PRELIMINARY RESEARCH ON THE OPTIMIZATION OF THE RECONDITIONING BY WELDING TECHNOLOGY OF CERTAIN ELEMENTS IN THE AUTOMOTIVE INDUSTRY

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The reconditioning by welding is an important technological process used in the automotive industry. This paper presents the results obtained by using the finite element analysis regarding the optimization of the reconditioning by welding technology of a crankshaft used in the automotive industry. The paper analyzes the influence of parts fixing and of the welding order of the crankpin journals for the reconditioning by welding process.

Keywords: reconditioning, crankshaft, welding, optimization

1. Introduction

The crankshaft is a part that ensures the quality of engine functioning; as the working conditions of the crankshaft are difficult, it must withstand the tensile stress, compressive stress, flexural moment and wearing, which cause the crankshaft journal wearing and fatigue fracture. The life of the crankshaft determines the life of the engine, so the crankshaft is important for the driver's safety. Many engine production enterprises pay great attention to the crankshaft processing, improving the technology of crankshaft processing, in order to improve the quality of crankshaft processing and extend its life [1, 2, 3].

If the components of equipment are damaged during functioning, they can be replaced or reconditioned so that they can be brought to the initial dimensional value or so that they can regain their initial mechanical properties. If the replacement of the parts is expensive, the parts are reconditioned [4].

Reconditioning by welding is one of the most frequent reconditioning methods used for the parts in the automotive industry due to its advantages:

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reduction of productions costs; possibility to recondition most of the parts; increase in the durability of the hard faced parts, etc. The optimization of the reconditioning technologies must be done so that both the economic and the technological aspects are taken into account [5].

The welding deformation is the most important factor that influences the quality of the welding. The welding distortion and residual stress can not only cause the welding cracks, cold cracks and brittle fracture, but also affect the load-bearing capacity, machining precision and dimensional stability of structures. However, due to numerous factors involved in welding process, we cannot predict welding deformation just depending on experimental data, especially for the large structure. With the development of the computer technology, the numerical simulation for the welding process is an effective method to simulate the welding process, which describes the welding process based on a set of mathematical equations [6].

The current trend in the field of welded products is to minimize or eliminate the time lost with preliminary tests for the approval of welds, respectively of welding technologies. One of the possible methods to achieve this goal is to simulate the real working conditions by using specialized software. The current research trends are trying to pre-establish the thermal history of the work pieces by using specialized software [7].

The FEA modeling process requires three types of input data: the geometry, the material properties and the loading. In order to determine the operating behavior, a FEA methodology was developed to predict possible material or welds/bonds failure locations. Then a solid model is designed and accurate material properties are applied for the crankshaft. Lastly FEA model is built, with localized meshing control.

Normally, the results of the structural FEA are provided in the form of displacements and stresses. Von Mises stress, also known as Huber stress, is a measure that accounts for all six stress components of a general 3-D state of stress (Fig. 1).

One can notice that von Mises stress is a non-negative, scalar stress measure. Von Mises stress is commonly used to present results because of the structural safety for many engineering materials showing elasto-plastic properties (for example, steel or aluminum alloy) [8].

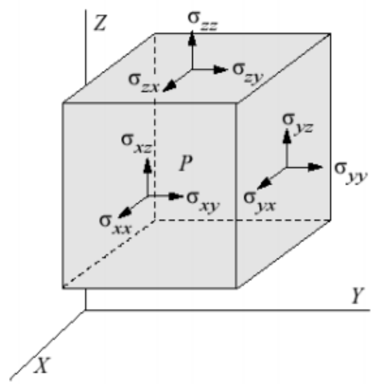


Fig. 1. Stress components

Von Mises stress σ_{vm}, can be expressed either by six stress components as:

$$\sigma_{vm} = \sqrt{0.5\left[\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + (\sigma_z - \sigma_x)^2 + 3\left(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2\right)\right]} \quad (1)$$

Von Misses stress σ_{vm} can also be expressed by its main stress components as:

$$\sigma_{vm} = \sqrt{0.5[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]} \quad (2)$$

2. Experimental procedure

The behavior of a crankshaft used in the automotive industry in case it is subject to reconditioning by welding was simulated by taking into account the initial conditions of the studied crankshaft. The base material used to make the crankshaft is EN-GJS-600-3 cast iron according to DIN EN 1564:2012. The mechanical properties and the chemical composition of the base material are presented in table 1 and table 2.

Starting from the real geometric configuration of the crankshaft as presented in Fig. 2.a, we created its 3D model, which is presented in Fig. 2.b.

In order to reduce the internal strain level and avoid the risk of occurrence of defects after the reconditioning process we preheat the crankshaft up to a temperature of 200^0C [9]. Considering this technological aspect, when we carry out the simulation we apply the thermal load of the crankshaft to the recommended temperature.

Table 1

Material properties measured an test pieces according to DIN EN 1563:2012

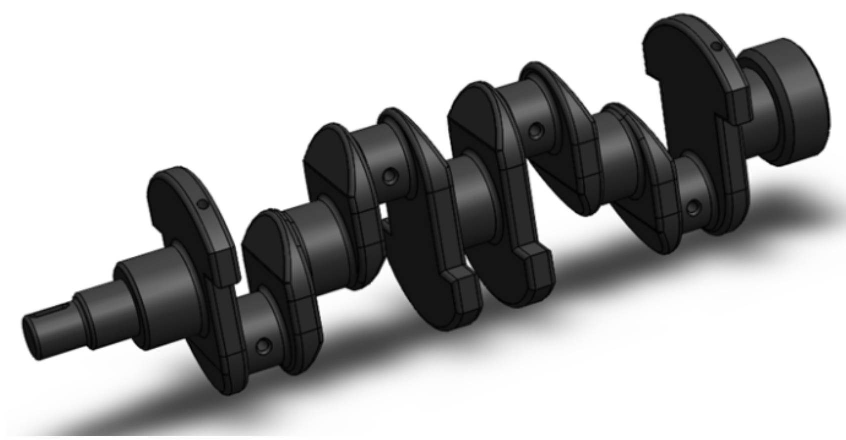
Material designation	Tensile strength R_m [N/mm^2]	0,2% Proof stress $R_{p0,2}$ [N/mm^2]	Elongation A [%]	Micro-structure
EN-GJS-600-3	600	370	3	Pearlite/ferrite

Table 2

Chemical composition of the base material according to EN-GJS-600-3

Base material	C [%]	Si [%]	Mn [%]	P [%]	S [%]
EN-GJS-600-3	2,5 -3,6	1,82,8	0,3-0,7	≤ 0,08	≤ 0,02

a)



b)

Fig. 2. Model of the analyzed crankshaft; a) – real model, b) – 3D model

During the reconditioning process the crankshaft will be fixed in clamping devices so as to ensure its better stability. From a technological point of view the crankshaft may be fixed at one of the ends or at both ends. The influence of the fixing possibilities is analyzed in the first case study (Fig. 3).

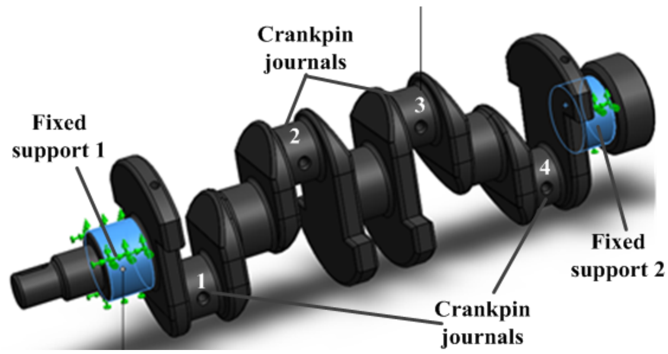


Fig. 3. Fixing and loading zones of the crankshaft

3. Results and discussions

After the initial thermal loading and after applying the fixing conditions on the 3D model (Fig. 3) we proceed to running the simulation program. The results obtained for the values of the resulted displacements are presented in Fig 4.a, for fixing at one end and in Fig. 4.b for fixing at both ends. From the analysis of the displacement values we observed that in the first case the maximum level of the displacements amounts to $d_1=6{,}10\cdot10^{-3}$ mm in the zone that is opposite to the fixing zone, whereas in the second case the maximum level of the displacements amounts to $d_1=3{,}57\cdot10^{-3}$ mm. Under these circumstances we observed that by choosing the technological solution of fixing at both ends of the crankshaft the level of the displacements is almost reduced to half. From the analysis of the values of the stresses presented in figure 6 we can observe that their maximum value, even in case of maximum stress by fixing at one end, is below the value of the yield strength of the material.

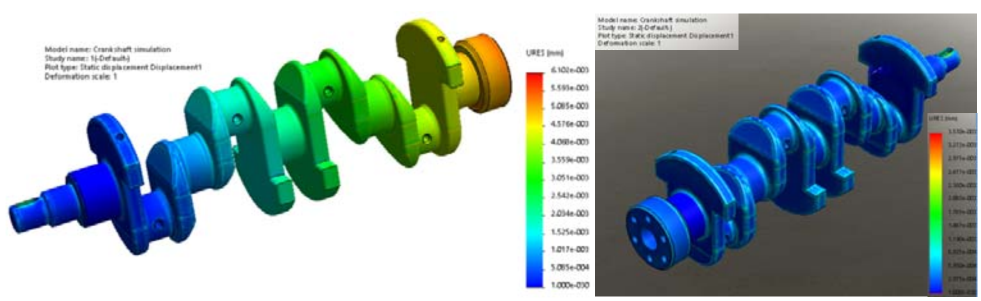

a) b)

Fig. 4. Variation of the displacements in the volume of the crankshaft: a) – in case the fixing is made at one end, b) – fixing at both ends.

Fig. 5 presents the values of von Mises stresses resulted after applying the load of the crankshaft fixed at one end.

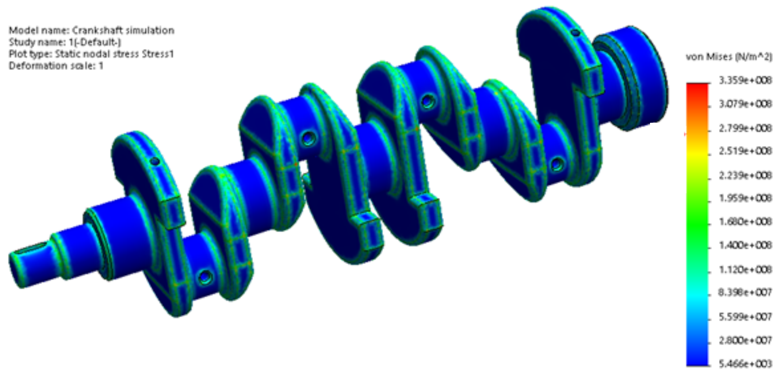


Fig. 5. Variation of the stresses in the crankshaft volume in case of fixing at one end for the hard facing process

Furthermore, from the analysis of the results we can observe that in the first case the zone with maximum displacement is in the free zone of the crankshaft, unlike the second case, where the level of the displacements decreases in the end zone and increases depending on the preheating temperature in the keyway edge zone (Fig. 6). From the analysis of the obtained results we can conclude that the optimum fixing variant of the crankshaft for reconditioning is fixing at both ends.

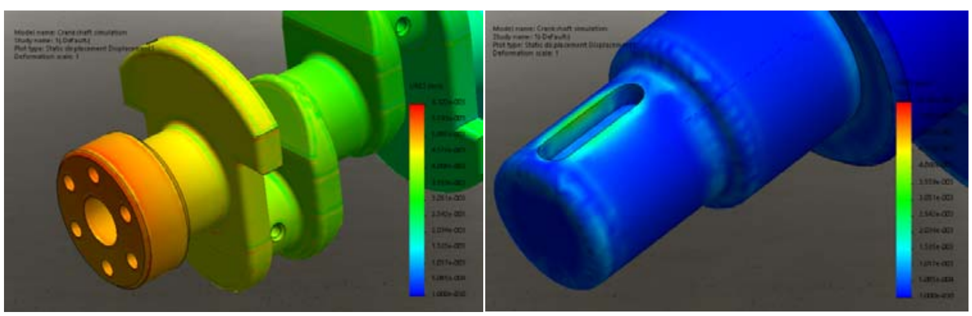


Fig. 6. Risk zones with maximum displacements

After determining the optimum fixing possibility for reconditioning we analyze the influence of the load temperature on the crankpin journals. Seeing that for the manual reconditioning hard facing is carried out on each crankpin journal, the 3D model was additionally loaded on the surface of journal 1 (Fig. 3) with the temperature of the molten filler material (approximately 1500^0C).

Following the running of the finite element analysis program based on the new loads and analyzing the obtained results presented in Fig. 7, it results that the maximum value of the displacements amounts to $d_3=4,12\cdot10^{-2}$ mm.

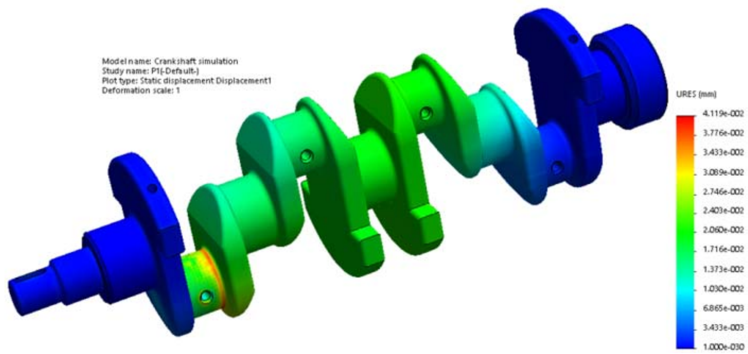


Fig. 7. Variation of the displacements in the crankshaft volume in case of loading the crankpin journal number 1

Fig. 8 presents the risk zones, when the crankpin journal is reconditioned, where the displacements are at maximum value.

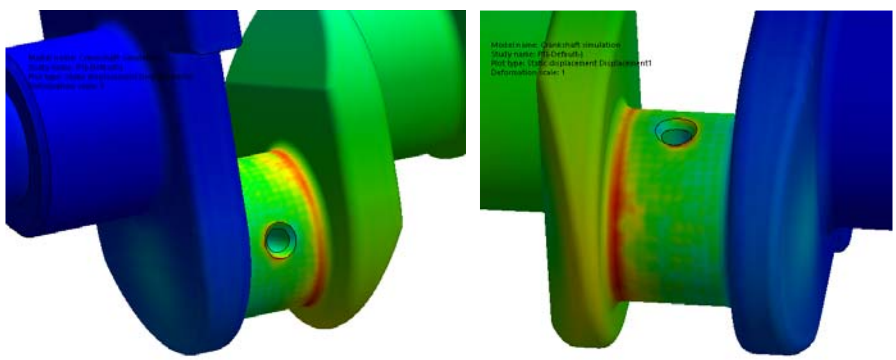


Fig. 8. Risk zones with maximum displacements in case journal 1 is reconditioned

From the analysis of Fig. 8 we can observe that the maximum values of the displacements are encountered in the passing zone between the crankpin journal and the adjacent elements of the crankshaft (counterweights), in the technological connection zones, as well as in the oilway zone.

4. Conclusions

The FEM analysis may be successfully used to establish the influence of the reconditioning by welding technologies on the displacements resulted during the repairs.

From the analysis of the results we can conclude that the way the crankshaft is positioned for reconditioning by welding significantly influences the displacement values of the crankshaft. From this point of view we can observe from the analysis of Fig. 4 that the optimum positioning solution is to fix it at both ends.

From the analysis of the risk zones resulted following the FEM process we can see that the product has the risk of strong deformation in the passing zone between the crankpin journals and their adjacent elements (counterweights) as well as in the oilway zone.

In order to avoid the occurrence of possible nonconformities it is recommended to properly process the technological zones (rounded corners and chamfers).

For the reconditioning by welding special attention will be paid to the oilway zones and the passing zones between the crankshaft parts.

In the risk zones it is recommended to deposit a bead at lower values of the welding current intensity before facing the crankpin journals, in order to limit the waving range of the electric arc and the possibility of unintentional touching of adjacent zones.

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