USING OF WELDING SIMULATION SOFTWARE SYSWELD FOR MODELING OF ROUNDNESS OF BEARING RINGS

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Abstract:

The contribution describes modeling of roundness of heat-treated bearing rings in simulation software SYSWELD. As the experimental material there was selected 100CrMnSi6-4 steel. This steel is most commonly used as a bearing steel for thick-walled bearing rings. For predicting of thermal properties during heat treatment we used the simulation software SYSWELD from ESI Group. Inputs of the numerical simulation are based on actual technological process of quenching of bearing rings. There were used proven parameters for quenching of these steels. Results represent a comparison of the measured values of roundness with the values provided by the numerical simulations.

1. INTRODUCTION

Production of antifriction bearings has a long tradition in our region. Present orientation of engineering industry at car industry has been bringing higher and higher quality and quantity requirements at efficient production costs. The offer of antifriction bearings of the highest quality (size accuracy, stability and durability) for acceptable price is the matter of competitive fight at the antifriction bearings market. These aims could be reached only by high-class semiproducts buying and using technological processes considering all dangers and experiences with machining and heat treatment of bearing parts in high-class equipped technological workplaces.

Heat treatment of antifriction bearing parts (rings and elements) creates an inseparable part of their production as well as an important item for the bearing price calculation. Technological process of heat treatment must be created reasonably. Besides required values of hardness it must be size accuracy minded.

They are the deformations of bearing rings and elements which markedly increase their production costs. In many cases there are such deformations irreversible or reversible only by their enormous production costs (additional heat treatment, more finishing work). Taking into account the shape of heat treated part, deformations are connected most of all with bearing rings whose circulating paths are more and more sofisticated.

For the prediction of the development of thermal and mechanical properties aimed at ovality of bearing rings made of the steel 100CrMnSi6-4 during heat treatment (quenching) there was used the simulation software by the company ESI Group.

Analysis of theoretical knowledge

Bearing rings are usually made of standard bearing steels. They are the steels especially for production of antifriction bearings. Following the standard these steels belong among construction steels even though their chemical composition is similar to tool steels. The steels for antifriction bearings are hyper-eutectoid chrome steels with the basic carbon content for about 1 % and with chrome content very often for about 1,5 %.

Properties of used material

Steel 100Cr6 is basic steel for production of thin-walled bearing rings and small-sized elements.

Modified steels with increased through-hardness, which is being increased by adding of manganese and molybdenum, are used for bigger-sized bearings.

The typical steel of such type of bearing steel is 100CrMn6 produced also in an alternative 100CrMnSi6-4.Chemical composition of the steeel according to the standard ISO 683-17 and the analysis of supplied material is in the Tab.1. This steel is suitable for production of bullets with the diameter over 30 mm, rollers, tapers, spherical rollers with the diameter over 35 mm and rings with the wall thickness up to 45 mm. Steel has an interval of austenitizing temperature during quenching from 830 to 870 °C. It is cooled down in quality mineral oil to reach required hardness values. Common temperatures of tempering are from 150 to 180°C.

Tab.1 *Chemical composition of experimental material*

norm	C%	Cr%	Mn%	Si%	Mo%	P%	S%
min.	0,93	1,40	1,00	0,50	0	0	0,003
max.	1,05	1,65	1,20	0,70	0,10	0,025	0,010
analysis	0,96	1,42	1,05	0,59	0,01	0,013	0,003

Hardness after quenching min. 64 HRC and hardness after tempering 59+4 HRC are required by a producer of rings. Ovality after processing before quenching cannot be over 0,1mm. Maximal allowed value of ovality after quenching given by a producer is 0,2 mm.

2. DEFORMATIONS OF BEARING RINGS.

Deformations of material and ovality of rings are caused by internal tensions, which are creeated during processing and heat treatment. During turning of bearing rings the external ring is fixed in three points. Deformation is caused (because of wrong fixing or breaking technological requirements) by bigger material removal. It is similar during grinding. Deformations occur during heat treatment (quenching) because of irregular heating and cooling.

Bearing rings have given geometrical tolerance mostly for circular, peripheral and front wobbling, circularity of chosen diametres (ovality) and parallelness of front surfaces.

Experimental part is aimed at simulation of ovality on an external diameter of bearing rings. Ovality (Fig.1) can be defined as a diametral difference measured in one plane vertically to each other and it can be calculated as a difference between the biggest and the smallest diameter measured in one plane. The thinnest is the ring wall, the highest is inclination to deformations after quenching and higher values of ovality. Standard value of ovality after grinding is 0,006mm. However requirements for ovality can be stricter – it depends on individual order.

It is necessary to reach after final heat treatment the values of ovality max 0,2 mm so that we could reach the ovality max 0,006 mm after final grinding. It is also very important to have a longer bearing run and lower carying capacity of axial loading mainly during a run. This is required because of higher ovality.

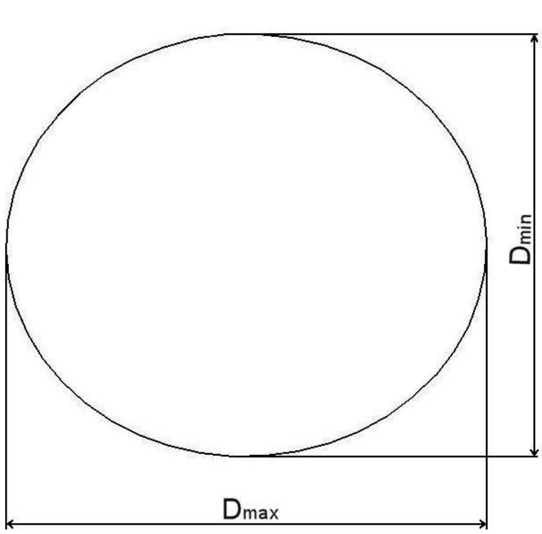

Fig.1 *Ovality graphical representation*

3. SIMULATION OF THERMAL PROCESSES IN STEELS.

Quenching is connected with the heat transfer, phase changes and mechanical influence. Physical fields influence each other either by sharing state values or by interaction. Although the solving of simulation of quenching is a complex physical problem, the heat transfer is a causative factor, because it initiates following processes. From a technical point of view the heat transfer from the part to the quenching medium can be always different so it is necessary to take into account the sort of quenching medium and the way of quenching itself including a dipping process.

Austenitizing temperature of the part is usually high above the boiling point of quenching medium.

During quenching the cooling process is characterized by three phases: a steam cushion, boiling and convection, each of them is connected with marked change of cooling. It is also necessary to take into account an initial phase when the cooling part is contacting with the liquid. Critical phases of the thermal flow and heat transfer are shown in a graph (Fig.2).

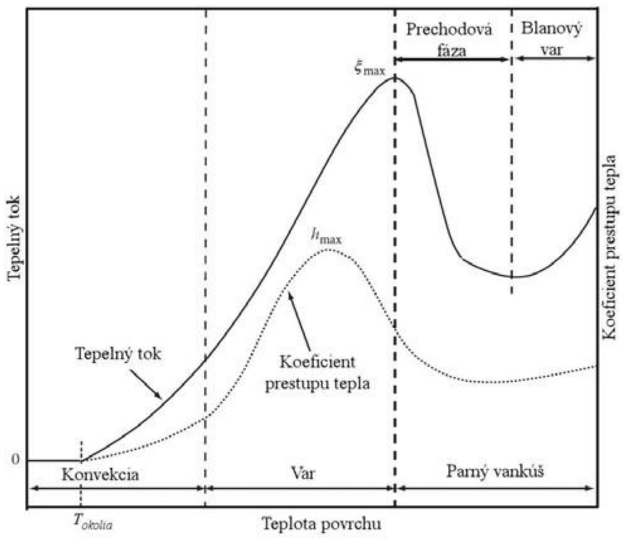

Fig.2 *Change of the thermal flow and heat – transfer coefficient from the temperature and the cooling phase.*

Heat transfer in the part during quenching is possible to describe by Fourier equation of heat conduction considering the change of the field of temperature in the form of latent heat of phasal transformations: $\rho c T = \nabla.(\nabla(\lambda T)) + Q$

Where ρ is thickness, c – heat capacity, λ conductivity of phase mixture like a function of temperature and Q is an internal source of heat in the form of latent heat which is the function of intensity of cooling and temperature.

Mechanical interactions in the case of quenching are usually expressed by the thermo-elasto-plastic constitutive equation. Creation of single phases depends on cooling speed.

Single phases have a different volume and they cause creation of local tensions in a quenched part. Cooling speed has an influence on creation latent heat which depends on the kind of created phase and its volume share. Thermal gradient and phase transformation have an important influence on dimensional changes and remanent voltages. Dependence between temperature change, phasal transformations and mechanical properties is connected with chemical composition of material.

Total deformations $d\varepsilon_{ij}$ created during continual cooling is possible to divide into elastic $d\varepsilon^{e}_{ij}$, unelastic $d\varepsilon^{p}_{ij}$, thermal deformations $d\varepsilon^{th}_{ij}$, deformations from phasal transformations $d\varepsilon^{ph}_{ij}$ and deformations caused by transformation induced by plasticity $d\varepsilon^{tp}_{ij}$. $d\varepsilon_{ij} = d\varepsilon^{e}_{ij} + d\varepsilon^{p}_{ij} + d\varepsilon^{th}_{ij} + d\varepsilon^{ph}_{ij} + d\varepsilon^{tp}_{ij}$

4. EXPERIMENTAL PART

Modelling of ovality of bearing rings after quenching consists of simulation by simulation software SYSWELD with the aim at the results of simulation of shifting of model points. These reults were compared with real measured values of ovality of bearing rings.

5. BEARING RING AND ITS MODEL

Experimental bearing rings have the biggest wall thickness 7,3mm. External diameter of the rings is 90,25mm (Fig.3).

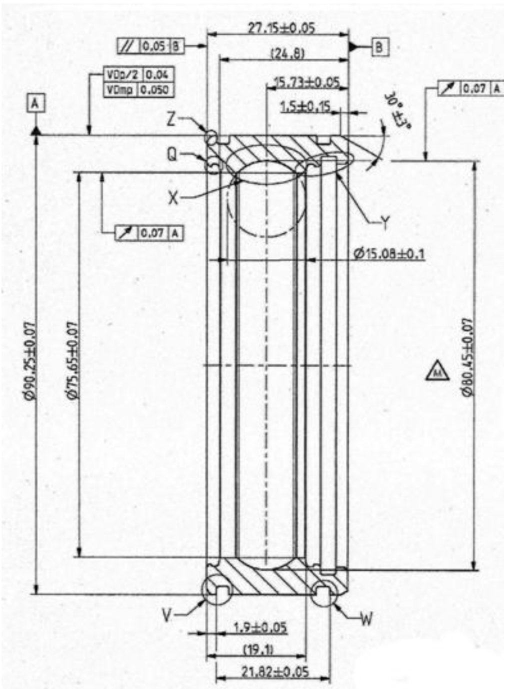

Fig.3 *Parametres of experimental bearing rings*

Computing model was creeated according to (Fig.3). It consists of volume part and the surface determined to define heat transfer between cooling part and cooling medium. On this model there were defined fringe requirements, which mean that the ring will be during cooling under the influence of self-weight put on the flat surface (Fig.4).

Fig.4 *Computing model of the bearing ring*

Input parametres of the simulation were the same as real technological process of heat treatment of bearing rings: austenitizing at 850°C for 20 minutes. Cooling in mineral oil Marquench 875 and tempering at 190°C for 120 minutes.

6. RESULTS OF SIMULATION OF OVALITY

Ovality from results is presented by shifting of points in axes Y and Z, which is the same (Fig.5). From the colour spectrum is evident that the result of ovality simulation is maximal shifting of the points. It is presented by one value 0,098 mm (summary of absolute values of maximal shifting of the points).

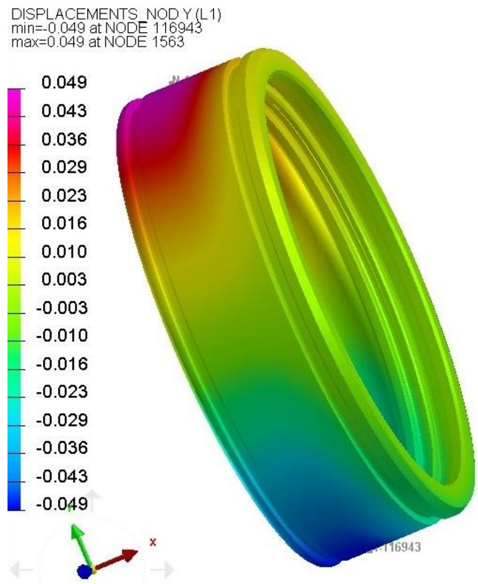

Fig.5 *Results of ovality simulation*

7. REACHED VALUES OF OVALITY

Measuring of values of bearing rings ovality was done by certificated Talyrond 73. There was evaluated 115 pieces of bearing rings by measuring of ovality in external diameter according to Fig.6. Ovality is an average of two measurements on each bearing ring.

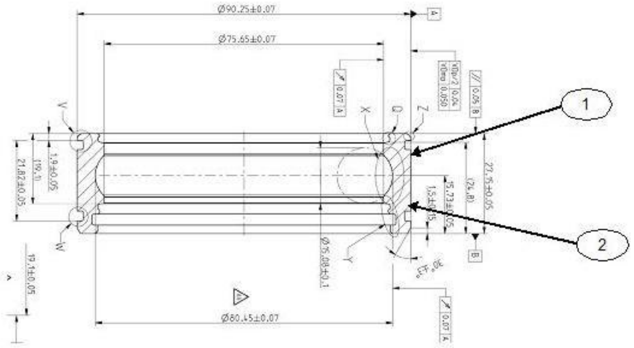

Fig.6 *Planes of measuring of ovality*

An average ovality of bearing rings before quenching and tempering was 0,023 mm. It means that requirements were fulfilled. An average ovality after quenching and tempering increased at 0,11mm.All the values are shown in Fig.7.

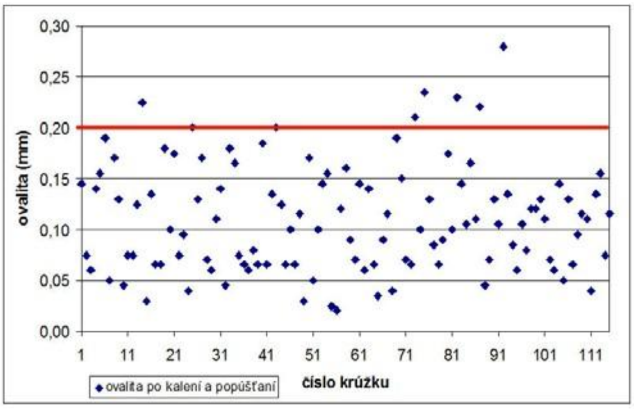

Fig.7 *Values of ovality after quenching and tempering.*

8. CONCLUSION

Simulation provides simplified view how from totally circular part can become a non – circular one. However bearing rings do not come into the quenching operation like totally circular, what is seen from measured ovality values. The result of simulation of ovality can be presented like increase of ovality of bearing rings during quenching. The result comparison is shown in Tab. 2.

Tab.2 *Comparison of ovality increase*

	Maximal increase of ovality on external diameter (mm)
Simulation	0,098
Reality	0,087

From theoretical point of view these results can be considered very successful. Especially in the case of austenitizing rings in shielding gas. Austenitizing without shielding gas can cause decarburization and creation of turnings and they are the ones which cause other combination of factors influencing ovality. From the practical point of view the results do not provide information about a share of bearing rings from given set where were and will be found out markedly higher ovality values.

Simulation provides one value in the form of maximal shifting of the points in one axe, which we were comparing with an average of measured values.

From the practical point of view it does not bring valuable, new and necessary information for a producer of thin – walled bearing rings. Ovality values are always within similar intervals. It is necessary to emphasize that scientific and practical view of the simulation of bearing rings quenching differ especially for this application: modeling of quenching of bearing rings, where data totally influencing optimalization of technological process of quenching (from the point of view of ovality), are by means of simulation practically unreachable because they are complicated and they have also a high share of random events existing in these processes.

9. ACKNOWLEDGEMENT

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