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Crack Simulation of Diesel Engine Crankshaft Using Finite Element Method

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ABSTRACT

Crankshaft is a diesel engine component that often fails due to fatigue loading. The diesel engine crankshaft in this simulation uses a performance specification of 140 cv (cheveaux vapeur) at an engine speed of 4000 rpm and a displacement of 1963m^3. Crankshaft damaged crank pin and main bearing cap. The failure occurred after this vehicle traveled 180,000 km in use and through repairs for 8 years of use. Crankshaft failure is the root cause of internal damage in combustion engines. Based on the simulation results on a 4-cylinder diesel engine crankshaft using the finite element method using ANSYS Workbench 18.1 software, the equivalent stress (von mises) results are obtained with a maximum stress value of 445.72 MPa. The concentration of stresses in the crankshaft will result in the initiation of cracks which can propagate and result in fracture of the crankshaft. The stress concentration lies in the crankshaft fillet body where this part is very susceptible to cracking and breaking if the fillet design is not suitable or if an error occurs when the crankshaft is in the initial machining process. Stress concentrations at a certain point can also be caused by errors during the fabrication process

Keywords: simulation, diesel engine, crankshaft, finite element method

ABSTRAK

Crankshaft merupakan salah satu komponen mesin diesel yang sering mengalami kegagalan karena pembebanan fatigue. Crankshaft mesin diesel pada simulasi ini menggunakan memiliki spesifikasi performa 140 cv (cheveaux vapeur) pada putaran mesin 4000 rpm dan displacement 1963m^3. Poros engkol rusak pada pin engkol dan main bearing cap. Kegagalan tersebut terjadi setelah kendaraan ini menempuh jarak 180.000 km dalam pemakaian dan melalui perbaikan selama 8 tahun pemakaian. Kegagalan poros engkol adalah akar penyebab kerusakan internal pada mesin pembakaran. Berdasarkan hasil simulasi pada crankshaft mesin diesel 4 silinder dengan metode elemen hingga menggunakan software ANSYS Workbench 18.1, diperoleh hasil tegangan ekuivalen (von mises) dengan nilai tegangan maksimum sebesar 445,72 MPa. Konsentrasi tegangan yang ada di poros engkol akan menghasilkan inisiasi retakan yang dapat merambat dan mengakibatkan patahnya poros engkol. Konsentrasi tegangan terletak pada badan fillet crankshaft dimana bagian ini sangat rentan retak dan patah jika desain fillet tidak sesuai atau jika terjadi kesalahan pada saat crankshaft dalam proses pemesinan awal. Konsentrasi tegangan pada titik tertentu juga dapat disebabkan oleh kesalahan selama proses fabrikasi.

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Kata Kunci: simulasi, mesin diesel, crankshaft, metode elemen hingga

1. Introduction

The diesel engine is an internal combustion engine that burns a mixture of air and fuel in a cylinder. The diesel engine has a system similar to the gasoline engine that is used in most cars. . The diesel engine is a reciprocating engine, driven by a laterally moving piston. The parts in the majority of diesel engines are the same as gasoline engines, but diesel engines have a greater weight and have high strength to withstand large dynamic forces from high combustion pressure. Diesel engines have constituent components, such as cylinder heads, pistons, crankcase , exhaust blow, injector, and crankshaft

The crankshaft is a diesel engine component with a complex geometry in an internal combustion engine, which converts the reciprocating motion of the piston into rotary or rotary motion. Crankshaft is a machine component that has a high stress value and failure usually occurs due to fatigue (M.Srihari, 2016). The crankshaft in this diesel engine is found in certain vehicles that have a performance specification of 140 cv (cheveaux vapeur) at 4000 rpm engine speed and displacement of 1963m3. Crankshaft failed on the crankpin and main bearing cap. The failure occurred after this vehicle traveled 180,000 km in use and through repairs during 8 years of use [1]

Failure of the crankshaft is the root cause of internal damage to the combustion engine. Fatigue is a phenomenon caused by repeated loading with a stress level lower than the yield or ultimate strength of the material [1]. Shaft fracture begins at a point where there are high stress concentrations caused by faulty design of the shaft. Stress concentrations at a certain point can also be caused by errors during the fabrication process. The causes of shaft fractures can be seen macroscopically or microscopically. The cause can be seen from the signs seen in the shape of the fracture. The visible distortion in the fracture may indicate the occurrence of plastic deformation because it exceeds the yield strength [2]. Poor material selection can cause a decrease in the performance of crankshaft components because the maximum stress generated in the cylinder is very high [3]. Failure can also be caused by the age of components that have exceeded the limit [4].

The crack on the crankshaft is located in an area that has a high stress concentration. The crack will propagate on the crankpin until the final fracture occurs. By analyzing the causes of crankshaft failure, a simulation can be carried out with the aim of determining the stress distribution that occurs on the crankshaft.

2. Methodology of Research

2.1. Crankshaft Material

The crankshaft material must have high strength and ductility, generally made of steel, cast steel, or forged steel. The crankshaft being analyzed uses SAE/AISI 4340 material. The material has mechanical properties with a Density of 7870kg/m3; Young's Modulus 20000 MPa ; Poisson Ratio 0.29 ; Tensile strength 930 – 1080 MPa ; Yield Strength 740 MPa ; 12% elongation [1]

2.2. Finite Element Method

The finite element method is a numerical method that can be used as an accurate solution to complex technical problems. This method is widely used to solve engineering and mathematical problems of physical phenomena. FEM is used to predict stresses, deformations and fractures that occur with steps such as designing, determining the mesh, applying force/loading to executing and obtaining simulation results [5]

Simulations were carried out on the crankshaft to determine the stress that occurs using ANSYS Workbench 18.1 software. During the simulation, the crankshaft is given a maximum moment of 320 N.m. The analysis obtained from the simulation shows the results of stress and deformation when the maximum moment is given. The results of the analysis can be used as a basis for determining where the stress concentration occurs which is the beginning of the crack initiation.

Meshing is the process of dividing the components to be analyzed into small or discrete elements. The better the quality of the mesh, the higher the degree of convergence.

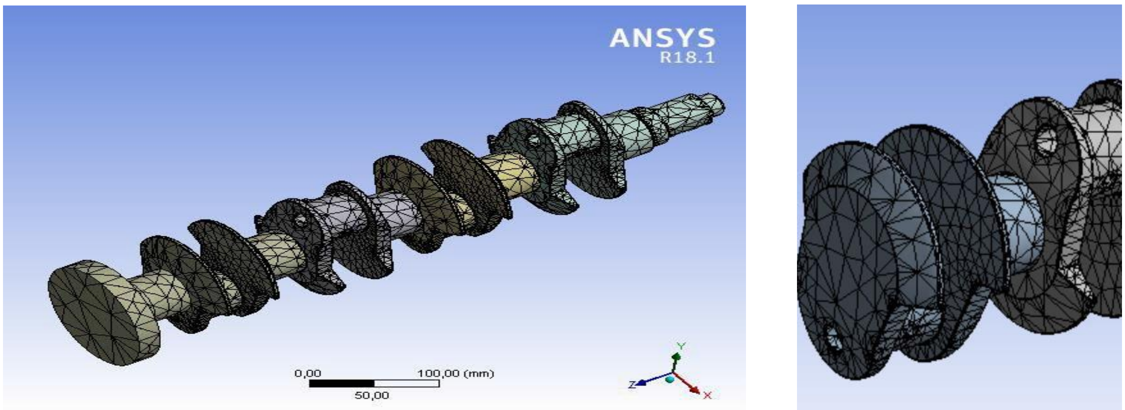

Figure 1. Crankshaft Design and Meshing Process

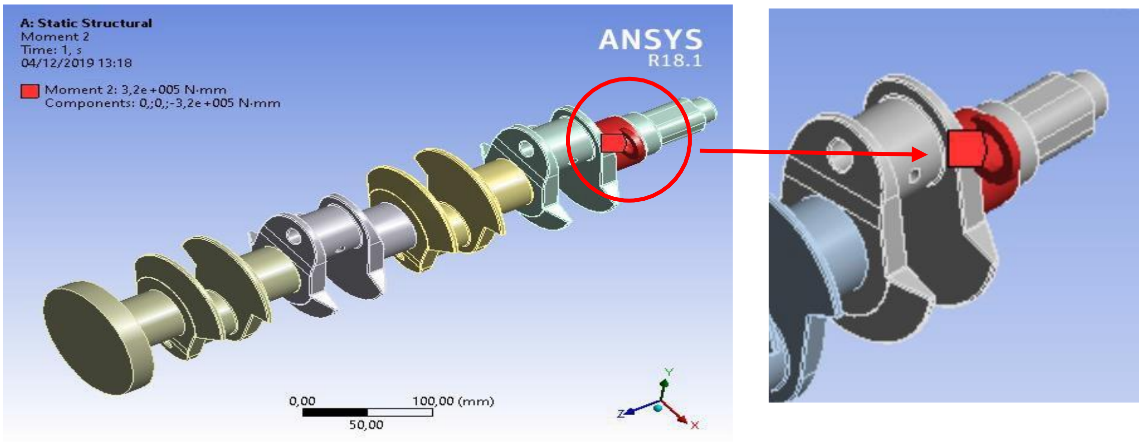

Figure 2. Position the Moment on the Crankshaft

3. Result and Discussion

3.1. Equivalent Von Misses Stress

Figure 3 shows the results of the crankshaft simulation at equivalent (von mises) stress. The maximum stress is shown in red on the crankshaft with a result of 445.72 MPa, and the minimum stress is shown in blue with a result of 3.1489 × 10-5 MPa. The simulation shows the location where the stress concentration occurs on the crankshaft. The part that has stress concentration is the location that is prone to crack initiation.

Cracks will be initiated where the stress concentration is located. In that part, cracks can propagate and cause fracture of the crankshaft until failure occurs in the diesel engine, this is in line with the opinion of the ASM Handbook Failure Analysis and Prevention, namely, Fractures on the shaft begin at the point where there is a high concentration of stress. Cracks in the crankshaft are also caused by continuous stress concentrations and result in surface fatigue. The actual strength of the material is always lower than the theoretical value because most materials contain small cracks which cause stress concentrations [4].

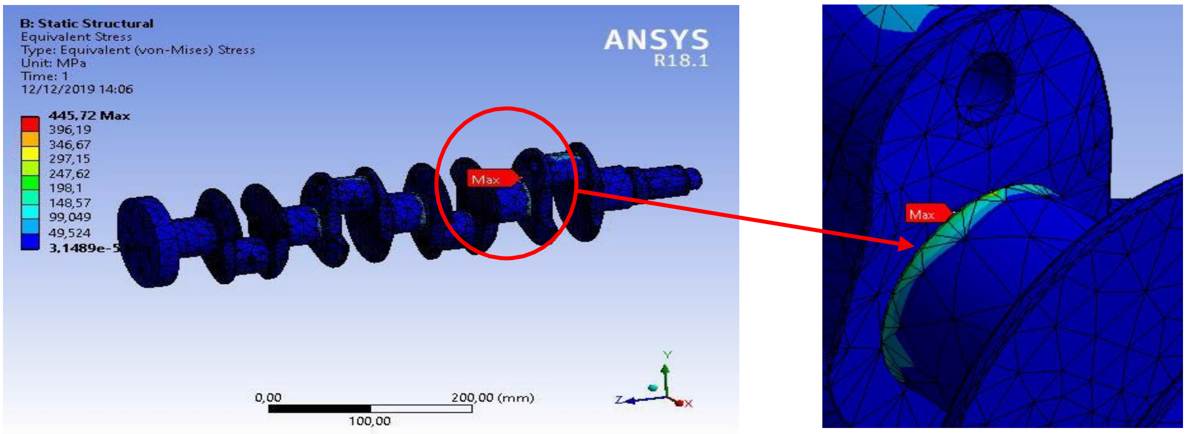

Figure 3. Equivalent (von Mises) stresses on the crankshaft

4. Conclusion

Based on a simulation on a 4-cylinder diesel engine crankshaft using the finite element method using ANSYS Workbench 18.1 software, the equivalent (von mises) stress results are obtained with a maximum stress value of 445.72 MPa. Stress concentrations present in the crankshaft will result in the initiation of cracks which can propagate and result in fracture of the crankshaft. The stress concentration lies in the fillet web of the crankshaft where this part is very susceptible to cracking and fracture if the fillet design is not suitable or if an error occurs when the crankshaft is in the initial machining process. Stress concentrations at a certain point can also be caused by errors during the fabrication process [2].

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