APPLICATION OF LOW-FREQUENCY VIBRATION PROCESSING AT A PERFORMANCE RESTORATION OF STEAM TURBINE BLADES

ПРИМЕНЕНИЕ НИЗКОЧАСТОТНОЙ ВИБРАЦИОННОЙ ОБРАБОТКИ ПРИ ВОССТАНОВЛЕНИИ РАБОТОСПОСОБНОСТИ ЛОПАТОК ПАРОВЫХ ТУРБИН

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Abstract: *the present article examines the technical and economic advantages of vibratory stress relief from the restored steam turbine blades. It is presented the background technology of the offered vibration method of the structure stabilization of weld metal that improves the operational reliability of turbine blades.*
***KEYWORDS:** VIBRATION PROCESSING, WELD FACING, LOW-TEMPERATURE CRACKS, RESIDUAL STRESSES, TURBINE BLADE, METAL STRUCTURE*

1.Introduction

The highly effective energy saving technological processes finds an extensive application in industry. In particular a low-frequency vibration processing belongs to such processes. More often application it finds for the decreasing of residual stresses at welding structure production [1,2]. Vibration processing in comparison with heat treatment allows considerably improving the organization of production.

2.Method relevance

The economic effect of the vibratory stress relief in comparison with the heat treatment is expressed in the following: the compact equipment can be installed in any point of the production shop; low operational costs; power consumption is much lower; the sizes and weight of the details are not almost limited;details surfaces aren't oxidized.

It is found that the significant effect on the low-temperature cracking in welding structures from middle and high-alloyed steel is rendered by residual stresses. Especially it concerns the products subjected to cyclic loadings. The first effort of the research in this direction showed that the critical stress of the low-temperature cracking as a result of a heat treatment and vibration approximately identical and makes 20-25%. On the other hand a vibration processing is almost not effective for cold-drawn materials since at the same time there is a distortion of a crystal latitude. Considering that at the production of a welding structure it is often used the cold-rolled metals, and after welding the seams and in particular a zone of a thermal influence is exposed to pro-forging, it is appropriate to make the vibratory stress relief in a complex with heat treatment. It is connected with the fact that a vibration processing doesn't change metallurgical structure of a metal. At the same time vibration processing needs to be carried out before heat treatment.

3.Main part

Recently, the method of restoration of working blade tips of the steam turbines with the use of a deposit welding is widespread in the world practice. Despite the recommendations of the certain authors about the need when welding to apply the materials of an austenitic class as additive materials, the problem of vibratory stress relief remains urgent. Undoubtedly, the use of the specified additive materials in the course of welding at a strict observance of a task requirements, the value of running energy and the sequence of welding don't allow to stabilize the structure of weld metal enough. In this regard the values of a residual stress need to be reduced unambiguously. Especially it touches the steam turbines blades manufactured from the high-chromium steel of martensitic -ferritic class. PT-13/90 and K-300-240 turbine blades of the last stage were restored. The restoration of the working tips was carried out with a multiple-bead deposit. After a multiple-bead deposit and HEZ(heat effective zone) pro-forging, the blades were subjected to low-frequency vibration tests at the stand presented on (the figure 1 – Vibration stand for tests of the turbines blades).

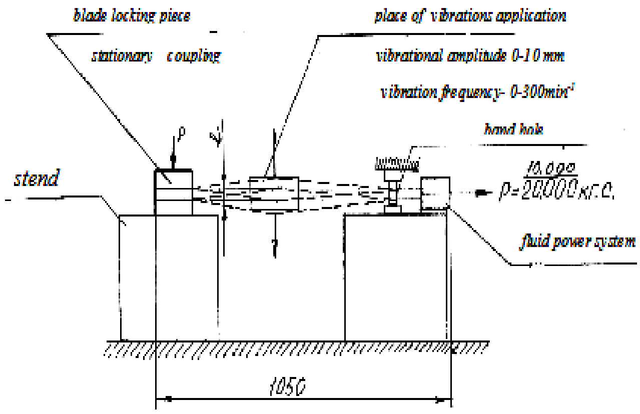

***Fig. 1** Vibration stand for tests of turbines blades*

Vibration processing was carried out on the following modes: frequency - from 0 to 200 Hertz; acceleration – to 10g; detail weight – 14 kg; the size in the plan – 1200 x 1200 mm; drive power – 10 kw; processing duration – 20-30 min.

After the vibration processing the working tips were subjected to face-hardening by a spraying method with a follow-up thermal reflowing of the stellite powder on the proven technology and carried out the machining with a profile finishing of a working blade in the drawing sizes.

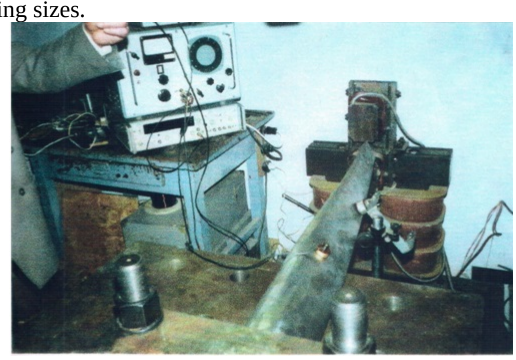

***Fig. 2** Vibration tests of blades at the stand*
in the conditions of "Remplazma" LLP Petropavlovsk

At a compliance of a blades profile to the technical requirements the residual stresses were fixed with the IKN-1M-4 device, the functional principle of which is based on a magnetic memory of metal, the developer is “Energodiagnostika” LLC. Here the use of the phenomenon of the units and parts magnetization while in operation for the identification of stresses concentration zones. This method was timely applied to the turbine blades definition which has the stresses concentration zones at a predestruction stage. An additional point is that the offered way of diagnostics allowed to define the vibration tone, i.e. to estimate its vibration reliability according to the characteristics of a field distribution of residual magnetization along a blades tip surface.

By researches it is established that the application of the hard-facing processes considerably reduces the fatigue durability of the restored details [3]. For turbine blades, working in the conditions of sign-variable cyclic loadings and restored by plasma spraying, fatigue durability was estimated by the following parameters: in coefficient of stresses concentration ($a_{\sigma}=\sigma_{max}/\sigma_{H)}$, where where σ_{max} – the maximum stresses are in the area of coverage of stresses concentration, МН/мм^2; σ_H– rated voltage in the same section, МН/мм^2 and a large-scale factor of distribution ($\varepsilon_{\sigma}=\sigma_{-1d}/\sigma_{-1}$), where σ_{-1d} – the limit of a sample endurance of any diameter, МН/мм^2; σ_{-1} – a limit of samples endurance with a diameter of 7,5 mm, МН/мм^2.

On the tests results it is established that an origin and development defect zone coincides with the plane of the design section. At the same time the concentration of the internal stresses increases in a point of the critical section. At the subsequent blade loading, the concentration of internal stresses increases in metal that is followed by the change of a structural component. Concentration of the internal stresses at the bending moment was fixed by the IKN-1M device, and results are presented in the form of the schedule (figure 3).

The test was carried out on the length of a blade working tip, in the places of the most subjected mechanical and erosive dynamic wear. Scanning by the sensor of the IKN-1M device was carried out from the radical section of a blade to peripheral or on the contrary.

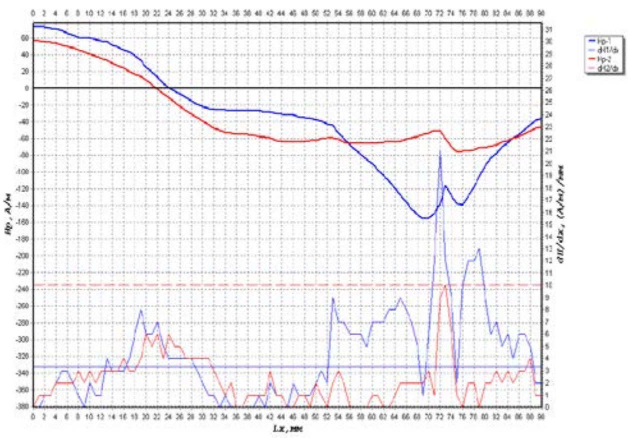

Fig. 3 *Schedule of stresses concentration zones in a hydraulic cylinder rod*

According to the characteristic of a field distribution of residual magnetization (Hp) along the blade surface, the tone of vibration was defined at the same time, i.e. the blade vibration reliability was estimated, based on the known effect of energy absorption of mechanical oscillations (damping of fluctuations),causes the corresponding growth of blade residual magnetization. The continuous red line on graphics (figure 3) shows the change of a magnetic field on a meter of a sample length (A/m) on which the accurate splashes aren't visible. The red dashed line shows the stresses admissible value for this type of a product. The blue continuous line of the schedule (gradient) shows the places of splash in KN on each mm of a sample (A/mm). The change of a sign shows about the direction of curvature.

On the control results the blade places working in the most intense conditions are defined. Such places are those ones which lines of stresses concentration and deformation (line $H_{p)}$ are located cross and having the maximum coefficient of stresses intensity. Values of this coefficient are defined automatically and displayed on the screen on the operator’s call.

The stresses concentration zone is located in the places of defects appearance of a sample on 65-80 mm on the test length and on 6-8 mm from a critical point, (figure 3). If in a critical section at the chosen scheme of jamming, the bending moment and the operating stresses have the greatest value, then at a bend of other types these sizes are about 20-25% less.

The values of the residual stresses in a zone of restoration didn't exceed the threshold values. The metalstructure of a metal represented the sorbite focused on martensite. The hardness was HB 260-280.

Blades passed tests in compliance to the standards. The following results of the tests are received: amplitude – 0-20 mm; frequency – 50 min^{-1}; number of symmetric cycles 3,1 x 10 $^{-6}$ before cracks emergence; number of symmetric cycles before cracks emergence for the blades which undergone a complex processing 5,2 x 10 $^{-6}$.

After working off of the processing methods and modes on the prototypes according to this scheme it was carried out the works on the restoration of full-scale blades on two turbines, the blades served not less than on 10 000 m/hour.

4.Conclusion

Consequently, for the early recognition of stresses concentration zones it’s shown the applicability of the "passive" methods of diagnostics using the energy of structure radiation: the method of acoustic emission and the method of a metal magnetic memory.

Tests results by these methods showed that the fatigue durability of TPP-2 turbine blades restored by a plasma spraying on “REMPLAZMA” NKSU-TOO technology is 16,3% more than the blades fatigue durability restored on the state standard specification 21448-75 technology.

This test method of the details on fatigue durability allows predicting the approach of possible defect on the stresses concentration zones on a detail, without removing it from the unit.

On the basis of the carried-out works it is established that the complex blades processing after their restoration by a weld facing increases the resistance to low-temperature cracks more than by 1,5 times. At the same time the structural disfunction of a metal basis wasn’t observed.

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