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Problems of support and elastics strains of a measured object

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Abstract
The author presents the results of research aimed at determining the best conditions of supporting large and elastic machine elements such as crankshafts. A number of simulation tests were performed with variable shaft support conditions changed using the author's system of elastic support of crankshafts. The selection criteria were established for support parameters. Meeting these criteria guarantees that shaft elastic deflections and strains are eliminated. Consequently, such strains will not affect the estimation of geometrical deviations of the measured object.

Introduction

The basic aim of geometric measurements of machine components is to assess the conformity of the actual part with the theoretical dimensions and shapes intended by the designer.

Issues related to measurements of geometric deviations of machine components mostly refer to items of relatively small dimensions for which it is arbitrarily assumed that the impact of component strains on the total measurement error is insignificant. In corresponding measurements of large machine parts, however, the need to take strains into account exists. In case of flexible components of large size (crankshafts or camshafts) it is a necessity. The reason for this is that while measuring geometrical errors of large machine components we have to eliminate elastic strains of the measured object that occur due to the specific support and setting up of the shaft. Regardless of how an object is set up, the problem that remains is to eliminate deflections in the central part [1, 2, 3, 4, 5].

The use of a system with fixed supports on which a shaft partially rests does not assure full

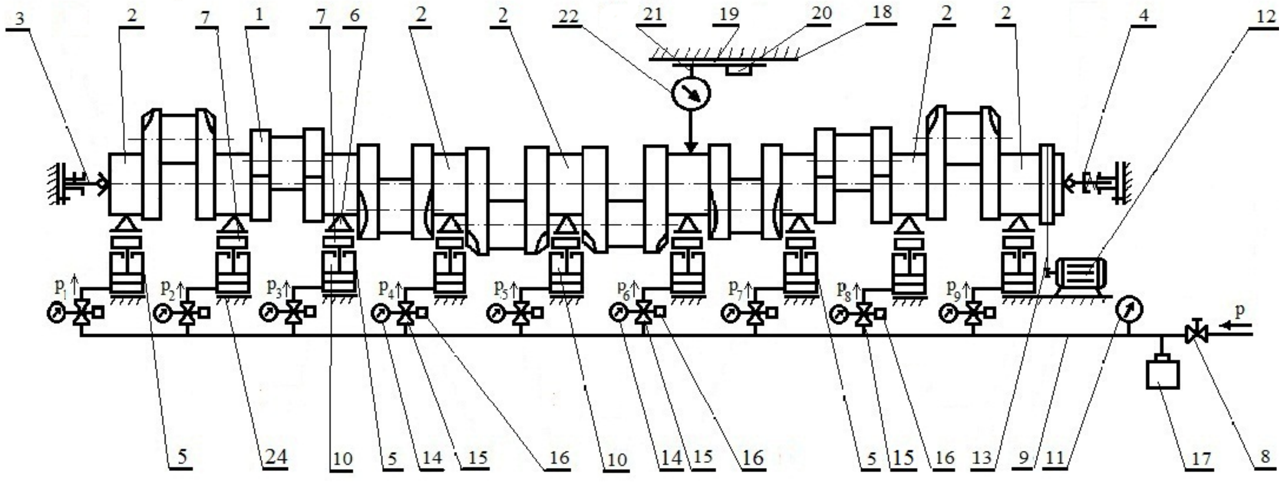


Fig. 1. A system of crankshaft elastic supports

elimination of deflections. In case of complex geometric deviations these deflections may cause elastic strains of the measured object that will be impossible to eliminate due to shaft rigidity changes during its rotation.

The application of the system of elastic support of the measured object (Fig. 1) removes these shortcomings, because passive forces are applied through elastic supports in order to eliminate elastic deflections of the shaft. However, it is essential to select properly the values of load lightening forces and make sure they are maintained during measurements [1].

Figure 1 shows a diagram illustrating a measuring set-up with a system of elastic supports of a crankshaft.

Selection of values and distribution of lightening forces

Research has shown that to completely eliminate shaft deflections we have to vary lightening forces applied along the shaft length through the supports and to adjust their values depending on the angle of shaft rotation. The relevant data have been obtained from calculations based on the strength computing

a)

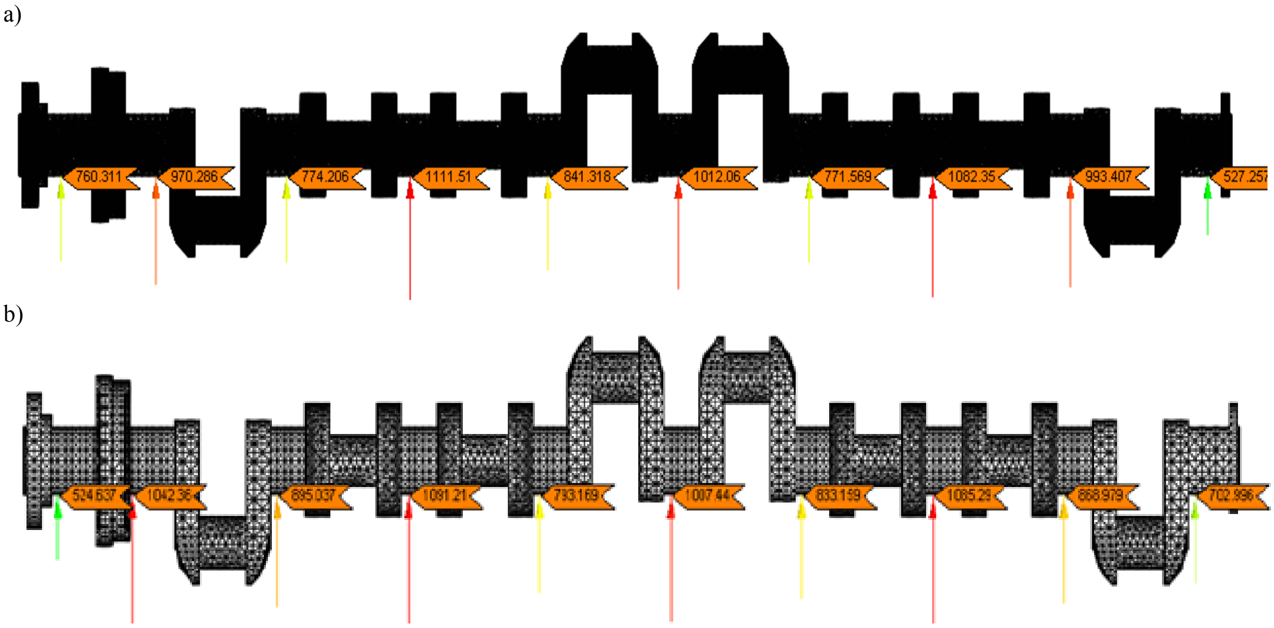


Fig. 3. Influence of changed support positions on the distribution of lightening forces: for supports arbitrarily placed along the journals (a) for all supports shifted asymmetrically to the left (b)

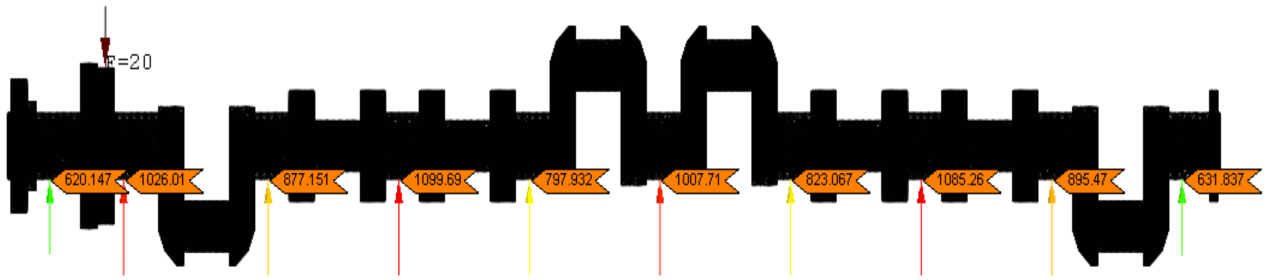


Fig. 4. Distribution of forces: supports are shifted symmetrically to the left in relation to the journal centres by a length corresponding to a distance between the lines of nodes

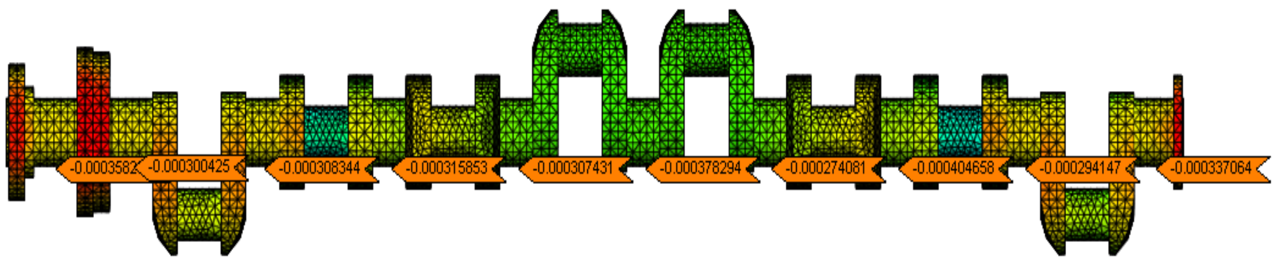


Fig. 5. Deflection values of shaft main journal centres for the support variant shown in figure 3a

by the finite elements method software Nastran 2010 FX. Examplary results of calculated values of lightening forces and corresponding angle of shaft turn are given in table 1. The tests included an actual object: crankshaft of a medium speed engine Buckau Wolf R8DV 136.

If the values of applied forces are the same, or the support arrangement is changed, deflections impossible to eliminate will appear.

It has been theoretically assumed that the force values and the distribution of lightening supports applying those forces are strictly specified. It was, therefore, decided to apply the lightening forces to main journals of the shaft at their half lengths. The distribution of forces for one of the angular positions of the shaft, assuming the supports will be placed at half lengths of the journals, are shown in figure 2.

However, taking into account the practical positioning of load lightening supports, we also calculated the values of load-reducing forces for a case where the supports will be shifted along the journal lengths. These calculations indicated that a change in support positions along the journals significantly affects the values of forces the supports have to apply in order to eliminate shaft deflections (Fig. 3). Figure 3a shows the distribution of forces when the supports are arbitrarily located along the journal lengths, while figure 3b depicts the distribution of forces when all supports are asymmetrically shifted to the left.

Additionally, the calculations showed that the best variant of support to eliminate deflections can be obtained not only by the proper choice of number and positioning of the supports and applied forces distribution, but also by changing the positions of supports along the journal lengths. Figure 4 presents the distribution of forces for the supports shifted symmetrically to the left in relation to the journal centres by a length corresponding to a distance between the rows of nodes. This allowed to obtain identical values of reaction forces at the end supports. The support variant that assures permanent values of reaction forces at the end supports is recommended for a case when the shaft is to be set up in V-blocks, i.e. when there are no centre holes on external front surfaces of the shaft. In calculations, the external force due to the tension of the belt of shaft rotating system was taken into account.

The change of support positions other than theoretical, i.e. at the half length of main journal lengths, may be caused by shaft construction features (grooves, passages, holes in main journals) or it may result from inaccurate positioning of the supports.

Considering the former reason for changed positioning of the supports, we can state that if the values of lightening forces are properly chosen to suit the precise support positions along the journal lengths, then the shaft deflection values may be regarded as negligibly small. Figure 5 presents the deflection values of shaft main journal centres for the support variant shown in figure 3a.

As a consequence of changed support positions resulting from errors made through imprecise positioning, lightening forces calculated for a specific position of supports along the journal lengths will be applied in other places. Uncontrolled location of lightening forces will result in increased deflections and strains of the shaft (Fig. 6). Figure 6 presents the points where lightening forces are applied (Fig. 6a) and corresponding values of deflections of shaft main journal centres (Fig. 6b) for the support variant where the calculated values of lightening forces

Table 1. Values of lightening forces in [N] at which no deflections occur at the shaft journals in relation to the shaft angle of rotation

Rotation angle	JOURNAL NUMBER									
	1	2	3	4	5	6	7	8	9	10
0º	780.064	907.144	831.740	1108.730	798.994	1015.020	804.985	1087.280	935.406	574.830
90º	863.160	712.929	1079.040	839.009	1050.540	779.562	1054.270	835.302	1102.380	528.102
180º	723.466	978.164	809.592	1118.820	793.023	1020.910	803.532	1087.120	933.822	575.833
270°	851.830	739.756	1054.390	840.085	1083.040	733.705	1079.510	841.511	1085.690	534.062

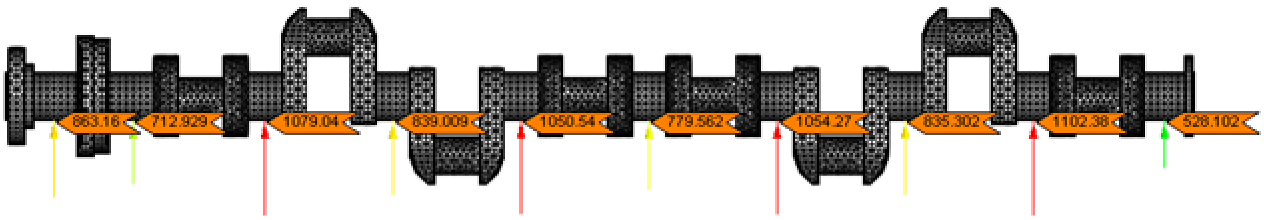
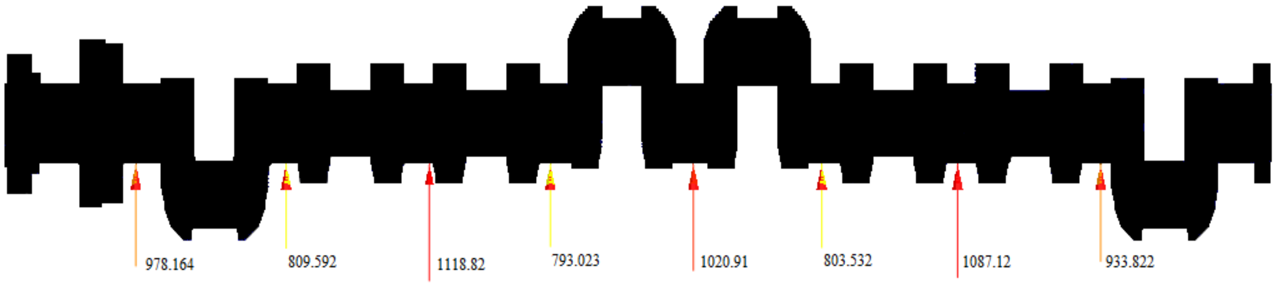


Fig. 2. Distribution of forces for a specific angular position of the shaft, supports are placed at half lengths of the journals

a)



b)

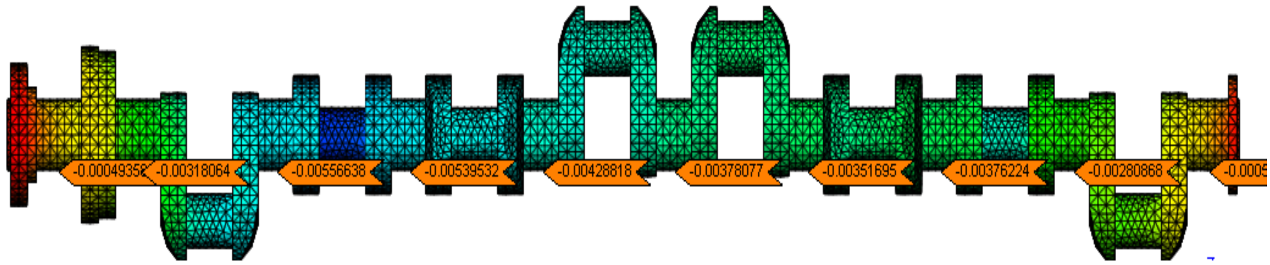
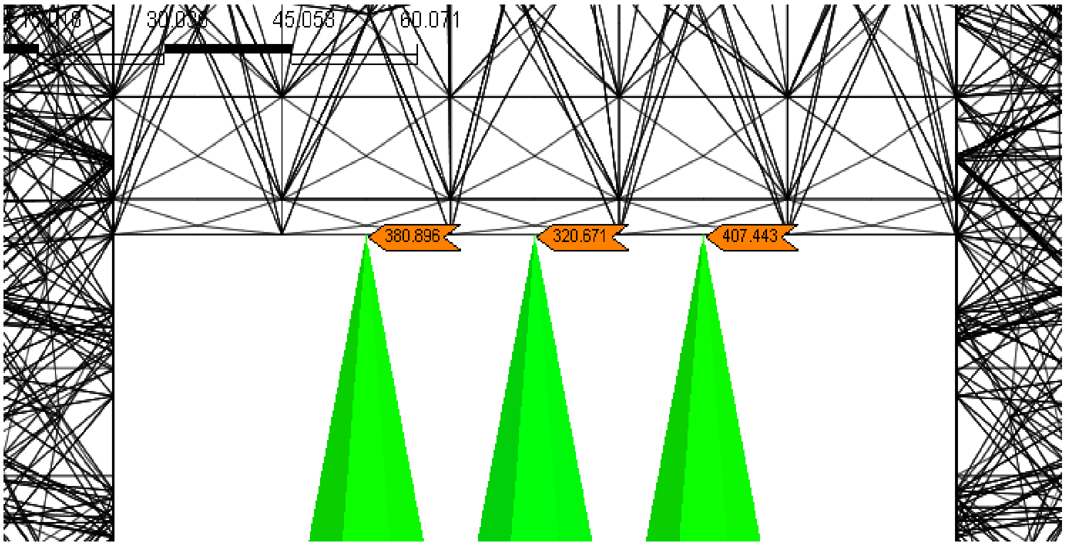


Fig. 6. Influence of uncontrolled support positions on the shaft deflection values: assumed force acting points (a), deflection values of shaft main journal centres (b)

a)



b)

Fig. 7. Distribution of forces for journal no. 8, counted from the left, with a three point contact of the head supporting the journal (a), distribution of forces for the whole shaft where its end journals are set up on supports assuring a single point contact with the journals, while central main journals of the shaft are based on a system of lightening supports providing three-point contact (b)

corresponding to their application at the journal centres (angular position of the shaft 180º – Table 1) are shifted in relation to theoretical assumptions.

More detailed research additionally revealed if when a shaft is supported in its central part by a system of elastic supports whose heads will provide not a single but a multipoint contact with the journals, then the distribution of forces at contact points is variable, and the sum of forces at contact points does not correspond to the force applied at one point. Figure 7a illustrates the distribution of forces for journal no. 8, counted from the left, with a three point contact of the head supporting the journal. Figure 7b, in turn, shows the distribution of forces for the whole shaft where its end journals are set up on support assuring a single point contact with the journals, while central main journals of the shaft are based on a system of lightening supports providing three-point contact. The results confirm earlier data which revealed interaction of individual cranks due to changes in the shaft rigidity during its rotation [1, 6]. Therefore, it is recommended that the support heads guarantee a point contact with the main journals.

Conclusions

The research results have unequivocally indicated that the right choice of support conditions for large and flexible machine elements, such as crankshafts, is an important and complex issue. The following conclusions can be drawn:

- the best support conditions are created by placing the shaft main bearings in a system of elastic supports applying variable load-lightening forces depending on the angular position of the shaft;
- the selection of these forces should be based on appropriate strength calculating programs, and during measurements the change of force values has to be continuously supervised by comparing it with the value preset in the feedback system;
- shaft deflections can be completely eliminated by locating the supports at strictly defined points and ensuring that the supports accurately apply specific forces;
- application of specified forces while the supports are inaccurately positioned significantly affects elastic deflections and strains of the shaft.

References

1. NOZDRZYKOWSKI K.: Crankshaft support requirements for measurement of its geometry errors. Mechanik, 2012, 05–06, 466–468 (in Polish).
2. NOZDRZYKOWSKI K.: A system for measurements of geometrical deviation of main-pin crankshaft assembly. Pomiary Automatyka Kontrola, 2011, 57, 12, 1592–1594 (in Polish).
3. WIECZOROWSKI M., CHAJDA J., GAPIŃSKI B., MATLIŃSKI K.: Wykorzystanie współrzędnościowej maszyny pomiarowej do korekcji obrabiarki. Przegląd Mechaniczny, 2007, 09, Suplement, 210–214.
4. SADOWSKI A., MIERNIK E., SOBOL J.: Metrologia długości i kąta. WNT, Warszawa 1978.
5. MALINOWSKI J.: Pomiary długości i kąta. Wydawnictwo Szkolne i Pedagogiczne, Warszawa 1998.
6. NOZDRZYKOWSKI K.: Comparative assessment of crankshaft strain measurement methods. 5th International Conference Measurement, Smolenice 2005 (SK), 425–428.