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Research Article

Mathematical Modeling of Intensified Heat Exchange with A Turbulent Flow of Nitric Acid HNO_3 in Pipes with Semicircular Turbulizers

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Abstract

In the article, mathematical modeling of turbulent flows and heat transfer in pipes with turbulators of a semicircular cross section was carried out to determine of these ranges numbers Reynolds (Re = 8000 ÷ 38000), investigated in the experiment [16] of the flows of nitric acid HNO_3 (Pr = 3.23). For an adequate comparison of the obtained calculationstn data from experienced [16] solved the problem of the effect of increasing the surface when using artificial turbulators of a semicircular cross-section flow in pipes on the effect of increasing heat transfer. As a result, of these settlement tov It was identified xgood agreement of theoretical data with the corresponding experimental data [16]; the influence of the geometrical parameters of the channel and the regimes of the coolant flow on the intensified heat transfer under the given conditions was revealed. Verification of settlements tn data experiment allowed spend similar calculations you for an extended range of Reynolds numbers, an order of magnitude higher than the experimental range (Re = 80000 ÷ 380000).

Keywords: Modeling; Mathematical; Intensification; Heat Exchange; Flow; Turbulent; Nitric Acid; Trumpet; Channel; Turbulator; Cross Flow; Semicircular; Reynolds Test; Prandtl Criterion; Low Reynolds; Menter's Model

Introduction

A well-known and very well-tested in practice method of vortex intensification of heat transfer is the application of periodic protrusions on the walls of the washed surfaces [1,2] (Figure 1). Investigation of the structure of the intensified flow is mainly carried out by experimental methods [1,2], while modern computational works on this topic are relatively few (eg, [3-6]) and are only partially devoted directly to the structure of the intensified flow; some of the methods (e.g., defining some of the works [6-10]) use only integral approaches to this problem. Recently, multi-unit computational technologies for solving problems of vortex aeromechanics and thermal physics, based on intersecting structured grids, have been intensively developed.

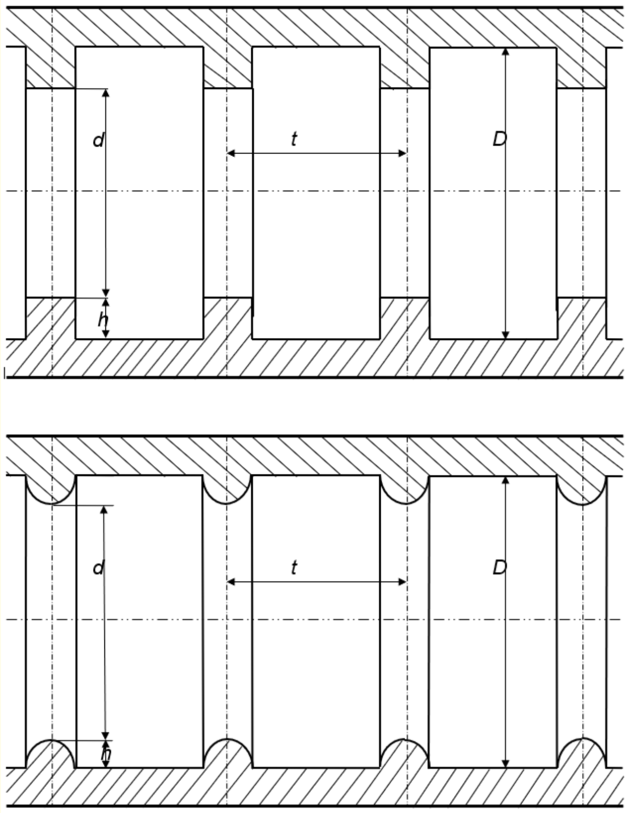


Figure 1: Sectional view of a straight round pipe with surface-located transverse flow turbulators of square (upper figure) and semicircular (lower figure) cross-sections.

This work is directly devoted to the study of intensified heat transfer during a turbulent flow of nitric acid HNO_3 in pipes with turbulators of a semicircular cross section, characteristic of knurled protrusions or pipes with diaphragms, since this range of parameters is still not sufficiently researched by theoretical calculations tonsmy methods; for comparison, analogous experimental data are presented for these conditions [16].

Prospective directions for the development of a numerical theoretical study of intensified heat exchange in pipes at different numbers of Reynold's and Prandtl

Theoretical study of local and averaged These parameters of flow and heat transfer in tubes with turbulators seem to be the most promising in the direction of developing specialized parallelized packages on the basis of multiblock computing technologies, the target areas of which can be characterized as follows.

Development of original multi-block computing technologies [3-6] based on multi-scale intersecting structured grids for highly efficient and accurate solution of non-stationary two-dimensional and tr dimensional problems of convective heat transfer in straight round tubes with organized roughness in the form of protrusions in a homogeneous working medium in a fairly wide range of Reynolds numbers (Re = 10000÷1000000) and Prandtl (Pr = 0.7÷12). The difference from the previous versions of the package [3-6] is that the methodology is supplemented by the use of periodic boundary conditions, which makes it possible to estimate the asymptotic characteristics of pipes with discrete roughness. The modification made it possible to increase the computational efficiency of the simulation, to implement correction for the curvature of streamlines. For pipes with turbulators, the following are determined: surface distributions of local and integral power and thermal characteristics (pressure, friction, heat fluxes, resistance to motion, hydraulic losses), profiles of velocity components, pressure, temperature and turbulence characteristics (turbulence energy, turbulent viscosity, components of the Reynoldsian tensor voltage, generation, dissipation, etc.).

The original system of partial differential equations - the Navier – Stokes and Reynolds equations - is closed using the shear stress transfer model modified taking into account the curvature of streamlines, according to Menter's approach. Initial information about the governing equations and acceptable boundary conditions is contained in [13]. Original pressure and mass average temperature correction procedures based on periodic boundary conditions are used. The methodology for solving the initial equations is a pressure correction procedure based on the concept of splitting into physical processes. For problems with periodic boundary conditions, procedures for correcting the pressure gradient and average mass temperature are applied. Methodological basis for prospective calculations tnogo tool - multi-block computational technologies based on the use of structured, intersecting multiscale grids associated with capturing the characteristic structural elements of the vortex flow and temperature field, which will provide acceptable accuracy and high efficiency comparable to the use of adaptive grids.

Here it is necessary to dwell in more detail on the specific features characteristic of periodic boundary conditions.

The pipe is split into several sections with a semicircular turbulator located in the middle of both inlet and outlet smooth sections (see Figure 2). Periodic boundary conditions lead to more optimal pipe mesh construction.

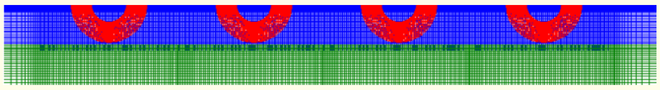


Figure 2: Pipe mesh, consisting of several sections with a semicircular turbulizer located in the middle, inlet and outlet smooth sections (in a periodic setting, only one section is considered).

In a periodic setting, only one section is considered, while in the general case it is necessary to use several sections (in [3-12], the number of sections reached 12; for verification, the same number of sections was used). To reduce the number of calculations tn knots in pipe stands out more detailed parietal region (blue grid) and less detailed axial (green naya). When this is power detailing is changing, as in longitudinal, So and in district directions (at application of tr ugly case). Besides Togo, for tr ugly settlement that in axial areas introduced t...n... "patch", eliminating unnecessary thickening nets near axes... Last thing circumstance, at other equal conditions, reduces necessary number settlement tn cells by about one and a half times (this circumstance becomes even more important at tr cold settlement tah). Can still fromto reduce the number of cells, if we apply periodic conditions along the longitudinal axis, because the inlet and outlet sections are eliminated and one section is left.

In terms of hydrodynamics, the periodic problem is posed as a problem with the preservation of a given mass flow rate calculated for a unit input velocity. In terms of heat transfer, depending on the selected boundary conditions for temperature, two options are possible. For isothermal walls, the problem is solved under the assumption that the mass-average temperature in the inlet section is constant. In the second, the gradient of the average mass temperature is considered known, calculated from the value of the heat flux on the walls. Naturally, the inlet temperature is not recorded in this case. In addition to the periodic complete recording of the current state of the task, the program provides the ability to execute sample records with a given interval with their accumulation in a file, which is especially important for use in solving non-stationary tasks.

3. The main attention is paid to the local and integral characteristics of convective heat transfer, including the components of the velocity, hydraulic losses and heat transfer averaged over the allocated area of the channel wall section, the results of calculations on the turbulent characteristics of the terms of the equation for the energy of turbulent pulsations (generation, dissipation, convective and diffusion transfer). For the external flow around rectangular protrusions, a similar approach was applied n, for example, in [12].

Similar numerous studies of intensified heat transfer in pipes and channels with turbulators for other conditions were previously performed in [17-52].

4. The main direction of this work can be briefly characterized as follows: you for relatively forward d given rangeof the Reynolds numbers (Re = 800 ÷ 38000), characteristic of the turbulent flow regimes of nitric acid HNO_3 (Pr = 3.23), which are characteristic of the experimentally investigated [16], as well as for an extended range of Reynolds numbers, an order of magnitude larger than the experimental one (Re = 80000÷380000).

In the above range, at this stage, there is still not there is over zhnykh thoseof the theoretical data, since the previously calculated t was carried out forother Reynolds and Prandtl numbers [3-12]; the focus is on the specific aspects of the calculation tnogo research intensified heat transfer in these areas, without dwelling in detail on the nonspecific aspects of intensified currents and heat transfer.

Solution of the problem of the influence of surface increase when using artificial turbulators of a semi-circular cross-section flow in pipes on the effect of increasing heat transfer

In order to compare the results on heat transfer in pipes with turbulators with heat transfer in smooth pipes, it is necessary that this be the case, all other things being equal, since the heat transfer surfaces are different. If this is not done, then it will not be possible to identify, per hour t what received increase heat transfer: of-per turbulization flow, or of-per increaseheat exchange surface.

In works [1,2,14,15] the Nusselt criterion for intensified heat transfer refers to a smooth surface.

In works [1,2] it is indicated that when threading on the insideThe heat exchange surface of the pipe can increase by about 40%, and for pipes with diaphragms this increase can be about 22%, which must be used when correcting the calculation tn data by warmchange during artificial turbulization of the flow.

The effect of increasing the heat exchange surface when using artificial flow turbulators on the intensified heat transfer is as follows. When threading, or with external knurling, or with a tight fit of plug-in turbulators, the formed inner surface of the pipe is always larger than the surface of a smooth pipe (the conditions under which a smooth surface will be larger than the surface with intensifiers were identified in [6-10]; this is realized when using transverse annular grooves, which is beyond the scope of this study).

However, due to the fact that when processing experimental data, the heat transfer coefficient is often referred to the surface of a smooth pipe, when comparing heat transfer in rough pipes with smooth pipes, the total contribution to the increase in heat transfer from both the effect of artificial turbulization of the flow and the increase heat surface ma; last thing comparable from effect ribbing.

From a practical point of view, uch t influence changes surfaces warmwasp ma not is an mainnd: indeed, if inside the pipe with a specific type of turbulators, a certain nnoe the rise coefficient warmreturn, then for calculations that heat exchange apparatus not It has no meaning, per mid t what specifically effects It was achieved abovethis increase. It's a different matter when it comes to t about evaluations quantitative influence sizes, raspthe position of turbulators to increase heat transfer, or when developing a method for intensifying heat transfer, or on the relationship between an increase in heat transfer and hydraulic resistance - in all these cases, nny interest pregives an estimate of the effect of increasing the surface.

In works [1,2,14,15] it is indicated that the effects of ribbing and artificial turbulization of the flow can be comparable, and this phenomenon must be taken into account when evaluating the effectiveness of the method for intensifying heat transfer.

Assessment of the extent to which heat can affect the increase in surface area ma height and step between turbulators in the form ring diaphragms, arrknurled externally, as well as in pipes with semicircular turbulators. In studies [1,2], the dependences of the ratios of the areas of the full surface of a pipe with turbulators to the surface area of a smooth pipe F/F_{SM} on the heights and pitches of diaphragms for pipes were given, which were directly used in authentic experiments. It is these data that will be used in the future to verify the calculations. tn data, received in framework real scientific work.

Simulation of the increase in the surface of heat ma will be be produced from through representations of a pipe with semicircular turbulators (Figure 1).

Pipe masonry area

$$F_{гл_т} = \pi D t \text{ , (1)}$$

where D is the inner diameter of the pipe with turbulators; t is the basic length corresponding to the step between the turbulators.

Pipe area with turbulators of semicircular cross-section:

$$F_т = \pi h \pi D + \pi D(t - 2h) \text{ , (2)}$$

where h is the height of the turbulators.

Dividing (2) by (1), we get:

$$\frac{F_т}{F_{гл_т}} = 1 + \frac{1}{(t/D)}(1 - d/D)\left(\frac{\pi}{2} - 1\right) \text{, (3)}$$

where d is the diameter of the pipe with turbulators, measured by the turbulators.

Formally, exactly the same result can be obtained for pipes with transverse annular grooves (Figure 2) of a semicircular cross-section:

$$\frac{F_к}{F_{гл_к}} = \frac{\pi d_1 \pi t + \pi d_1 (t - 2h)}{\pi d_1 t} = 1 + (h/t)(\pi - 2) = 1 + \frac{1}{(t/D_1)}(1 - d_1/D_1)\left(\frac{\pi}{2} - 1\right) \text{ , (4)}$$

where d_1 is the inner diameter of the grooved pipe; D_1 is the diameter measured from the grooves.

We can bring the last expression (4) in the form of expression (3), since: $d_1 = D = d + 2h$ and $D_1 = D + 2h = d + 4h$:

$$\frac{F_к}{F_{гл_к}} = 1 + \frac{(2-d/D)}{(t/D)}\left(1-\frac{1}{(2-d/D)}\right)\left(\frac{\pi}{2}-1\right) = 1 + \frac{1}{(t/D)}(1-d/D)\left(\frac{\pi}{2}-1\right). \quad (5)$$

Consequently, the relative values for pipes with semicircular turbulators and semicircular annular grooves are completely identical $\frac{F_т}{F_{гл_т}} \frac{F_к}{F_{гл_к}}$.

Ha figure 3 shows a comparison of the obtained theoretical data with experimental data, given $\frac{F_т}{F_{гл_т}}$ data in [1,2], which shows a good correlation between them.

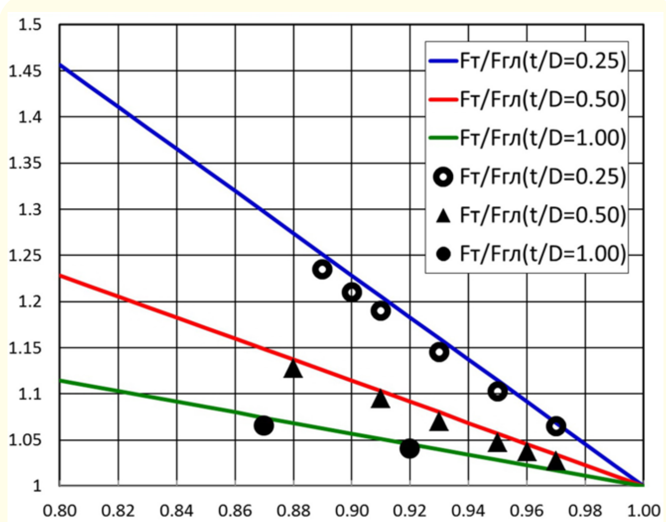


Figure 3: Calculation tne and experienced meaning parameters heat transfer turnvalues depending on the height and pitch of the diaphragms in rolled pipes (lines - calculation t; points - experiment [12]).

Thus, there is a theoretical solution to the problem of the effect of increasing the surface when using artificial turbulators of a semicircular cross-section flow in pipes on the effect of increasing heat transfer, which must be used to compare, other things being equal, the results on heat transfer in pipes with turbulators with heat transfer in smooth pipes.

Modeling of intensified heat exchange and hydraulic resistance in pipes with turbulators of semi-circular cross section with nitric acid (HNO_3) flow in turbulent mode

It can be stated that the structure of a turbulent flow in a pipe, in which it is required to intensify heat transfer, has been studied experimentally and theoretically, which necessitates a maximum increase in the intensity of turbulent pulsations in certain areas of the flow, in which this will give the greatest intensification effect.

In order to successfully use the separation zones, it is necessary to know the mechanism of their interaction with the main turbulent flow and the mechanism of processes in the separation zone itself. The above processes are quite complex.

Qualitatively, on the basis of experimental data, they have been studied to the extent that it is possible to purposefully use vortex zones in order to intensify heat transfer in pipes [5,6].

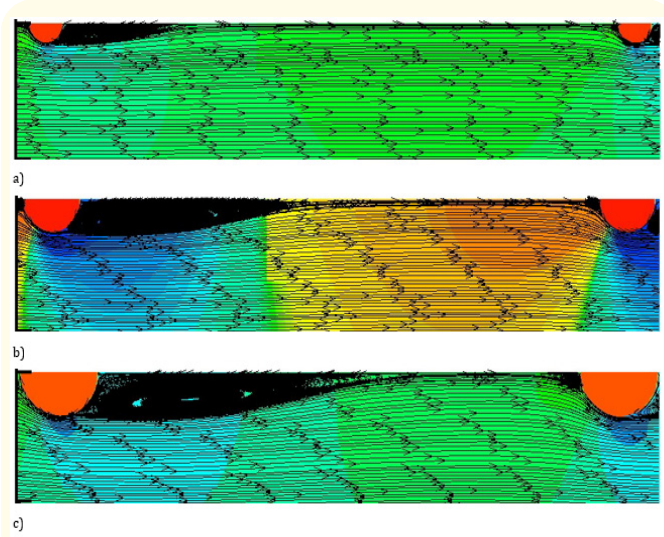
The main goal of this study is a theoretical study of heat transfer during the flow of nitric acid (HNO_3) in a turbulent mode in pipes with turbulators of a semicircular cross section using a factorized finite volume manyabout the method (FKOM), which was successfully tested when calculating those similar flows in [1-4], where the main attention was paid to the calculation tat averaged of these heat exchange parameters.

The article discusses the cases of application of periodic surface-located turbulators of a semicircular cross-section, as typical for experimental conditions [16], namely: Pr = 3.23; Re = 8000÷38000 · 104; d/D = 0.97÷0.89; t/D = 0.50 (D and d are the larger and smaller inner diameters of the pipe with turbulators, respectively; t is the step between the turbulators), and for conditions when the Reynolds criterion is an order of magnitude higher than the experimental ones, namely Re = 80000÷380000 (object of research).

Structure of the intensified flow at a relatively small step between turbulators *t/d* = 0.50 for relative turbulator heights *d/d* = 0.89÷0.97 at a flow of nitric acid (hno_3) at turbulent mode in pipes with turbulators of semi-circular cross section

This article does not consider the case with a short pitch between the turbulators (the height of the turbulator is comparable to the distance between the turbulators), which is typical for pipes with grooves, since the use of grooves is less effective than turbulators for intensifying heat transfer in round pipes [4-12].

First, consider the calculation tne the lines current at flow nitrogen acid (HNO_3) in turbulent mode in pipes with turbulators of semicircular cross-section t/D = 0.50 and d/D = 0.97; 0.95; 0.93; 0.89 at Reynolds numbers limited by experimental data [16] (Re = 8000÷380000).



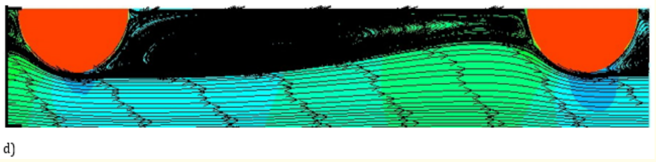


Figure 4: Calculationtne the lines current at flow nitrogen acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross section (from top to bottom): a) Re = 8000, d/D = 0.97, t/D = 0.50; b) Re = 8000, d/D = 0.95, t/D = 0.50; c) Re = 8000, d/D = 0.93, t/D = 0.50; d) Re = 8000, d/D = 0.97, t/D = 0.50.

In figure 4 shows the calculated tnestreamlines in the flow of nitric acid (HNO_3) in turbulent mode in pipes with turbulators of semicircular cross-section *t/D* = 0.50 and Re = 8000 for *d/D* = 0.97; 0.95; 0.93; 0.89.

As can be seen from figure 4, for lower turbulators there are h tco in Expressed separation and reattachment of a turbulent boundary layer, and only for the case with *d/D* = 0.89 a half-open depression is realized. The latter is a factor in reducing the level of relative heat transfer.

For open depressions (Figure 4, a, b, c), the higher the turbulator, the further away from it the flow reattachment point will be, which increases the relative intensification of heat transfer.

In fig. 5 shows on an enlarged scale the zones of separation and attachment of the flow for cases with the corresponding relative heights of the turbulators *d/D* = 0.97; 0.95; 0.93.

Figure 5 it can be seen that the angular vortex to semicircular turbulators increases with an increase in the relative height of the turbulator. Angular vortices after semicircular turbulators at low Reynolds numbers Re = 8000 are formed only on relatively high turbulators *d/D* = 0.93. The point of attachment of the turbulent boundary layer will be located at a distance of approximately diameters turbulators.

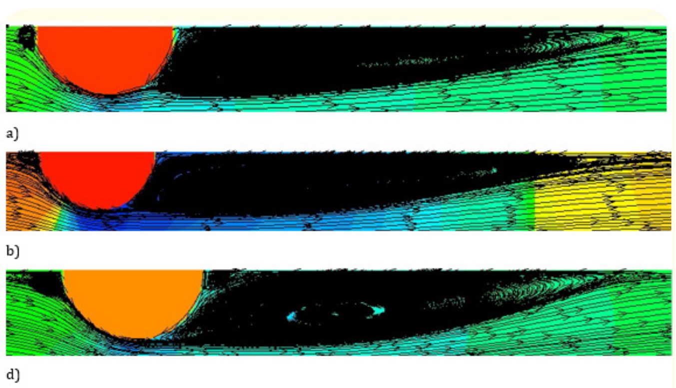


Figure 5: Calculation tne the lines currentfor separation and reattachment of the flow during the flow of nitric acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross section (from top to bottom): a) Re = 8000, d/D = 0.97, t/D = 0.50 ; b) Re = 8000, d/D = 0.95, t/D = 0.50; c) Re = 8000, d/D = 0.93, t/D = 0.50.

As the calculation showed you, paintings vortex zones between turbulators for conditions intermediate numbers Reynolds will be fit in betweenpositions between the minimum and maximum values of the Reynolds numbers, which were considered in the experiment [16] (Re = 8000÷380000).

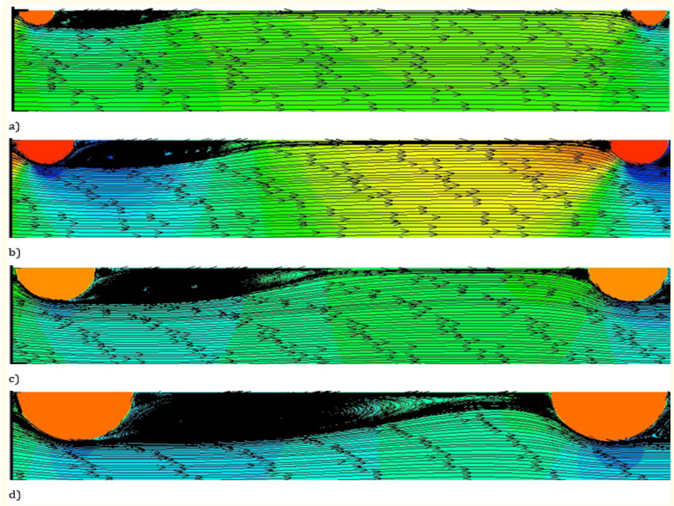


Figure 6: Calculation tne the lines current at flow nitrogen acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross-section (from top to bottom): a) Re = 380000, d/D = 0.97, t/D = 0.50; b) Re = 38000, d/D = 0.95, t/D = 0.50; c) Re = 38000, d/D = 0.93, t/D = 0.50; d) Re = 38000, d/D = 0.97, t/D = 0.50.

In figure 6 shows the calculated tne the lines current at flow nitrogen acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross section *t/D* = 0.50 and Re = 38000 for *d/D* = 0.97; 0.95; 0.93; 0.89, i.e. for the largest values of the Reynolds numbers considered in the experiments [16].

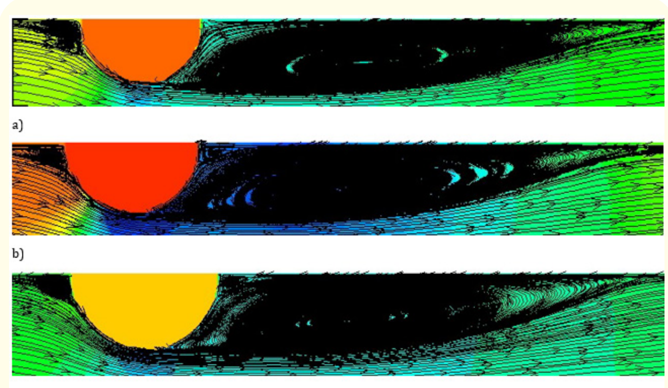


Figure 7: Calculation tne the lines current at flow nitrogen acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross-section (from top to bottom): a) Re = 380000, d/D = 0.97, t/D = 0.50; b) Re = 38000, d/D = 0.95, t/D = 0.50; c) Re = 38000, d/D = 0.93, t/D = 0.50; d) Re = 38000, d/D = 0.97, t/D = 0.50.

As can be seen from figure 6, the angular vortices after the turbulators become larger with an increase in the Reynolds number (compare with figure 4), and the angular vortices before the turbulators change insignificantly. The locations of the points of attachment of the turbulent boundary layer (Figure 7) also undergo insignificant changes within the above-considered Reynolds numbers.

In the future, intensified heat transfer should be investigated during the flow of nitric acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross section for d/D = 0.97; 0.95; 0.93; 0.89 and t/D = 0.50 for higher Reynolds numbers, an order of magnitude higher than in the experiment [16]: Re = 80000÷380000.

Data similar to figure 4 and figure 6, but for Re = 80000÷380000, i.e. an order of magnitude higher than in the aforementioned experiment are shown in figure 8 and figure 9 respectively. Streamlines for separation and reattachment of flows in a more detailed scale are shown in figure 10 and figure 11 respectively.

An increase in the relative hydraulic resistance occurs in at exit the main vortex in core Poutflow, while the relative heat transfer even decreases per hourt practically no removal of the point of attachment from the turbulator with an increase in the Reynolds number.

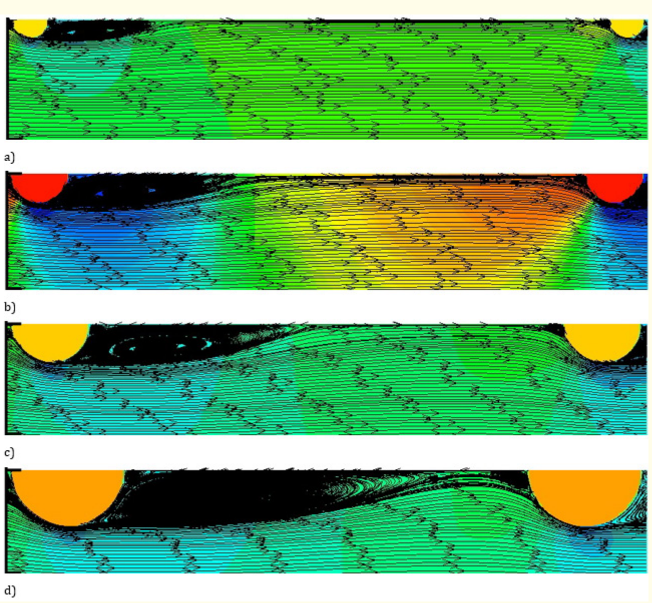


Figure 8: Calculation tne the lines current at flow nitrogen acid(HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross-section (from top to bottom): a) Re = 800000, d/D = 0.97, t/D = 0.50; b) Re = 800000, d/D = 0.95, t/D = 0.50; c) Re = 800000, d/D = 0.93, t/D = 0.50; d) Re = 800000, d/D = 0.97, t/D = 0.50.

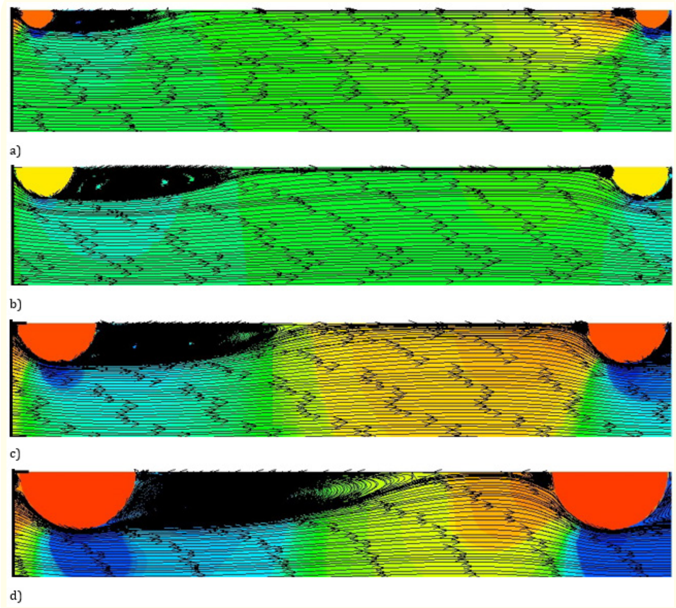


Figure 9: Calculation tne the lines current at flow nitrogen acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross section (from top to bottom): a) Re = 380000, d/D = 0.97, t/D = 0.50; b) Re = 380000, d/D = 0.95, t/D = 0.50; c) Re = 380000, d/D = 0.93, t/D = 0.50; d) Re = 380000, d/D = 0.97, t/D = 0.50.

As already noted in [3-12], the use of turbulators with a semicircular cross-section reduces the elongation of the recirculation zones, in comparison with turbulators of a square cross-section, which leads to a decrease in hydraulic losses in them.

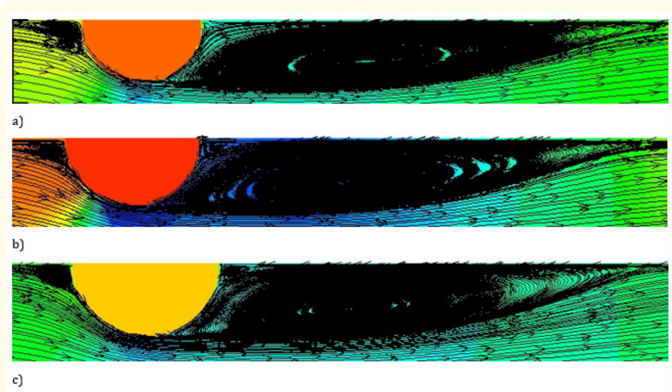


Figure 10: Calculation tne the lines currentfor separation and reattachment of the flow during the flow of nitric acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross section (from top to bottom): a) Re = 80000, d/D = 0.97, t/D = 0.50 ; b) Re = 80000, d/D = 0.95, t/D = 0.50; c) Re = 80000, d/D = 0.93, t/D = 0.50.

Analysis of calculations TNH integral characteristics of flow and heat exchange in pipes with semi-circular cross section turbulators at flow of nitric acid (hno_3) in turbulent mode

As a result, of these numerical settlement tov were received local and integral characteristics currents and heat transfer in direct round pipes from semicircular turbulators under the aforementioned conditions [1-12].

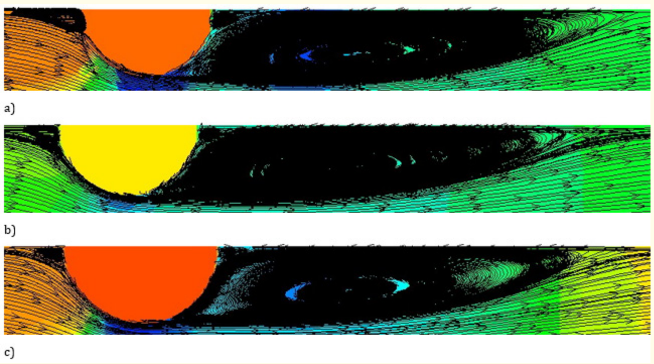


Figure 11: Calculation tne the lines currentfor separation and reattachment of the flow during the flow of nitric acid (HNO_3) in turbulent mode in pipes with turbulators of a semicircular cross section (from top to bottom): a) Re = 380000, d/D = 0.97, t/D = 0,50; b) Re = 380000, d/D = 0.95, t/D = 0.50; c) Re = 380000, d/D = 0.93, t/D = 0.50.

The main aspect when calculating those was given verifierthe study of theoretical data by experiment for nitric acid [16], in the range where it is available; then calculate the intensified heat transfer in the regions with higher Reynolds numbers, which are of interest in terms of the intensification of heat transfer, as indicated in [1-2].

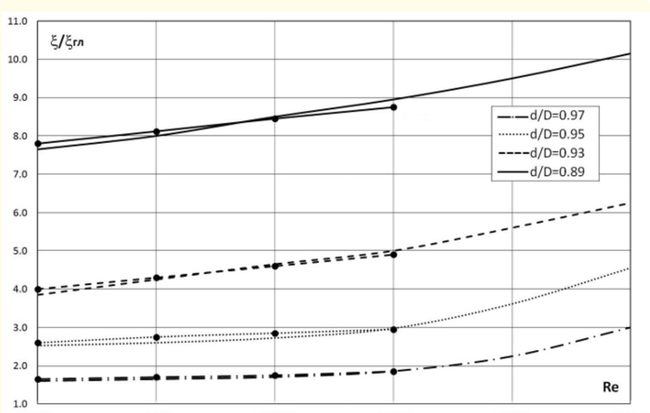


Figure 12: Comparison of calculations tn data by hydraulic resistance at turbulent flow nitrogen acid (HNO_3) for conditions d/D = 0.97; 0.95; 0.93; 0.89 and t/D = 0.50; Pr = 3.23; Re = 8000÷38000; Re = 80000÷380000, obtained by the developed FKOM-method (lines), with experimental data [16] (points).

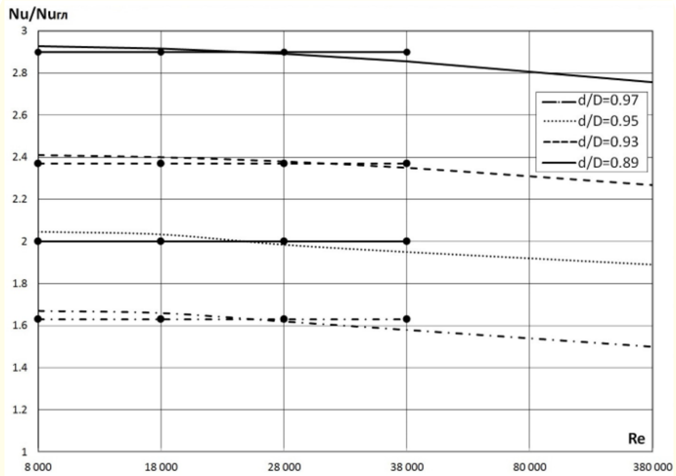


Figure 13: Comparison of calculations tn data byintensified heat exchange during turbulent flow of nitric acid (HNO_3) for conditions d/D = 0.97; 0.95; 0.93; 0.89 and t/D = 0.50; Pr = 3.23; Re = 8000÷38000; Re = 80000÷380000, obtained by the developed FKOM-method (lines), with experimental data [16] (points).

Settlement tne data by hydraulic resistance and heat exchangewith a turbulent flow of nitric acid (HNO_3) for conditions *d/D* = 0.97; 0.95; 0.93; 0.89 and *t/D* = 0.50; Pr = 3.23; Re = 800÷38000; Re = 80000÷380000 obtained by the developed FKOM method are shown in Fig. 12 and fig. 13 respectively; in order to compare the settlement tn data from experimental data [sixteen] be used the corrections for the increase in the heat transfer surface described in this article (5).

As can be seen from figure 12 and figure 13, calc tne data OK correspond eq experimental in the sun m range parameters, limited framework expert therefore, they can be extended to regions with higher Reynolds numbers with the same reason.

As can be seen from figure 12, for higher Reynolds numbers, there is a slight decrease in the relative heat transfer Nu/Nu_{SM} with a more noticeable increase in the hydraulic resistance (Figure 13), which increases as, what at relatively large numbers Reynolds is happening output the main vortex in side kernels flow.

Thus, holding nnoe in given work successful modeling thoseflat exchange in pipes with turbulators based on Menter's low Reynolds model under conditions of turbulent flow of nitric acid (HNO_3) for conditions *d/D* = 0.97; 0.95; 0.93; 0.89 and *t/D* = 0.50; Pr = 3.23; Re = 8000÷38000; Re = 80000÷380000, verified by experiment [16], determines the promising application of modeling intensified heat transfer in pipes with turbulators by this method and for an extended range of geometric parameters of the channel and flow regimes of coolants.

Conclusions

In the article, mathematical modeling of turbulent flows and heat transfer in pipes with turbulators of a semicircular cross section was carried out to determine of these ranges of Reynolds numbers (Re = 8000÷38000), investigated in the experiment [16] of the flows of nitric acid HNO_3 (Pr = 3.23).

In order to adequately compare the obtained calculations tn data from experienced [16] solved the problem of the effect of increasing the surface when using artificial turbulators of a semicircular cross-section flow in pipes on the effect of increasing heat transfer.

As a result, of these settlement tov It was identified good reconciliation theoretical data from appropriate experienced [16].

Verification of settlements tn data experiment callolila to check flow and heat transfer for an extended range of Reynolds numbers, an order of magnitude higher than the experimental range (Re = 80000 ÷ 380000).

As a result, of these settlement tov the influence of the geometric parameters of the channel and the flow regimes of the coolant on the intensified heat transfer in the turbulent flow of nitric acid HNO_3 was revealed.

The data obtained in the article on the low-Reynol's model on intensified flows and heat exchange during the flow of the considered coolant (nitric acid HNO_3) in pipes with turbulators of a semicircular cross section correspond to the physical representations of the processes being implemented [1,2].

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