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Inspection of Generator Shield Heat Treatment by Hole Drilling Method

Otakar Weinberg[1, a], Petra Hájková[2, b], Stanislav Holý[3, c], Jiří Janovec[4,d] and Jaroslav Václavík[1, e]

[1]Výzkumný a zkušební ústav Plzeň s.r.o., Tylova 1581/46, 301 00 Plzeň, Česká republika

[2]ČEZ, a. s., Jaderná elektrárna Temelín, 373 05 Temelín, Česká republika

[3]Ústav mechaniky, biomechaniky a mechatroniky, Strojní fakulta, ČVUT Praha, Karlovo náměstí 13, 121 35 Praha, Česká republika

[4]Ústav materiálového inženýrství, Strojní fakulta, ČVUT Praha, Karlovo náměstí 13, 121 35 Praha, Česká republika

[a]weinberg@vzuplzen.cz, [b]petra.hajkova@cez.cz, [c]stanislav.holy@fs.cvut.cz, [d]jiri.janovec@fs.cvut.cz, [a]vaclavik@vzuplzen.cz

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Abstract. In this article, the level of residual stresses on the set of several large-size castings of turbo-generator shield block is investigated to optimize the heat treatment and machining using hole-drilling method. Heat treatment of castings and methods and arrangements of the investigations including results are described as well.

Introduction

The residual stresses, put to the structure during the incorrect casting process, can lead to change of dimensions, problems with the assembly, induce higher operational stresses and subsequently may cause the fatigue damage of the structure.

The level of residual stresses on the set of several large-size castings of turbo-generator shield block was investigated to optimize the heat treatment and machining using hole-drilling method. Heat treatment of castings and methods and arrangements of the investigations including results are described as well.

Description of the Problem

The Goal of Performed Investigations. The measurement of residual stresses of six sets of the generator shield from the turbine side which should determinate the necessary heat treatment for minimum costs and minimum residual stresses was the goal of the investigation. The producer effort also was to avoid the stress relief annealing (SRA).

The shield is built from bottom and upper part; both halves are designed as the ø3780 mm semicircular plates with stiffening ribs and flanges, mutually connected with pins and bolts (Fig. 1a, 1b). The masses of the bottom an upper parts are 9500 kg and 6500 kg, used material GS-30Mn5 with $R_{p0.2}$ = 450 MPa and R_m= 600 MPa.

The problems were started at the moment, when both finish-machined parts were replaced for new ones. The assembly of both parts with dowel pins was impossible due to the different dimensions overlap at the assembly plane. It was estimated, that the cause of this feature can be high level of residual stresses, lead to the both parts during casting, heat treatment or raw machining. Therefore a comprehensive program of production conditions to the shields stability was performed.

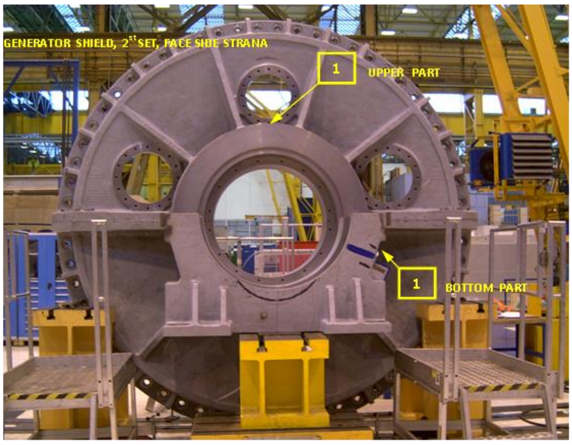

Fig. 1a Generator shield, face side

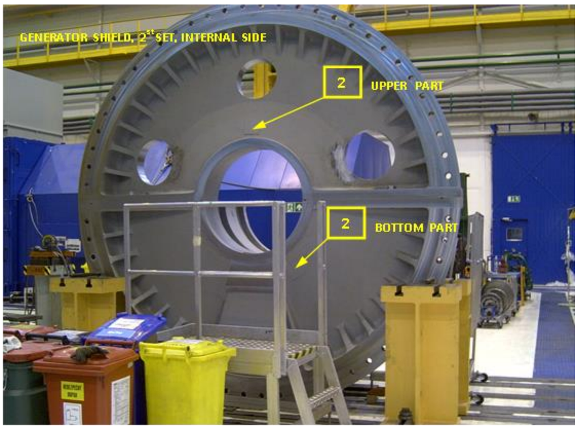

Fig. 1b Generator shield, internal side

Heat treatment. The positions for the measurement were selected according the calculation model. Both the distribution of temperature stresses coming from the controlled heat treatment and acting operational stresses were taken in considerations. The final decision of the places was performed according measurement limits of hole-drilling method.

Meeting the criteria of stated heat treatment conditions is critical for keeping the calculated mechanical parameters of castings. The used procedure comes therefore from the analysis of the chemical compositions of the used castings. Subsequently the individual phases of heat treatment are performed. It concerns the normalization, hardening, tempering and the stress relief annealing (SRA). Setting and controlling the particular operations of heat treatment is performed according theoretical and empirical knowledge of the producer. According this scheme the heat treatment of investigated parts was performed. The basic parameters for heat treatment were: normalization at 920°C/8÷12 hours in the air, hardening at 920°C/8÷12 hours to water, tempering 570÷620°C/6÷8 hours in the air and the annealing for residual stress removing 550÷600°C/8 hours in the air.

Used Method and Measurement Positions

Measurement Method. The hole drilling method was used for residual stress investigation. Using the standard equipment for hand-drilling, the hole ø4 mm was drilled up to 4 mm depth with 2-edge eccentric end mill ø 4 mm and the residual stresses were evaluated according the own procedure, which is in conformity with the methodology, used in [1]. The advantage of this procedure is the possibility of measurement of residual stresses in large depths. The used strain gauge rosette HBM 3/120 RY21 was pre-drilled with the end mill ø2 mm at each step. It was verified that using this procedure no significant stresses are induced during the low speed drilling.

Measurement Positions. Two measured positions were chosen at each casting, one measuring point on the face side marked “1” and one on the internal back side marked “2” (see Fig. 1 and 2). On the bottom part face side the position was chosen on the lug side of the bearing housings. On the upper part face side the position was chosen in the cavity of the bush for shaft leading. The measurement positions on the internal shield sides were at the similar positions at the annual area for the shaft leading.

Fig. 2 On-site measurements of the shield

Performed tests and results

Performed Tests. Six sets of shields were chosen for the test from which results from three sets are presented here. Each set differs with heat treatment and machining parameters. The pulsed pressuring with 0.9MPa (PP) was also investigated to be able to lower the residual stresses.
The first shield set was as delivered from the producer on final mechanical conditions – at these parts the problem has occurred. The expectations of high residual stresses were confirmed. The measured residual stresses reached the levels higher than 500 MPa in compressive sense. No other heat treatment investigations were performed with this set. Probably no stress relief annealing was performed by the producer (Fig. 3a, 3b).
The second shield set was new product with all heat treatment steps including the annealing for residual stress removing. The manufacture was followed by the customer. The shield has left only the finish allowance. The measured residual stresses were very low < 25 MPa. The second step was the investigation residual stress change after the final machining and (PP). Both procedures have insignificant influence to residual stress level, the measured residual stresses were very low < 30 MPa (Fig. 4a, 4b).
The third shield set was delivered from metallurgical works with only standard heat treatment. The measures residual stresses were again high compressive about 300 MPa, but lower in comparison with the original set. After this step the rough machining (RM) was performed. The raw machining also has no significant influence to the level of residual stresses; measured values were again compressive about 300 MPa. The final step was the stress relief annealing. The residual stresses after this step fall down significantly down to 30 MPa (Fig. 5a, 5b). All measured residual stresses for all sets were compressive.

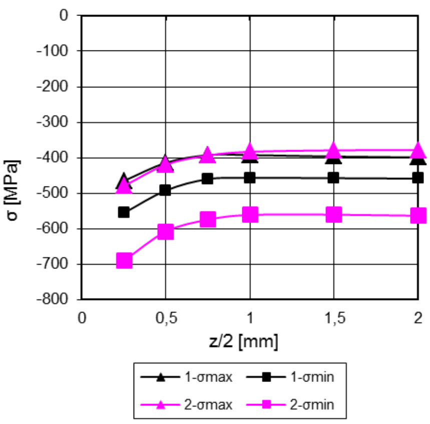

Fig. 3a 1st set, upper part, without SRA

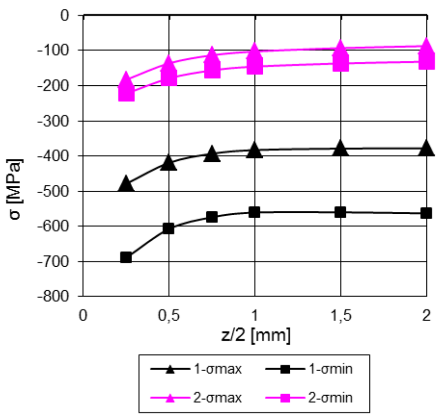

Fig. 3b 1st set, bottom part, without SRA

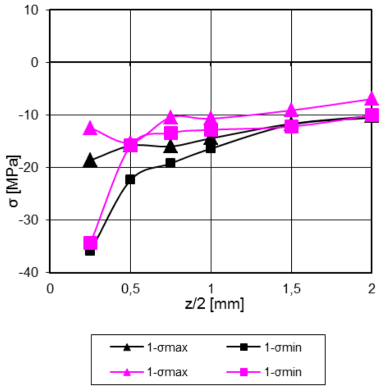

Fig. 4a 2^{nd} set, bottom part, SRA+PP

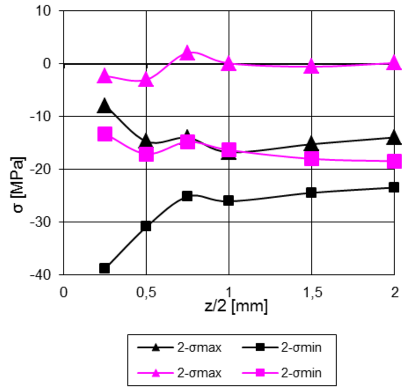

Fig. 4b 2^{nd}set, bottom part, SRA+PP

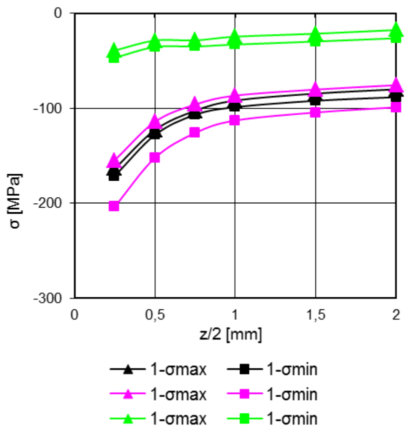

Fig. 5a 3^{rd} set, bottom part, RM+SRA

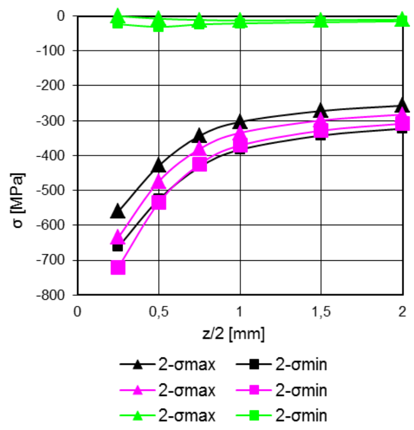

Fig. 5b 3^{rd} set bottom part, RM+SRA

Conclusions

The resulting residual stresses for all sets of investigated pairs of turbo generator shield did not fulfill the condition for low values for the technological operations, where as the final technological operation the annealing for residual stresses was not presented. The exact complex tuning of this heat treatment (heat velocity, temperature holding time, the velocity of cooling, kinds of cooling) influence significantly the required controlled features. The technological operation of pulsed pressuring has only marginal effect and does not considerably influence the level of residual stresses. Its account is only in slight redistribution of residual stresses.

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