POSSIBILITIES OF REDUCING THERMAL STRESSES AND POWER LOSSES IN THE STATOR OF VARIABLE TURBOCHARGER

ВОЗМОЖНОСТИ УМЕНЬШЕНИЯ ТЕПЛОВОГО СТРЕССА И МОЩНОСТЬ ПОТЕРЬ В СТАТОРЕ ИЗ ТУРБОНАГНЕТАТЕЛЯ ПЕРЕМЕННОЙ ГЕОМЕТРИЕЙ

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Abstract:
Turbines with focusing turning blades and 'insert' have been used to increase the work efficiency of the turbocharger at low engine rotation. Insert is part of the stator whose function is to provide routing streams of exhaust gases to turbine rotor. Here by, available pressure streams of exhaust gases is used to improving pre-compression at lower rotations. Detail CFD analysis has been conducted to achieve a clearer flowchart of flow phenomenon between focusing turning blades and influence of this stator part to streams of exhaust gases. The fact that the 'insert' has negative influence to streams of exhaust gases has been approached to obtain possibilities to reduce its negative effect.
***Keywords**: CFD, turbocharger, blades, stream.*

1. *Introduction*

Turbocharger is device which is used to increase power, in reference to improve engine working characteristics and decreasing fuel consumption, comparing it with the same engine with a natural suction. In order to achieve efficient work of turbocharger at lower engine rotation numbers, turbine with stator blade variable geometry is used. Direction of exhaust gases' entrance changes by rotating stator blades in the turbine rotor and optimum of exhaust gases angle flow is reaches, on which accession, the stator flange velocity changes in entire work area is compensated. The so-called 'insert', which represents a separate housing of stator blades with function for a better handover of exhaust streams, is installed in stator construction. Power of energy losses due to friction, shock, changes in the flow direction and due to swirling, are increases by adding stator blades and later 'insert' in the turbocharger construction. These losses reduce turbine efficiency factor, since less energy of exhaust gases is transformed into rotor turbine torque.

2. *Previous research*

During CFD analysis of streams exhaust gases throughout stator part of turbocharger, it has been obtained illustration of the streams, which indicates disturbances streams of exhaust gases throughout stator part of turbocharger, Figure 2.1.

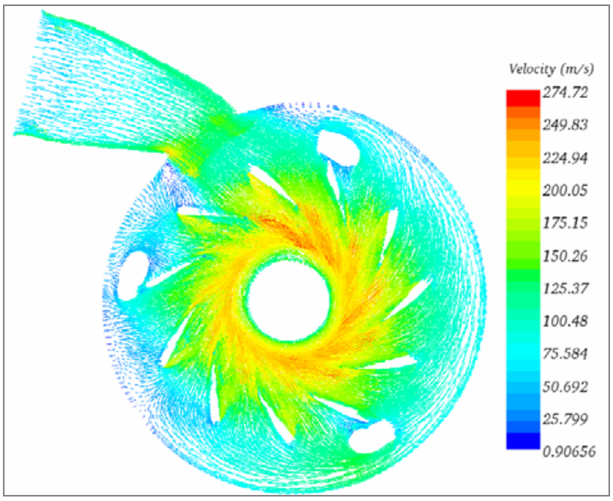

Figure 2.1 Real model velocity distribution

Figure 2.1, shows the distribution rate of exhaust gases through the stator of the turbocharger in the typical cross section, with shows the tabs of 'insert' and stator blades. From real model of velocity distribution illustration, it is possible to conclude that the tabs of 'insert' cause disturbance in streams of exhaust gases. Tabs of 'insert' that adhere router streams of exhaust gases to turbine rotor has a such a position in the stream of exhaust gases which cause disturbance of exhaust gases flow. Since they are in direct streams of exhaust gases, it becomes batting to streams of exhaust gases and creating hydraulic resistant to streaming exhaust gases. due streaming resistant, exhaust gases change flow direction, which leads to unequal filling of between blades channels, hitting streams of exhaust gases to blades and tabs, and creating eddies. In order to eliminate the influence of 'insert' tabs and improve stream characteristics in stator of the turbocharger, it has been tried with several models by changing position of 'insert' tabs.

3. *Model creation for streaming characteristics improvement*

Three models have been created, by turning 'insert' tabs for an angle in order to detect changes in the stream field with the tab changing position of 'insert', model No.1, No. 2, No. 3. Figure 3.1, shows models No.1, No.2 and model No.3.

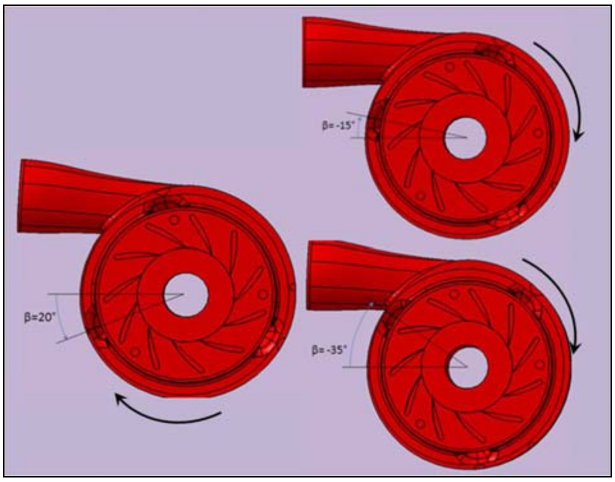

Figure 3.1 Models No.1, No.2 and model No.3

Model No.1 shows position of 'insert' in stream field, where the 'insert' is rotated in the opposite direction for angle of 20° from the direction of movement, clockwise, in relation to the realistic model. This tabs position of 'insert', the right of the entrance of exhaust gases, should reduce or eliminate the disturbance of stream exhaust gases in this area. Figure 3.1, also shows a model No.2 and it shows the position of 'insert' in streams of exhaust gases, where the 'insert' rotated in the direction of movement clockwise for angle of 15°, in relation to the realistic model. Herewith tab of 'insert' is placed between two neighboring passing blades changing of angle of stream exhaust gases. Figure 3.1, also shows a model No.3, where the position of 'insert' is presented in streams of exhaust gases and ‘insert’ is rotated for angle of 35° in the opposite direction of movement clockwise.

This way created model allows the position of ‘insert’ where one of the tabs of ‘insert’ is left to the entry of exhaust gases in the turbine housing. This position should reduce or eliminate disturbances of streams in the area.

4. Results and discussion

After the CFD analysis with the same data as in the real model analysis, results are shown and discussed.

Firstly, model No.1 is analyzed and considered. The impact of ‘insert’ tab on velocity distribution of exhaust gases has been noted in places that are highlighted in Figure 4.1.

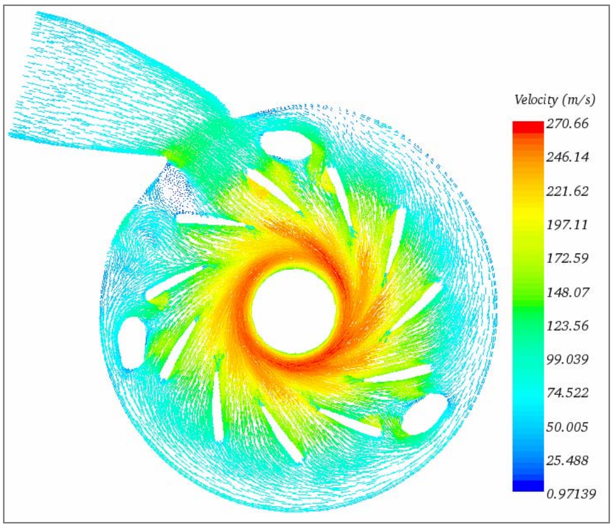

Figure 4.1 Displaying velocity distribution of model No. 1

Since ‘insert’ tabs are located at the entrance between blades channels, velocity distribution happens in those channels. Streams of exhaust gases directly strike the tabs and in the area behind them, velocity disturbances occur while velocity decreases. This is most expressed on the third tab run in the direction of movement clockwise, counting from the entrance.

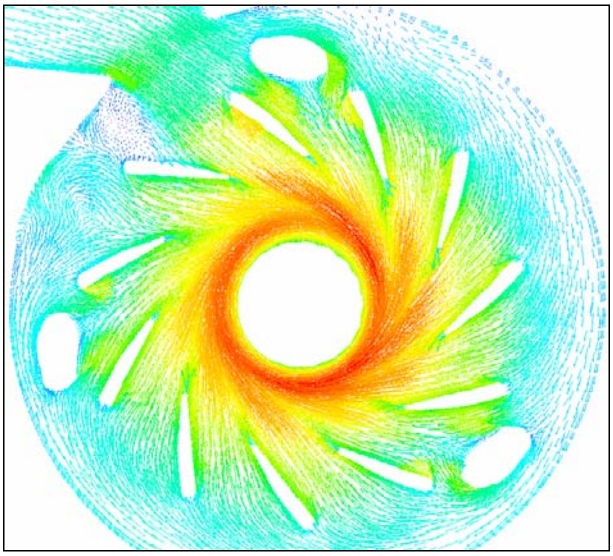

Figure 4.2 Disported velocity distribution field part of model No. 1

In this case, negative tab impact is transferred to larger area which occupies between blades channels and a large area after the ‘insert’ tab. This effect is supported by a negative impact of sharp exhaust gases entry in turbocharger expander.

Stream disturbed areas of exhaust gases are circled on Figure 4.2. It is noted an area of streaming eddies at entrance, which occurs due to a sharp entry of exhaust gases in the housing and the streaming impact. Influence of tab position which disturbs streaming distribution between blades channels after the tab, can be noticed on marked areas. By its body, tab partly turns stream to tab power in part in between blades channels, and partly next to between blades channel. The result is uniformly stuffed between blades channels and unbalanced load of rotor blades.

Pressure distribution field is presented on Figure 4.3 and marked the area in between blades channels with uniformly pressure distribution of stream exhaust gases.

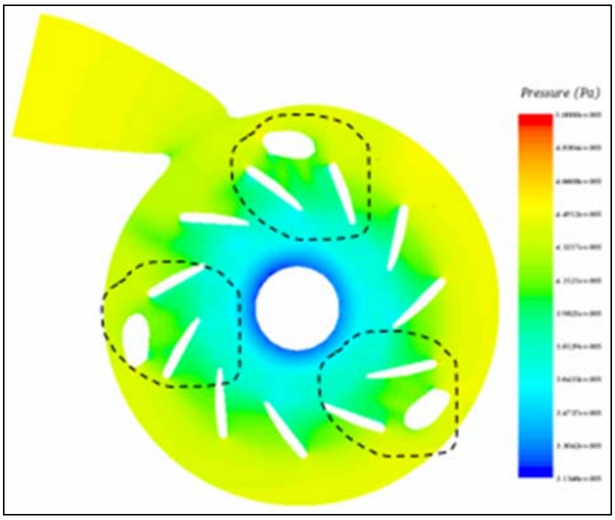

Figure 4.3 Displaying exhaust gases *pressure of model No. 1*

Disturbance of homogeneous distribution within between blades channels is the most expressed at between blades channels at first ‘insert’ tab, right from the entrance of exhaust gases in the housing expander. It can be stated in this case, Δp is less than in the real model. Figure 4.4, shows the appearance of field temperature in model No.2, where is possible to notice that the blades in the marked areas are located in heat asymmetry.

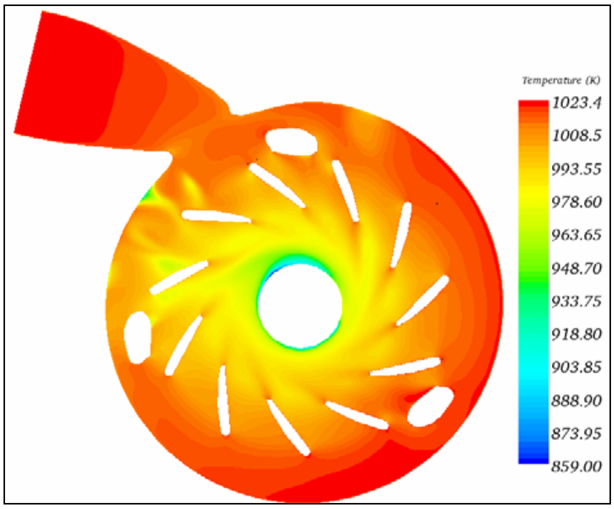

Figure 4.4 Disported velocity distribution field part of model No.2

At the place where eddies occurs, it can be noticed that temperature field is mainly balanced, with small heat asymmetry. However, in comparison to the rest of the temperature field, difference exists. In other marked areas, temperature is increased which is manifested by red color. Noted facts have result in thermal load of specified blades and it is manifested by thermal expanding and as a result in creating gap in working regime at the zero blade position. Thermal asymmetry, demonstrated through thermal stress distribution, bears the routing blades ring and a rotating blade mechanism, which entails a technical limitation of proper turbocharger function.

The display speed of the distribution of exhaust gases in the No.2, which is shown in Figure 4.5, identified the areas of disturbance flows of exhaust gases. Namely, as the tabs of the ‘insert’ are rotated to come in the no circulation area of exhaust gases between blades channels, they disturb streams in between blades channels by their position.

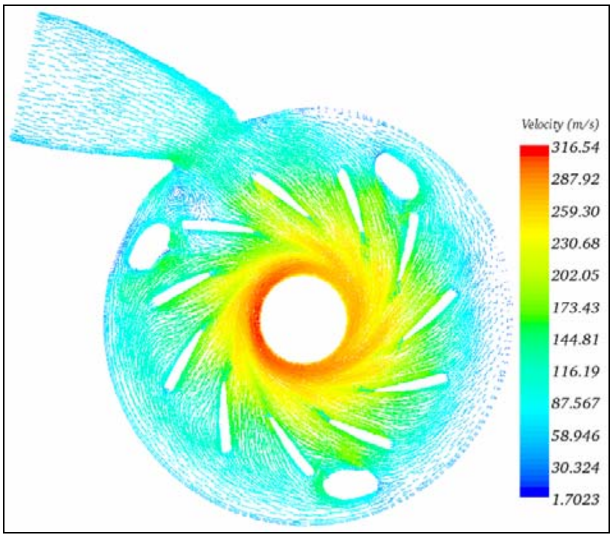

Figure 4.5 Exhaust gases velocity distribution of model No.2

However, in Figure 4.5, the tabs of ‘insert’ are located in part of between blades channels, which is opposite of to the direction of no circulation emissions. They also have a partial flow diversion exhaust gases in between blades channels. Because of this action, tabs of ‘insert’, especially on the first tab of the entrance in the direction of movement clockwise, it results in weakening of flow of exhaust gases, on the other hand of ‘insert’ tabs. This can result in deposition of particles in the turbine housing and other parts of the stator. Also, the area of swirling flow is noticeable. This area is located behind the third tab of ‘insert’, counting from the entrance in the direction of movement clockwise or immediately next to the entrance to the turbine housing to the left. This turbulence results in different circulation in between blades channels which are located next to the ‘insert’ tabs. It causes e colliding of flow in between blades channels which resulted in the loss of energy. Distribution of the pressure field is shown in Figure 4.6.

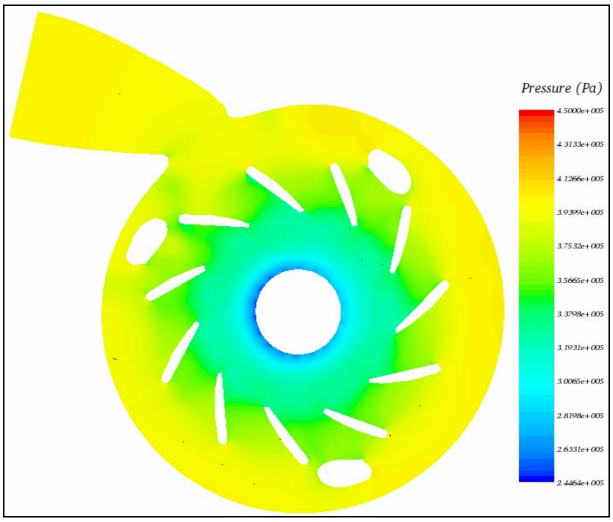

Figure 4.6 Exhaust gases pressure distribution of model No.2

In this view, it is clearly evident that disturbance pressure field homogeneity occurs in between blades channels in place of tab of the ‘insert’. Bearing in mind the transformation of pressure energy to blade rotor spinning moment is unevenly distribution of pressure in between blades channels can lead to unequal load of rotor and at thus exerts the same.

Analyzing the temperature field shown on Figure 4.7, a great heat to asymmetry in between blades channels and also in the area before them, can be noticed.

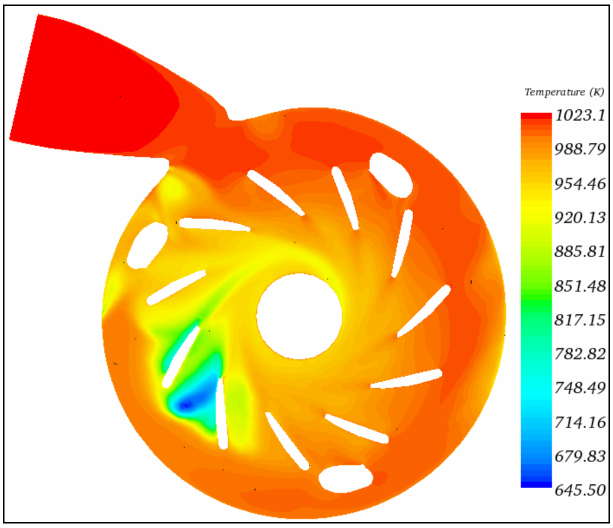

Figure 4.7 Temperature distribution of model No. 2

In the place between the second and the third ‘insert’ tab, counting from the entrance in the direction of movement clockwise, the area of low temperature load noticeable. Due to low velocity in this area, shown in Figure 4.5, and small amounts of stream in this area, less temperature load occurs. Also, in place of second and third ‘insert’ tab, temperature field homogeneity disorders occur. The stated has impact on uniformly thermal routing blades load and there, as result, creating gap in working regime at the zero position of blades. Thermal asymmetry, demonstrated throughout thermal stress distribution bears separating ring of routing blades and stator of turbocharger expander, which entails a technical limitation of proper turbocharger function. Figure 4.8, shows velocity distribution of exhaust gases in a specific cross section for model No.3. It can be noticed unfavorable ‘insert’ tabs effect to velocity field of exhaust gases as to other models.

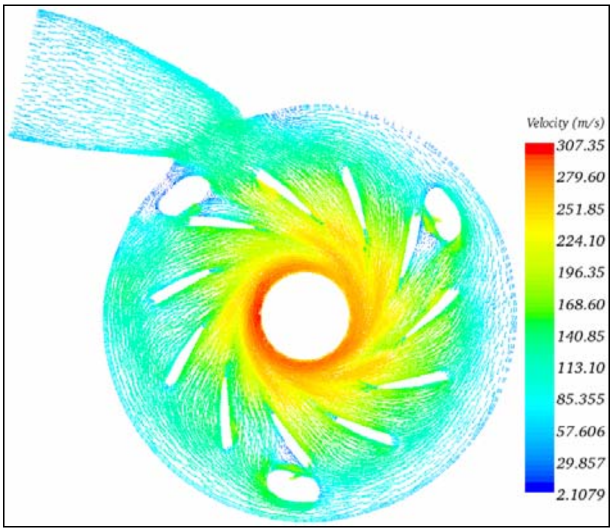

Figure 4.8 Exhaust gases velocity distribution of model No.3

The ‘insert’ tabs are positioned on that way they come to places characterized as places noted as stream exhaust gases disturbance ones. The greatest disturbance of velocity distribution of exhaust gases is on third ‘insert’ tab facing in the direction of movement clockwise, following the entry of exhaust gases. This creates turbulence that reduces kinetic energy stream of exhaust gases.

In Figure 4.9, it is noted areas of exhaust gases stream swirling at third ‘insert’ tab and stream disturbance at first ‘insert’ tab counting from the entrance to the housing movement in the direction to clockwise.

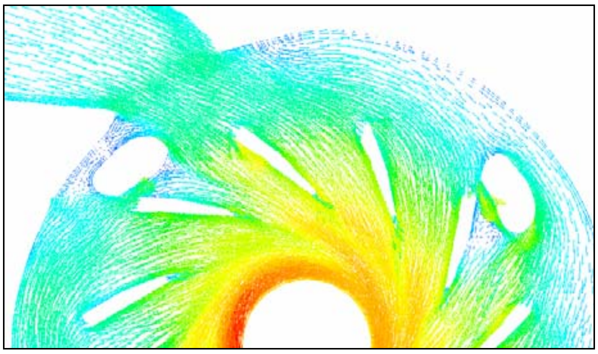

Figure 4.9 Disported velocity distribution field part of model No. 3

Asymmetric distribution in channels after 'insert' tabs can be found during analysis of pressure distribution of exhaust gases in between blades channels, shown on Figure 4.10, it this leads to larger values of Δp, which result in a lower energy transformation of exhaust gases to rotor turbine blades.

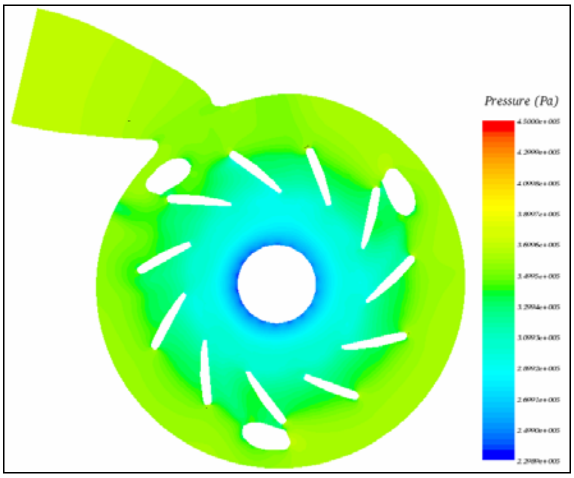

Figure 4.10 Exhaust gases pressure distribution of model No.3

From temperature distribution, Figure 4.11, it could be noticed there appears the area with lower temperatures on blades after the second tab of 'insert' following the entry of exhaust gases in the direction of movement clockwise.

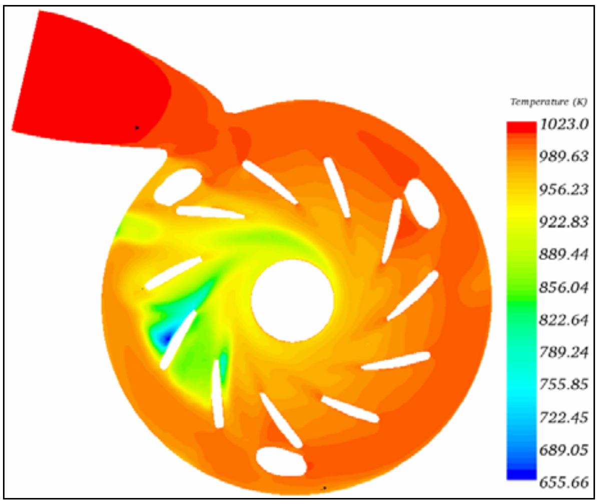

Figure 4.11 Temperature distribution of model No. 3

The appearance of this negative result has a different thermal blades load, and also different thermal expansion with the consequent creation of clearance. Routing blades holding disk and part of the mechanism for blade rotation bears thermal asymmetry, which entails a technical limitation of proper turbocharger function.

5. *Conclusion*

Based on detail analysis carried out in the velocity, pressure and temperature distribution of exhaust gases in the turbine stator, there is result that point out the possibility to increase the efficiency of the turbocharger, improving conditions of exhaust gases streaming and reducing corresponding losses. The analysis indicates the 'insert' tabs cause disorder within the streaming flow between blades channels, which inevitably entails homogeneous pressure distribution disorder within between blades channels. The influence of 'insert' tab position to streaming of exhaust gases and distribution of pressure within between blades channels has been analyzed by modeling of three models with different position of 'insert' tabs. Analysis showed that for model No. 1 position of 'insert' tab, has the least impact to homogeneous pressure distribution of exhaust gases within between blades channels. Also this model has the most homogenous heat transfer with the region, which inevitably causes higher turbochargers efficiency and extension of turbochargers life.

6. *Reference*

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