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Research on Hogging Process of Crankshafts With Five Rod Journals Because of Fillets Stamping

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ABSTARCT

The paper presents the results of experimental and computer research on hogging process of spatial crankshafts with five rod journals at hardening their fillets by stamping. We describe the computer program with which it is possible to produce a computer research on the influence of various factors such as crankshaft hogging value, to calculate an expected value and a direction of hogging, as well as to choose a combination of strengthened fillets rates where the total hogging value is the smallest.

Keywords : crankshaft, fillets, stamping, hogging, computer program.

INTRODUCTION

Crankshafts ***(CS)*** are widely used in modern engineering. However, despite extensive experience gained by experts in design, manufacture and operation of ***CS***, they are often destroyed during operation due to insufficient margin of fatigue strength. Destruction occurs mainly in fillets. The most effective and easy viable job to harden ***CS*** fillets is to use surface plastic deformation ***(SPD***), for example, by rollers rolling, stamping, etc. [1]. However, experience and numerous experiments have shown that processing of ***CS*** fillets by means of ***SPD*** leads to ***CS*** hogging [2]. Moreover, the more efficient treatment method from the standpoint of the fatigue strength improving is, the greater crankshaft hogging it leads to. Intensification of hardening rates leads to increase of crankshafts fatigue strength, but at the same time the range of ***CS*** hogging increases also.

Main principles of theory about ***CS*** hogging through fillets hardening with ***SPD*** are given in [3]. There was made an experimental and computational research on hogging process of spatial crankshafts with six rod journals arranged pair-wise at angles of 120 ° [4]. The purpose of this article is to research and describe consistent patterns of hogging of spatial crankshafts with five rod journals, which have not previously been studied.

MATERIALS AND METHODS

Routing Protocols A ***CS*** of engine ***WH*** was chosen for investigation purposes. The crankshaft has five rod journals (***RJ***), angled 72˚ to each other. Main bearing journals ***(MBJ)*** diameter is 58mm, rod journals ***(RJ)*** diameter is 48mm**.** Crankshaft throw radius is 38.7 mm. Crankshaft webs have the same thickness - 19.6 mm. **MBJ** fillets radius is 3.2 mm**,** ***RJ*** fillets radius is 2.5 mm. **CS** length = 396mm.

Experiments were carried out by the sequential stamping of fillets. Impact energy equaled to 18.5 J. Basing on the experiment results there was built an experimental curve of engine ***WH CS*** hogging. Analysis of the diagram shows that vectors of hogging due to hardening single fillets lie in the plane of the crankshaft throw with an error not exceeding 10%. The total ***CS*** hogging amount after stamping of fillets 1-19 is δ = 0,55 mm, the hogging vector is directed at an angle α = 261 ˚ relative to the first ***RJ.*** Basing on theoretical models of ***CS*** hogging process [3] and experimental data we worked out a computer program both with the help of programming language C # (C Sharp) and programming environment Microsoft Visual C # 2010 Express.

With the help of this program we calculated: the amount of ***CS*** hogging after stamping of 19 fillets and a deflection angle of the hogging vector with respect to hogging of the first ***RJ***. Deviation of total ***CS*** hogging estimated value from an experimental one was 10.4%, direction deviation of the hogging vector became 19.2%.

RESULT AND DISCUSSION

Experimental and theoretical (calculated) curves of ***WH*** engine ***CS*** hogging values were built depending upon the distance to fillets supports, i.e. fillets number (Fig. 1). The curves are characterized by a wavelike rate. Average mismatch of experimental and theoretical points is 43.3%. The result can be considered satisfactory in view of the fact that fillets were stamped manually. It follows that the developed program satisfactory describes the ***CS*** hogging process.

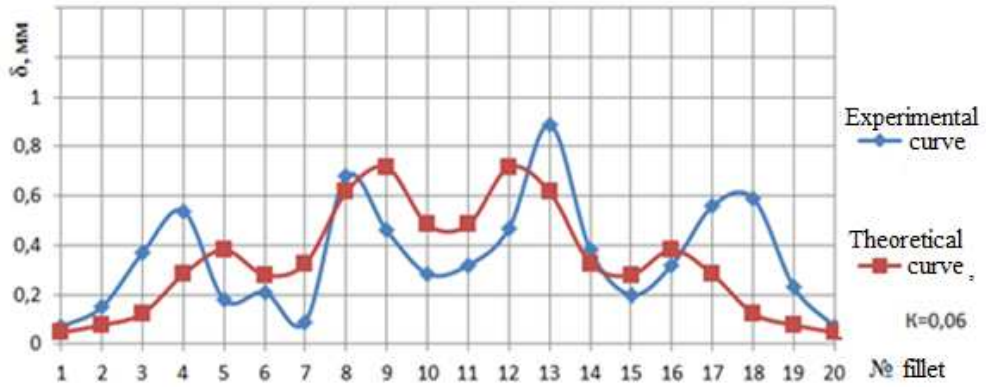

Fig. 1. Experimental and theoretical characteristic curves of CS hogging values on distance between CS fillets and their supports (on fillet number)

With the help of this program we investigated the influence of various factors on crankshafts hogging. As a basis there was adopted a "perfect" crankshaft - symmetrical with respect to the middle of center ***RJ*** (not taking into consideration outer main bearing journals), ***MBJ*** and ***RJ*** diameters are equal (54mm), ***MBJ*** and ***RJ*** fillet radii are equal (3mm), and crankshaft webs thickness is the same (19.6 mm). Crankshaft throw radius - 38.7 mm.

Fig. 2 shows characteristic curves of ***CS*** hogging depending on impact energy when stamping different fillets. It follows from Fig. 2 that increase of impact energy ***Ei*** during single fillets processing leads to growth of ***CS*** hogging amount. Besides, the closer to the ***CS*** middle the processed fillet is, the stronger impact energy influences hogging amount. However, total hogging amount of processed fillets 1-20 rises slightly, as hogging vectors from single fillets hardening considerably cancel each other out.

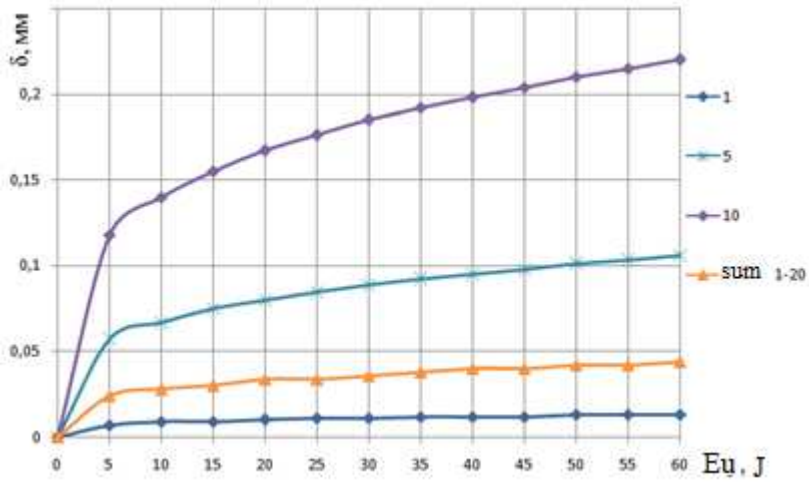

Fig. 2. Characteristic curves of *CS* hogging depending on impact energy:
1– stamping fillet No 1; 5 - stamping fillet No 5; 10 – stamping fillet No 10;
Sum 1-20 - stamping fillets 1-20.

Fig. 3 shows characteristic curves of **CS** hogging depending on main bearing journals diameter. It is evident that with increase of **MBJ** diameter during single fillets processing **CS** hogging amount grows. As in the previous case, the closer to the ***CS*** middle the processed fillet is, the stronger ***MBJ*** diameter influences hogging amount. Total hogging amount growth after processing of fillets 1-20 is more sizeable than in the previous case.

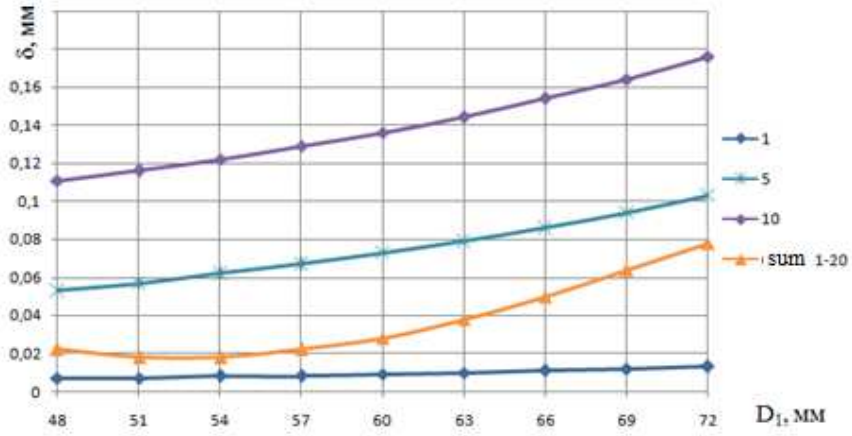

Fig. 3. Characteristic curves of *CS* hogging depending on MBJ diameter:
1– stamping fillet No 1; 5 - stamping fillet No 5; 10 - stamping fillet No 10;
Sum 1-20 - stamping fillets No 1-20.

Fig. 4 shows characteristic curves of ***CS*** hogging depending on crankshaft webs thickness. It is evident that with increase of ***CS*** webs thickness ***CS*** hogging value decreases sharply. This dependence increases with approach of the processed fillet to the middle of the **CS**. During

overlapped processing of fillets 1-20 this dependence decreases.

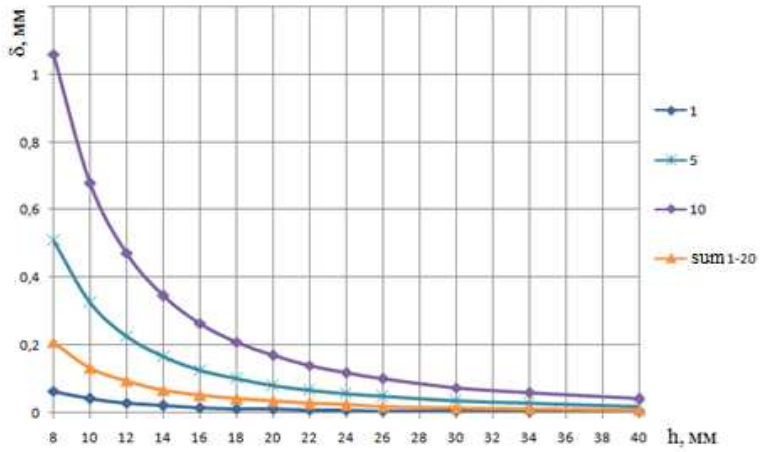

Fig. 4. Characteristic curves *CS* hogging depending on *CS* webs thickness: 1– stamping fillet No 1; 5 - stamping fillet No 5; 10 - stamping fillet No 10; Sum 1-20 - stamping fillets No 1-20.

With the help of this program we calculated total hogging value during stamping of all fillets of the «perfect» ***CS***. It amounts to 0,133 mm, hogging vector is directed at an angle α = 36 ˚. During stamping of all engine WH ***CS*** fillets estimated hogging amount became 0.461 mm, angle α = 216 ˚.

As long as even during stamping of «perfect» **CS** fillets there is a significant (but inadmissible) hogging, there appears a task to develop **CS** fillets stamping so as to reduce hogging value to an allowable amount. To solve this problem we must process different ***CS*** fillets with different impact energy. The table below shows a combination of different impact energy values **Ei** for different pairs of engine WH ***CS*** fillets, which allowed to reduce ***CS*** hogging amount to $\boldsymbol{\delta}$ = 0,002 mm, with hogging vector direction $\boldsymbol{\alpha}$ = 36 ˚. Processing fillets in pairs is mainly due to design features of equipment for processing crankshaft fillets by means of ***SPD.***

Table-1

Impact energy for stamping of engine WH CS fillets

Fillets No	1	2,3	4,5	6,7	8,9	10,11	12,13	14,15	16,17	18,19	20
Ei, J	22	22	20	20	23	16	23	20	20	22	22

CONCLUSION

Thus, computational research on hogging process of spatial crankshafts with five rod journals has revealed the following:

- ***CS*** hogging value is mainly influenced by a power factor - impact energy, Ei, together with ***CS*** configuration and mutual arrangement of ***CS*** supports, a hardened fillet and a section where hogging amount is measured;

- Even during stamping of «perfect» **CS** fillets there is a significant (but inadmissible) hogging.

With the help of developed computer program we can:
a) produce a computer research about influence of various factors on hogging of spatial ***CS*** with five rod journals having any sizing combinations of their structural elements, which basically cannot be investigated by experiment;
b) calculate expected values of hogging and its direction as early as the design stage of fillets hardening operation by means of ***SPD***, as well as choose such a combination of hardened fillets rates, when total hogging value will be the smallest.

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