Influence of rotation and geometry change of distance rings in panel radiators

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Abstract

The aim of this paper is to introduce the issue of distance rings in panel heating radiators, which are an integral part of their construction and which have an effect on the flow of water in the radiators. As a part of the research an experiment was carried out to compare two types of distance rings and obtaining the results of temperature fields for use in validation of a simulation model. Thus the research is based on a mathematical simulation with the help of which the temperature and velocity fields within a panel radiator are described in detail. In the simulation model it is possible to turn the distance ring and observe the effect in changes to the velocity and temperature fields. In addition research into my own shape of the distance ring is described and whether there is a greater influence from a change in the geometry on the temperature field than just turning it. In the end of the contribution the results of a mathematical simulation of the heating radiator at low operating temperatures are discussed.

Keywords: distance ring, panel radiator; CFD

1. Introduction

These days panel radiators are among the most commonly used radiators for heating in residential and public buildings. This is because of their compact dimensions and their wide dimensional and performance ranges for covering heat losses. Compared to other radiators the lower types have a high percentage of radiant elements of heat performance. Their other advantage is a low water volume, which allows a quick reaction to changes in regulation and they also have a lower weight than, for instance, sectional radiators [1]. So that the radiant part of the heat output of the radiator is primarily transferred through the front panel as even as possible over its entire surface and also to balance the convection flows rising upwards, it is necessary to equalise the temperature field over the area or length of the radiator. In order to achieve this from a hydraulic point of view it is necessary to optimize flows into the individual channels, so that the radiator is equally heated. This type of radiator can then be used both for higher operating temperatures and primarily for low operating temperature systems in low energy or passive houses. The equalizing of temperature fields has a positive effect on the above effects from a physical point of view, but also a psychological effect on a person, who checks the heat along the entire length of the radiator by touch and feels the even heating of the surface of the radiator particularly in the transitory period.

The most common channel shape is polygon, which is formed from a depression of two steel plates. These plates are presure welded together around the perimeter and between the channels. Such a radiating panels are hydraulically connected by interposing, in twos, a connection element. The connection element is pressure welded to the relative radiating panels, in order to guarantee the watertight seal of the connection.

To prevent the radiating panels from deforming during the pressure welding steps, it is known to insert inside them a distance ring which contrasts the pressure exerted, and thus prevent possible deformations. This distance ring is thus an integral part of the radiator for structural and technological reasons and has a significant effect on the flow of water in the radiator.

There can be varying opinions on resolving the issue of equalizing the flow in the individual channels of the radiator by means of changes in the cross section of the upper distribution chamber, for instance, using the constant static pressure method. This however does not resolve the problem with the distance ring, which must be used for technological reasons. In addition panel radiators have an infinite number of dimensional ranges and it is not possible to have a different depressing head for each radiator of different length. There is also an aesthetic issue here, where the user requires an upper distribution chamber parallel to the parapet and not a narrowing profile. Therefore the most advantageous solution is to first modify the flow by optimizing the distance ring which is always placed at the inlet and outlet point of the radiator. This optimization is intended to allow for the rotation and the geometry of the radial hole of the distance ring and the distance ring itself.

2. Distance ring

Historically the distance ring has undergone considerable development. In the beginning emphasis was placed only on simplicity and cheap manufacture. Distance rings were formed by shaping, pressing, bending, casting and later also machining. It is also important to describe the method, by which the distance ring is centred in the precise position before the presure welding of the connection elements. At the position of entry hole of the distance ring the plate was cut and then the ring was centred using a spike which opened the cut plate in the

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direction of the ring. This method however leads to creating burrs, which reaches the radial opening of the distance ring. That is why it is necessary to resolve the geometric detailing of the separating ring so that the radial opening is not blocked by these burrs.

A radiator has a minimum of 4 distance rings in the corners of the chambers. The most crucial issue for flow and temperature fields is the positioning of the distance ring at the water inlet to the radiator. Distance rings in other places, including at the water outlet from the radiator, have a negligible effect on the flow field. Here we can observe the same effect as in a ventilated space, where only the inlets have any effect on the division of flow in the ventilated space.

Fig. 1. *Distance ring with 4 radial holes [2]*

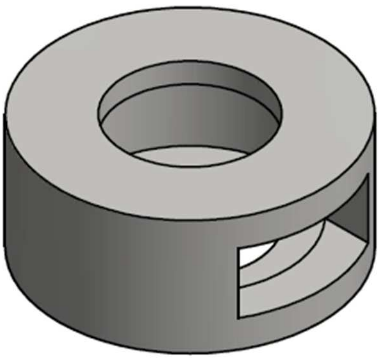

Fig. 2. *3D model of newer type of distance ring*

3. Experiment

One of the common solutions to the issue of the effect of rotating the distance rings is an experiment. This was carried out in the laboratory, where a thermal imaging camera captured the progress of the temperature fields of two radiators with different distance rings. In this case, an older panel radiator with an older type of distance ring which has four equally sized radial holes around its circumference and whose turning during manufacture was totally random and a panel radiator with a newer type of distance ring, which has one rectangular hole with exact rotation from manufacture. A detailed description of the experiment is given in [2].

A comparison of the temperature fields was carried out for various time intervals from the moment the warm up of the radiator began. Detailed images of the inlet area of the radiator were also made, where the development of the temperature field allowed a study of the rotation of an older type of distance ring. The exact rotation was found after the measurement of all data after the radiator was cut up. The rotation of the new type of distance ring was such that the upper distance ring intended for inlet was turned in the direction of the axis of the upper distribution chamber and the lower outlet distance ring was turned downwards to the lowest part of the lower collection chambers of the radiator. Only a comparison of the temperature fields during a constant operating state is given, where the unevenness of flow in both radiators is visible particularly in the area of the first two channels.

The temperature field of the panel radiator with a distance ring with four holes is given first. The temperature field is uneven and higher flows occur in the first channel. This is because of one hole of this distance ring is directed towards the first channel.

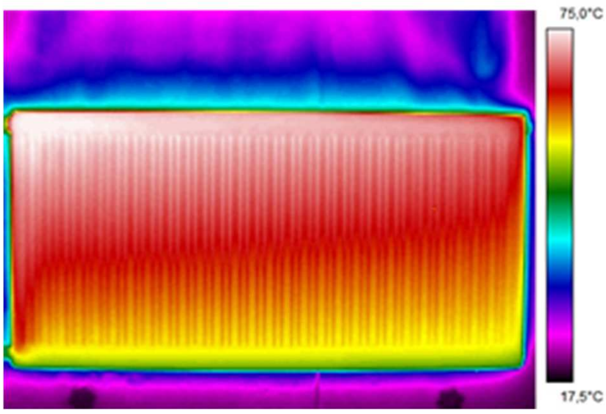

Fig. 3. *Temperature field of radiator with distance ring with 4 holes [2].*

Figure 4 shows the temperature field of the radiator with a distance ring, which has only one hole directed towards the axis of the upper distribution channel. In this case the direction causes a lowering of the flow in the second channel.

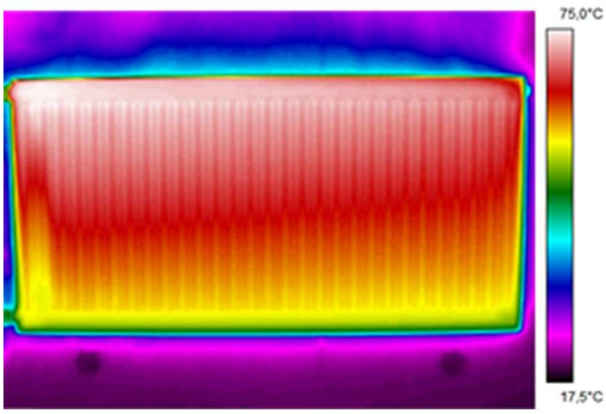

Fig. 4. *Temperature field of radiator with newer type of distance ring [2].*

4. Mathematical simulation

A research approach by means of mathematical simulation is chosen because the manufacture of radiators with a new or rotated distance ring would be demanding from a time and financial point of view. This is why it is more advantageous to study the effect of changes in geometry and rotation on equalized temperature fields of a radiator by means of mathematical simulation.

4.1. Geometric model

The geometric model of the radiator is formed in accordance with real dimensions of a panel radiator with dimensions of 1000x500 mm type 10 and the connection is one sided top-bottom. It is one of the most commonly used radiator panel dimensions and connections to a heating system.

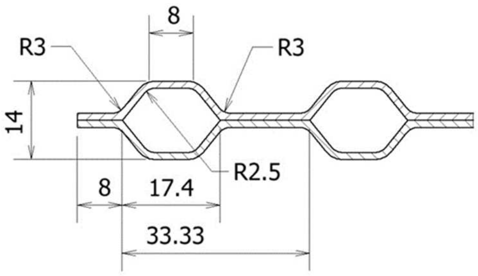

Fig. 5. Drawing of the dimensions of the channels

The geometry and rotatin of the distance ring is allowed for based on the actual dimensions in a real radiator. When creating the model it is sufficient to model only its steel parts and the internal inverse volume will be created using integrated functions in Fluent Meshing when creating the mesh.

4.2. Meshing

The actual creation of the mathematical simulation has two main parts. First suitable mesh is created to calculate using the method of final volumes and secondly the setting of the parameters (boundary conditions, flow model, etc.) so that the model is replaced by mathematical equations corresponds to the real radiator. In order to mesh the Fluent Meshing environment is used. This tool is optimized for creating mesh in mathematical simulations where there are flows of fluids.

Gradually by creating a surface mesh and checks on its quality, by creating an inverse volume, a large volume of final volumes are created – cells, which form the entire model. A new polyedric shape of cell is used. This shape is suitable for calculations, because it does not form edges with sharp angles. Another advantage when compared with tetrahedron cells is that in the same volume with the same edge sizes there are less of these cells. The overall model has fewer cells and it lowers the demands on computing performance.

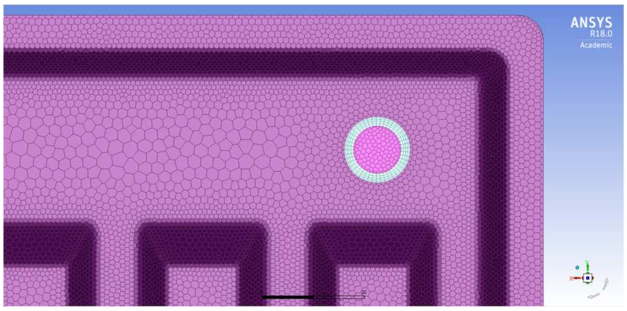

Fig. 6. The mesh density of panel radiator

In order to model the flow area near the walls. I.e. modelling the boundary layers, there is a function available, which allows the creation of the given number of layers of prismatic cells at the wall. The size of the first cells must meet the maximum size according to the parameter y^+ according to the method used for calculating flow at the walls.

The size of the first cells of the prismatic layer was determined such as it was not greater than what the y^+ parameter allows and also that the size of the cells in the last prismatic layer corresponded to the first cells in the volume outside of the boundary layers. A number of set ups were carried out and one was chosen, which most closely complied. The number of layers was set at 5 and the cell size set at 0.25mm after research into various settings. The growth factor of the thickness of the resulting layers is 1.2. Sections showing the modelling at the walls are shown on Figure 7. The total number of cells has a value of 8.5 million.

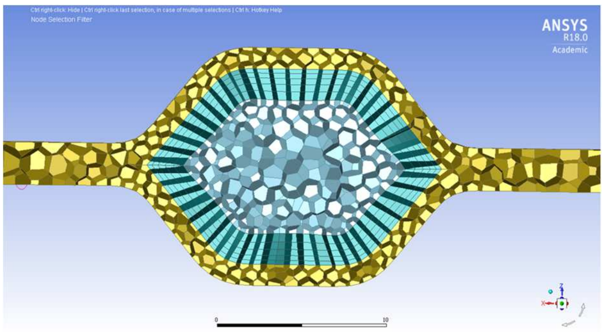

Fig. 7. Meshing of boundary layer in channel

4.3. Processing

Boundary conditions of the panel radiator geometry are listed in Table 1.

Table 1. Boundary conditions of the panel radiator geometry [3]

Inlet	Mass flow inlet	Mass flow rate	0,0136 kg/s
		Temperature	75 °C
		Hydraulic diameter	0,13 m
		Intensity of turbulence	10 %
Outlet	Pressure outlet	Hydraulic diameter	0,13 m
		Intensity of turbulence	10 %
Panel surface	Wall	Thermal specification	Convection
		Ambient temperature	20 °C
		Heat transfer coefficient	11,8 - 12,2 W/m^2K

It is also important to use a suitable model for turbulence. A calculation was made for the most commonly used turbulence models and the best convergence for this task was the two equation turbulence model Realizable k- ε, which is the latest model from the k- ε group and which should have the best computing performance [4]. The results of the mathematical simulation will thus be on the basis of the Realizable k- ε turbulence model.

5. Rotation of distance ring

One of the main aims of this research is to concentrate on the equalization of temperature fields on the radiator panel and primarily over the length of the radiator. On the Figure 8 the temperature field from the mathematical simulation is shown for the parameters given above. The palette of colours is chosen such that the unevenness of the temperature field is easily seen. On first examination the lowered flow in the second channel is easily seen, which occurs, because on entering the second channel the flow is turned in the direction of the outflow hole of the distance ring. This is clear from Figure 9. It is also clear that the upper part of the front panel is unevenly heated. This happens because the primary flow gradually loses its kinetic energy as it flows into the individual channels and pressure losses rise.

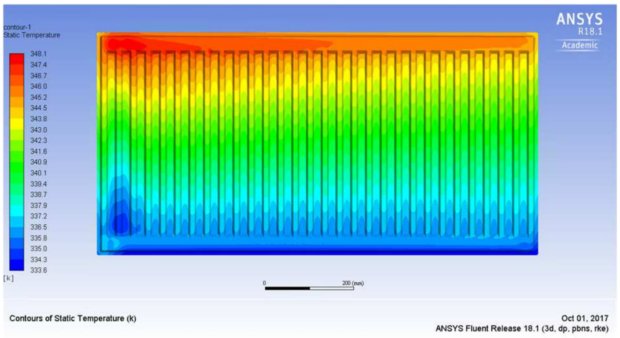

Fig. 8. Temperature field of radiator with distance ring with one hole

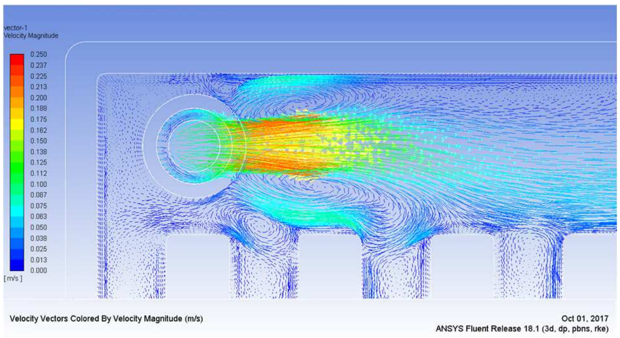

Fig. 9. Temperature field around inlet distance ring

In another mathematical simulation, whose mesh is formed with the same parameters as were given in the description of the previous model, the setting of the boundary conditions and the simulation are the same. In this mathematical simulation the rotation of the distance ring is changed anticlockwise by 10 degrees from the axis of the upper distribution chamber, that is to the upper edge of the distribution chamber. The turning shows its effect on the flows in the individual channels. It would be advantageous to raise the flow of the channels in the second half of the body, so that the temperature fields were equal. And it is exactly the rotation of the hole towards the upper edge of the distribution chamber that can have a positive effect on extending the range of the primary flow, which in the case of not rotated distance ring was at the level of the fourth channel lead to the lower edge of the distribution chamber.

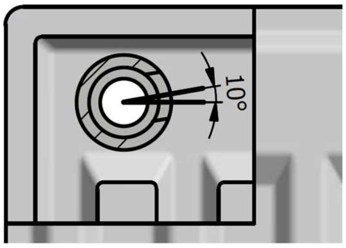

Fig. 10. Distance ring rotated by 10 degrees

The Figure 11 shows the radiators temperature field with a rotation of 10 degrees and the changes can be clearly seen compared to the temperature field without turning the distance ring.

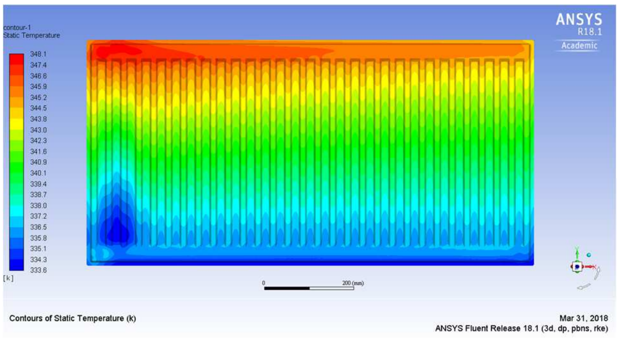

Fig. 11. Temperature field of radiator with distance ring rotated by 10 degrees

The greatest change is visible as a cooler area in the lower part of the second to fourth channels. This is because the turning of the rings lowers the flow in these channels. In the right hand part of the radiator the distribution of the temperature field is very similar. Based on flow checks the flow in the 3rd to 5th channels is lowered. The velocity field drawn near the inlet distance ring shows that a change in the direction of the primary flow occurred. It flows in the length of two channels just under the upper edge of the distribution chamber and creates a large secondary flow under itself, which lowers the flow to the third through to fifth channel.

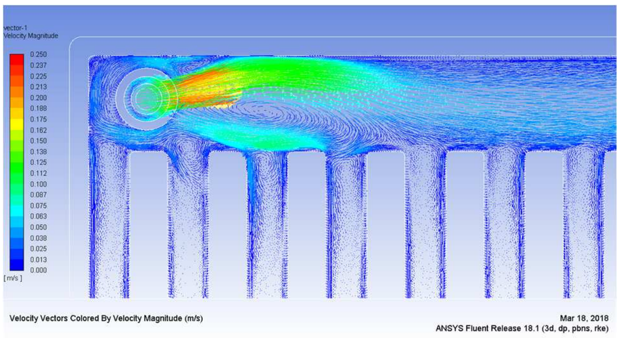

Fig. 12. Velocity field of radiator with distance ring rotated by 10 degrees

In another simulation the distance ring in the radiator is rotated by 20° in the same direction as in the previous simulation. The results can be seen on the Figure 13. On the temperature field a larger cooler area can be seen in the lower part of the 2nd to 4th channels so the flow in these channels is lowered even further. On the other hand the flow in the channels in the second half of the radiator rises equally, which in this part does not lead to an obvious change in the temperature field.

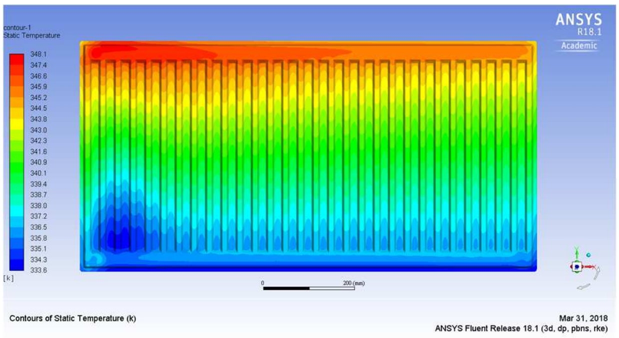

Fig. 13. *Temperature field of radiator with distance ring rotated by 20 degrees*

The velocity field shows, that the primary flow is turned even more towards the upper edge of the distribution chamber up to the level of the 7th channel. This is proof of why the flow in the first channels is lowered even more.

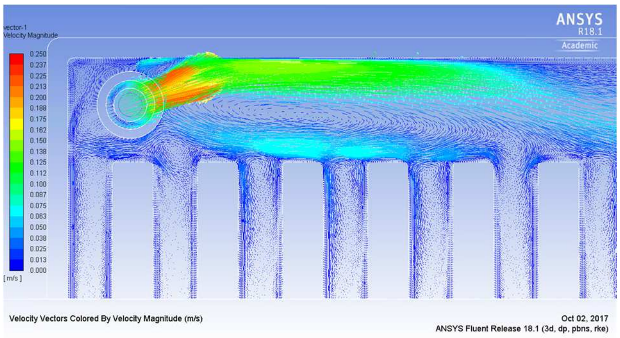

Fig. 14. *Velocity field of radiator with distance ring rotated by 20 degrees*

As in the previous simulation shows that the rotation of the distance ring in the direction of the upper distribution chamber does not have a positive effect on the equalization of the temperature field of the radiator. If the distance ring was rotated with its hole in a clockwise direction, then in this case a significant increase in flow occurs. This gives a further direction for research concentrating on changes in the geometry of the distance ring, that is, in particular, its holes.

6. Geometry change of distance ring

Distance rings were previously manufactured with a larger number of radial holes as was shown on Figure 1. I estimate that the change of the size or shape of one hole will not lead to an equalization of the temperature field because the main issue is how to correctly set up the direction and speed of the flow from the distance rings. It is advantageous to maintain part of the flow in the direction of the upper distribution chamber and then direct the second hole towards the channels which showed lower flows and had lower surface temperatures in their lower sections.

A research direction into a two hole distance ring was thus chosen. The area of both holes will total the same area as the area of one hole was. A division ratio of 10/3 was chosen where the larger hole will be directed at an angle of 20° to the upper edge of the distribution chamber and the smaller hole will be directed between the 2nd and 3rd channels.

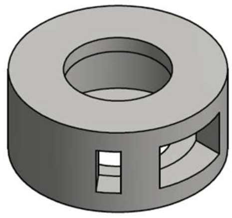

Fig. 15. *Model of distance ring with two holes*

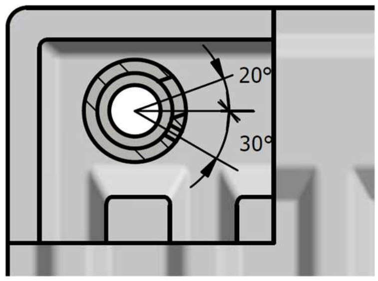

Fig. 16. *Distance ring with two holes 10/3 rotated by 20 degrees*

As can be seen on the Figure 17, when compared with the temperature field on the Figure 8, clear changes in the temperature field in the lower part of the first channels can be seen.

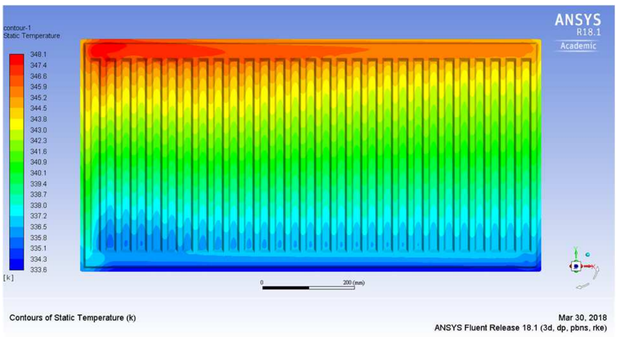

Fig. 17. *Temperature field of radiator with distance ring with two holes 10/3*

The temperature field of a radiator with a distance ring which has two holes is, in the front part, more equalized when compared to radiators with distance rings with one hole rotated towards the axis of the upper distribution chamber. Despite this, in the second half occurs no change in the temperature field. In order to achieve this change it is necessary to increase flow speeds in the upper distribution chamber so that less water cooling occurs. In another mathematical simulation the ratio of the surface outs of both holes changes from 10/3 to 8/5.

This change could bring increased flow velocity in the upper hole and thus influence the temperature field in the second half of the radiator. The temperature field is shown on Figure 18. The temperature field and on its basis also the velocity field do not develop in accordance with requirements. There is a visible change once again in the first half of the radiator, where flow increased in the upper part of the first channels and thus negative heating of channels to a greater depth and the temperature field appears more uneven than it was in the previous simulation.

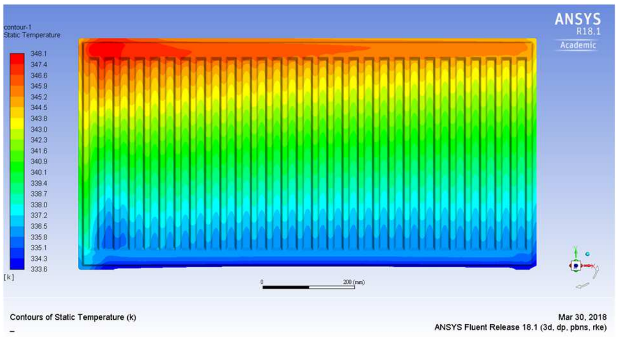

Fig. 18. *Temperature field of radiator with distance ring with two holes 8/5*

This is caused by the increase of the lower hole, which raises the flow in the 2nd to 4th channels. The distance ring with two holes is the correct direction to an even temperature field on the front panel of the radiator, based on the initial results. The change in ratio of the hole dimensions to 8/5 did not lead to a positive change, in spite of this we will continue to concentrate on modifying the distance ring with two holes.

7. Low operating temperatures

These days' radiators are operated much more often in low temperature heating systems. It is thus important to check changes in the geometry of the distance ring at lower temperature parameters other than just 75/65 °C. As another mathematical simulation a change in boundary conditions to a 50/40 °C temperature gradient was carried out. The change involved the setting of the flow, input temperatures, and the overall heat transfer coefficient to the outer surface of the radiator.

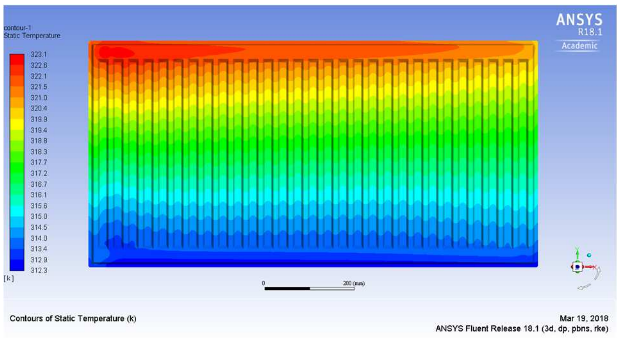

Fig. 19. *Temperature field of radiator with one hole distance ring on operating temperatures 50/40 °C*

As can be seen from the temperature field of the radiator with a distance ring with one hole and lower temperatures of 50/40 °C, the imbalance of the spread of the temperature is not as critical as for higher temperatures. The lower the temperature, the better the situation from the point of view of unbalanced distribution of temperature. Despite this, I will continue with simulations with a low operating temperature and it will be proved whether two holes distance rings have a positive influence on balancing the temperature field in radiators operated at low temperatures.

Conclusions

The issue of flows in radiators is very important. The fact that the flows are optimized, means the division of temperature is also optimized and the exchange of temperature and thus the whole length of the radiator will have equal transfers of convected heat and radiation into heated spaces. It was found that the distance ring with two holes is the correct route to balancing the temperature field and I will continue to devote myself to changes in its geometry and rotation. It is also important to ascertain what effect lower operating temperatures have on the temperature field of distance rings with two holes.

Acknowledgements

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Nomenclature

y^+	dimensionless wall distance (-)
k	turbulence kinetic energy (m^2/s^2)
ε	turbulent dissipation rate (m^2/s^3)

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