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Issue Article

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PRESSURE DISTRIBUTION CURVES ON THE SURFACES OF THE IMPELLER BLADES AND THE PERFORMANCE OF THE CENTRIFUGAL PUMP

Abstract: *The results of computer calculation of the pressure distribution of the fluid flow on the surfaces of the impeller blades at different rotational speeds of the rotor shaft of a centrifugal pump were presented in the article. It is noted that on the suction face of the impeller blade, the pressure increases at a distance from the inlet to the diffuser. At the back face of the impeller blade, the pressure increases to the middle of the chord length of the element and decreases to the diffuser. At the same time, this effect is not observed at low rotational speeds of the rotor shaft of the centrifugal pump. Also, recommendations are given on the performance of the centrifugal pump in terms of mass flow rates at different rotational speeds of the rotor shaft.*

Key words: *centrifugal pump, pressure, blade, surface, rotation, mass flow rates.*

Language: *English*

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Introduction

A centrifugal pump is a dynamic vane pump that provides movement of fluid or gas due to a rotating impeller and fixed body blades [1]. One of the main characteristics of the centrifugal pump is its performance, i.e. a certain flow rate of fluid passing through the pump per unit of time [2]. However, various factors, such as local hydraulic resistances, can reduce the performance of the centrifugal pump. This problematic issue is corrected through verification calculations and optimization of the configuration of the centrifugal pump parts [3-10].

Since the rotating impeller is a dynamic element, it is rational to consider the effect of the blade configuration on the performance losses of the centrifugal pump. The impeller consists of several blades of various configurations. The blades may have some curvature, thus these surfaces create local resistances.

The purpose of this study is to analyze the pressure changes on the suction face and back face of some blades and the effect of this change on the loss of performance of the centrifugal pump after computer calculation of the impeller rotation cycle.

Materials and methods

To calculate the pressure distribution on the suction face and back face of the impeller blade and the overall performance of the centrifugal pump, a solid-state model of it was built in a special engineering analysis program. The design of the centrifugal pump model was performed based on the following parameters: blade angle in – 1.5708 rad, blade angle out – 0.17453 rad, angle of the inside blade plate – 0 rad, angle of outside blade plate – 1.3963 rad, difference between angles – 1.3963 rad, maximum angle of the blade plane – 1.3963 rad, segment angle – 0.69813 rad, blade height – 0.02 m, radial chord – 0.05 m, chord – 0.06527 m, inner diameter – 0.04 m, impeller diameter – 0.10597 m, expansion rate of the outlet channel – 1, spiral exponential – 0.045, distance control parameter between plate and spiral and rotating domain construction – 0.005 m, inlet channel diameter – 0.035 m, number of blades – 7, plate thickness – 0.004 m, construction radius – 0.050771 m, shaft diameter – 0.02 m, distance between volute and plate from the bottom – 0.003 m, blade thickness – 0.002 m, upper clearance – 0.0015 m, volute height – 0.0285 m and reference temperature – 293.15 K. The variable operating parameter of the centrifugal pump was the rotational speed of the rotor shaft in the values of 500, 1000, 2000 and 3000 rpm. The fluid flow moved in the centrifugal pump body in accordance with the k-ω turbulence model. The computer simulation was carried out by the PARDISO solver.

Results and discussion

The change in the calculated pressure values on the surfaces of the impeller blades at a rotor shaft rotation speed of 500, 1000, 2000 and 3000 rpm was presented in the Figs. 1-3. The surfaces of the suction and back of some impeller blades of the centrifugal pump were considered. Each figure is divided into two parts by a thin solid vertical line. In each part, the configuration of the centrifugal pump model on a plane is demonstrated and the surfaces of the impeller blades are highlighted, according to which changes in fluid pressure were determined. When the impeller blade is close to the outlet of the centrifugal pump (the Fig. 1) on the suction face of the blade, the pressure increases in the direction from the inlet to the diffuser cavity at speeds of rotation of the rotor shaft of 1000-3000 rpm. From the side of the suction face of the blade, there is a slight increase in pressure at a distance of half the chord length, and towards the diffuser cavity there is a slight decrease in pressure at the same rotational speeds of the rotor shaft of the centrifugal pump. It is noted that in the case of the suction face of the blade, the effective pressure has only negative values, and in the case of the back face of the blade, the effective pressure has both negative and positive values.

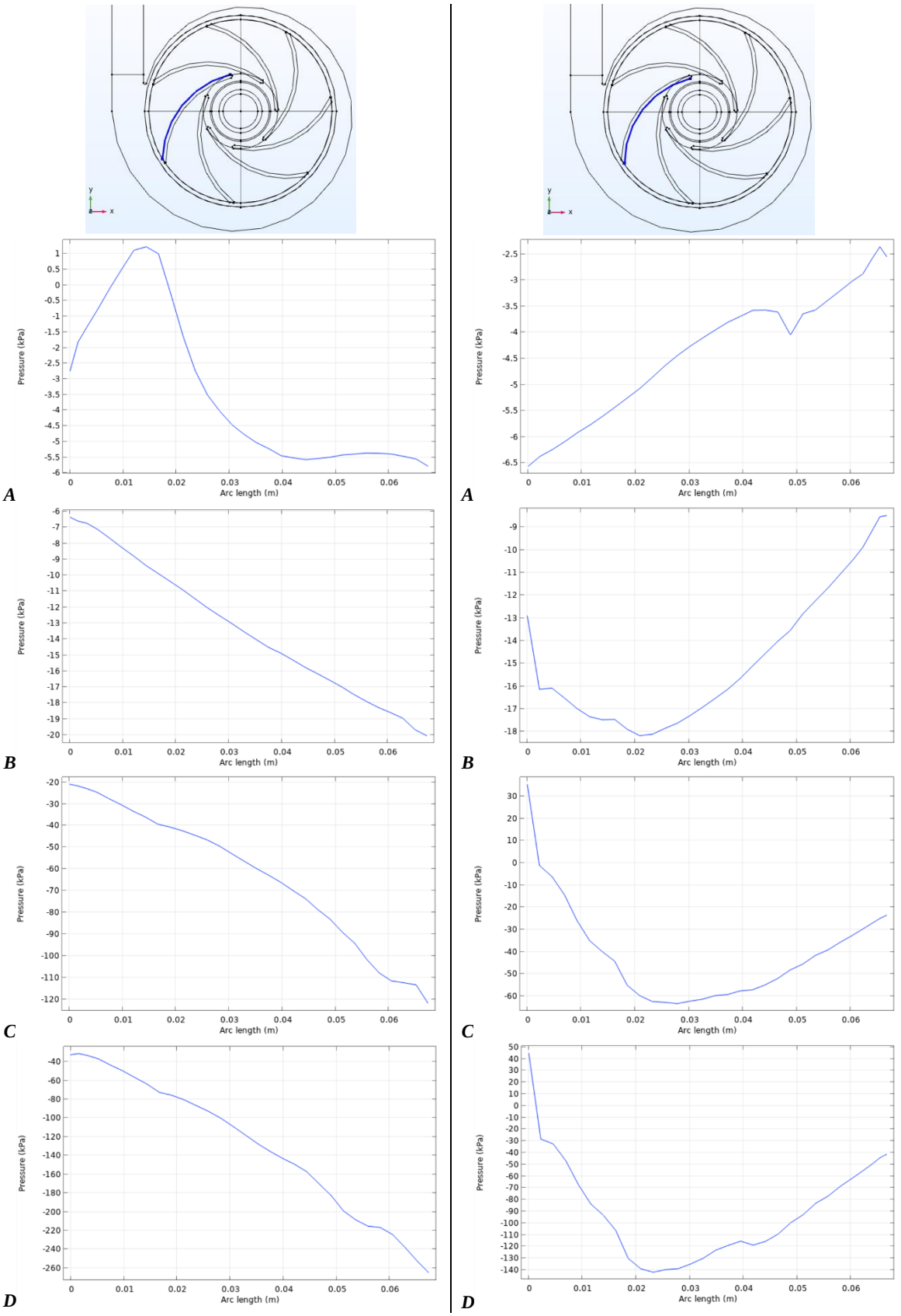

Figure 1. Calculated pressures on the surfaces of the impeller blade of the centrifugal pump: *A* – the shaft rotation speed is 500 rpm; *B* – the shaft rotation speed is 1000 rpm; *C* – the shaft rotation speed is 2000 rpm; *D* – the shaft rotation speed is 3000 rpm.

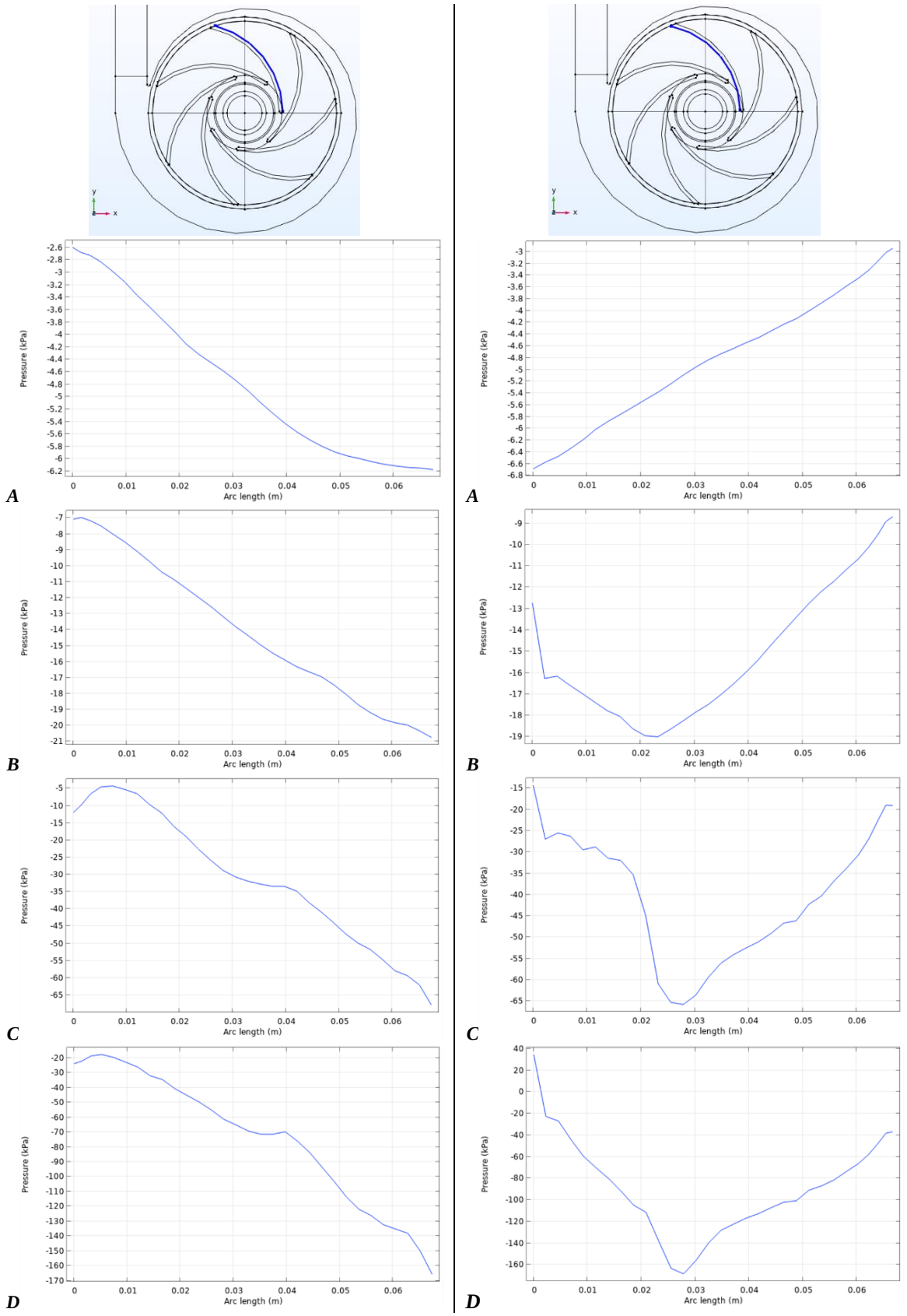

Figure 2. Calculated pressures on the surfaces of the impeller blade of the centrifugal pump: *A* – the shaft rotation speed is 500 rpm; *B* – the shaft rotation speed is 1000 rpm; *C* – the shaft rotation speed is 2000 rpm; *D* – the shaft rotation speed is 3000 rpm.

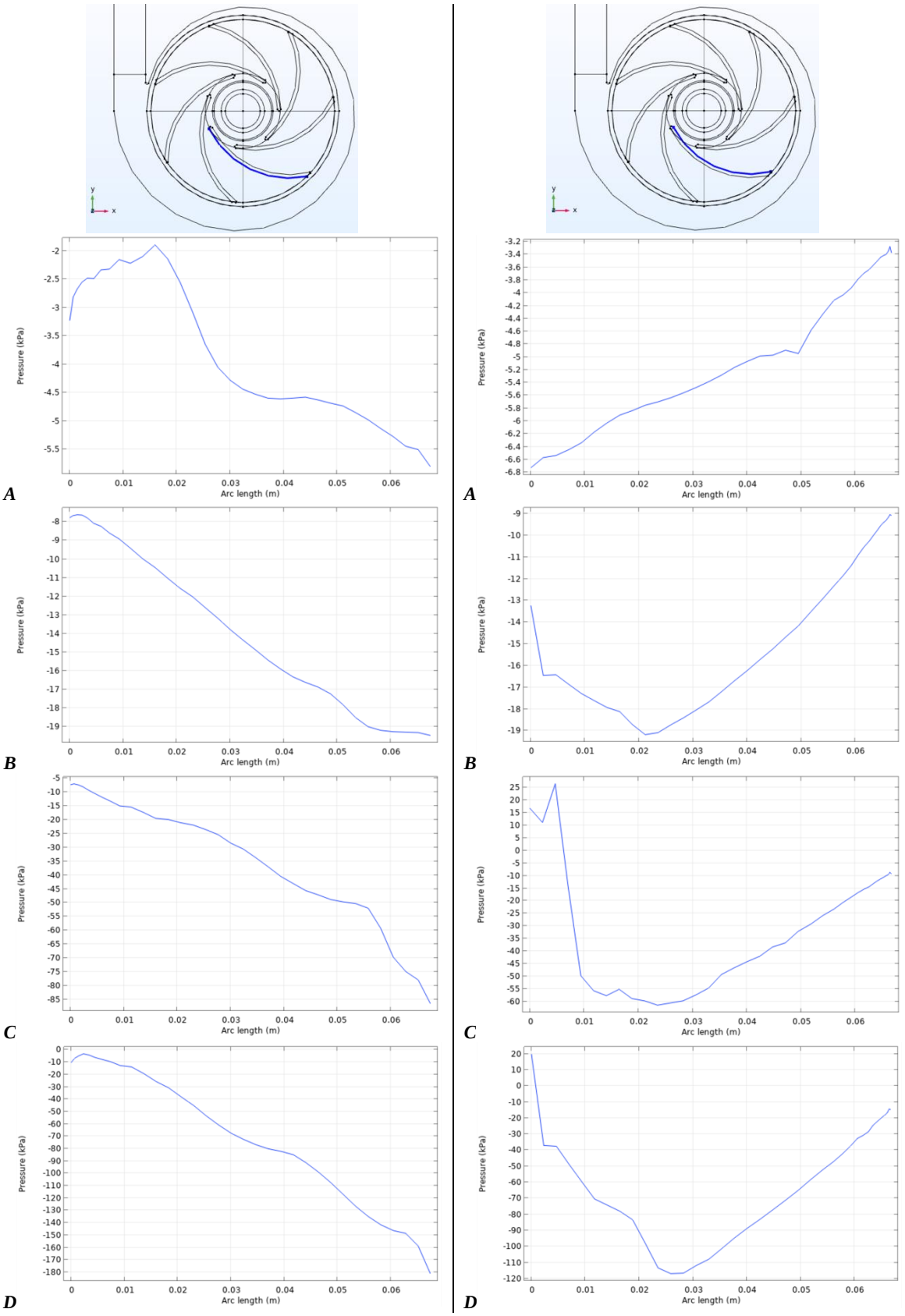

Figure 3. Calculated pressures on the surfaces of the impeller blade of the centrifugal pump: *A* – the shaft rotation speed is 500 rpm; *B* – the shaft rotation speed is 1000 rpm; *C* – the shaft rotation speed is 2000 rpm; *D* – the shaft rotation speed is 3000 rpm.

At a rotation speed of the rotor shaft of 500 rpm, a positive pressure acts on a certain surface area of the suction of the blade, and on the surface of the back of the blade, the pressure decreases in the direction from the inlet to the diffuser cavity. The greatest pressure acts on the suction face of the impeller blade of the centrifugal pump.

The pressure change on the suction face of the blade, shown in the Fig. 2, is characterized by a constant increase in pressure values for the considered direction. The pressure change on the back face of the blade is almost similar to the dependencies in the Fig. 1. The calculated pressure values are shown in the corresponding dependency graphs.

The pressure changes on the suction and back faces of the impeller blade shown in the Fig. 3 have the same descriptions as for the Fig. 1. The calculated pressure values are shown in the corresponding dependency graphs.

The performance of the centrifugal pump is represented by a change in the input and output mass flow rates of fluid in the Fig. 4. A decrease in the performance of the centrifugal pump is observed in the case of the rotor shaft rotation speed of 500 and 1000 rpm. This is expressed in a decrease in mass flow rates at the inlet and outlet of the centrifugal pump, depending on the number of iterations of the computer calculation. The values of the input and output mass flow rates are the same. The higher performance of the centrifugal pump is calculated at a rotational speed of the rotor shaft of 2000 and 3000 rpm. However, deviations in the values of the input and output mass flow rates of the centrifugal pump were noted at 210 and 230 iterations of the calculation at a rotational speed of the rotor shaft of 2000 rpm.

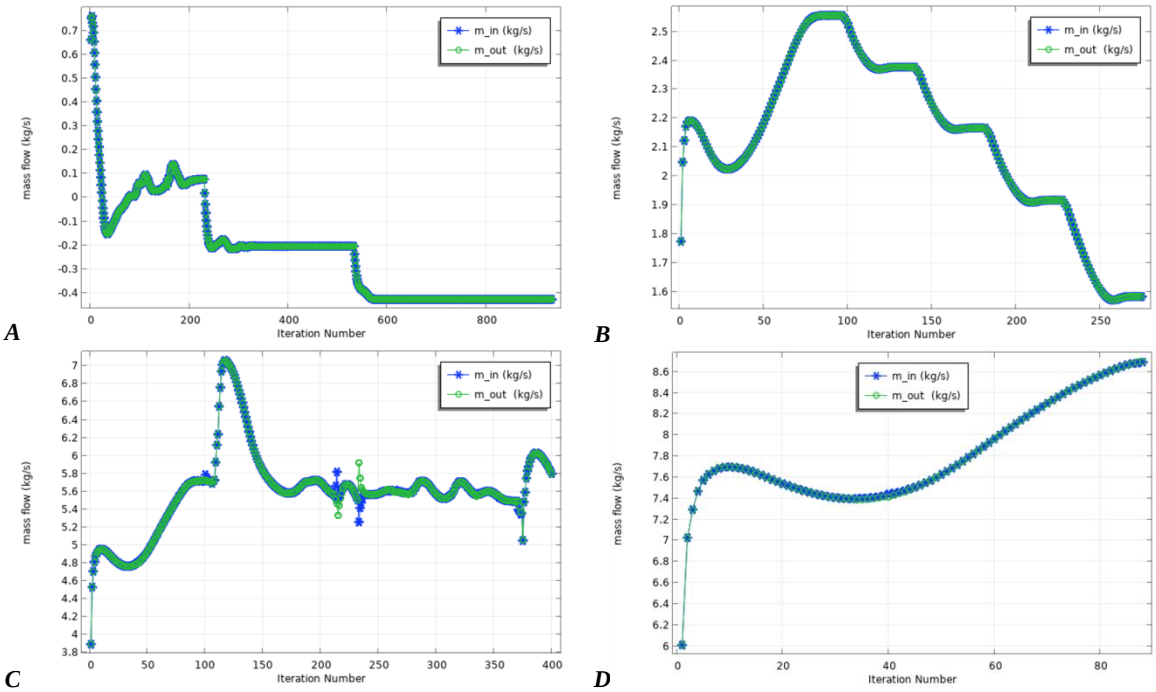

Figure 4. Dependences of input and output mass flow rates on the number of iterations: *A* – the shaft rotation speed is 500 rpm; *B* – the shaft rotation speed is 1000 rpm; *C* – the shaft rotation speed is 2000 rpm; *D* – the shaft rotation speed is 3000 rpm.

Conclusion

Thus, at all considered rotational speeds of the rotor shaft of the centrifugal pump, an increase in the pressure of the fluid flow from the inlet to the diffuser cavity is observed on the suction face of the impeller blade. At the same time, the maximum pressure of -260 kPa acts on the suction face of the blade, which is closest to the outlet, when the impeller rotates at a frequency of 2000 rpm. However, on the back face of the impeller blades, the pressure increases to the middle of the chord length of the element, and then decreases. When the rotor shaft rotates at 500 rpm, the pressure on the back face decreases in the direction of the diffuser cavity. The centrifugal pump has the highest performance at a rotor shaft rotation speed of over 2000 rpm.

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