Numerical simulation of mixing process

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ABSTRACT

In addressing technical and procedural motions mixers and stirrers, are quite often used analytical solution of the phenomenon. It is now possible to implement a solution using FEM numerical simulation of the phenomenon. Studied the mixing process is used for the homogenization of mixed substances stirrer rotation about an axis of rotation, which is also the axis of symmetry of the mixer. To achieve homogeneity and prevent the establishment of mixed substances, it is necessary that the bottom of the mixer should be a certain angle, thus ensuring better discharge of the homogeneity mixture. Accordingly, most mixers have conical bottom of the container. The shape and dimensions of the stirrer depends on the type and quantity of the mixed substances. Another important parameter for the design of technical facilities is itself a form of power blender. In most cases, rotating stirrer, stirrer in motion describes the geometric shape of the mixer itself. To ensure thorough homogenization of substances is necessary to ensure wiping mixed materials from the walls and bottom of the blender. Therefore the agitator, seal the edge. In this case, it is the examination of the pressure and velocity field in the mixing process in the technical equipment of circular cross-section. Examination of this issue is under consideration with dynamic effects agitator blades and ignoring dynamic effects. The shape and dimensions of the mixer and agitator shall be maintained at the same performance for Newtonian fluid with the same density and viscosity.

Keywords: FEM, viscosity, mixing process, pressure field, velocity field, density, fluid

1. INTRODUCTION

Mixing is very important technological operations using the most common in the chemical and food industries. With the blending process may be encountered in other technologies. Mixing process, the hydrodynamic process in which there is relative movement of particles mixed substance. The mixing process is used to homogeneous mutually soluble liquids for suspending particulate material, dispersion, intensification of the process of exchange of heat, mass and momentum, also for blending the desired properties and for other purposes. The mixing process is used for mixing heterogeneous or homogeneous mixture of particulates and liquids.

Study the mixing process is given much attention. In addressing the issue is very often used in laboratory xperiments. Calculations are very important for the design of the shape, type and size of the mixing element. n the design of the facilities is used similarity theory, based on the results obtained from laboratory xperiments. Theory of similarity enables to certain simplex design the plant while maintaining the main rocess parameters, such as the nature of flow, quality of homogenization, the intensity of mass and heat ransfer, etc. [1, 2].

In the process of mixing, in examining the nature of flow in the mixer and mixing element pressure load, it s now possible to use, in addition to laboratory equipment, the experiment using computer simulation of the process under examination. To investigate the velocity and pressure field, emerging in the process of mixing a technical device, it is possible to use numerical simulation using FEM.

2. THE PROCESS OF MIXING AND THE DRIVING FORCE

Mixing is a process which generates a more or less homogeneous mixture of two or more phases of the same or different physical state, by the force action of the mixing element. The design of mixing devices are designed to blended substances come into contact with each other. Shape mixing machine and mixing elements also depends on the physical state of mixed substances used to produce a homogeneous mixture. Using a mixing element is needed to make the blender came convective diffusion process, molecular or turbulent, mixed substances. The driving force behind the mixing effect is weight mixing element for mixing substances of different concentrations or temperatures in different areas blender. Thus, the driving force behind the mixing process is pressure, concentration or temperature gradient of mixed substances. To stop the mixing process occurs in the case of termination of pressure, concentration or temperature gradient. In this case we speak of an ideal mixture of ideal and process that never actually occurs, it may be marginally closer to him. After completion of the mixing process, almost never real mixture reaches a homogeneous composition at any point of the system [1, 2].

2.1 The basic differential equations of fluid mechanics

Examination of fluid flow is very complex case of three-dimensional viscous liquid movement. Fluid motion is not possible to analytically solve the so far available physical knowledge.

In determining the velocity distribution and pressure is based on the fundamental equations of fluid mechanics, which are the continuity equation and the equations of motion.

Continuity equation was derived in the form [3, 4, 5]:

$$\frac{\partial \rho}{\partial t} + \nabla.(\mathrm{w}\rho) = 0 \qquad (1)$$

Motion equations - Cauchy equation in the ingredients voltage can be expressed in the form [3, 4, 5]:

$$\rho \frac{\mathrm{Dw}}{\mathrm{Dt}} = -\nabla.p + \nabla.\vec{\tau} + \rho\,\mathrm{R} \qquad (2)$$

Dynamic stress tensor of Newtovn law for incompressible fluid is expressed in the form [3, 4, 5]:

$$\vec{\tau} = 2\,\eta\,\vec{d} \qquad (3)$$

On the basis of Newton's law and the continuity equation Navier - Stokes equation, then the vector form we get the expression [3, 4, 5]

$$\mathrm{a} = \mathrm{R} - \frac{1}{\rho}\,grad\,p + \nu\,\nabla.\mathrm{w} \qquad (4)$$

The importance of symbols in equations 1-4:

ρ – density,
t – time,
∇ – nabla operator,
w – velocity vector,
p – pressure,

R – vector unit volume forces acting on the fluid,
a – acceleration vector,
$\vec{\tau}$ – dynamic stress tensor,
$\vec{d}$ – strain rate tensor liquid,
η – dynamic viscosity of the fluid,
ν – kinematic viscosity fluids.

Therefore when examining fluid flow, establishes certain simplifying, conditions, that allow solving tasks with precision satisfactory in technical applications. In solving need to respect two fundamental laws of nature, law of conservation of mass and the energy.

3. NUMERICAL SIMULATION OF MIXING PROCESS

For the numerical solution of the hydrodynamic experiment mixing process is based on the real facts of technical equipment and the stirred mixture of substances with Newtonian properties of a fluid, assuming a homogeneous mixture with the desired properties. Process of examining the velocity and the pressure fields, the implementation of numerical experiment of mixing substances in a plane perpendicular to the axis of rotation. We consider the agitator circular cross-section. How many elected mixing element is placed in the axis of rotation, then the creation of the geometric model can be used stirrer rotation axis for axis of symmetry for solving examination process. Therefore, it is possible to use planar model with arbitrarily chosen angular cut-outs so that simplify geometry model satisfies all the conditions and the requirements of examination process**.**

Velocity and the pressure fields have been investigated in the process of mixing in a plane perpendicular to the axis of rotation of the mixing device.

3.1 The geometric model

To investigate the effects of hydrodynamic mixing process numerical simulation was selected industrial mixer circular cross-section with an inner diameter of 0.97 m. Since this is a symmetric role, sufficient for numerical simulation of 2D model with an angle of 135 degree. Planar model is perpendicular to the axis of rotation of agitator located below the mixing of the substance, Fig. 1.

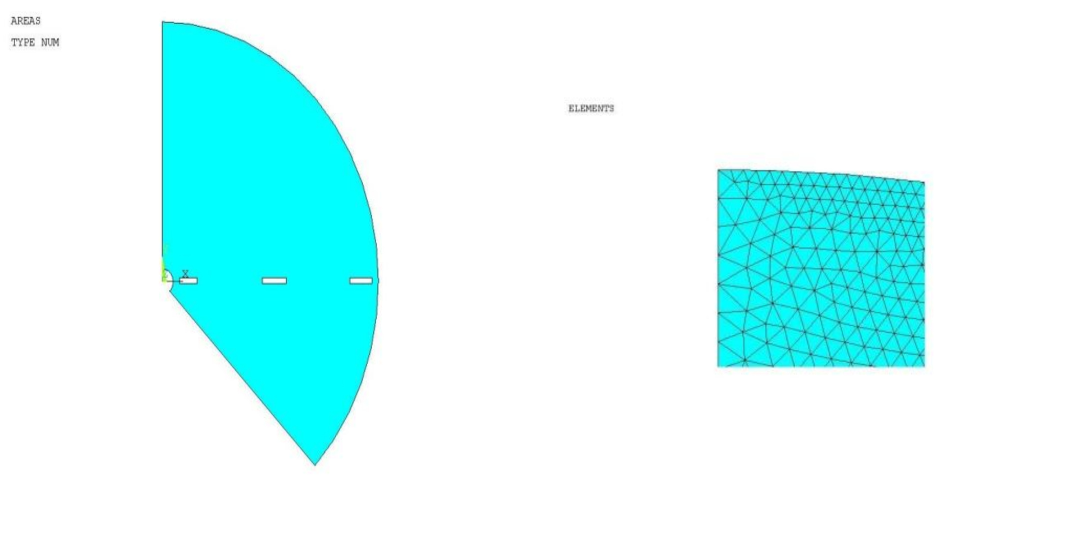

Fig. 1 The geometrical model and generated network

3.3 Terms of implementing numerical simulation

The numerical experiment was carried out on the basis of the required power blender 4 kW rotating with a speed of 35 rev./min. Mixing substance mixtures with a density of 1630 kg/m3 was used paddle. By value wattages numbers were determined Reynolds number. Reynolds number determines the character of the flow. Based on the value of Reynolds number, in this case the mixing of the substance within equipment, it is a laminar flow. The solution was implemented with uneven peripheral speed of mixed substances. Mixing substances were identified paddle with ribs, between which flowed stirred the mixture. In our case, numerical simulation task was designed as a 2D assuming constant density and viscosity of the mixed substances. To deal with the selected cut plane mixer so that it can be examined and the velocity pressure field between ribs blades. Examination of the velocity and the pressure field in the mixing process is stationary job with a steady flow. Numerical experiment mixing process using FEM has been implemented in ANSYS program files. Solving numerical simulation of mixing process in the technical equipment was subject to ongoing reflection and the dynamic effects of the blade without considering the dynamic effects of the blade.

4. RESULTS OF NUMERICAL SIMULATION

By examining the speed and pressure fields resulting from the rotation of the mixing device performance, initial and boundary conditions can be obtained from the results of numerical simulations to evaluate the two parts.

4.1 The speed and pressure field without considering the dynamic effects of blade

Velocity fields generated in a plane perpendicular to the rotation axis, if without considering the dynamic effects of the blade, is shown in Figure 2.

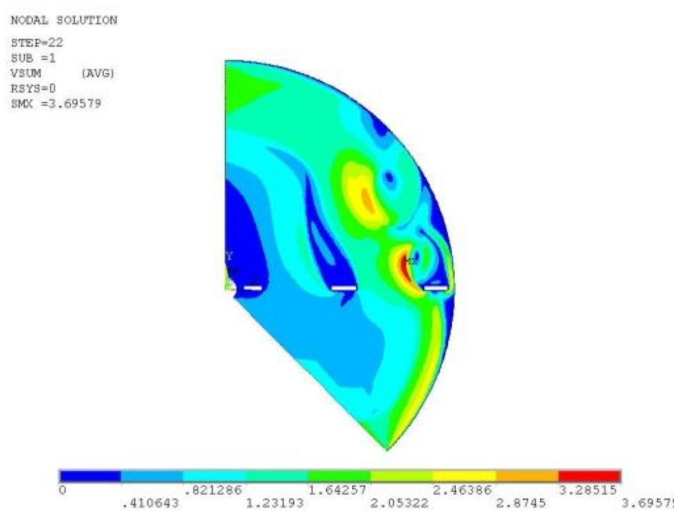

Fig. 2 Velocity field in the study area without considering dynamic effects on blade [s^{-1}]

Flow rate of mixing of the substance ranges from zero to a maximum of 3,7 s^{-1}. The maximum value of the velocity field occurs at the wrap of the blade located at the edge of the wall of the blender and start-up. Just a blade is velocity fields with zero velocity, Figure 3.

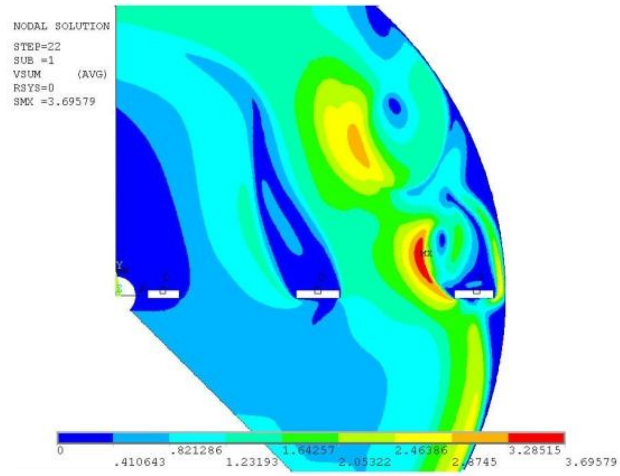

Fig. 3 Velocity fields with zero flow velocity of fluid located just behind the shoulders [s^{-1}]

In Figure 4 is a graphical representation of the velocity field located before the blade. From the picture we see that the velocity of the fluid increases with the diameter of the mixing equipment.

Figure 5 graphically illustrates the uneven progress of the pressure field.

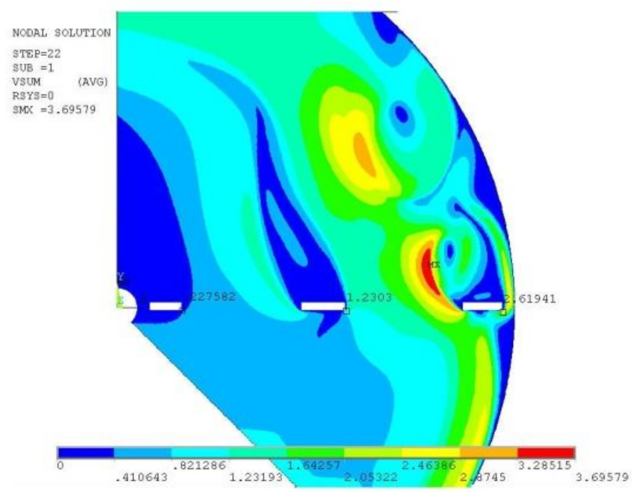

Fig. 4 Graphical representation of the velocity field located before the blade [s^{-1}]

Minimum pressure field with a value of 131 Pa stress the blade near the axis of rotation. The maximum value of 8357 Pa pressure field charged to paddle the greatest distance axis rotation axis, Fig. 6. Figure 7 shows the area the resulting vacuum with a maximum value – 8,4 Pa.

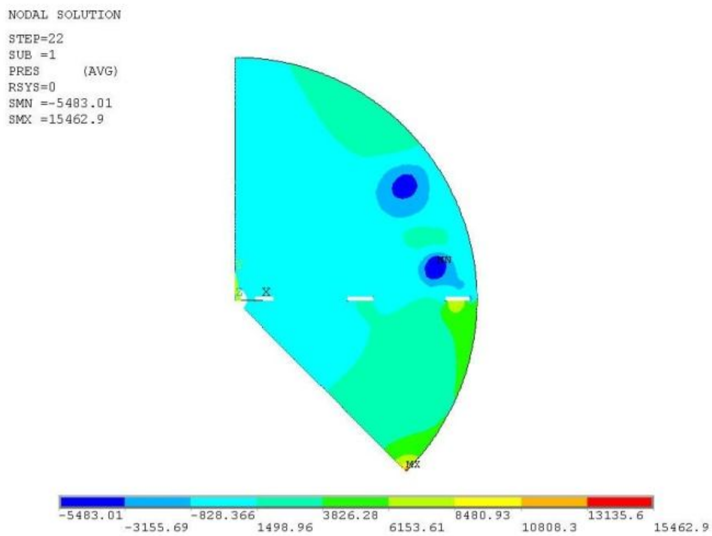

Fig. 5 Graphical representation of the pressure field [Pa]

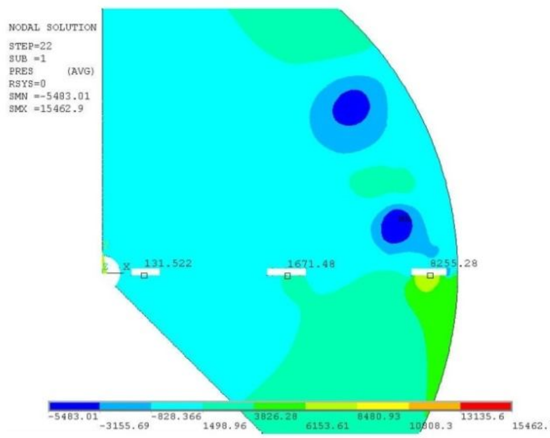

Fig. 6 Graphical representation of the pressure field located before the blade [Pa]

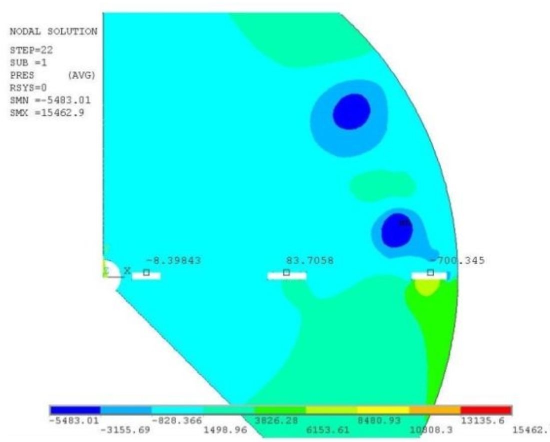

Fig. 7 Graphical representation pressure field distribution for the blade [Pa]

4.2 The speed and pressure field with considering the dynamic effects of blade

Velocity fields generated in a plane perpendicular to the rotation axis, if without considering the dynamic effects of the blade, is shown in Figure 8.

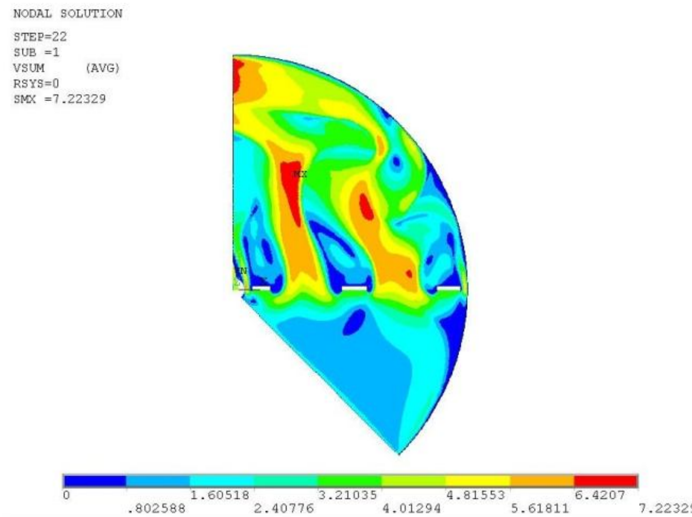

Fig. 8 Velocity field in the study area with considering dynamic effects on blade [s^{-1}]

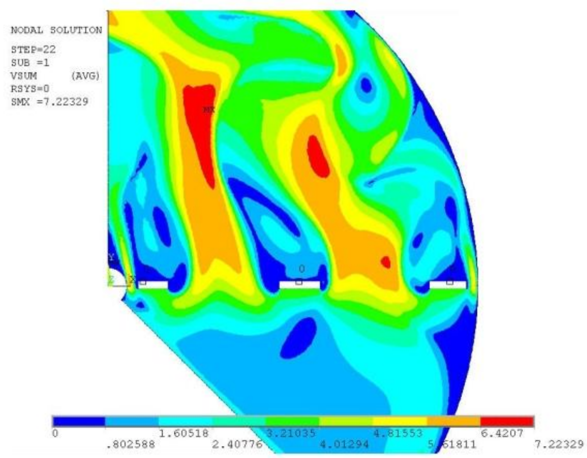

Fig. 9 Velocity fields with zero flow velocity of fluid located just behind the shoulders [s^{-1}]

Flow rate of mixing of the substance ranges from zero to a maximum of 7,22 s^{-1}. The maximum value of the velocity field occurs at the wrap of the blade located at the edge of the wall of the blender and start-up. Just a blade is velocity fields with zero velocity, Fig. 9.

In Figure 10 is a graphical representation of the velocity field located before the blade. The located velocity is 3,66 s^{-1} . From the picture we see that the velocity of the fluid increases with the diameter of the mixing equipment.

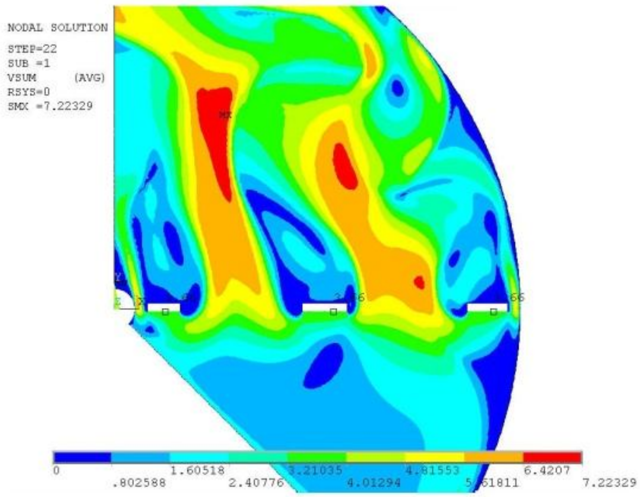

Fig. 10 Graphical representation of the velocity field located before the blade [s^{-1}]

Figure 11 graphically shows uneven progress of the pressure field.

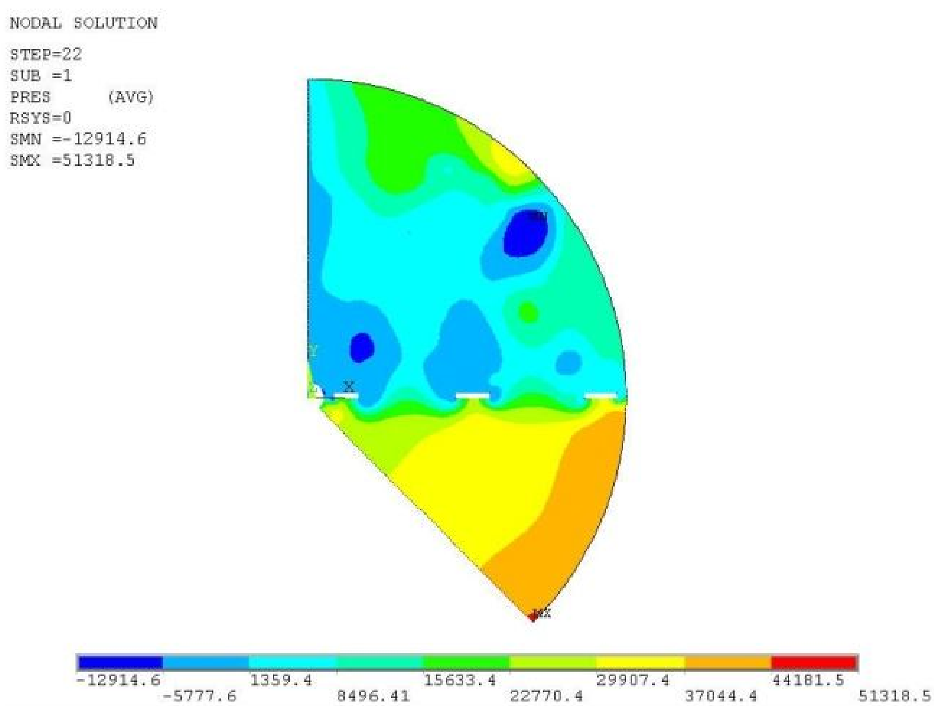

Fig. 11 Graphical representation of the pressure field [Pa]

Minimum pressure field with a value of 20754,6 Pa stress the blade near the axis of rotation. The maximum value of the pressure field 30836,4 Pa charged to paddle the greatest distance axis rotation axis, Fig. 12.

In Figure 13 is shows the area the resulting vacuum with a maximum value – 2388,16 Pa.

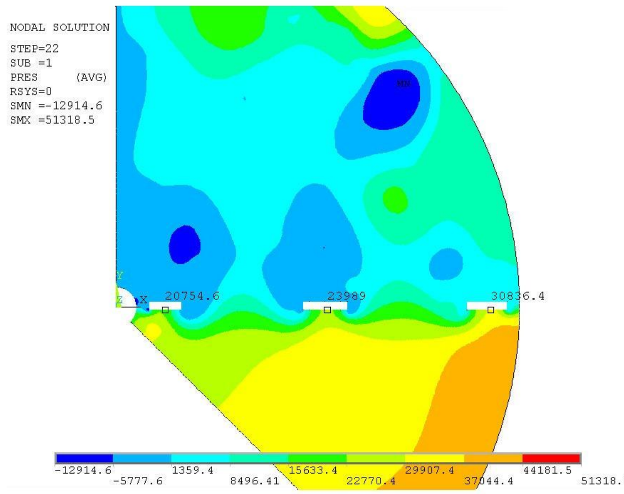

Fig. 12 Graphical representation of the pressure field located before the blade [Pa]

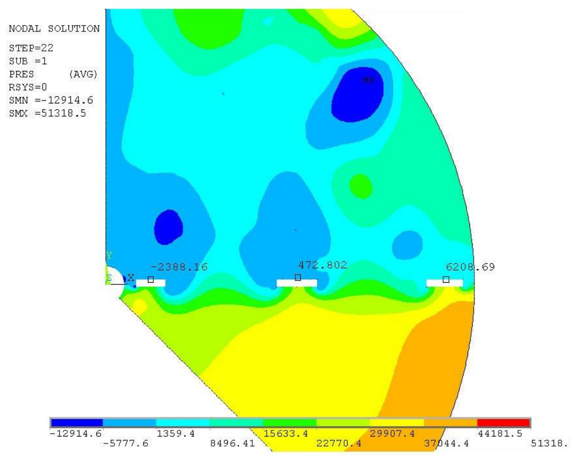

Fig. 13 Graphical representation pressure field distribution for the blade [Pa]

5. CONCLUSIONS

Based on these simplifying assumptions set out to solve 2D tasks we obtained results for stationary solutions MKP role of dynamic effects and without dynamic effects acting on the blade. In numerical calculations we obtain uneven pressure and velocity fields in both solutions. Results solutions with dynamic effects and without dynamic effects acting on the blade, vary quite a big difference pressure value applied to the rib mixer and also the shape of the velocity field and a maximum flow rate of mixed substances. The results obtained by numerical simulation shows that the dynamic effects acting on the blade have a great influence on the shape of the pressure and velocity fields and their maximum value. Therefore, the design of mixers, are not insignificant, but it is necessary to consider them. Based on these examples, it is possible to flexibly use numerical experiment for different variants of review conditions of pressure and velocity field in the mixing process.

6. ACKNOWLEDGEMENTS

This paper was supported by projects VEGA 1/389/11, 1/390/11, 1/1041/11

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