



Various inlet spiral geometries in 1MW steam turbine

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Abstract. In small turbines, inlets can be designed using an inlet spiral. This paper analyses the efficiency of eight turbine variants, including seven with three stator and rotor blades and inlet spirals of various geometries, and one variant with a spiral, three stages and an outlet. This involves a 3D steady viscous flow using ANSYS CFX. The analysis shows that the spiral has a considerable influence on turbine efficiency.

1 Introduction

Steam turbine inlets usually comprise inlet boxes for partial and full admission. Inlet design in small turbines is normally simplified to economise on production costs.

Kryłowicz et al. [1] described in a condensing steam turbine (50 kW) and a back pressure turbine (165 kW). The general parameters are: inlet temperature 340 C, inlet pressure 12 bar, mass flow 270 kg/h and rotation speed 6276 rpm. The turbine inlets are of the standard type used in turbines.

Škach and Uher [2] showed design process of stator blades for spiral inlets.

Hecker et al. [3] presented the design of spiral inlets. The structure and aerodynamics analyses were shown.

This paper for the first time studies different inlet spiral geometries for a 1MW, three-stage steam turbine with a 30t/h mass flow.

2 Numerical studies

ANSYS CFX was used to calculate steady viscous flow in four inlet spirals and three stages, each with 32 stator blades and 99 rotor blades. Design Modeller was used to create the geometries of rotor and stator blades as well as turbine inlets and outlets. TurboGrid was used to prepare the blade, inlet and outlet meshes.

The purpose of the analysis was to determine the efficiency of the eight turbine variants.

2.1 Variant one

Here, the circular pipe entered the rectangular channel of the spiral at a low angle to allow for a smoother flow. The outlet spiral leading the steam to the stator blades was in the form tapered diffuser (Fig. 1, 2). The inlet spiral caused a reversal of flow towards in the stator blades. There were 32 stator blades with an S-9012A profile [4].

A stall flow appeared in the inlet pipe and spiral as well as the stator blades when there was a flow velocity perpendicular to stator the pressure side in the first stage (Fig. 3, 4).

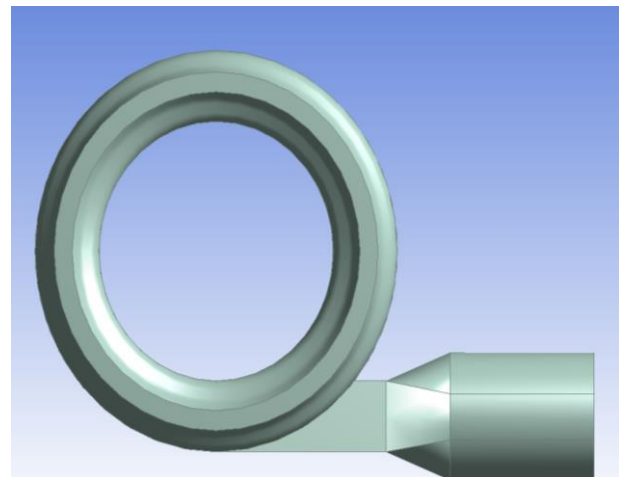


Fig. 1. Side view of Variant one spiral.

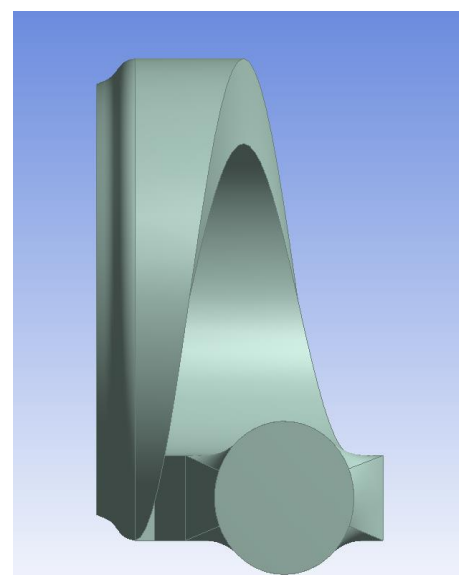


Fig. 2. Front view of variant one spiral.

According to the CFD calculations, the turbine generated 1.368 MW with a mass flow of 9.78 kg/s (35.21 t/h) and an inlet pressure drop of 5.64kPa and was 86.17% efficient.

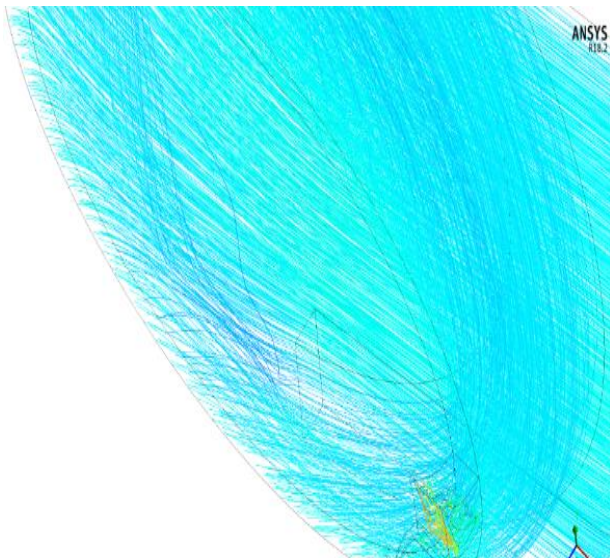


Fig. 3. Spiral inlet flow, variant one.

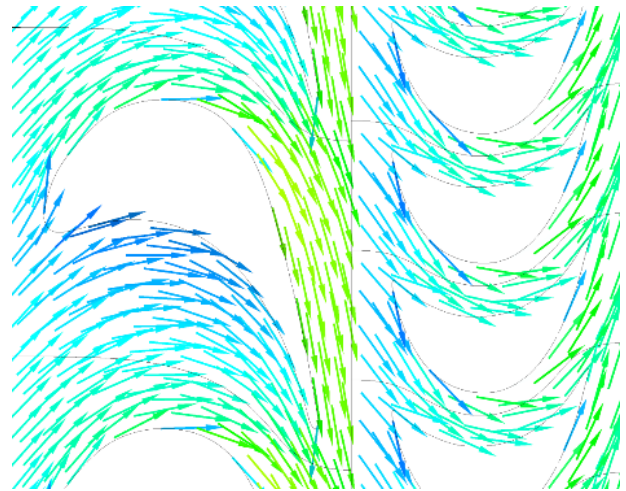


Fig. 5. Velocity field at 0.5 of the stator blade length, variant two.

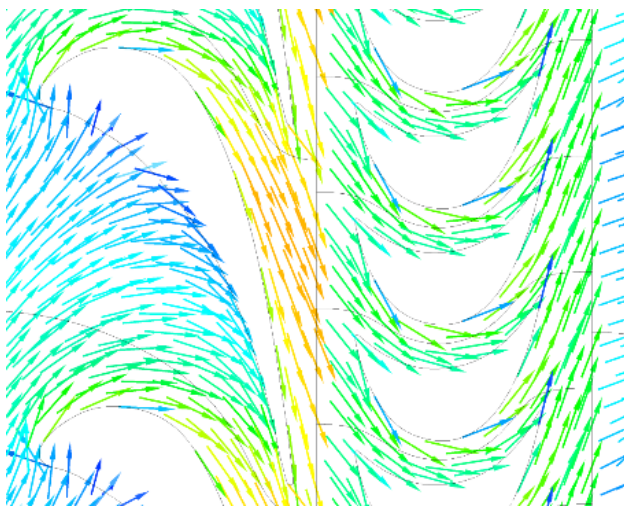


Fig. 4. Velocity field at 0.5 of stator blade, variant one.

2.2 Variant two

The geometry of the spiral in variant two was the same as in variant one. The differences concerned the profile of the first stator (S-5515A) [4] and the number of stator blades was increased to 39. The altered stator blade profile prevented stall in the stator area and the velocity vector was no longer vertical to the pressure side (Fig. 5).

According to the CFD calculations, the turbine generated 1.516 MW with a mass flow of 10.73 kg/s (38.64 t/h) and an inlet pressure drop of 6.55kPa, resulting in 86.9% efficiency. The altered first stator blade profile prevented steam flow stall around the stator blades and caused efficiency to rise from 86.17% to 86.9%.

2.3 Variant three

The circular pipe entered the rectangular spiral channel at a zero angle. The first stator profile was S-9012A [4] and there were 32 stator blades. In contrast to variants one and two, where the steam flowed through the centre of the spiral, in variant three, the steam flowed down the inner side of the spiral. A diffuser was not applied in this case (Fig. 6, 7, 8).

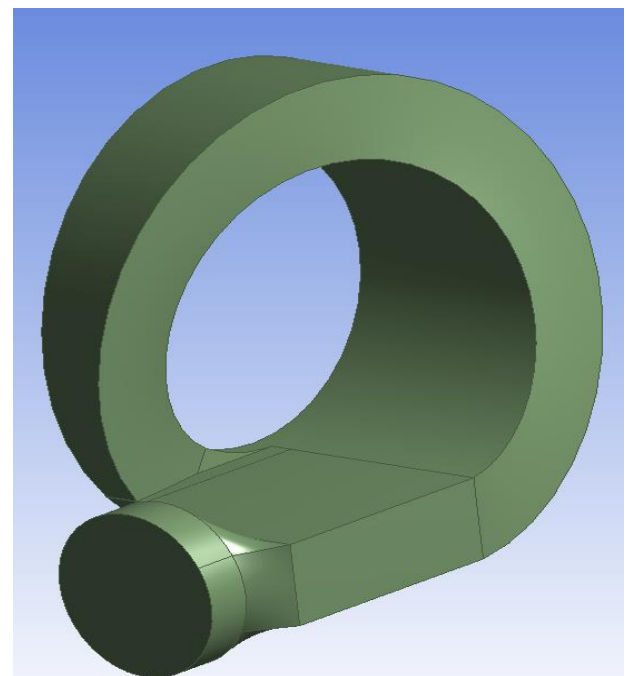


Fig. 6. Variant three spiral.

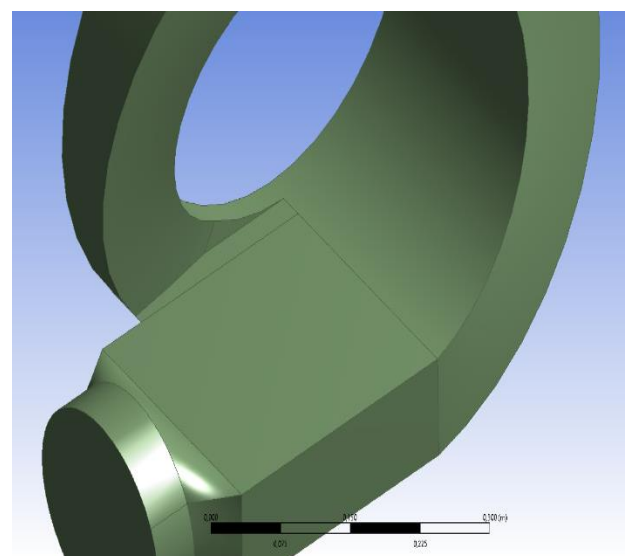


Fig. 7. Variant three spiral, enlarged.

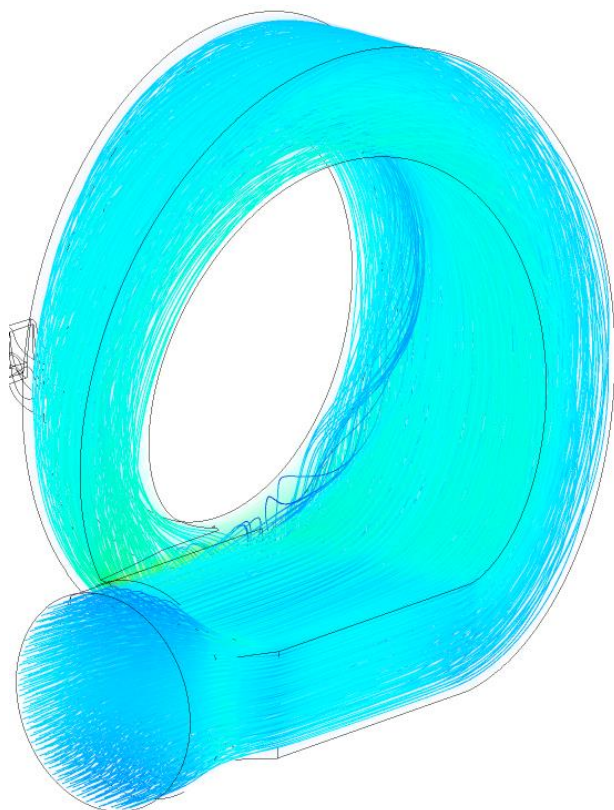


Fig. 8. Streamlines in inlet, variant three

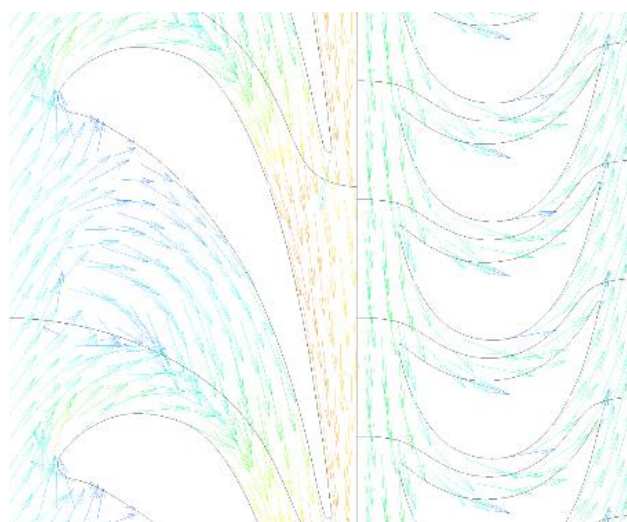


Fig. 9. Variant three velocity field at 0.5 stator blade length.

Due to the altered geometry, a stall appeared in the stator region (Fig. 9), causing efficiency to drop to 83.7%.

According to the CFD calculations, the turbine generated 1.293 MW with a mass flow of 9.50 kg/s (34.21 t/h) and inlet pressure drop of 21.15kPa. Reducing the inlet pipe angle to zero caused a perpendicular flow on the pressure side, as in Variant one, and the reduced efficiency to 83.7%.

2.4 Variant four

Variants four and three had the same geometries, but the profile of the first stator blade in the former was altered to

(S-5515A) [4]. As in variant two, there were 39 stator blades.

The altered stator blade profile prevent stall at 0.5 length of the blade but a stall did occur in the root and at the tip (Fig. 10, 11).

The turbine generated 1.458 MW with a mass flow of 10.49 kg/s (37.75 t/h) and an inlet pressure drop of 24.49kPa. The variant four stator blade profile improved turbine efficiency from 83.7% to 85.69%.

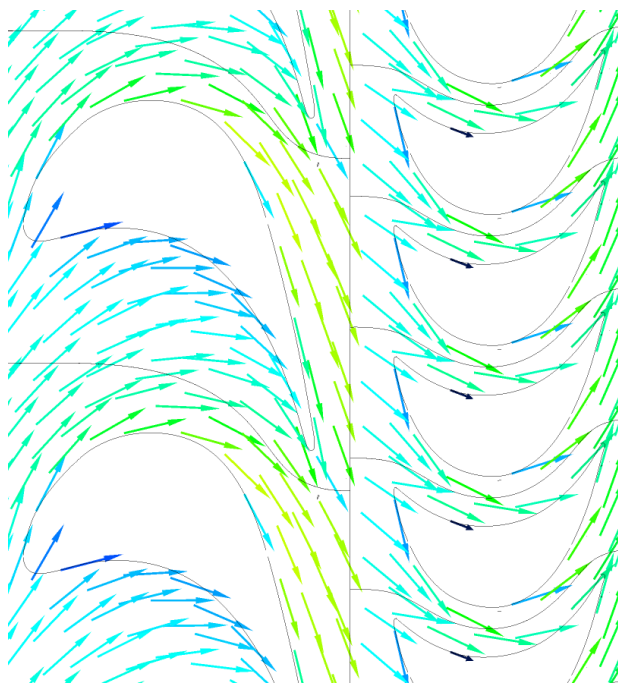


Fig. 10. Variant four velocity field at 0.5 of stator blade length.

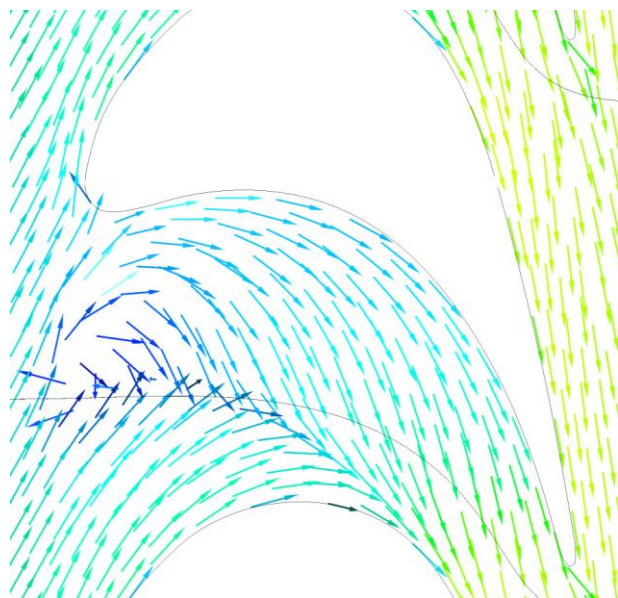


Fig. 11. Variant four velocity field at 0.05 of stator blade length.

2.5 Variant five

Variant 5 inlet spiral was altered to prevent flow reversal (Fig. 12, 13). The length of the first stator (S-9012A) [4] was reduced from 62.5 mm to 56 mm and there were 32 stator blades. In other stages, the number of stator blades

was the same as in variants one to four. Fig.8 presents the flow velocity, which did not stall.

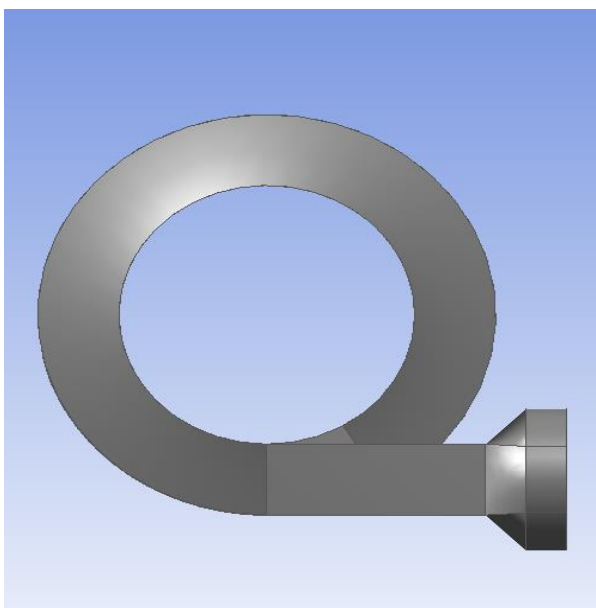


Fig. 12. Side view of variant five spiral.

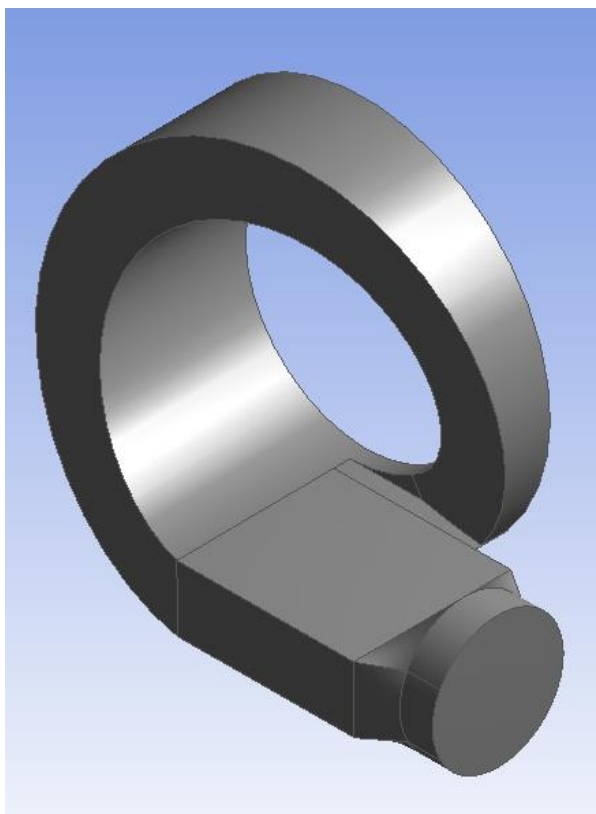


Fig. 13. Variant five inlet spiral.

The turbine generated 1.373 MW, with a mass flow of 9.68 kg/s (34.86 t/h) and a 20.99kPa pressure drop in the inlet. The variant five alterations improved turbine efficiency from 85.7% to 87.3%. Fig. 14 presents the flow velocity, which did not stall.

2.6 Variant six

Here, the first stator blade profile (S-9012A) [4] was reduced from 62.5 mm to 54 mm, blade thickness was

reduced on the suction side and this variant included 32 stator blades.

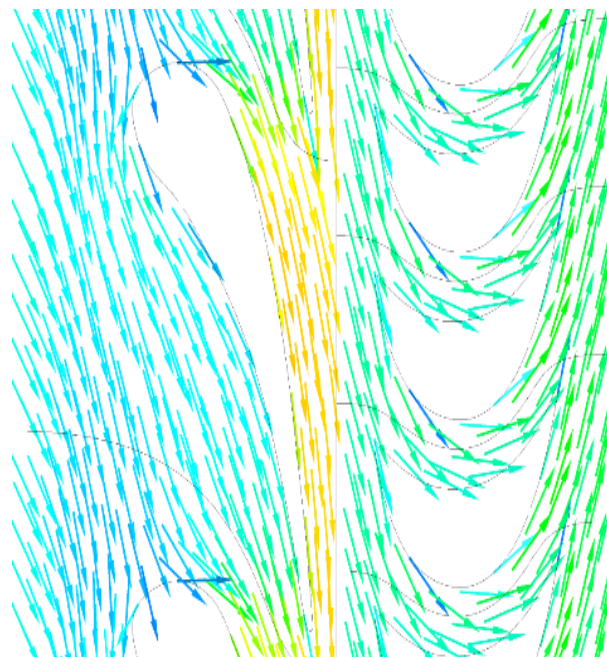


Fig. 14. Variant five velocity field at 0.5 of stator blade length.

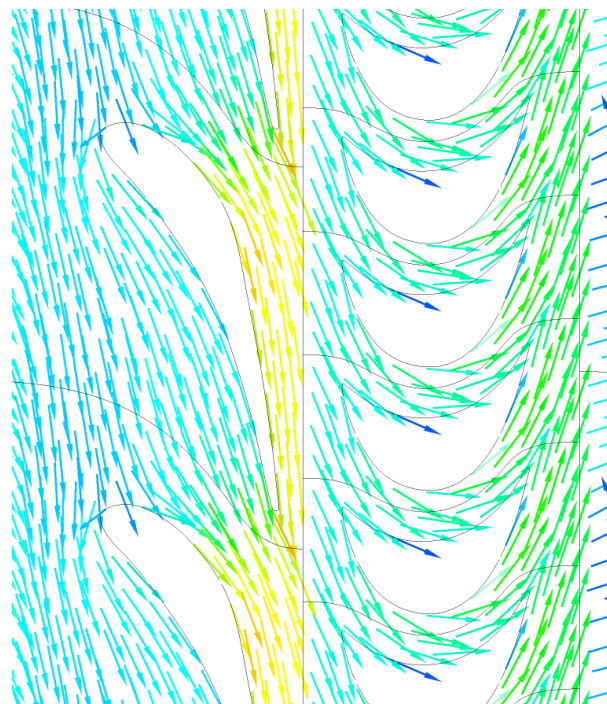


Fig. 15. Variant six velocity field at 0.5 of stator blade length

The turbine generated 1.428 MW with a mass flow of 10.08 kg/s (36.31 t/h) and a 23.02kPa pressure drop at the inlet. The altered first stator blade profile in variant six reduced turbine efficiency from 87.3% to 87.15%. Fig. 15 presents the flow velocity, which did not stall.

2.7 Variant seven

Two inlet pipes were applied in variant seven instead of one (Fig. 16, 17, 18).

The turbine generated 1.178 MW with a mass flow 8.21 kg/s (29.31 t/h) and a 1.24kPa pressure drop at

the inlet. The application of two pipe in variant seven improved turbine efficiency from 87.3% to 88.87%. Fig. 19 presents the flow velocity, which did not stall.

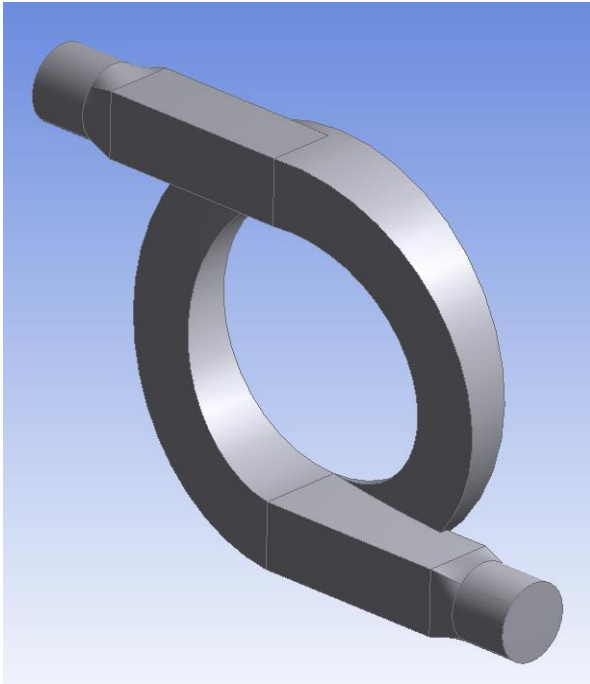


Fig. 16. Variant seven spiral.

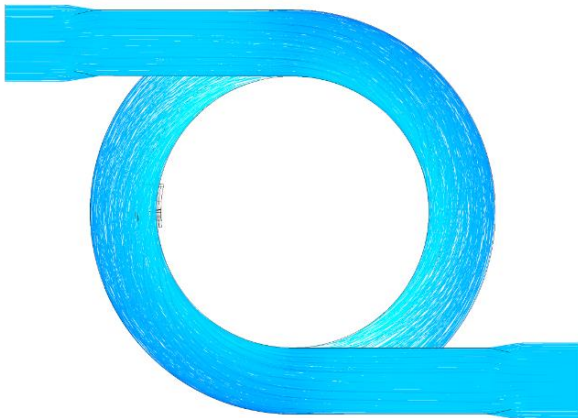


Fig. 17. Streamlines in inlet, variant seven

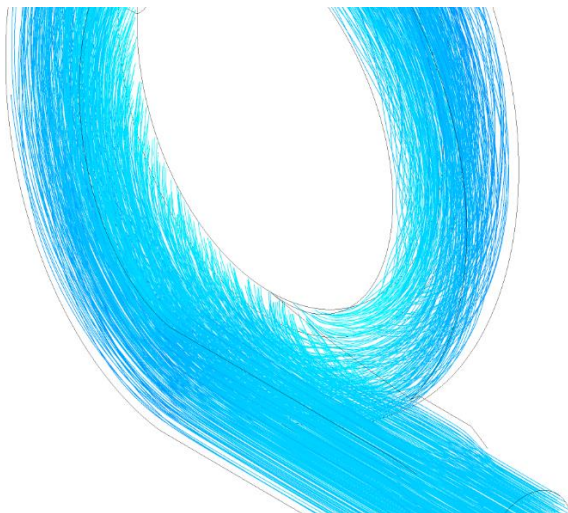


Fig. 18. Streamlines in inlet, variant seven

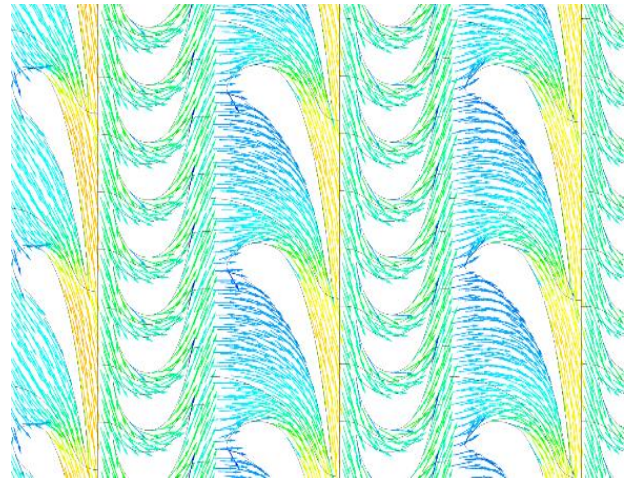


Fig. 19. Variant seven velocity field at 0.5 of stator blade length.

2.8. Variant eight

Variant eight had the same spiral and three stages as in variant seven, and the only difference was the addition of an outlet (Fig. 20, 21).

The turbine generated 1.100 MW with 7.99 kg/s (28.76 t/h) mass flow and 118kPa inlet pressure drop. The inclusion of the outlet reduced turbine efficiency from 88.87% (Variant seven) to 85.31%. This was due to the fact that the outlet was causing the flow to whirl in many place (Fig. 23). Fig. 22 shows the velocity of the flow, which did not stall in the stator and rotor regions.

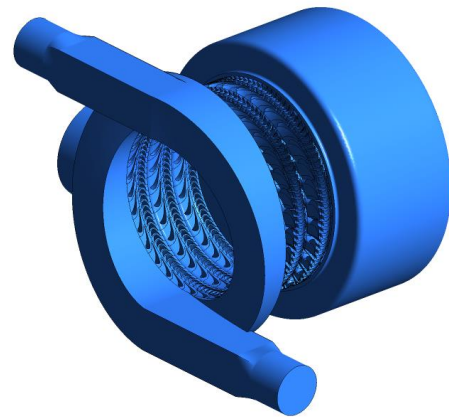


Fig. 20. Variant eight inlet with 3 stages and an outlet.

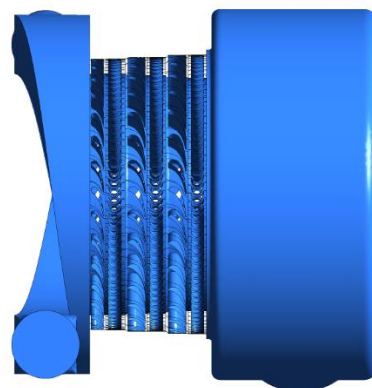


Fig. 21. Side view of variant eight.

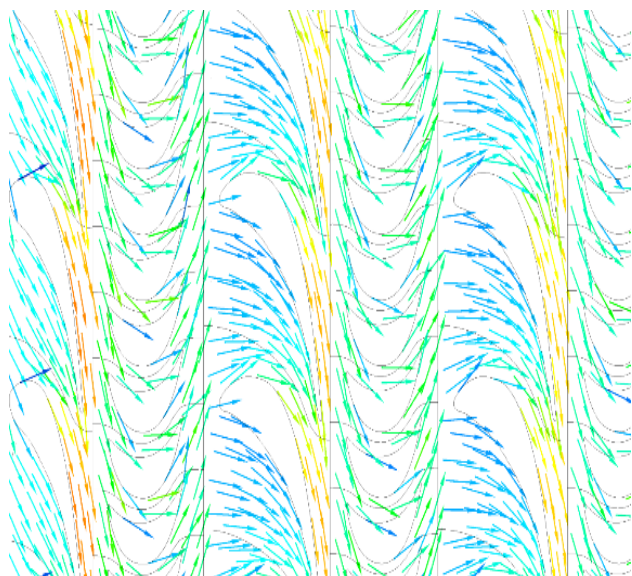


Fig. 22. Variant eight velocity field at 0.5 of stator blade length.

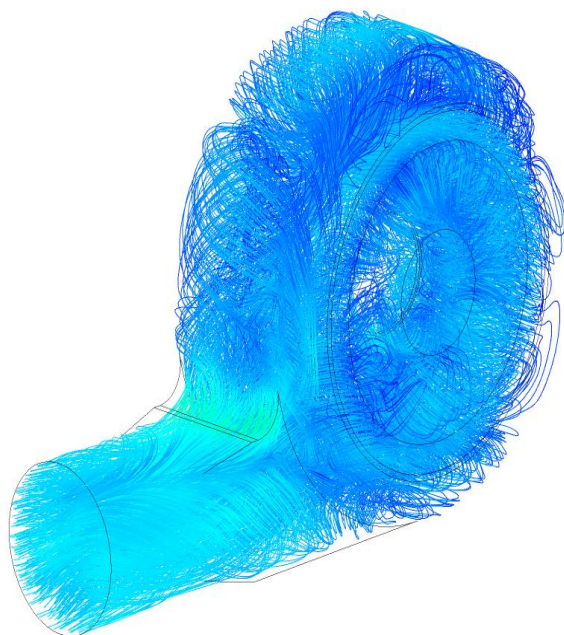


Fig. 23. Streamlines in outlet, variant 8

3 Conclusions

This paper for the first time analyses the flow in various inlet spirals in a 1 MW steam turbine inlets. In addition to altering the spiral geometries, the stator blade profiles were also changed. Adding a second pipe to the inlet spiral improved efficiency from 87.3% to 88.87%.

Efficiency was also increased changing the first stator blade profile from S-5515A to S-9012A.

The changed profile increased the mass flow, which could next be reduced by shortening of the length of the stator blades. In the last variant, an outlet was added to calculate the efficiency of the entire flow system. This reduced efficiency from 88.87% to 85.87%.

Acknowledgement

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