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INFLUENCE ENGINE FIRING ORDER IN REACTION OF THE MEAN CRANKSHAFT JOURNALS

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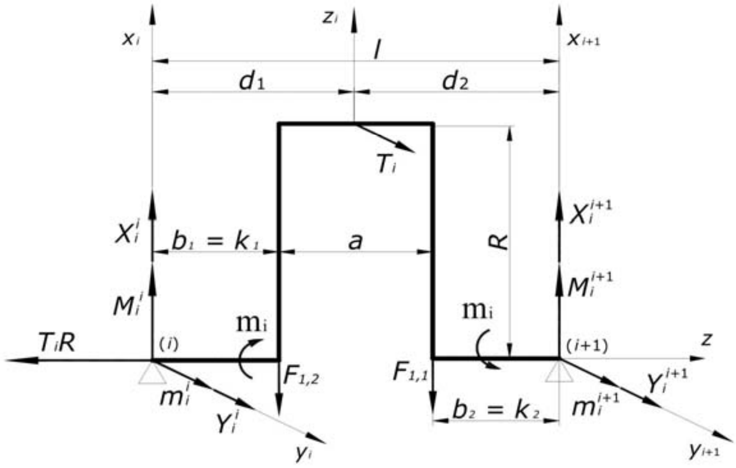
ABSTRACT
In practice during repair of engines crankshaft, as well as during its impairment, we face up phenomena of high intensity wear or malfunction on the crankshaft journal that is located close to the front of the rear crankshaft journal, in direction of power transmission. This happens due to the elevated load concentrated on that crankshaft journal.
Determination of forces and torques that act on the crankshaft journals can be derived from various methods that can be found in literature.
Determination of forces and torques that act on the crankshaft journals firstly requires determination of forces that act on components of engines mechanism: piston, connecting rod and crankpins of the crankshaft.
In this paper, calculation of reactions on crankshaft journals is done according to literature [1], where in computation of reactions on the crankshaft journals; the effects of detached parts of the crankshaft is taking into consideration by substituting them with torques located above the supporters, in the analyses rod. This is a method that differs from classical methods, in which the effect of other rods of crankshaft is not taken into considerations
In this paper, a concrete case of Perkins P4 Massey Ferguson engine is analyzed.
In this engine are determined two possibilities firing order.
The calculation is performed for working ranges of engines operating with load, rotations n_e =1600 rpm and power P_e = 36.8 kW, using method of torques substitution.
Key word: Internal combustion engine, engine dynamics, crankshaft, and reaction forces on the crankshaft journals.

1. DETERMINATION OF FORCES THAT ACT ON THE CRANKSHAFT

In this paper, is analysed only the case of crankshaft of a engine in which the transmission of power is done in one direction.
Right coordinate system **xyz** is immovably connected to the crankshaft. Plane of the elbow concurs with the **xz** plane; **z** axis is oriented in a way that if observed from the end of **z** axis, rotation of the crankshaft is contra clock wise. The torques, in accordance to the laws of mechanic for orthogonal coordinate systems are represented in vectorial forms.
In the presented case from figure 1, subscript is the number of elbows, while superscript is the number of supporters. Explanations of used indices are as follows:
$\mathbf{Z_i}$, $\mathbf{T_i}$ – radial and tangential force that affects the i elbow of the crankpin, including the inertial force of the elbows supporters itself.



$X_i^i, X_i^{i+1}, \mathbf{Y_i}, \mathbf{Y_i^{i+1}}$ - components of reactions on the main supporters in the i elbow , on the respective planes

F_i, X_i, Y_i -resultant reaction of the crankshaft journal in the i supporter and his projections.

All the components of forces will be assumed as positive, if their direction matches with the positive direction of the parallel coordinate axis.

Figure 1. Schematics of i elbow of the crankshaft

$m_i^i, m_i^{i+1}, M_i^i, M_i^{i+1}$ - torques above the supporter of the elbow, in the respective planes.

Torques above the supporters are positive, if their vectorial direction matches with the positive direction of the respective coordinate axes.

m$_i$ –Torsion torques given to i elbow, through the crankshaft journal that is furthest away from the position where the delivery of power takes place. If there is only one place of delivery, the torque **m**$_i$ is determined through calculations of the dynamics. Positive direction of the torque **m**$_i$ is given in the Figure 1.

$\varphi_i^i, \varphi_i^{i+1}, \phi_i^i, \phi_i^{i+1}$ - angles of rotation.

Angles of rotation of the section plane above the supporters are positive, if when they are observed from the end of the respective coordinate axis, are seen to be rotating contra clock-wise. Angles of rotation are given in the vectorial form according to the same rules as the torques; in that way positive vectorial angles φ and ϕ match with the positive direction of coordinate axis

β_i - Angles between elbows (indices given in the [2]).

2. CONDITIONS OF CONTINUALITY ON THE SUPPORTERS

For determining torques on the supporters, ensuing correlations, which can be expressed for any crankshaft journal, must be used:

a) Torques resultants m_{i-1}^i i M_{i-1}^i are equal by intensity and direction with torques resultants m_i^i i M_i^i but have converse orientation. If we project vectors of all torques on the coordinate axis of $(i-1-es)$ elbows journal, we have following results:

$$m_{i-1}^i + M_i^i \cdot \sin\beta_i + m_i^i \cdot \cos\beta_i = 0 \qquad \ldots (1)$$
$$M_{i-1}^i + M_i^i \cdot \cos\beta_i + m_i^i \cdot \sin\beta_i = 0$$

b) Angle of rotation of the i section plane in relation to two corresponding normal direction is determined from relation that they are equal for i and $(i-1)$ elbow. By projecting angle of rotation on the coordinate axis of the $(i-1)$ elbow we have :

$$\varphi_{i-1}^i = \varphi_i^i \cos\beta_i + \phi_i^i \sin\beta_i \qquad \ldots (2)$$
$$\phi_{i-1}^i = -\varphi_i^i \sin\beta_i + \phi_i^i \cos\beta_i$$

Relations deduced from equations 1 and 2 [2] are important during crankshaft calculations, having the same level of significance as three torques relations derived from the calculation of the indeterminate beams.

After the determination of the torques located above the supporters, the problem is reduced on the determination of the statically undetermined crankshafts with only one elbow.

3. CALCULATION RESULTS

Engines technical characteristics	Technical data
Number of cylinders	4 in line
Bore	91.4 mm
Stroke	127 mm
Engine swept volume	3.33 l
Maximum brake power	36.8 kW
Maximum RPM	1600
Main cinematic characteristic	λ=R/L=0.28
Material	E=55000 N/cm^2; G=180000 N/cm^3
Crankshaft journals diameter	d_R=70
Crankpins diameter	d_r=57.3
Piston group mass	m_p=1.32
Connecting road mass	m_b=1.68
Angle between elbow 1 and 2	β_{12}=180^o
Angle between elbow 2 and 3	β_{23}=0^o
Angle between elbow 3 and 4	β_{34}=180^o

For determining the crankshaft of the Perkins P4-Massey Ferguson four cylinder, four stroke engine, which is three time statically undetermined (five crankshaft journals and four crankpins) following values are known

Perkins P4-Massey Ferguson engine crankshaft dimensions with right hand coordinate system xyz, immovable connected to the crankshaft, are presented in the figure 2

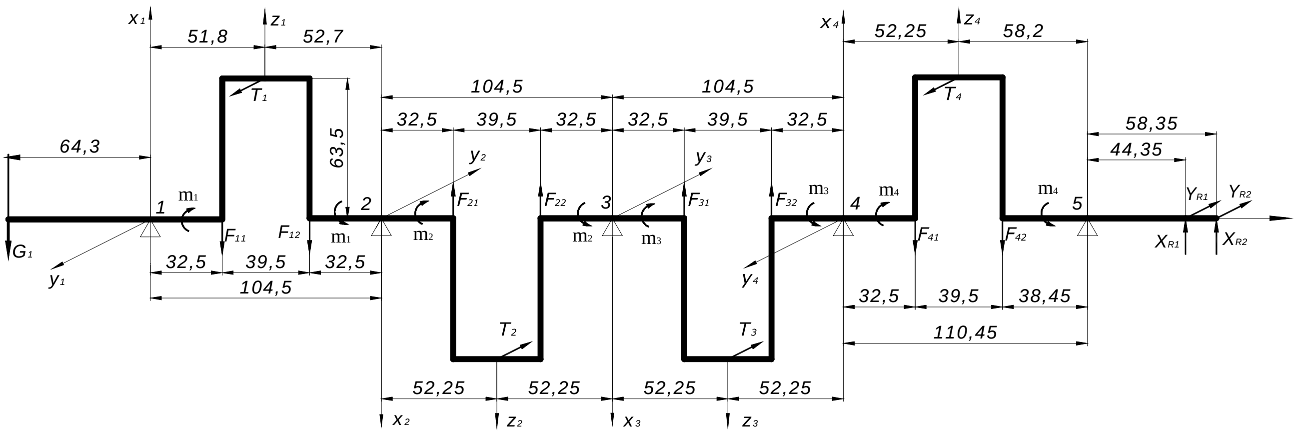


Figure 2. Crankshaft

In the figures 3, 4, 5, 6 and 7, the resulting diagrams of reactions for the all five main (supporting) journals are given, calculated by using method of torques located above the supporters for first case (firing order 1 – 3 – 4 - 2) and second case (firing order 1 – 2 – 4 -3).

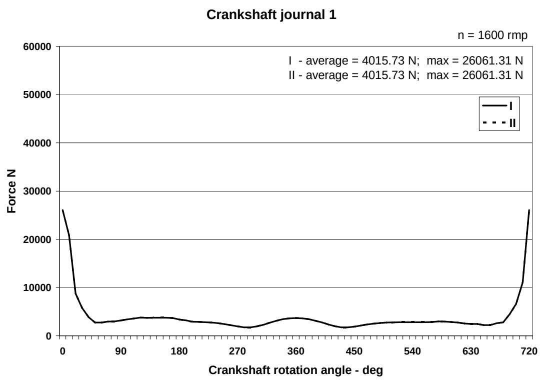


Figure 3. Crankshaft Journals 1

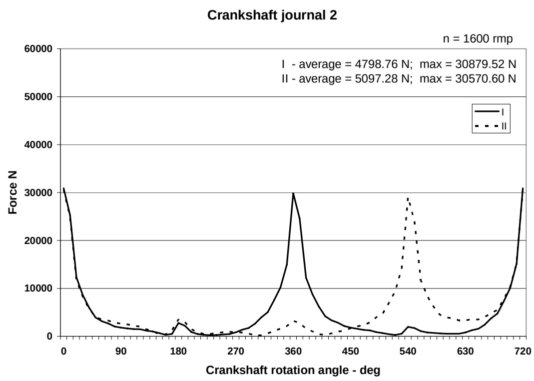


Figure 4. Crankshaft Journals 2

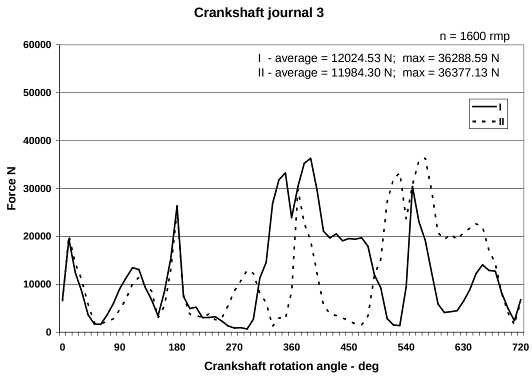


Figure 5. Crankshaft Journals 3

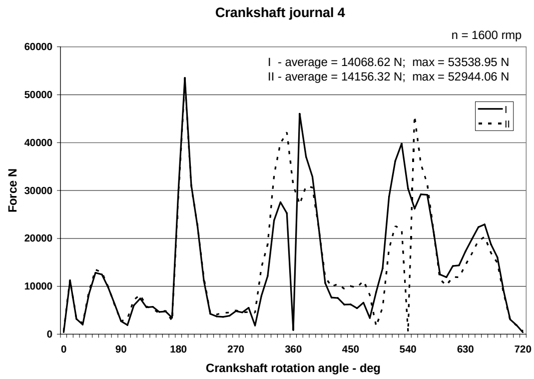


Figure 6. Crankshaft Journals 4

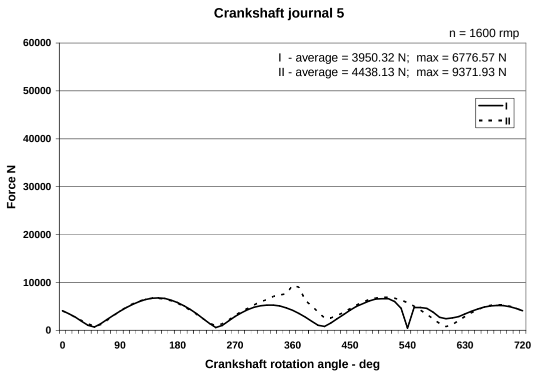


Figure 7. Crankshaft Journals 5

4. CONCLUSIONS

According figure 1 changing reaction of support 1 is same for case I and II.

For supports 2, 3, 4 and 5 observe change, which are more accents at critic support 4.

In support 2 we have unfazed between angles 360 to 540 crankshaft rotation angle while amplitude are approximately similar.

In support 3 also shown unfazed same with support 2 but now medium and maximal forces is for one value little.

In support 3 also shown unfazed same with support 2 but now medium and maximal forces have little small value for case II.

At support 4 we have great changing of loading with changing firing order. Medium value of reaction in supports is the greater for case II, but maximal value is shown in case I. Difference are for 0,16 % respectively 0,17 %.

In support 5 can not observed load unfazed although from angle 300 to 690 crankshaft rotation angle shows changing loads where for case II the loads are more greater.

5. REFERENCES

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