Optimization of Distance Rings in Panel Radiators

T Legner and J Bašta
Czech Technical University in Prague, Czech Republic
tomas.legner@fs.cvut.cz, jiri.basta@fs.cvut.cz

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 influence the flow of water in the radiators. A new way of meshing the simulation model in Ansys Meshing, including the boundary layer modelling, is described. 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.

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 [1]. Compared to other radiators the lower types have a high percentage of heat output by radiation [2]. Moreover, metallic paint finishes have been shown to reduce radiant heat output by up to 10% [3]. Their other advantage is a low water volume, which allows a quick reaction to change in regulation and they also have a lower weight than, for instance, sectional radiators. 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 to balance the convection flows rising upwards [4], it is necessary to equalise the temperature field over the area or length of the radiator. 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 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 a transition heating period.

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

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 pressure welding of the connection elements. At the position of inlet, the plate was cut and then the ring was centred using a spike which opened the cut plate in the direction of the ring. This method however leads to creating burrs, which reaches the radial opening of the distance ring.

A radiator has a minimum of 4 distance rings in the corners of the chambers. The most decisive factor 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.

3. Mathematical simulation
The 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. Therefore, 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.

3.1. 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.

The geometry and rotation 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.

3.2. Meshing
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 is 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.

![Figure 3. The mesh density of panel radiator](image3)

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. Several 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 in figure 4. The total number of cells has a value of 8.5 million.

![Figure 4. Meshing of boundary layer in channel.](image4)

### 3.3. Processing

Boundary conditions of the panel radiator geometry are listed in table 1. The temperature distribution over the surface of the radiator was analysed. Thermal infrared (IR) imaging was used for this purpose. Thermal IR imaging has proved to be a powerful technique for studying the thermal behaviour of panel radiators [5]. 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 simulation has 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. The results of the mathematical simulation will thus be on the basis of the Realizable k-ε turbulence model.

**Table 1. Boundary conditions of the panel radiator geometry**

| Inlet          | Mass flow inlet | Mass flow rate | 0.0136 kg/s |
|----------------|-----------------|----------------|-------------|
|                |                 | Temperature    | 75°C        |
|                |                 | Hydraulic diameter | 0.13m    |
|                |                 | Intensity of turbulence | 10%      |
| Outlet         | Pressure outlet | Hydraulic diameter | 0.13m    |
|                |                 | Intensity of turbulence | 10%      |
| Panel surface  | Wall            | Thermal specification | Convection |
|                |                 | Ambient temperature | 20°C      |
|                |                 | Heat transfer coefficient | 11.8–12.2 W/m²K |

4. **Results from mathematical simulation**

One of the main aims of this research is to focus on the equalization of temperature fields on the radiator panel and primarily over the length of the radiator. In the figure 5 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 6. It is also evident 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.

![Figure 5. Temperature field of radiator with distance ring with one hole](image1)

![Figure 6. Velocity field around inlet distance ring](image2)
5. Rotation of 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 rotation 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.

The figure 8 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.

![Figure 7. Distance ring rotated by 10 degrees](image1)

![Figure 8. Temperature field of radiator with distance ring rotated by 10 degrees](image2)

The greatest change is visible as a cooler area in the lower part of the second to fourth channels. This is because the rotation of the ring decreases the flow in these channels. In the right-hand part of the radiator the distribution of the temperature field is very similar. The flow in the 3rd to 5th channels is decreased. 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 decreases the flow to the third through to fifth channel.

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 in [6]. 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 decreased 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.

As shown in the previous simulation 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 its holes.
6. Geometry change of distance ring

6.1. Distance ring with two holes
Distance rings were previously manufactured with a larger number of radial holes. It has proved that the change of the size or shape of one hole will be not leading 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.

![Figure 9. Model of distance ring with two holes.](image)

![Figure 10. Distance ring with two holes 10/3](image)

As can be seen in the figure 11, when compared with the temperature field in the figure 5, visible changes in the temperature field in the lower part of the first channels.

![Figure 11. Temperature field of radiator with distance ring with two holes 10/3](image)

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.

6.2. Distance ring with wedge-shaped hole
The two-hole distance ring had a positive effect on the flow. It would be advantageous to provide one hole to include the advantages of the spacer ring with two holes, i.e. the direction to the left half of the
body has a smaller flow and the main flow to be directed into the right half of the body. This could be accomplished by a spacer ring with a hole in the wedge face, where the lower part of the hole will be narrower, and a smaller flow will flow and the major part of the flow will flow through the wider upper part.

Figure 12. Model of distance ring with wedge-shaped hole.

A model of a distance ring with a wedge-shaped hole is shown in the figure 12. The wedge-shaped hole is tapered at the top and bottom to extend the flow through the hole. Overall, the spacer ring is rotated to respect the rotation of the previous 10/3 split hole ring.

Figure 13. Rotation of distance ring with wedge-shaped hole

The figure 14 shows that the temperature field belongs to the more balanced ones. Compared to the temperature field for the two-hole spacer ring in the figure 11, there is a cooler area in the lower portion of the second channel. There was no significant change in the temperature field in the right part of the radiator. Based on these results, in which the spacer ring had one hole that was modified, it would be better to focus on a two-hole spacer ring. The rotation of the holes will be adjusted to affect the flow mainly in the first channel.

Figure 14. Temperature field of radiator with distance ring with wedge-shaped hole

7. Conclusion
The issue of flows in radiators is very important. By optimizing the flow, the heat is also optimized and hence the heat of the convection and radiation to the heated space will be shared equally. With low-temperature parameters, the temperature field is always more equally due to a lower temperature difference. Therefore, it is better to monitor all changes at higher temperatures of radiators.

In the overall comparison, the most uniform temperature field along the length of the body is in the radiator with a distance ring with two holes because there is no greater warming of the left part of the body compared to other cases. From the temperature field results, there is a higher flow rate in the second channel compared to the model with a common distance ring. However, there is a markedly
increased flow through the first channel from the results of the velocity field, which should be further reduced by adjusting the size or geometry of the two holes. In the right part of the body, this flow is without significant changes compared to the one-hole distance ring.

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