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Con-Rod Accelerations, Forces & Displacements

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1. Introduction

Automobile internal combustion engine connecting rod is a production component subjected to complex loading. Proper optimization of this component, which is critical to the engine fuel efficiency and more vigorously pursued by the automotive industry in recent years, necessitates a detailed understanding of the applied loads and resulting stresses under in-service conditions. The report is written to analyse the accelerations, forces and displacements of the conrod. All the basic certain data is given or measured on FORD 1.6N/A engine, then some modified data are created after the calculation to improve the performance of engine. By calculating them with EXCEL, some visual graphs are produced, on which we could directly compare the changes between them. Ultimately, the modified data has been checked by calculating the nominal static safety factors.

2. Data

	Production engine	Modified engine	
Cylinder Bore	0.079	0.079	m
Con-rod Length (L)	0.134	0.124	m
Crank Radius	0.0407	0.047	m
RPM	6000	6000	
Con Rod CSA	0.000136	0.000136	m²
Cylinder Pressure	AVRG P	1.2*AVRG P	Bar
Piston mass	0.3504	0.3504	Kg
FORCED STEEL UT	1200	1200	N/mm²
Youngs Mod of steel	210000	210000	N/mm²

Fig2.1 Production engine data and modified engine data

3. Peak gas forces

Force = Pressure * Area

Production engine: Peak gas force= Peak Pressure*Bore Area

F gas = 9560600 * PI * 0.079^2 / 4

=46862.91N

Modified engine:

$$F_{gas} = 9560600*1.2*PI*0.079^{\wedge 2}/4$$

$$=56235.49N$$

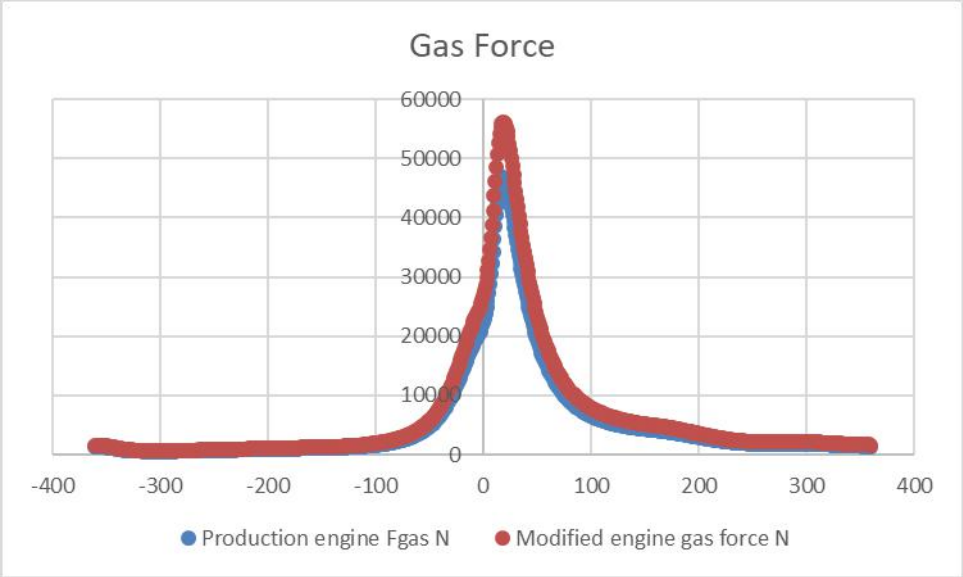


Fig3.1 Gas force vs crank angle@6000RPM

The graph shows that higher cylinder pressure will bring greater gas force. The greatest gas force both production engine and modified engine occurs on almost 20 degrees.

4.1 First order inertia loads

$$1st\ Order\ Inertia = M_{piston} R\omega^2 Cos\theta$$

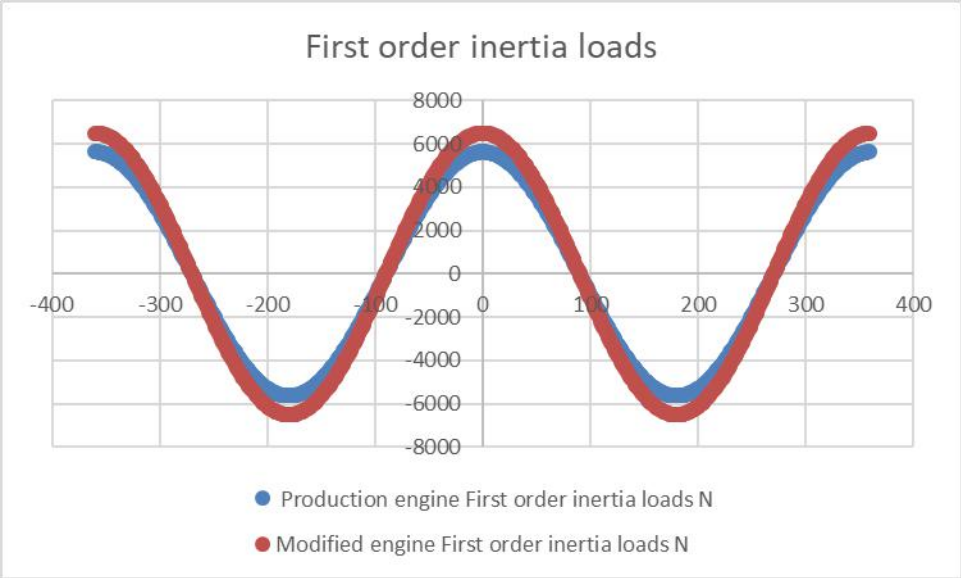


Fig 4.1 First order inertia loads vs crank angle@6000RPM, modified engine is greater than production engine.

4.2 Second order inertia loads

$$2nd\ Order\ Inetia = M_{piston} \left(\frac{R}{l}\right) R\omega^2 Cos2\theta$$

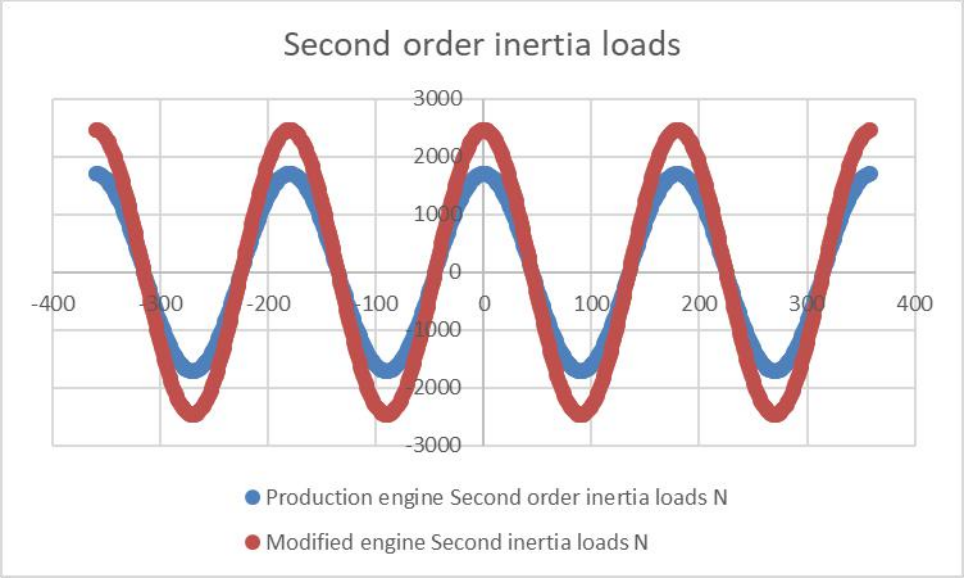


Fig 4.2 2nd order inertia loads vs crank angle@6000RPM, which shows modified engine is bigger than production engine.

4.3 Inertia loads

$$Finertia = (M_{Piston}(R\omega^2 Cos\theta)) + M_{piston}(\left(\frac{R}{l}\right) R\omega^2 Cos2\theta)$$

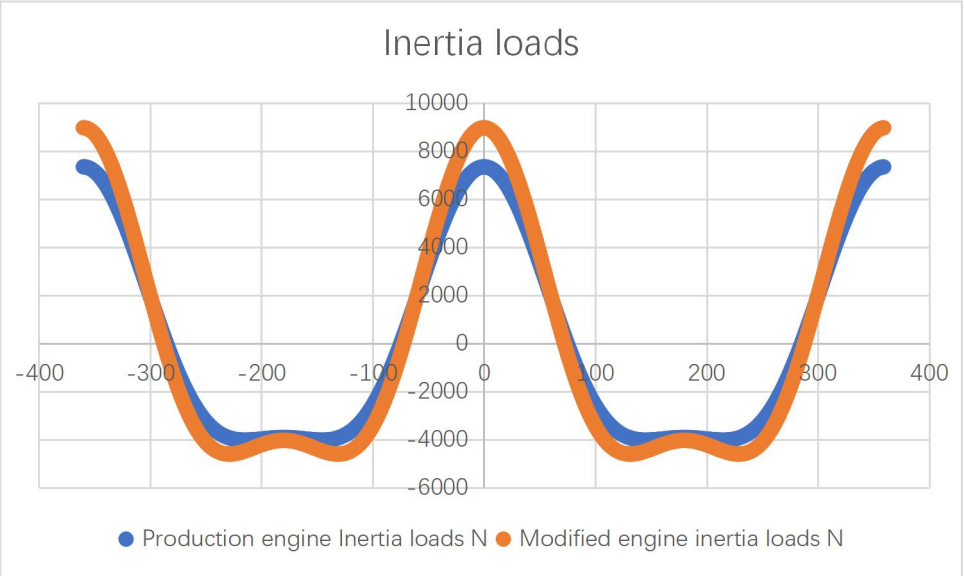


Fig 4.3 The total inertia loads vs crank angle@6000RPM, modified engine inertia loads obviously greater than the production one

5. Net compressive force

$$F_{CNet} = F_{Gas} - F_{Inertia}$$

The net compressive force which is equal to gas force minus total inertia loads is important because of these two forces involved during piston travel.

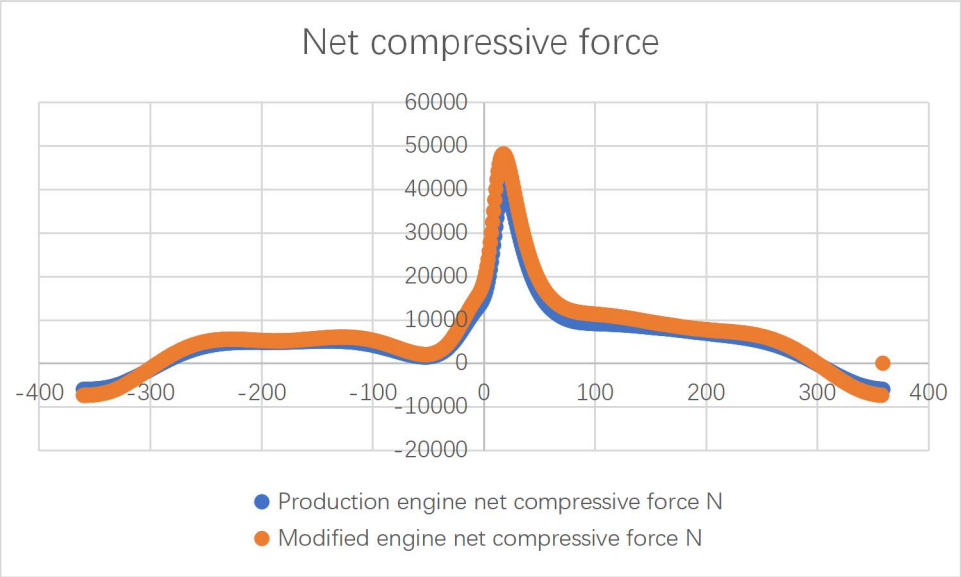


Fig5.1 Net compressive force vs crank angle@6000RPM

Then the results of max net compressive force have shown @ 6000RPM @19°

Production engine: 40188.79N

Modified engine: 48058.4N

6. Net tensile loads

Actually, the net tensile force on rod will be the highest with the piston stop @TDC. Then the crank angle is 0°.

$$F_T = M_{Piston} R\omega^2 \left(1 + \frac{R}{L}\right)$$

@6000RPM @0°

Production engine: Ft = 0.3504* 0.0407* (20PI)^2(1+0.0407/0.134)

$$F_T = 7340.21N$$

Modified engine: Ft = 0.3504* 0.0470*(20PI)^2(1+0.0470/0.124)

$$F_T = 8965.99\ N$$

7. Stresses

With the data measured, the cross-sectional area (CSA) is 0.000136m^2.

Maximum compressive stresses occur at 6000RPM and it could be calculated as the net force divided by CSA.

Production engine: $\sigma = \frac{40188.79}{0.000136} = 295505808.8 N/m^2$

Modified engine: $\sigma = \frac{48058.4}{0.000136} = 353370588.2\ N/m^2$

With the same way Max tensile stresses occur at 6000RPM could be calculated

Production engine: $\sigma = \frac{7430.21}{0.000136} = 53972119.4 N/m^2$

Modified engine: $\sigma = \frac{8965.99}{0.000136} = 65926397.1 N/m^2$

8. Safety factors

The ratio of a structure's absolute strength (structural capability) to actual applied load; this is a measure of reliability of a particular design. This a calculated value, and is sometimes referred to, for the sake of clarity, as a realized factor of safety.

Compression factors of safety:

$$Safety\ Factor = \frac{UTS}{\sigma}$$

Production engine: 1200000000/295505808.8= 4.06

Modified engine: 1200000000/353370588.2= 3.40

Tensile factors of safety:

Production engine: 1200000000/53972119.4= 22.23

Modified engine: 1200000000/65926397.1= 18.20

The results show that safety factors are always much greater than 1, which means the strength is much bigger than stress.

9. Compression distance and stretch

A connecting rod works in variably complicated conditions, and is subjected to not only the pressure due to the connecting rod mechanism, but also due to the inertia

forces. It is affected by the fatigue phenomenon due to the reversible cyclic loadings. When the repetitive stresses are developed in the connecting rod it leads to fatigue phenomenon which can cause dangerous ruptures and damage. The strain could be calculated as all the compressive forces and tensile forces have been acquired and the Youngs Mod of steel is 210 N/mm² @6000RPM. The dimensions for the shank at its thinnest section is measured as 100mm.

Stress= E* Strain

Strain= Stress/ E

Stress= F/ A

Compression distance:

Production engine: 40188.79* 0.100/210000000000/0.000136= 0.00014m

Modified engine: 48058.4*0.090/210000000000/0.000136= 0.00015m

Stretch:

Production engine: 7430.21*0.100/210000000000/0.000136= 0.000026m

Modified engine: 8965.99*0.090/210000000000/0.000136= 0.000028m

Due to the rod being short, strain should have been less but not. The inertia force is greater too and author should choose a better rod length definitely which is shorter to ensure the strain less.

10. Titanium engine

High strength, low density and excellent corrosion resistance makes titanium an excellent choice for lightweight Automotive application. Titanium is an excellent material for high performance conrods. With the same strength and half the weight of Steel, Titanium is very effective for designing lightweight conrods. Here author will analyse the difference compressive distance and stretch between the Titanium and steel@6000RPM. And the data about Titanium is given.

UTS (titanium)= 950 N/mm² Youngs Mod of titanium= 110000 N/mm²

Density= 4500kg/m^3

Compression distance:

Production engine: 40188.79* 0.100/210000000000/0.000136= 0.000147m

Modified engine: 48058.4*0.090/110000000000/0.000136= 0.000289m

Stretch:

Production engine: 7430.21*0.100/210000000000/0.000136= 0.000025m

Modified engine: 8965.99*0.090/110000000000/0.000136= 0.000054m

By calculating the data author could find the titanium offer better strength properties both compression and tensile on conrod.

11. Conclusion

In this paper author have investigated the forces and stresses on conrod which include different two types of them, compression and tension. Author could directly find the changes between production engine and modified engine and compare them. Meanwhile, safety factors and new material are calculated to analyse the property of conrod. After it, FEA will offer better accuracy in stresses on conrod, and stresses analysis will be visual.