

# Numerical Analysis of Straight Wire and Helical Wire Wrap 2×2 Rod Bundle with Supercritical Water

Gaurav Kumar<sup>1,\*</sup>, Raj Kumar Singh<sup>2</sup>

## Abstract

*Investigations using computational fluid dynamics (CFD) have been conducted on a 2×2 rod bundle that has been wrapped with both straight and helical spacer wires. The bundle has been wrapped with both types of spacer wires. There have been investigations conducted in this regard. The wires that have been coiled have been wrapped around another rod bundle that has been looped around them. An examination and investigation into the employment of helical wire spacers have been carried out in the past. This assessment and investigation have been carried out. To construct flow disseminations in the rod bundle, it is possible to use a commercial computer to solve the equations for the conservation of mass, momentum, and energy that are contained within the Ansys Fluent software. This will allow the flow disseminations to be constructed. The generation of flow disseminations will be made possible as a result of this. During its passage through the rod bundle, it is possible to observe that the supercritical water flows not only in the axial direction but also in the transverse direction. This is something that can be accomplished. At this point, it is possible to make this observation. Specifically, this is because the spacer is wrapped in a helical form, which permits the water to flow in both directions. This is the reason why this occurs. As a result of the presence of this transverse flow, the coolant is dispersed among the subchannels in a manner that is even more comprehensive than it would have been under any other set of circumstances.*

**Keywords:** CFD, rod, supercritical water, wire, hydraulics

## INTRODUCTION

Among the six Generation IV reactors currently under investigation by the Global Initiative for Nuclear Energy (GIF), the supercritical water-cooled reactor (SCWR) is the most promising. This is because it has enhanced thermal efficiency, in addition to the fact that its components have been

simplified. Both factors contributed to this result. In the core of the reactor, grid spacers are responsible for providing support for the fuel rod bundles and for carrying out the mixing of fluids in the subchannels. Grid spacers are also responsible for ensuring that fuel rod bundles are properly supported. Grid spacers were positioned inside the core of the reactor where the reactor was located. It has been proven that it is possible to bring about significant changes in the flow structures and heat transfer characteristics using a spacer grid. This was demonstrated by the fact that it was possible to bring about these changes [1, 2]. The wire-wrapping spacers not only preserve the geometric structure of the rod bundle but also contribute to

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the facilitation of fusion within the flow field and play a role in the transfer of heat. In addition, they play a role in heat transfer. In addition, they are also involved in heat transmission. This is because they can actively participate in the process of heat transmission. Furthermore, this is in addition to the mechanism that they utilized to guarantee that the geometric structure of the rod bundle is maintained. This is in addition to the original mechanism [3,4]. Optimizing the fusing process is vital because it reduces the temperature at hot locations, which in turn reduces the possibility of damage to the fuel covering. Therefore, it is extremely important to improve the fusion process. In addition, it raises the safety margin, which in turn increases the overall probability that no one will get any injuries throughout the course of the event [5,6]. The wire wrap structures contribute to the development of a powerful tangential flow provision on the surface of the fuel rod. This is in contrast to the situation in which the wire wraps would generate regional disruption at the location of the spacer and the immediate next area. In contrast to the circumstances that would have arisen if the wire wraps had been utilized, this is the condition that has transpired. However, spacer grids produce regional disturbances not only at the location of the spacer but also in the region that is provoking the next spacer. This is because the spacer grids are responsible for producing regional disturbances. To put this into perspective, in contrast to the situation described earlier, this is called the situation [7–9]. As a result, both the temperature contour of the coolant contained within the rod assembly and the required pumping capacity of the coolant are reduced. In addition, the temperature contour of the coolant is reduced. The amounts of both components were reduced to levels that correspond to their respective constituents. As an additional enhancement, the temperature contour of the coolant has been reduced as a consequence of this, which is yet another improvement that has been made. The temperature contour of the coolant was reduced compared to that initially. This is another alteration that occurred. This pertains to the enhancement that was implemented. The fact that this has been accomplished is that it cannot be refuted in any scenario. Consequently, the maximum temperature of the cladding decreases, which cannot be prevented regardless of the circumstances. This fallout cannot be prevented under any circumstances. In light of the fact that this particular event took place, this result will be brought about. The effects that will result from this predicament cannot be avoided under any circumstances. There is no way to avoid the consequences of this position, and there is no way to prevent them from occurring under any circumstances. However, it is impossible to find a solution for this issue [10–13]. Additionally, wire-wrapped spacers may also have the ability to increase heat transmission, which is yet another prospective application of these spacers that may be applied. In addition to the potential benefits mentioned earlier in the literature, this additional potential benefit is also within the realm of possibility. One of the potential benefits that might be achieved via their utilization is the acquisition of this prospective benefit, which is one of the potential benefits that could be obtained through their utilization. This is a really useful development in the present period, considering the fact that it is common information that the SCWR assembly suffers a reduction in heat transmission, which is a really good development. The reason for this scenario is that there has been a reduction in the amount of heat carried out, which results in this circumstance [14].

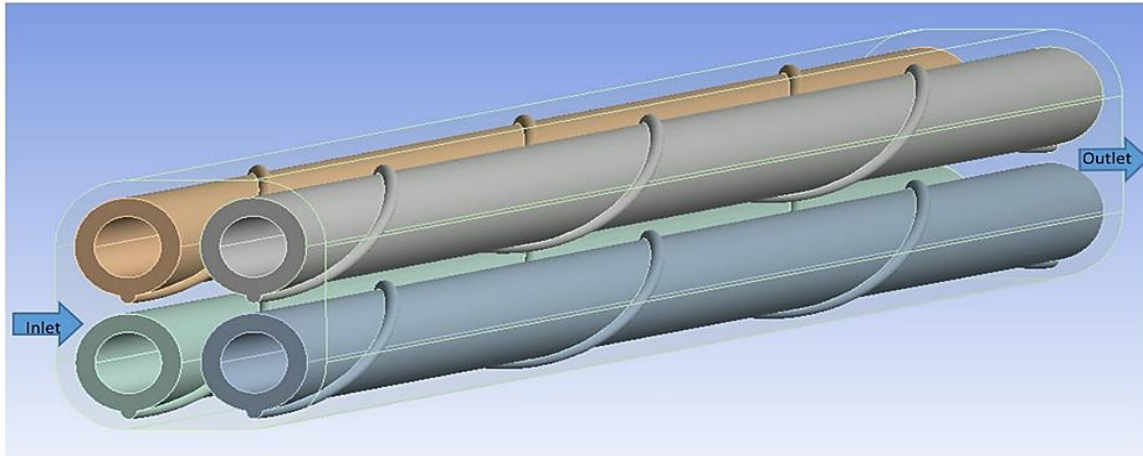
## NUMERICAL MODEL

It should be brought to attention that the commercial program known as Ansys Fluent 2021 was the one that was utilized in each and every one of the simulations that were carried out. This information is necessary to attract attention. Shared information is important. Because of the geometry displayed in Figure 1, it can be seen that the Ansys spacecraft was utilized to successfully conclude the process of constructing the geometries from the beginning to the end. During that particular time period in history, the knowledge that was readily available to the general public was utilized to arrive at the proportions that were achieved [15].

### Governing Equations

Continuity Equation for steady state

$$\frac{\partial}{\partial x_j}(\rho u_j) = 0 \quad (1)$$



**Figure 1.** Geometry of helical wire-wrapped rod bundle.

Momentum equation for steady state

$$\frac{\partial}{\partial x_j} (\rho u_j u_i - \tau_{ij}) = -\frac{\partial p}{\partial x_i} \quad (2)$$

Energy equation for steady state

$$\frac{\partial}{\partial x_j} (\rho u_j c_p T - F_{h,j}) = 0 \quad (3)$$

### Boundary Conditions

It is applied to the inner wall of the rod, which results in a steady heat flow of 400 KW/m<sup>2</sup> being given to the rod. Although the temperature at the inlet was 419.3°C, the pressure of the fluid was maintained at 25 megapascals (MPa). This was performed even though the temperature was maintained. One of the most important aspects that was considered was ensuring that the mass flux at the intake remained constant at 1000 kg/m<sup>2</sup>s.

### Grid Independence Test

For the goal of this evaluation, a study was conducted on the independence of the mesh was carried out in order to establish the quantity of mesh pieces that would be most effective in accomplishing the desired results that were wanted. Because the information shown in Table 1 indicates that the relative inaccuracy of the sectional pressure between mesh 2 and mesh 3 is 1.62 percent, the study was conducted using mesh 2 in its entirety from beginning to end.

**Table 1.** The relative inaccuracy of the sectional pressure between mesh 2 and mesh 3.

Mesh	Number of elements (millions)	Sectional pressure (Pa)	Relative error (%)
1	7.1	4825	-
2	8.2	4669	3.23
3	12	4593	1.62

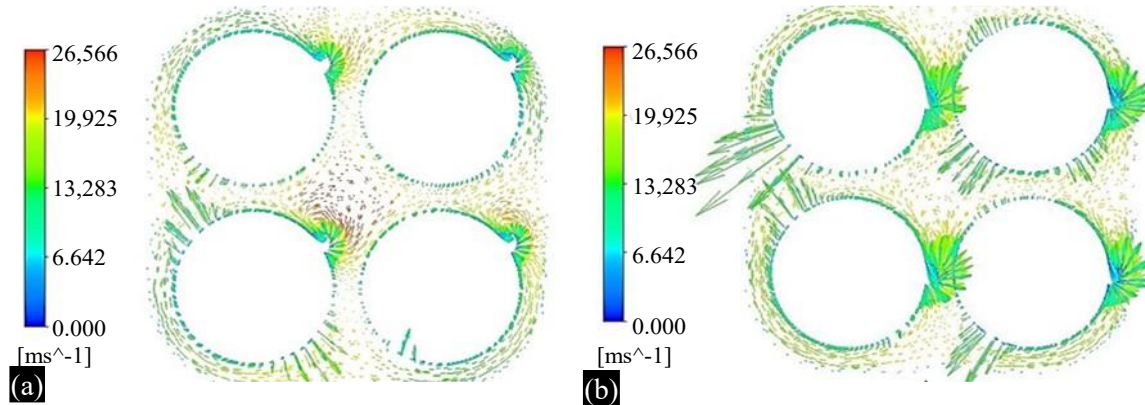
## RESULTS AND DISCUSSIONS

Each and every one of the results was computed at a sectional plane that was located 500 millimeters away from the starting point of the domain. This procedure was performed throughout the process.

### Velocity Vector

Figure 2 illustrates that the velocity vector of the rod with helical wire wrapping is greater than that of the rod with straight wire wrapping. This was observed from a comparison between the two velocity

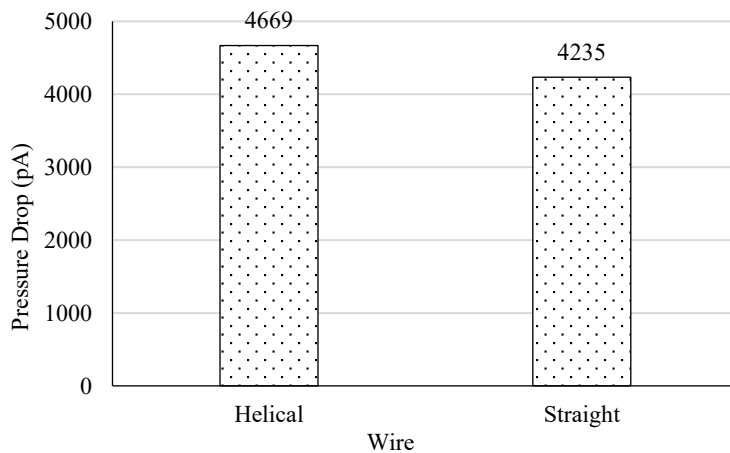
vectors. This serves as an illustration of the connection between two different wraps of the wire. The swirl will be broader in helical wrapping, which makes it simpler to observe the mixing. This is because the swirl is more widespread. A greater quantity of mixing leads to a higher degree of homogeneity in the temperature distribution, and it also leads to an improvement in the heat transfer from the rod to the fluid. Both these outcomes are a consequence of an increase in the quantity of mixing.



**Figure 2.** Velocity vector of (a) helical wire, and (b) straight wire.

**Pressure Drop**

The average pressure drop for the helical wire was 4669 Pa at the sectional plane, whereas the pressure drop for the straight wire wrap was 4235 Pa. Both the pressure drops were reported. The distinction between these two values is as follows.



**Figure 3.** Pressure drops of helical and straight wire-wrapped rod bundle.

Figure 3 provides an illustration of this crucial information. The pressure drop will certainly increase as the number of spins increases because of the increased resistance. Because of the increased resistance, this is the result.

**CONCLUSIONS**

In light of the findings of the investigation presented previously on the helical and straight wire-wrapped rod bundle with supercritical water serving as the fluid, the following conclusions can be drawn:

1. First, the helical turns produce an increase in the transverse velocity, which in turn causes the swirl to grow, which in turn causes the heat transfer phenomenon that occurs between the rod and fluid to increase.

2. An increase in the pressure drop is caused by helical wrapping, which may increase the pumping power of the fluid. The helical wrapping resulted in an increase in the pressure drop experienced. However, if we want the heat transfer to be more evident than the pressure decrease, helical wrapping of the wire is preferred. This is because the heat transmission is more noticeable.

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