11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Fatigue Life Analysis of an Upgraded Diesel Engine Crankshaft

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Key Words: *Crankshaft fatigue analysis, Connecting rod dynamics, Upgraded engine, URM standard, Finite Elements Analysis.*

Abstract. In this article, a 6 cylinder diesel engine is investigated. Engine power is upgraded via engine rpm increase from 2000 to 2600, change in fuel injection and valves timing. To study the effects of power upgrade on engine life, a fatigue life prediction was performed for the crankshaft in two cases of original and upgraded engine. Firstly, regards to connecting rod movement mechanism and using gas pressure inside the cylinder, the dynamic forces excreted on two sides of connecting rod over a complete cycle of combustion are calculated. After dynamic analysis, the fatigue analysis is carried out by two methods; the first is using URM standard. After calculating forces and applying torques, the safety factor in three important areas of the crankshaft namely, crankpin fillet, oil orifice and journal pin fillet was estimated in two cases of original and upgraded engine. The second method used the common finite elements analysis and fatigue life prediction via stress. Finally, the two methods are compared.

Dynamic analysis of forces applied to the crankshaft assembly

Crankshaft suffers a large force from combustion chamber via connecting rod. The magnitude of this force depends on various factors such as crankshaft radius, connecting rod size, connecting rod weight, piston and etc. The applied forces on crankshaft can be calculated from applied forces on crankshaft and equilibrium equations.

For calculating applying forces to the connecting rod over a complete combustion cycle, a MATLAB code was developed and all resulted equations were applied. Inputs to this code are the engine configurations under the study. The input to the code is gas pressure inside the cylinder for crankshaft angle over a complete combustion cycle which is 720 degrees of crankshaft rotation. Applied forces to the connecting rod are directly dependant to the engine rpm and also gas pressure inside the cylinder varies by rotation angle so affecting the forces.
Calculated forces applied to connecting rod in three RPMs of 800 as idle speed, 2000 and 2600 respectively as original and upgraded engine's maximum speed are illustrated in Fig1.

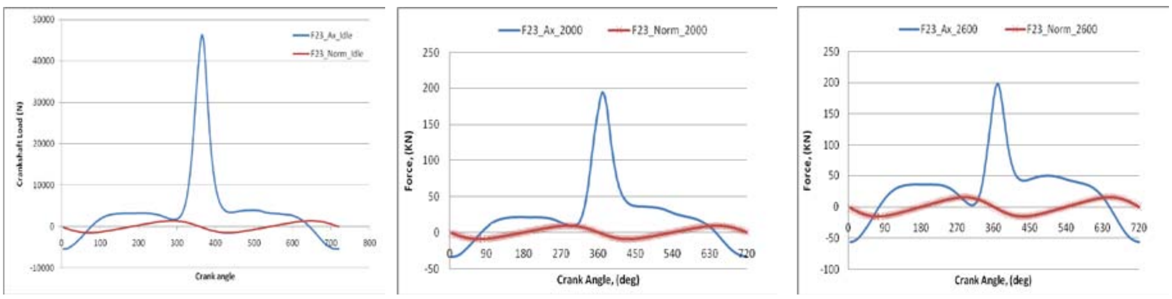

Figure 1. Axial and Normal Loads on Connecting Rod big eye (800, 2000 and 2600 RPMs)

URM 53 standard fatigue analysis

Tables 1 and 2, illustrate URM 53 safety factor in 5 important working speeds for original and upgraded engines, respectively.

Table 1. URM 53 Safety Factor, Base Engine

Location/RPM	RPM 800	RPM 1260	RPM 1600	RPM 1820	RPM 2000
Q_Cpin fillet	3.503	2.561	1.872	1.482	1.189
Q_Cpin oilbore	5.057	3.602	2.713	2.143	1.715
Q_Cpin journal	4.202	2.995	2.116	1.669	1.348

Table 2. URM 53 Safety Factor, Upgraded Engine

Location/RPM	RPM 800	RPM 1260	RPM 1600	RPM 1820	RPM 2000
Q_Cpin fillet	4.127	1.607	1.056	0.840	0.737
Q_Cpin oilbore	6.031	2.405	1.564	1.262	1.125
Q_Cpin journal	4.883	1.768	1.158	0.914	0.787

Crankshaft Modeling. The crankshaft was modelled by SOLID WORK software. HYPERMESH software is used as mesh generator. After meshing, the finite element analysis was handed to Abaqus. For quasi-dynamic analysis, 25 analyses were performed in different angles. Fig. 2 and 3 illustrates von misses stress contour for base and upgraded engine respectively. Fig. 3 compares the most critical stress variation for base and upgraded engines.

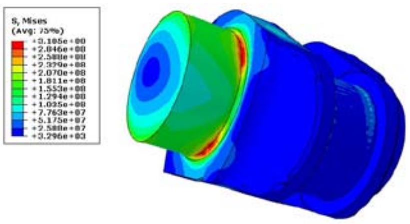

Figure 2. Von Misses Stress contour for base engine(angle 370, 2000 RPM)

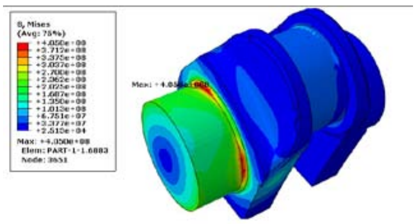

Figure 3. Von Misses Stress contour for upgraded engine(angle 400, 2600 RPM)

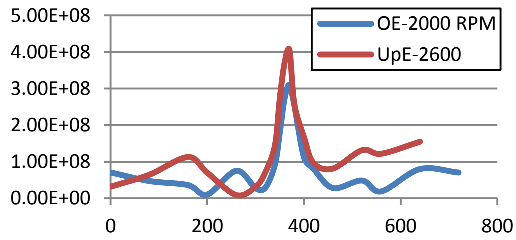

Figure 4. Stress History(original & upgraded engine)

Fatigue Analysis

Stress analysis result from Abaqus is feed as a readable file to FEM/FAT. According to stress analysis result, critical areas are specified and these areas are considered for the rest of analysis. As all know, crankshaft is a component which endures some repeated loads with lots of cycles and as this component is designed in a way its stress stays in elastic area, its fatigue is of type high cycle. So, stress base high cycle fatigue criterion is used for fatigue life prediction. Affecting parameters are put in the solution. As in mentioned velocities, stress results showed maximum values, fatigue was predicted for the case in which loads are applied in combination of these three velocities. Table 3 summarizes safety factor calculated by different theories in five RPMs for original and upgraded engine.

Table 3. safety factor in engines at different RPMs

	800	1260	1650	1600	2075	1820	2350	2000	2600
Original engine	3.53	2.78	-	2.09	-	1.611	-	1.323	-
Upgraded Engine	4.25	-	1.678	-	1.227	-	1.08	-	0.99

Conclusion

As URM standard is naturally more conservative and this standard considers infinite life time for crankshaft, the component in this research failed in lower, while the method of stress analysis in life prediction showed different numbers, showing fail in only upgraded engine at 2600 RPM. For the upgraded engine the component life time has been decreased more than 100 times which may be due to combustion pressure, RPM increase and subsequent inertia and torque loads increase. The component has been acceptably designed for original engine.