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ENERGY SAVING FOR HYDRAULIC EQUIPMENT ON THE BASE OF ADJUSTMENT OF FLOW STRUCTURE

Modern equipment which operation is linked with the movement of liquids and gases (pumps, turbines, boilers, pipelines, heat exchanger, etc), often has a low efficiency. The substantial energy losses connect with overcoming hydraulic resistance. Besides the substantial energy losses, during the movement of liquids and gases, the resistance leads to noise, vibration and other negative phenomena, too.

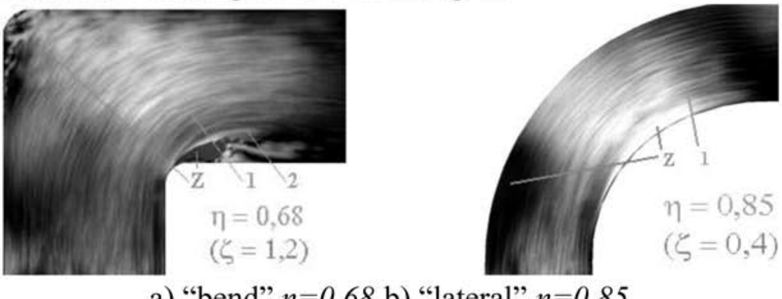
The listed disadvantages are explained by imperfect geometry of flow parts, which are often made according to the simplicity of technologies of equipment production.

The main reason of these problems is the optical transparency of liquids and gases (water, air, oil and gas), so their flow structure is unavailable for studying. So far, mechanics of liquids has no any laws describing organization of hydrodynamic structure and applicable to design optimal flow parts. Hydraulic reference books, which are used to design equipment, have unjustifiably accustomed technologically-simple flow parts for pipes, turns, t-joints, valves, etc. and their great hydraulic resistance, respectively.

Method of visual diagnosis of flow structure allowed FSVD to develop technology to improve the energy equipment. Using the flow structure organization laws while improving the flowing parts allows us to develop new or improve existing equipment with the opportunity to achieve a new level of energy, dimensional, acoustic, vibration, ejection and other characteristics.

The distinction of new energy-efficient equipment improving technology from the traditional design is the presence of an additional step - equipment flowing parts improving on the basis of flow structure visual diagnosis and the equipment parameter system optimization based on the efficiency specific indicators analysis.

Methods of application the FSVD are shown on the example of designing an optimal flow passage of flow turn by 90°. VDSP method is a physical modeling of fluid flows optically active, which ensures high reliability of research results. The examples of modernization are illustrated by results of visual diagnostic of flow structures in characteristic sections of flow parts. The flow structures in a device, which is referred to as “bend” and “lateral” – a turn with equal internal and external corners or radiuses of rounding are shown in Fig. 1.



a) “bend” $\eta=0,68$ b) “lateral” $\eta=0,85$

Figure 1. Flow structure in flow turn by 90°

The visual images characterize the field of hydraulic dynamic parameters (speed or pressure) gradients' instance meanings, based on optical density values (intensive white or grey) in every point of the flow. In other words, whilst decoding the field of speed instant meanings, "light areas" characterize positive speed gradients in the point in question and "dark areas" stand for negative speed gradients, whereas the received images enable to judge on the character of speed or pressure value changes in every point of the flow.

To characterize optimal movement of liquids or gases, let us introduce a term called "hydraulic efficiency of flow passage" η is applicable to hydraulic or aerodynamic equipment. For this purpose, we use a known meaning of consumption coefficient μ, which can be calculated based on a meaning of hydraulic resistance ζ:

$$\eta = \mu = \frac{1}{\sqrt{1+\varsigma}} = \frac{Q_a}{Q_t} \tag{1}$$

Thus, movement efficiency of liquids and gases in flow parts η can be characterized by a relation of actual consumption Q_a to theoretical consumption Q_t. In case resistance ζ in flow passage are equal to zero, then $Q = Q_t$, in which case the efficiency amounts to $\eta = 1$.

If the meaning of hydraulic resistance $\zeta = 1{,}2$, then movement efficiency η of liquids or gases in the "bend" amounts to $\eta = 0{,}68$. The illustrations demonstrate reasons for such a poor efficiency. The dissipated areas, in which the flow comes off the walls Z, are the ones, where energy losses are maximum. The chaotically located transverse structures, presented as the current lines 1, and longitudinal flow structures, presented as homogeneous optical areas 2, do not contribute to an organized movement in the flow passage of the turn.

To improve efficiency of complicated hydraulic systems (pipelines, inlet and outlet elements of pumps, turbines, boilers, etc.), the flow turn, known as "lateral", is used, which is made of radiuses of the same center (Fig. 1,b). However, the "lateral" also has areas of losses in energy Z, a meaning of its hydraulic resistance $\zeta = 0{,}4$ and efficiency does not exceed $\eta = 0{,}85$.

The first experience of implementation the FSVD-technology in order to raise productivity and efficiency of the energy equipment was the modernization of the Westinghouse 25 MW gas turbine at the Bruch Power Plant (Colorado, USA) in 1997. The Bruch Power Plant is located at the height of 2500 meters, therefore, due to lack of oxygen in the air, its gas turbine plant Westinghouse could not secure an estimated power output.

With the assistance of FSVD-method of the structure of gas flow in the Compressor Inlet Duct was diagnosed. Modernization of the Westinghouse Gas Turbine enabled to reduce pressure losses in "the compressor inlet duct" by 59%, whereas consumption of air for the turbine was increased by more than 19%.

One of the latest projects is reconstructed improvement of main and auxiliary equipment HPS Moldavian Thermal Power Plant in 2012. Has been realized the project of the modernization of steam-gas power unit SGP-250 #11 when two problems have been solved successfully: increasing capacity of the gas turbine and the oxidizer regular supply to the boiler burners. The important element of the gas system is the oxidizer distribution on the burners. Fig. 2 shows the result of visual diagnosis oxidant flow structure in the dispensing reservoir model.

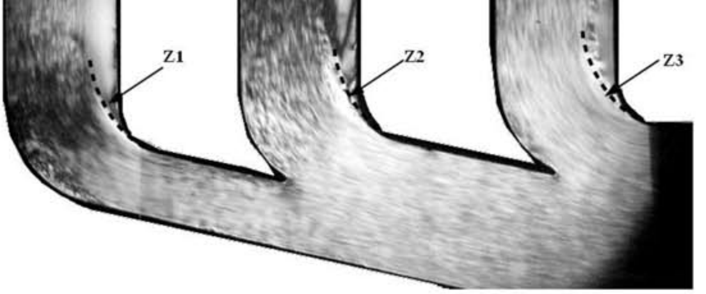


Figure 2. The flow structure in the collector Z1, Z2, Z3 – areas, in which flow comes off from the collector walls

Analysis of the flow structure eliminates flow comes off from the collector walls and to ensure uniform oxidizer distribution. Changes in the geometry of the collector shown in Fig. 3.

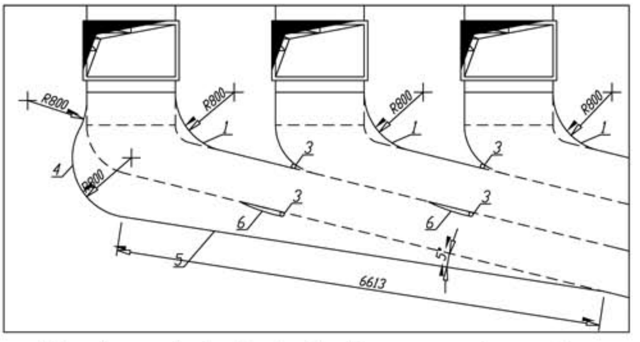


Figure 3. Collector oxidant supply to the boiler burners prior and upon FS modernization

At Fig. 3 the dotted lines show the old geometry of the flow collector. The new geometry of the collector with less resistance is shown as solid lines. New values of the flow turning radii are also shown.

As a result of project, two problems have been successfully solved: electric capacity of Gas Turbine N11 increased from 24.6 MW to 25.1 MW and uneven distribution of the oxidant for burners is reduced from 37% to 5%.

Flow Structure Visual Diagnostic method can solve also the problems of environment protection. E.g., reconstruction of the electric filters inlet parts of power unit #4 of Thermal Power Plant in Krivoy Rog (Ukraine) allowed to reduce the amount of harmful emissions from the flue gases by more than 80%. Reducing of electricity consumption for the smoke exhausts working after the reconstruction allows to decrease the payback period of project to two years.

Next project was to make the insert into thermostat valve HERZ Armaturen company for anti-noise modification.

The diagnosis of dynamic processes (Fig. 4.) showed the steady flow in the narrow valve outlet section. Due to the small size of the outlet section high speed is created in the flow, which can be the cause of vibrations, so it can be a source of noise.

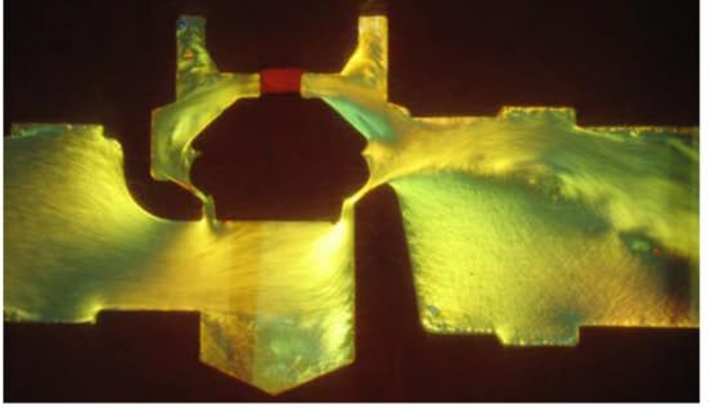


Figure 4. The results of visual diagnosis of the flow structure in the thermostatic valve TS-90 when fully opened

On the basis of the known laws of the structure of stream motion the insert has been developed which takes into account the size of the organizational structure of the flow in the valve (Fig. 5.). The hydraulic characteristics of the valve are unchanged, despite the design change.

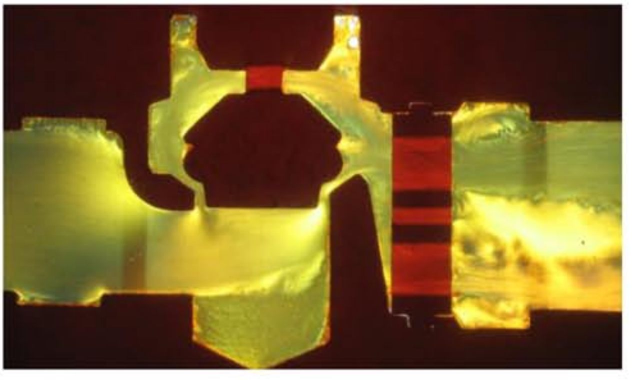


Figure 5. Visual flow diagnosis in the valve TS-90 with an insert

Conclusions

The method of flow structure visual diagnosis (FSVD) can detect previously unknown information about the laws of motion of liquids and gases. The "flow structure" new model replaces the old "turbulence" model, where the chaos of "averaged parameters" was an obstacle in energy saving problems solving. For the implementation of projects improving the equipment is necessary to develop efficiency indicators of equipment and systems that should stimulate cost-effectiveness of the equipment and processes.

Using the flow structure organization laws while improving the flowing parts allows us to develop new or improve existing equipment with the opportunity to achieve a new level of energy, dimensional, acoustic, vibration, ejection and other characteristics. The proposed technology based at flow structure visual diagnosis gives the opportunity to develop of new energy equipment with high efficiency and It helps to solve complex problems of energy saving.