because of the incorporation of the 0.06% Mo element, the steel becomes more ductile and has heat-resistant properties. The insertion of the V element between 0.039% and 0.047% provides the friction resistance properties at high temperatures. Even though it becomes brittle at high temperatures, the addition of the 0.026% to 0.03% Co element lowers friction. Co is utilized in the production of carbides, which improve strength and hardness at high temperatures. W elements are required for sharpness, resistance to high temperatures, and friction resistance.

4. Conclusions

Microstructure testing at the interface between the valve material region and stellite material is used to determine thermal fatigue corrosion. At the fissure's end, a deposit product with high-temperature corrosion attack properties is seen. The valve base material likewise suffers from high-temperature corrosion on the stellite layer, though the corrosion is caused by a combustion explosion, which has a similar impact. This hardness test shows how the hardness of the material steadily diminishes away from the valve. This indicates that the hardness of the valve will decrease as its useful life grows. Three (3) test samples yielded a minimum value of 229 HV in the valve stem position. The highest value for the location of the lip valve, which is frequently in contact with the insert, is 523. In the second sample test, where a value of 558 HV was observed, the lip valve position regularly comes into contact with the insert and is frequently traversed by exhaust gases. Despite having a 1.67% composition, this Fe-C alloy is nevertheless referred to as alloy steel. Because of the Si-added material of 3.02% to 3.34%, it possesses high elastic and ductility capabilities. A Cr alloy with 8.98% to 9.30% Cr provides corrosion resistance. Both Si and Cr provide friction protection. Adding Co components in the range of 0.026% to 0.03% decreases friction at high temperatures despite the fact that it becomes brittle.

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