The Evaluation of the Joist Elastic Line with No Right Axis

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Abstract **:- Complex shapes of some joist with no right axis and difficult working conditions have dictated the need for accurate estimates of the elastic line deformation of their support necks in order to increase the accuracy of assessing job security during use.**
In the study was taken crankshaft of engines with four times and four cylinders. Theoretical methods of calculating elastic line crankshaft necks, because of concessions made to the physical model as well as the homogeneity of the material assumptions, completeness and isotropy produce deformations results that have a difference with a real detail.
In this case these divergences depend not only on the form and crankshaft constructive properties, but the conditions of support, material and technology of its preparation. For these reasons the crankshaft test no used in the models, but experimental test in natural size, where loading conditions to be closer to those of real use.
Results of experimental measurements performed in 4 crankshaft s show that the real values of the elastic deformation of line compared with the theoretical method for spheroidal crankshaft cast iron GS BM 60-2 have a big change that goes up to 85%. For this purpose during the calculations of loads and solidity due to deformation of supports to this type crankshaft it should be used the corrective coefficient 1.85

Keyword: **corrective coefficient, crankshaft, deformation of the elastic line**

I. INRODUCTION

In the technique have many cases, of the use of joist with no right axis in plan and space. One important detail that has the shape of a joist with no right axis and used in engines is the crankshaft . Crankshaft form is different depending on the type of engine and the number of cylinders. We will treat the crankshaft of engines with four cylinder with four stroke, which have the form with the cranks in plan, shown in Fig. 1.

Fig. 1 Crankshaft of tractor 75 HP

It consists of five main journals that are on one axis and serve as points of support in the engine body and the four journals of piston rod that are dislocated in the same distance with the radiance of crank. These journals are related with eight crank throw of crankshaft.
During the work of engine on the crankshaft transmitted the pressure gas forces and inertia forces of components details of the piston rod- crank mechanism, which differ for each position of the crankshaft . Due to the action of different loads on the bearings supporting, they and journal have a different consumption, which causes that support of joist are not on an axis. Axis shifts of support can also come due to deformation of crankshaft and support bearings, during initial assembly
This affects the changing forces acting on the main journal and moments acting on crank throw of crankshaft . Physical model of crankshaft for calculation is shown in Figure 2. It represents a break joist, which consists of several joists with constant section, but different from each other, which have four support , being three times statically undetermined [1].

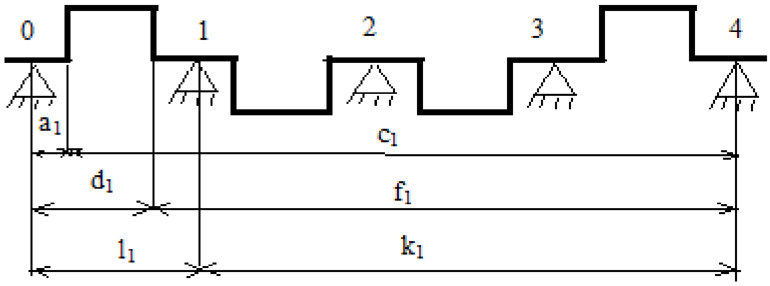

Fig 2 Calculation scheme of the crankshaft

Constructive data of crankshaft get in the study are given in table 1 [2],

Table 1

R mm	l mm	Ψ_a	EJ dN/ mm2	l_1 mm	l_2 mm	l_3 mm	k_1 mm	k_2 mm	k_3 mm
76	**752.5**	**8.339**	**537.6**	**183.7**	**369.9**	**556.1**	**568.8**	**382.6**	**196.4**

a_1 mm	a_2 mm	a_3 mm	a_4 mm	c_1 mm	c_2 mm	c_3 mm	c_4 mm
46.3	**229.5**	**413.7**	**601.9**	**706.2**	**523**	**333.8**	**150.6**
d_1 mm	d_2 mm	d_3 mm	d_4 mm	f_1 mm	f_2 mm	f_3 mm	f_4 mm
137.9	**321.1**	**510.3**	**693.5**	**613.6**	**431.4**	**242.2**	**59**

The precise determination of deformation of the support points impact in the exact dynamic and constructive calculations of crankshaft.

The calculation of these deformations become with theoretical and experimental methods. Due to the non-regular shape of the crankshaft, but also the not uniform distribution of material, determination of axis deformation with the theoretical method differ significantly from experimental measurements. For this purpose during dynamic calculation of crankshaft used a corrective coefficient of rigidities, arising from the report of the deformation calculated with the theoretical method on it the issue of experimental measurements. The following is the theoretical calculations treat elastic line of crankshaft for determining the deformation of support journal of crankshaft and then their experimental determination.

II. ANALYTIC DETERMINATION OF MAIN JOURNAL DEFORMATIONS OF CRANKSHAFT

To check the impact of the crankshaft construction on the deformation of it are used too charging scheme of crankshaft, with loading on the main journal and in the rod journal. We are choosing the charging scheme in force acting on the main journal, which indicated in figure 3.

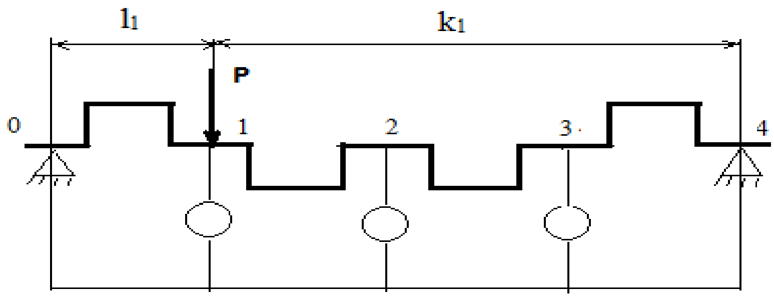

Fig. 3 Loading scheme on the main journal

For crankshaft with n cranks in a plan, when the unit force act of the first journal, elastic line equation have the form [3], [4]:

$$EJx = Bz - \frac{k_1}{6\ l} z^3 + \frac{1}{6}(z - l_1)^3 + \frac{\psi - 1}{6}\sum_1^4 (z - d_i)^3 - \frac{k_1}{2\ l} R(\psi - 1)\sum_1^n a_i (z - a_i)^2 -$$

$$- \frac{k_1}{2\,l} R(\psi - 1)\sum_1^n d_i (z - d_i) - \frac{k_1}{l} R \sum_1^4 (a_i (z - a_i)\psi_a + d_i (z - d_i)\psi_a) + \tag{1}$$

$$+ R \sum_1^n [a_i - l_1)(z - a_i)\psi_a + (d_i - l_1)(z - d_i)\psi_a)$$

Where:
B- is a constant determined by the limited conditions (for z = 1, x = 0).
$\psi_a = \frac{EJ_k}{EJ_a}$
E - elasticity module, which for the crankshaft material given (spheroidal cast iron GS 60-2) measured experimentally in the laboratory of Mechanics of Structures results 1850 N /mm^2 [5].
J_k –express the inertia moment of the main journal
J_a - express the inertia moment of the crank throw, which is the same for all cranks
$\psi = \frac{EJ_k}{EJ_b}$
J_b - express the inertia moment of rod journal

By replacing the constant B and for given crankshaft $\psi = 1$, finally we take:

$$x = \frac{1}{E\,J} \left\{ \left[\frac{k_1}{6\,l} (l^2 - k_1^2) + \frac{k_1 R\,\psi_a}{l^2} \left(\sum_1^4 (a_i c_i + d_i f_i) - \frac{1}{k_1} \sum_1^4 ((a_i - l_1)c_1 + (d_i - l_1) f_i) \right)) \right] z - \right.$$

$$- \frac{k_1}{6\,l} z + \frac{1}{6}(z - l_1)^3 - \frac{k_1 R \psi_a}{l} \sum_1^4 a_i (z - a_i) + d_i (z - d_i)) + \tag{2}$$

$$\left. + R\,\psi_a \sum_1^4 [a_i - l_1)(z - a_i) + (d_i - l_1)(z - d_i)] \right\}$$

Where: $(a_i - l_1) \geq 0$; $(d_i - l_1) \geq 0$; $(z - l_1) \geq 0$; $(z - a_i) \geq 0$; $(z - d_i) \geq 0$

Replacing the parameters of locations deformation, z with lj and locations loading k_1, l_1 with k_k, l_k ,we take the expression for calculating the deformation of support points from the action of force respectively on the first, second and third journal:

$$b_{k\,j} = \left\{ \left[\frac{k_k}{6\,l} (l^2 - k^2) + \frac{k_1 R\,\psi_a}{l^2} \left(\sum_1^4 (a_i c_i + d_i f_i) - \frac{1}{k_k} \sum_1^4 ((a_i - l_i)c_i + (d_i - l_k) f_i) \right)) \right] l_j - \right.$$

$$- \frac{k_k}{6\,l} l_j^3 + \frac{1}{6}(l_j - k_k)^3 - \frac{k_k R\,\psi_a}{l} \sum_1^4 a_i (l_j - a_i) + d_i (l_j - d_i)) + \tag{3}$$

$$\left. + R\,\psi_a \sum_1^4 [a_i - l_k)(l_j - a_i) + (d_i - l_k)(l_j - d_i)] \right\} \frac{1}{E\,J}$$

From calculations made based on the formula (3) were defined respective deformations of main journals by the action of force on the first second and third journal in mm/kN, which are shown in Table 2.

Table 2

Place, Where acts the force	Deformation in first journal, b_{1j}	Deformation in Second journal, b_{2j}	Deformation in Third journal, b_{3j}
In the first support	0.0747	0.0929	0.0613
In the second support	0.0929	0.1369	0.0973
In the third support	0.0613	0.0973	0.0816

III. EXPERIMENTAL DETERMINATION OF CRANKSHAFT MAIN JOURNAL DEFORMATION

For the experimental determination of crankshaft deformations in natural size is necessary to:

-To select charging scheme
-To determine the load size and the measurement method of force and deformation
-To construct the test stands
The loading scheme is selected with active force on the main journal [6] (Figure 3)

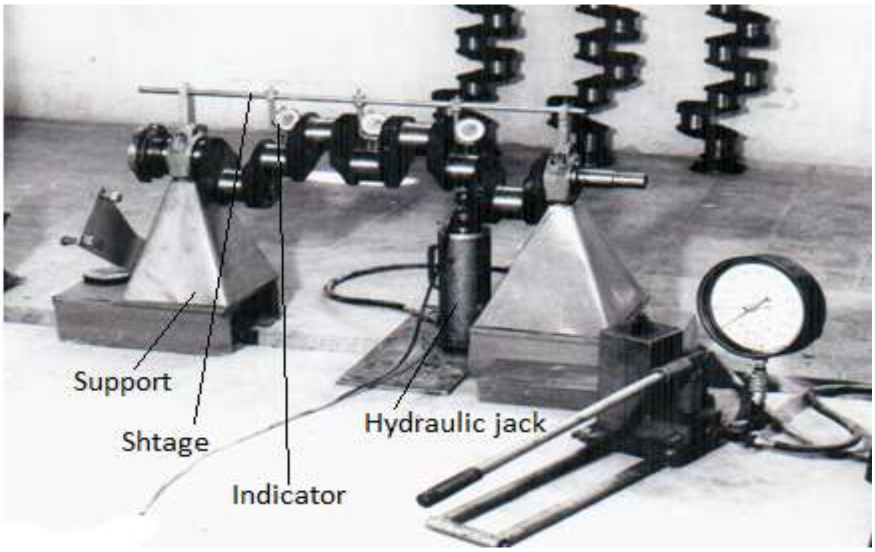

Figure 4 General appearance of the stand for deformations measurement of crankshaft

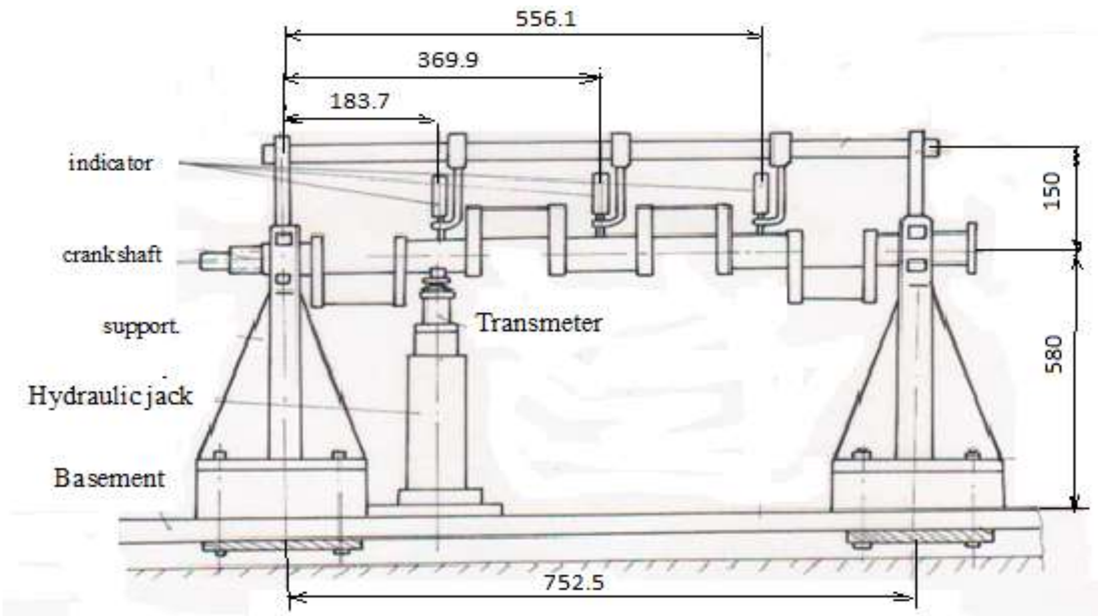

Figure 5 Stand scheme for measurement of crankshaft deformations

The size of the load is determined by the conditions of work, which must be in the limits of elasticity. Loading method used with the scale, in order to follow the work of measuring deformation apparatus. The size of any scale it selected such to obtain accurate measurements of the deformations. Measurement of deformation performed relatively axis of journal 1 and 4.
Experimental stands built for this purpose, shown in Figure 4, while the its scheme and main dimensions are shown in figure 5.
Parts of the stand are [6],[7]:

- Supports holder who are great solidity and caught in a basement with rigidities many times greater than that of the crankshaft .Crankshaft supported freely amongst of support point of the main journals 1 and 4.

- Apparatus measuring deformation of intermediate journals consists from 3 indicator with accurately 0.001mm, connected to a rigid rod, which is fixed at 2 supports of side journals, which takes no deformation.
- For giving load served a hydraulic jack with a capacity to 50,000 pounds (11,000 KN). To measure the loading force serves transmitter and tenzometer bridge, which carry the load measurement with sufficient accuracy (5 N). Built Stand has advantages that can be used for experimental determination of deformations in torsion of crankshaft [a h] but also for other crankshafts .

A. The method of the experiment

At first the crankshaft placed in between the supports 1 and 4 and fixed it in basement with e bolts. Then the crankshaft rotate, that plan of cranks to be vertical. Then transmitter and jack are placed between the first intermediate journal, to be charged and then the second and third journal (the measurements of distance performed relatively frontal crank throw).
To doing the test the following operations are performed:
1- Determine the initial size of the force Po, doing 1-2 loading, which is necessary for the elimination of spaces of mechanical connections.
2- Determine the loading rate for 2-4 loading, depending on the maximum upload size. At first it is given chosen initial load (Po= 40 dN) and then made 2 loadings by 200 dN. After each uploading measuring deformation is fixed in three points of measurement and the results are placed in Table 3.
3- After the maximum loading become the removal of loading with scale and the reading of deformation measurement is fixed in three points of measurement and the results are placed in Table 3
4- Proof is repeated three times and the result represents the average of three measurements.

Measurement results of first crankshaft, when the force acts on first journal are shown in Table 3. Equally tables formed when the force acts on the second and third journal.

Table 3.Force acts on the first main journal

Place of measurement	Active Force [dN]	Proof						Average Deformation Δ_{mes} x10^{-2}mm
		I		II		III		
		Reading	Deformation	Reading	Deformation	Reading	Deformation	
First main Journal	0	-10		-9		-9		
	200	12.5		13		13		
	400	21	9.5	22	9.5	22	9	9.3
	600	27.8	6.8	29	7	29.5	7.5	7.1
	800	35	7.2	35.5	6.5	36	7	6.9
	1000	41.5	6.5	41.5	6	42.5	6.5	6.3
	800	34	7.5	34	7.5	35	7.5	7.5
	600	26.8	7.2	27	7	27.5	7.5	7.4
	400	19.5	7.3	20	7	20	7.5	7.3
	200	11	8.5	11	9	11.5	8.5	8.8
	ΔP= 200							7.58

The value of deformation per unit of force is calculated:

$$b_e = \frac{\Delta_{mes}}{\Delta P} \qquad [\text{mm/kN}]$$

The average values of deformations derived from experimental measuring for four crankshafts are shown in Table 4

Table 4

Deformation b_e mm/kN	Crankshaft I	Crankshaft II	Crankshaft III	Crankshaft IV
b_{11}	0.038	0.0401	0.038	0.038
b_{12}	0.0505	0.0445	0.04	0.049
b_{13}	0.034	0.033	0.031	0.035
b_{21}	0.052	0.0436	0.045	0.052
b_{22}	0.077	0.065	0.065	0.075
b_{23}	0.056	0.045	0.0465	0.058
b_{31}	0.0395	0.0365	0.036	0.038
b_{32}	0.0572	0.053	0.0526	0.058
b_{33}	0.0479	0.046	0.0458	0.0481

The comparison of theoretical and experimental deformation only for the first crankshaft is shown in fig 6.

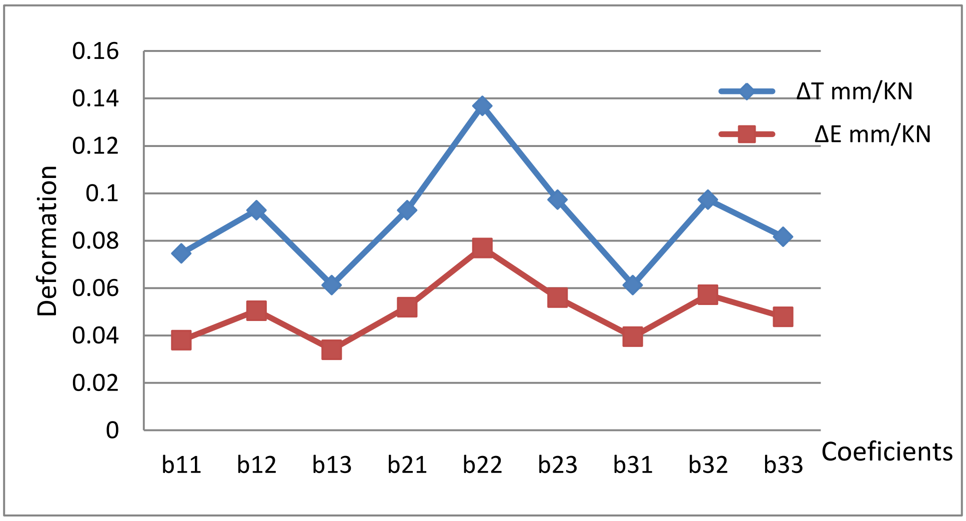

Figure 6 Assessment of theoretical and experimental deformation per unit force

Coefficient that reflects the change of the theoretical value with the experimental value express [6]:

$$c=b/be$$

The average coefficient for each crankshaft calculated based on all the deformation coefficients given in table 5 and the average correction coefficient for four crankshaft results 1.85.

Table 5

Coefficient c=b/be	Crankshaft I	Crankshaft II	Crankshaft III	Crankshaft IV
c_{11}	1.96	1.86	1.95	1.96
c_{12}	1.83	2.05	1.96	1.86
c_{13}	1.8	1.85	1.97	1.78
c_{21}	1.78	2.12	2.06	1.78
c_{22}	1.76	2.09	2.09	1.79
c_{23}	1.73	2.16	20.9	1.76
c_{31}	1.56	1.68	1.7	1.66
c_{32}	1.7	1.83	1.86	1.73
c_{33}	1.7	1.77	1.8	1.72
Average Coeff.	1.75	1.93	1.94	1.8

This show on the impact of construction and completeness of the crankshaft material on the deformation of the elastic line of crankshaft and this should be taken into account for the dynamic calculation of the crankshaft with the consumption of his support bearings.

IV. CONCLUSIONS

The theoretical method of calculating elastic line of crankshaft journal, give the results of deformations of elastic line with major changes with real details, because of concessions made to the physical model as well as the homogeneity and the completeness of the crankshaft material. These changes depend not only on the form and constructive properties of crankshaft, but the conditions of support, material and its preparation technology.

-Results of experimental measurements performed in four crankshafts show that the real values of deformation of the elastic line for crankshaft from spheroidal cast iron GS BM 60-2 have a big change that goes up to 85%. For this purpose the calculations of charges and solidity due to the deformation of supports for this type crankshaft should be used the corrective coefficient 1.85

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