COBEM 2023 27TH INTERNATIONAL CONGRESS OF MECHANICAL ENGINEERING

ABCM Brazilian Society of Mechanical Sciences and Engineering
27th ABCM International Congress of Mechanical Engineering
December 04-08, 2023, Florianópolis-SC, Brazil

COB-2023- 1478
FAULT ANALYSIS IN ROAD SPRINTER OM611

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Abstract. *The connecting rod, one of the main components of the engine, generates impressive results, since, together with the crankshaft, they manage to transform an alternating linear movement of the piston into a continuous circular movement. To fully perform its function, the connecting rod needs to be robust and resistant at the same time, to support the transmission of movement, and be light, so that the inertia of the system is reduced at each stage of the combustion engine cycle, improving its energy efficiency. The present study sought to understand the existing automotive connecting rods on the market, the operating principle and the most common mechanical failures, and from this, understand what preventive measures could be taken so that they have a longer useful life without compromising the function performed. The main objective of this work is to identify the main mechanical failures of the connecting rod/crankshaft system of the Mercedes Benz Sprinter OM611, through a visual inspection of 20 parts, presenting the possible causes, as well as proposing solutions and improvements in order to minimize them. Through the study it was possible to perceive that most of the mechanical failures in the system occur due to errors during use, such as excessive efforts, lack of lubrication, high temperature, lack of maintenance. When considering that engine maintenance, as a whole, has a high cost, it is believed that, through instructions for good use of vehicles, the final price attributed to consumers can be reduced and guarantee less interventions in the system from the elucidation of these failure mechanisms and investing knowledge to prevent these damages from occurring. With this article, we hope to reach a diverse audience and share knowledge in order to indicate better ways of use, damage prevention and, consequently, make the system something more durable and with less harmful impact on the final consumer. The data provided can be used in booklets made available along with the user manual, and documents that address the operation of engines or even in automotive maintenance centers.*

Keywords: Connecting rod, combustion engine, mechanical failures, visual inspection.

1. INTRODUCTION

An engine is made up of several parts, with a planned useful life, and a reasonable duration of change due to the efforts assigned to the system. However, premature failures can always occur, especially when recommendations and revisions do not follow those specified by the manufacturers.

One of the main parts, the connecting rod, is considered one of the critical components of an engine as it is responsible for transforming the alternating linear displacement of the piston into rotational displacement of the crankshaft. Therefore, the connecting rod is a component that must meet two technically contradictory criteria: it must be robust and resistant to withstand the efforts of this movement transmission and, at the same time, it must be light

enough to reduce the inertia of this mobile system when changes in direction occur at each stage of the motor cycle (ANAC, 2021).

The function of the connecting rod, shown in Figure 1, is to transform a rectilinear movement into a continuous circular movement. In combustion engines, the connecting rod is responsible for transmitting the force generated in the combustion chamber (received by the piston) to the crankshaft, which has the function of generating and sending torque, force and rotation to the transmission system (BARROS, 2017). That is, it is a fundamental part for the movement of the engine.

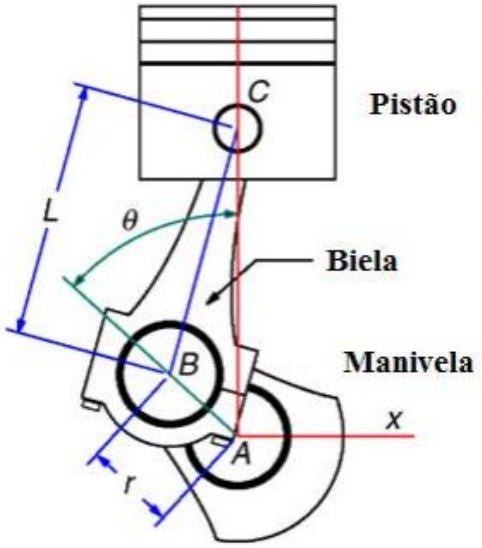

Figure 1. Side view of the Conventional Connecting Rod.

In order to fulfill its role and create this link between the piston and the crankshaft, the connecting rod is formed by a metal rod with two ends with holes of different diameters. The upper part of the connecting rod, called the foot, is fixed to the piston, by means of a pin that allows the oscillation of the movement. The bottom part, the head, is connected to the crankshaft, transmitting the circular motion. (BARROS, 2017).

Problems in the connecting rod can result in a malfunction of the vehicle, with the engine losing synchrony, known by the term “engine knocking”, which can have serious consequences for various components of the car. One of the signs of a possible connecting rod problem is the noise of an engine knocking. This noise may even disappear after a certain period of operation, but this does not mean that the problem has disappeared. The only way to know for sure if the defect is in the connecting rod is to disassemble the engine and check directly. Therefore, any sign of malfunction, or even a strange noise, the vehicle should be taken immediately to a trusted mechanic, to check the possible causes. Failure to resolve the problem can make the problem worse and increase repair costs.

The failure analysis process is of vital importance in the maintenance management of industries, as through it it is possible to identify the root causes of defects, as well as the damage mechanisms associated with them, establishing forms of prevention to avoid future damage to assets, directly contributing to the safety of facilities, people and the environment (PASSOS, 2019)

The objective of this work is to identify the main mechanical failures of the connecting rod/crankshaft system of the Mercedes Benz Sprinter OM611, through a visual inspection of 20 parts, presenting the possible causes, as well as proposing solutions and improvements in order to minimize them. Finally, guide all audiences who use means of transport using this mechanism, through forms of prevention to avoid damage and unnecessary expenses.

2. THEORETICAL REFERENCE

This reference will address connecting rods, citing the different types, their components and applications.

2.1 Manufacturing processes/materials

The vast majority of connecting rods is made of steel and is manufactured through the cold or hot forging process. In the manufacture of connecting rods, the hot process is the most interesting, to guarantee greater mechanical resistance for the piece.

SAE 4340 steel is generally used for hot forging of connecting rods, due to its characteristics of high mechanical and fracture resistance, high hardenability and high toughness.

In smaller quantities, they are also produced by the process of casting in pig iron. And in some cases, lighter materials, such as aluminum, can be manufactured using the machining process, which generates a higher cost, longer production time and lower resistance of the part, in return for a great reduction in weight.

2.2 Damage and failure analysis

Damage or failures can occur due to different circumstances, from mechanical failures to errors in maintenance, such as the lack of proper repair in the necessary time, or causing the process to efforts that are not supported.

Analyzing the surface of the structure of the piece in a more visible way, with the aid of magnifying glasses, associating it with the concept of factography which, according to Rezende (2007) is one of the main forms used after damage or failures to establish the differences and relationships between the presence or absence of fractographic aspects. Aspects that, with the analysis, can lead to determining the conditions of the efforts at the time the failure occurred.

The interaction between moving parts of the engine requires the presence of a small layer of lubricating oil that attenuates the friction between the parts. This friction reduction, in addition to improving engine performance, is essential to prevent shear wear and to reduce heat production.

Excessive heat is capable of altering the physical properties of metals, especially reducing resistance to compression and traction, and as a result, components will not be able to withstand the efforts necessary for engine operation. Darkening of the material demonstrates that excessive heating may have occurred, resulting in a material failure.

In plastic deformation there is a permanent change in its dimension, this happens when it passes the limits of elastic deformation. After the efforts suffered by the metal, it cannot return to its original shape, that is, it is the procedure where a permanent dimensional change occurs (FERRAMENTAL, 2023).

Brittle fracture occurs without appreciable deformation by rapidly propagating cracks. The direction of crack movement is nearly perpendicular to the direction of applied tensile stress, creating a relatively flat fracture surface.

The predominant factor for a fracture to be defined as ductile is the predominance of plastic deformation to the detriment of crack propagation, that is, ductile fractures have slow crack propagation and the stressed material tends to deform plastically. Ductile fractures usually occur in such a way that the stressed structure undergoes gradual compression in the stress region.

Fatigue failure starts with a crack (nucleation) or a small surface flaw that propagates by increasing in size due to cyclic demands. When the size of the crack increases to such an extent that the rest of the material can no longer withstand the applied stress, the part suddenly fails. (ESSEL, 2017)

2.3 The road

The connecting rod, shown in Figure 2, is an extremely important internal part of the engine. Its function is to transmit the pressure that is exerted by the gases, inside the cylinders, acting on the pistons to the crankshaft shaft.

Figure 2. Connecting rod mounted on the piston.

As it is an internal component of the engine, as shown in Figure 3, which works together with the pistons in the cylinders, due to combustion, the connecting rods are one of the components that suffers the most efforts. It is subjected to large loads ranging from high tensile loads due to inertia to high compressive loads due to the combustion process. (SILVA, 2019)

Figure 3. Connecting Rod Mounted on the Engine.

For proper functioning, the connecting rods depend entirely on the perfect functioning of other parts of the system, such as the crankshaft shaft and the pistons, shown in Figure 4, therefore, we can say that the set must be completely in tune for perfection.

Figure 4. Mounted Connecting Rod.

The conventional connecting rod, shown in Figure 5, has a process where the connecting rod and the connecting rod cap are produced separately.

Figure 5. Conventional Connecting Rod.

The fractured connecting rod, shown in Figure 6, has the process where the connecting rod and the cap are produced together, being a single piece that is later fractured, separating both pieces. One advantage is that, as it is made in a single piece, it is more uniform and less prone to deformation, in addition to being faster to produce.

Figure 6. Fractured connecting rod.

2.3.1 ROUND COMPONENTS

As mentioned, there are different types of connecting rods, each with its function resulting from the operating process that will be used and exerted on the piece.
The connecting rod that works on the Sprinter OM611 engine is composed as shown in Figure 7.

Figure 7. Connecting Rod Components.

1 - Connecting rod bushing
2 – Small connecting rod foot
3 - Bearing base hole
4 - Big connecting rod foot
5 - Connecting rod screw
6 - Bearing cover
7 - Connecting rod body

2.4 CHARACTERISTICS FAULTS OF THE CONNECTOR

Several factors in engine operation can lead to connecting rod failures. The set of engine components working irregularly, outside the specifications established by the manufacturer, can be crucial for the engine to present a connecting rod failure. The main failures are described in the following topics.

2.4.1 Failures due to lubrication

Main cause of problems that causes failure in connecting rods and occasionally in the connecting rod, piston, crankshaft assembly, the lack of lubrication can come from several factors.

The use of incorrect lubricating oil outside the specification results in greater friction and higher working temperature. Consequently, the components that make up the engine work outside their normal working conditions.

Proper maintenance helps to prevent premature wear. Performing the lubricating oil change in the correct period eliminates the possibility of the fluid losing its viscosity properties, important for carrying out one of its functions, which is the creation of a lubricating film between the moving parts.

Another fact that is essential is to keep the maintenance up to date with the change of the lubricating oil and due to the contamination of the lubricant by debris that are generated by the engine components. With the accumulation of such debris, the channels and galleries where the lubricant should travel can be obstructed, generating changes in the lubricating oil circulation pressure. Components such as the oil filter and oil pump are crucial in engine operation, with the function of maintaining lubricant circulation pressure. The pump creates a flow in the lubricating oil forcing it through the filter in order to retain any debris present in the oil.

2.4.2 Heating failures

The heating of the connecting rods can be due to the lack of proper engine cooling. Water pump, radiator, electric fans, heat exchanger, among other parts, all are extremely important for proper cooling of the system. Any inoperative component cited influences proper cooling which may raise proper operating temperature.

Failure to function properly will cause excess heat to alter the physical properties of metals, mainly reducing tensile and compressive strengths, causing the connecting rods to not withstand the efforts necessary for proper engine operation, resulting in material failure. (ANAC, 2021)

2.4.3 Failures due to warranty

Factors that lead to failures due to warping of connecting rods are failures that occurred in other components of the engine assembly, or external factors. One of the examples that can be cited is the occurrence of excess fuel injected into the combustion chamber, a fact that occurs due to a failure in the injector nozzle. There may also be a failure in the gasket between the engine block and the cylinder head, whose function is to obtain a perfect union of the block and cylinder head parts. The galleries of lubricating oil and coolant present in the engine can stop in the combustion chamber if the cylinder head gasket fails. Complementing by citing an external factor that can lead to a connecting rod warping is if excessive water aspiration occurs by the engine if it is taken to extreme conditions of use in inappropriate places.

3. METHODOLOGY

With the use of topics, we will identify the necessary steps for the analysis of failures that occurred in connecting rods of the Mercedes-Benz Sprinter OM611 diesel engine.

At first, through visual analysis, we will identify the anomalies presented in the connecting rod. After identifying the damaged parts, it is time to collect information through surveys. It is a step of great importance, since it will affect the entire context worked on.

In the next phase, a study is carried out with the collected data, associating it with what is visually analyzed in the piece.

With the alignment of all the previous steps, we will be able to define the probable causes that caused the part to fail.

Finally, we also understand that explaining preventive methods to end consumers makes them understand the importance of this act and, thus, helps prevent damage. In this way, we faithfully believe that the availability of educational booklets, together with a user manual made available by the dealerships, in addition to lectures on communication networks that address the operation of engines or even in automotive maintenance centers.

4. RESULTS AND DISCUSSIONS

The facts that lead to failures in connecting rods can be due to several factors as previously mentioned, one of the main facts that lead to failures in connecting rods we can mention the lack of lubrication. In Figures 8 and 9, one can see the failure of a connecting rod due to lack of lubrication.

Figure 8. Connecting rod with lack of lubrication.

Figure 9. Connecting rod with lack of lubrication.

In Figures 8 and 9, which shows a connecting rod that failed due to lack of lubrication, the wear that was generated on the part is clear. The following characteristics are observed due to lack of lubrication: scratches and wear on the bearings that always occur in the direction of rotation of the shaft. An irregular noise is usually observed in the operation of the engine when such a failure occurs.

Another failure that occurs in connecting rods is failure due to heating. The connecting rods that suffer failures due to heating have changes in their characteristics, one of the main ones and the clearest is the change in color located where there was a greater increase in temperature. What leads to overheating failure is the lack of engine heat exchange. A cooling system with irregular operation is one of the main causes that can lead to connecting rod failure due to heating. In Figures 10 and 11 you can see a connecting rod that suffered overheating.

Figure 10. Heated connecting rod.

Figure 11. Heated connecting rod.

We cannot fail to mention that after a connecting rod assembly error or wrong application outside the correct characteristics of the specific model, it may present failures due to heating due to excess torque or measurements outside the specified range.

Another fatality that can occur is connecting rod warping failure. This failure is common to happen due to failure factors of other components. In Figures 12 and 13, a bent connecting rod can be seen.

Figure 12. Warped connecting rod.

Figure 13. Warped connecting rod.

What leads a connecting rod to suffer failure due to warping is the occurrence of hydraulic wedge in the engine combustion chamber. Failures in fuel injection components, valve gasket burning that retains coolant and even external factors such as driving the vehicle in inappropriate places (flooding), can cause water to be aspirated by the engine. At the time of compression, if there is any liquid inside the cylinder, be it fuel, coolant or water, the volumetric capacity of the combustion chamber may not be enough to accommodate such liquids, causing failure in the connecting rod due to warping.

There is a case of failure of the connecting rod due to breakage, such failure can occur due to the symptoms presented above, such as lack of lubrication and heating, but it is more common that there is a failure due to breakage due to other factors such as: failures in the crankshaft shaft or in the camshaft can lead to this failure of the connecting rod breakage. Mounting or even application of wrong force, leads to such a failure. Part breakage can occur in different areas. In Figures 14 and 15, a broken connecting rod can be seen in its upper hole, also known as connecting rod foot.

Figure 14. Broken Connecting Rod.

Figure 15. Broken Connecting Rod.

5. CONCLUSION

As previously explained, the present study presented as a basis the importance of the connecting rod in the full operation of the engine and the analysis of how failures in this system can be harmful to the final consumer and the automotive industry. From the analysis of the prevalence of these failures, we tried to decipher the main causes of the defects, as well as the damage mechanisms associated with them. Forms of prevention were established to avoid future damage, contributing directly to the safety of facilities, individuals and the environment.

For better elucidation of the work, the methodology was systematized in the analysis of failures that occurred in connecting rods of the Mercedes-Benz Sprinter OM611 diesel engine. This study was systematized in visual inspection, data collection, fact analysis and problem definition.

At first, our study demonstrated from the visual analysis that excessive heating, as well as the lack of lubrication and the presence of hydraulic wedge were responsible for the main problems for inappropriate use. It is important to point out that our visual analysis was based exclusively on macroscopic visualization.

The other methodological steps were carried out based on detailed and structured bibliographical research. This made the elucidation of the main existing flaws possible to occur in a clear way and, with that, to unveil the preventive ways in which we can act in the future so that the system is always improved.

Thus, we can conclude that the best way to guarantee the effectiveness of the system, as well as the reduction of existing failures, is based on preventive maintenance. Keep the vehicle in good condition; periodically check the engine lubrication and cooling system, analyzing the oil and water level; pay attention to the notifications displayed on the panel; pay attention to leaks and abnormal system noises by immediately looking for a specialized professional to analyze and correct possible errors.

5.1 FUTURE STUDIES

It is suggested as future studies the expansion of the sample of connecting rods for a macroscopic analysis, associated with a micrographic analysis, to carry out a more adequate evaluation of the facts that occurred with the analyzed parts and the ways to manage to prevent such errors.

Another suggestion is to carry out FEA simulations of the failure modes of the connecting rod/crankshaft system to substantiate the theoretical causes of mechanical failures raised through visual inspection.

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7. RESPONSIBILITY NOTICE

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