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EXPERIENCE OF REPAIR OF PARTS OF TPS POWER UNIT EQUIPMENT

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Technology of welding and recovery of performance of the shaft of regulator of limiting number of revolutions in automatic safety device of turbo feed pump in No.1 power unit of Trypillya TPS is presented. Operating conditions of automatic safety device of regulator shaft and causes for its damage have been analyzed. Parameters of the mode of welding and heat treatment of the regulator shaft from steel 40Kh were optimized. Microstructure and mechanical properties of witness-samples were studied, and optimum technological conditions of producing a sound repair welded joint were determined. Obtained results were confirmed by successful operation of the turboset for 2743 h. 7 Ref., 3 Tables, 5 Figures.

Keywords: *reconditioning repair of power equipment, TIG welding, welded joints, heat treatment, microstructure, mechanical properties*

Feed pump PN-1135-340 with turbo drive OR-12PM is used in TPS power units of 300 MW power for supplying the feed water from deaerator to boiler TPP-210A through high pressure heaters [1]. The driving turbine of the feed pump consumes steam of III extraction (P = 1.56 MPa, T = 440 °C).

Regulator of critical number of revolutions is one of the main elements of the automatic safety device, which is installed on the turbo feed pump (TFP) and is used for its protection from exceeding the rotor speed (Figure 1).

Purpose, operating conditions and causes for damage. Regulator of critical number of revolutions of circular type is located on driving turbine rotor and is set to the number of revolutions of 5700 rpm.

During the service period of TFP automatic safety device, cases of both partial damage of the regulator shaft and of its complete destruction were observed. During the scheduled repair period of the power unit in 2016, after the regulator has operated for 75000 h, damage of regulator shaft in the area of fillet transition was detected in the form of a not through-thickness circular crack. The damage site is shown in Figure 2.

The crack was eliminated by turning the neck shaft to the depth of 3.1 mm. After cutting out the crack, a metal layer was further removed to the depth of 0.5 mm for guaranteed elimination of undetected microcracks. The completeness of crack removal was

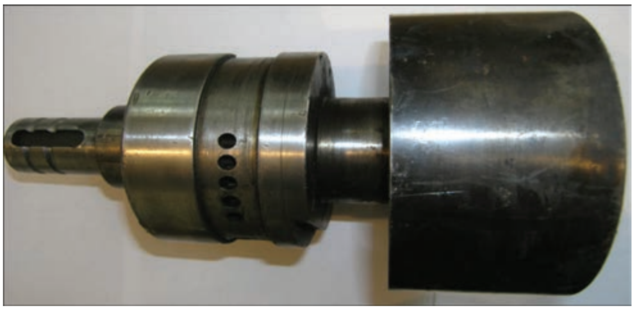

Figure 1. General view of the regulator of critical number of revolutions of automatic safety device in TFP of K-300-240 turbine

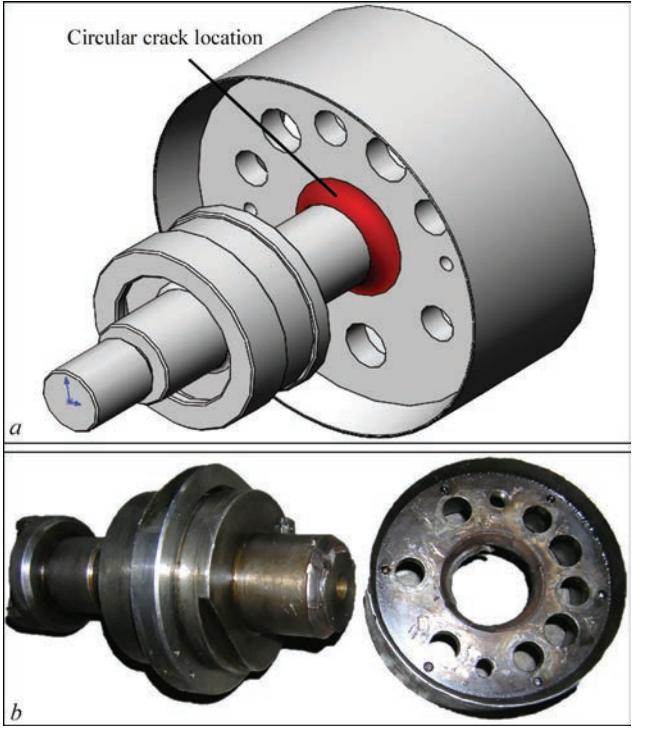

Figure 2. Location of fatigue damage of regulator shaft (*a*) and case of total destruction of the shaft as a result of cyclic loading (*b*)

Table 1. Chemical composition of 40Kh steel according to GOST 4543–71 and determined by PMI Master Pro chemical composition of 40Kh steel and Sv-04Kh19N11M3 deposited metal

Material	C	Si	Mn	Ni	S	P	Cr	Cu
40Kh (GOST 4543–71)	0.36–0.44	0.17–0.37	0.5–0.8	Before 0.3	Before 0.035	Before 0.035	0.8–1.1	Before 0.3
40Kh (PMI Master Pro)	0.451	0.277	0.977	0.0824	–	–	1.09	0.0962
Sv-04Kh19N11M3 deposited metal	0.216	0.288	1.19	5.41	–	–	8.10	0.201

Table 2. Mechanical properties of 40Kh steel at T = 20 °C

Product range	Size, mm	σ_t, MPa	σ_y, MPa	δ, %	Ψ, %	*KCU*, kJ/m^2	Heat treatment
Forging GOST 8479–70	150	655	490	13	40	540	Hardening 860 °C, oil; tempering 550 °C, water
40Kh hardness after tempering							*HB* 218–248

controlled by visual examination and conducting dye penetrant testing.

Analysis of the conditions of regulator shaft operation (intensive alternating loads in the stress concentration area) and fractographic studies of fracture of a similar shaft, which was replaced by a new one, are indicative of a transcrystalline type of fracture and fatigue nature of damage.

After taking into account all the factors (absence of experience of performing repair of such parts by welding, precision of geometrical dimensions of the shaft and rather high requirements to their deviations, short time frame of the repair campaign and absence of the required spare parts), a decision was taken to perform the repair operations under the conditions of the enterprise shop.

The objective of the work is development and testing of the technology of repair of TFP regulator shaft in the area of fatigue damage by welding under shop conditions with application of electrode material of austenitic class, performance of thermal tempering of the item and application of special technological fixtures.

Investigation procedure. Regulator shaft is made from structural alloyed steel 40Kh to GOST 8479–70. Addition of chromium promotes reduction of the critical hardening rate, and, thus, improvement of hardenability. Tables 1, 2 present the chemical composition and mechanical properties of 40Kh steel, accordingly.

Considering the limited weldability of 40Kh steel [2–4], the need for preheating and finish heat treatment of part, the procedure of optimization of welding technology and selection of mode parameters was performed on witness-samples.

Conducted investigations were realized with application of the following equipment:

- spectral analysis was conducted using optical-emission spectrometer PMI-MASTER Pro;
- mechanical testing was performed in tensile testing machine UMM-10;
- Brinell and Rockwell hardness was determined in UT hardness meter TKM-459;
- microstructure was assessed in Metam RV-21-2 microscope with x100–500 magnification.

Table 3 gives the welding process and mode parameters. VD-306D was used as the welding source.

TIG welding was performed in the downhand position, in two layers. After welding the samples were subjected to general heating in an electric furnace up to 300 °C temperature. At the next stage, the samples were cooled with the furnace for two hours and controlled. Examination of outer surface of welded joints after polishing with subsequent etching in acid showed absence of defects.

Conducted macroexaminations revealed a dense structure of the deposited metal of the weld and near-weld zone. Microstructure of the zone of Sv-04Kh19N11M3 deposited metal consists of austenite with finely-dispersed carbide particles (Figure 3).

Results of mechanical testing of samples with welded joints for ultimate strength σ_t and relative reduction in area ψ meet the requirements to base metal and are equal to σ_t = 806.7 MPa, ψ = 40 %. Sample fracture was of tough type and ran in the HAZ.

Table 3. Parameters of the modes of welding witness-samples from steel 40Kh

Sample number	Welding process	Filler material	Electrode diameter, mm	*I*, A	$U_{o.-c}$, V	Heat treatment temperature, °C	Initial and final hardness, *HB*		
							Base metal	Weld	HAZ
1	TIG	Sv-04Kh19N11M3	2	80	Not more than 95	300	183–192	270–275	290–295

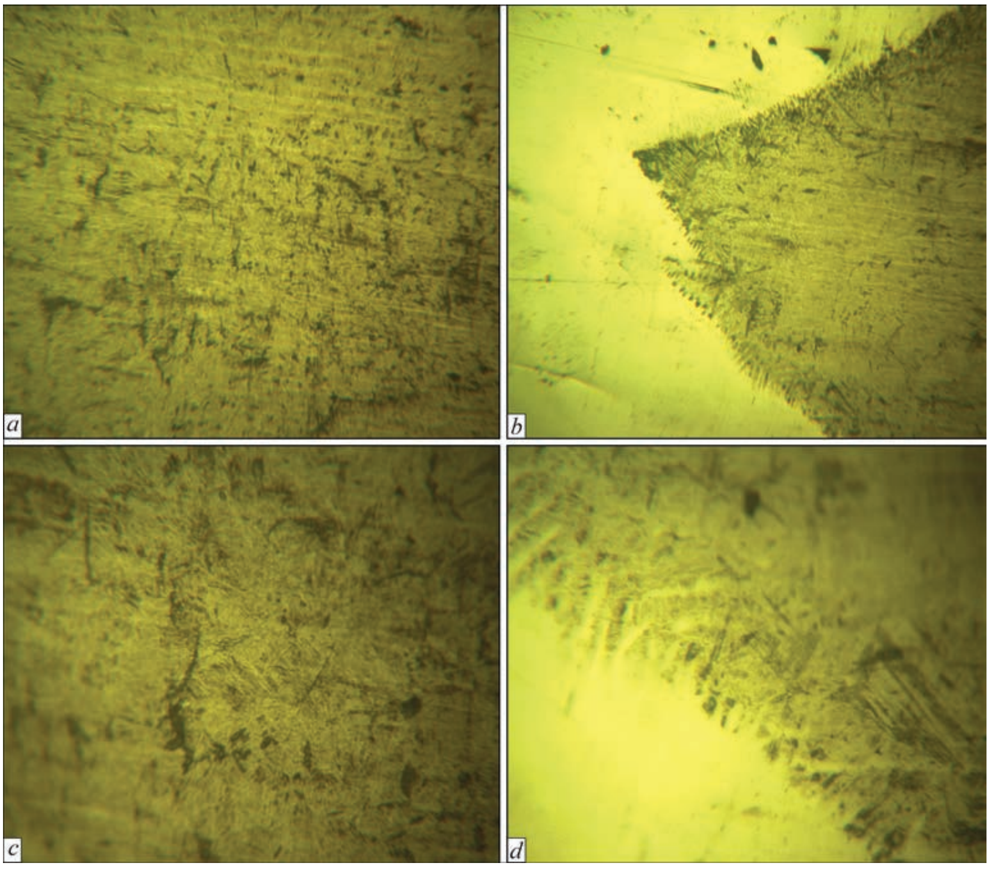

Figure 3. Microstructure of areas of 40Kh steel welded joint: *a* — Sv-04Kh19N11M3; HAZ; ×100, TIG; *b* — weld; ×100, TIG; *c* — Sv-04Kh19N11M3, HAZ, ×500, TIG; *d* — weld, ×500, TIG

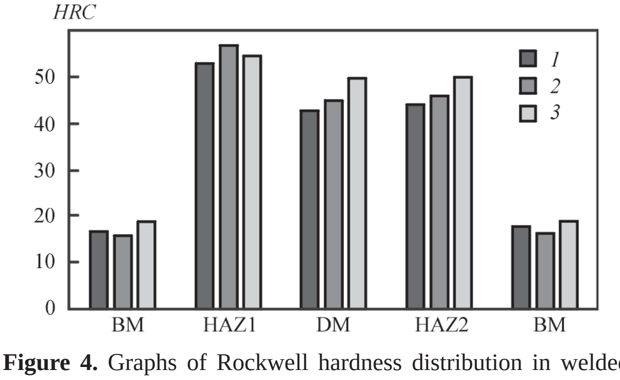

Figure 4. Graphs of Rockwell hardness distribution in welded samples made by Sv-04Kh19N11M3; *1* — plane 1; *2* — 2; *3* — 3

Welded samples were tested for hardness. Measurements were taken in three longitudinal planes with reference point on welded joint central axis and 1.5–2.0 mm step.

Test results showed that welding of 40Kh steel by the specified technology changes the structure and hardness of base metal in the HAZ (Figure 4). The scheme of edge beveling in fillet transition of the shaft and the fixture used during repair welding, are shown in Figure 5. After performance of repair welding with all the stages of heat treatment, vibration-based diagnostics of the shaft was performed with success.

Analysis of the results. Results of post-operational inspection show the possibility of application

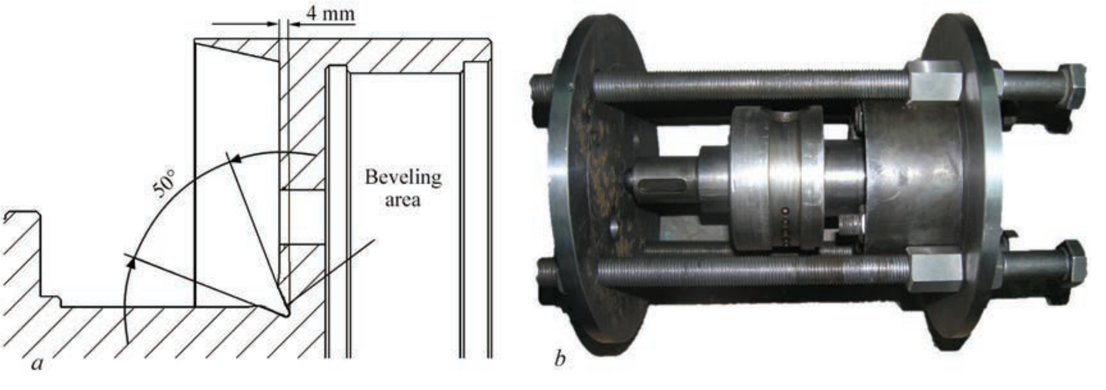

Figure 5. Scheme of beveling the edges of regulator shaft fillet transition (*a*) and fixture for realization of the technology of shaft welding (*b*)

of austenitic filler material for repair of the regulator shaft with simultaneous preheating (200–300 °C) and thermal recovery (250 °C). Thus, application of technological measures (special fixture for shaft fastening) in combination with optimized welding technology, ensured successful operation of regulator shaft of TFP PN-1135-340 with turbo drive OR-12PM during the overhaul period of 300 MW power unit.

It should be noted that there is a rather long-time experience of repair of power equipment (particularly, large-sized) with application of dissimilar (austenite + pearlite) materials [5, 6]. The main advantages of this approach are the possibility to avoid performance of finish heat treatment, owing to the ductility margin of the deposited metal, as it is technologically impossible in TPS in some cases. In order to reduce hydrogen embrittlement and lower the diffusion level of mobile hydrogen in the shaft weld metal, thermal tempering was applied after welding, which leads to lowering of hydrogen content in the welded joints [7], and a certain lowering of the level of residual welding stresses.

The short-term effect and low reliability of this kind of repair, because of the above-mentioned factors, should be regarded as its disadvantages.

Conclusions

Selection of austenitic class of the deposited metal, despite the obvious disadvantages, such as chemical and structural inhomogeneity, allowed minimizing the mode of finish heat treatment and reducing the risk of part deformation and, as a result, deviations of the high-precision geometry of the shaft after the welding operations, from the requirements of the drawing that is confirmed by the results of vibration diagnostics.

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