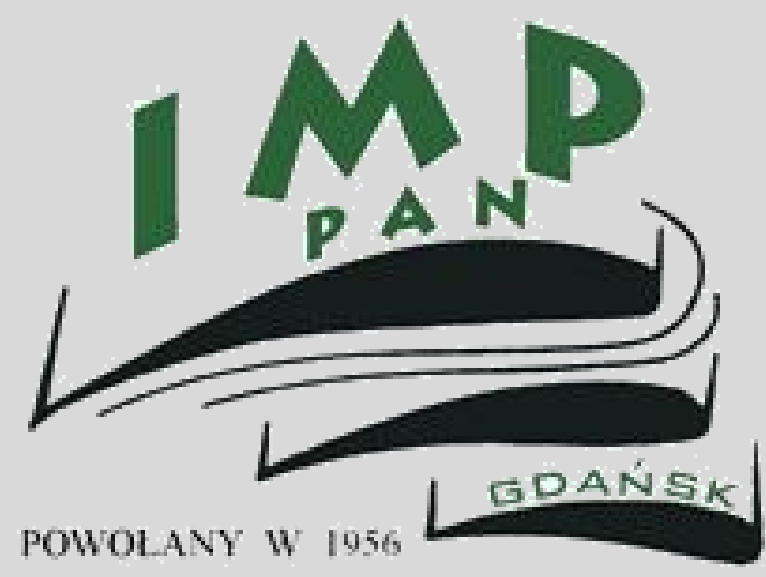


THE SZEWALSKI INSTITUTE OF FLUID-FLOW MACHINERY, PAS (IMP PAN)

CENTRE FOR MECHANICS OF LIQUIDS, DEPARTMENT OF HYDRAULIC MACHINERY



THE EXPERIENCE IN THE DESIGN AND CFD ANALYSIS OF LOW-HEAD KAPLAN TURBINES FOR SMALL HYDRO

Nowadays the Kaplan and semi-Kaplan hydraulic turbines seem to be the most popular solutions for the minimal low head turbine applications. In Poland the hydraulic potential is concentrated in lowland rivers, with relatively high mean-year flows. Most of small hydro power plants are situated on such lowland rivers, thus the low head hydraulic turbines are becoming the objects of investors' interests. Unfortunately the costs of the low head infrastructure construction are relatively high (high installation unit costs per kW), hence it significantly limits the low head turbine applications. To reduce the costs of manufactory and installation of Kaplan turbines in a Small Hydro (SH), the designers often decide to equip the turbine only with a single regulation mechanism (in most cases only the runner blades regulation – semi Kaplan) and single or double (S-shaped) bended draft tube. The Institute of Fluid Flow Machinery has long-term experiences in designs, tests and installation of such simplified designed low head turbines for various SH in Poland (the semi-Kaplan low head series of siphon TSP turbines and TSPu turbines). Since eighties and nineties of last century the design methodology and related programmes for axial flow turbines have been developed in the institute. Nowadays, in the Institute the design process and analysis of the flow through the flow system of Kaplan turbines are effectively supported by 3D Computational Fluid Dynamics. Authors utilize the commercial and their own CFD codes and CAD application programmes for academic studies of design process and complex flow analysis. Recent activities of the department is directed both on development of the Kaplan low head turbines construction and application of numerical tools and laboratory tests for increasing the operating parameters of the Kaplan turbines.

1. Hydraulic turbine designing (flow systems and constructions)

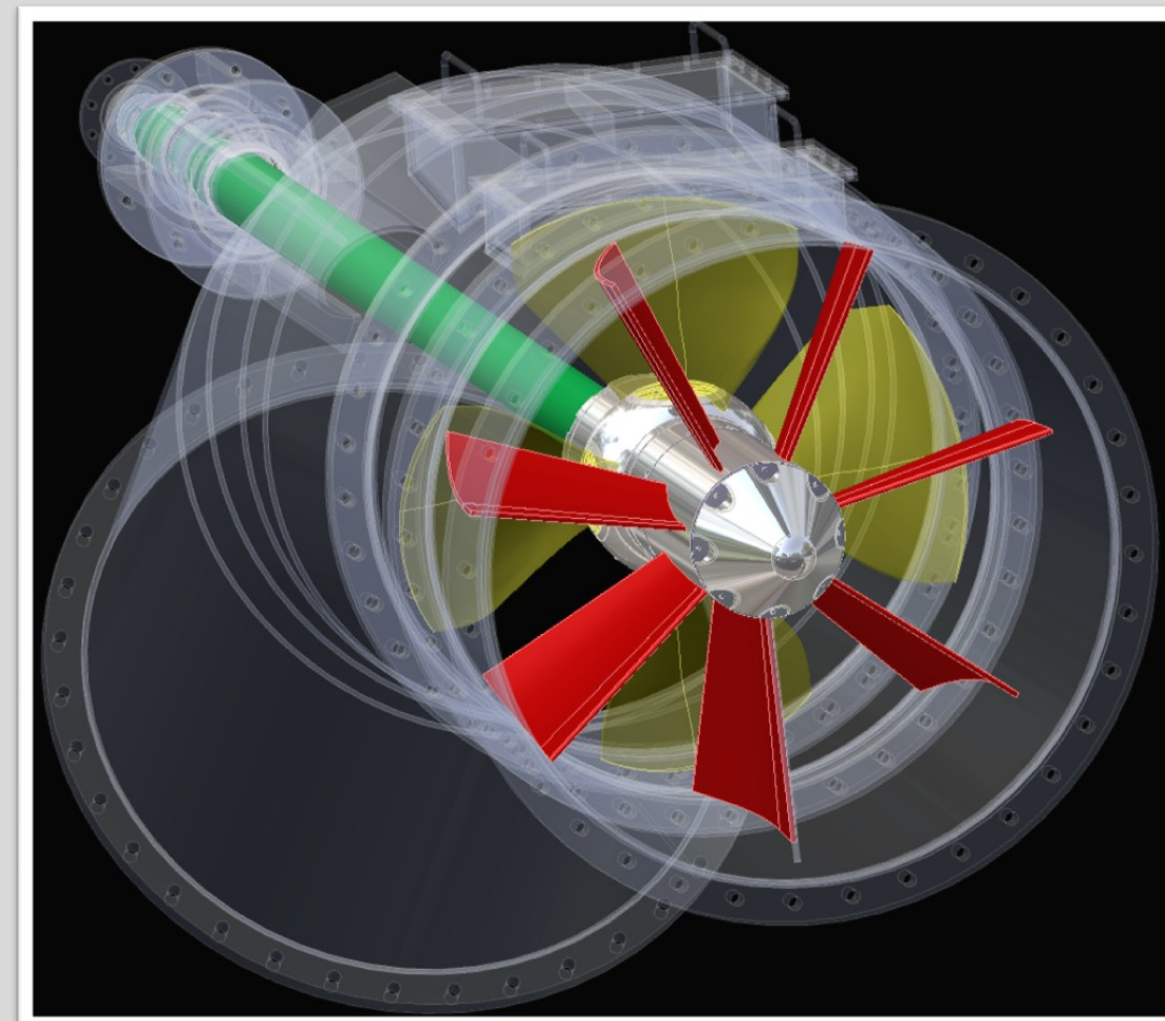


Fig. 1. Hydraulic turbine TSPu construction for the Small Hydro Powerplants application.

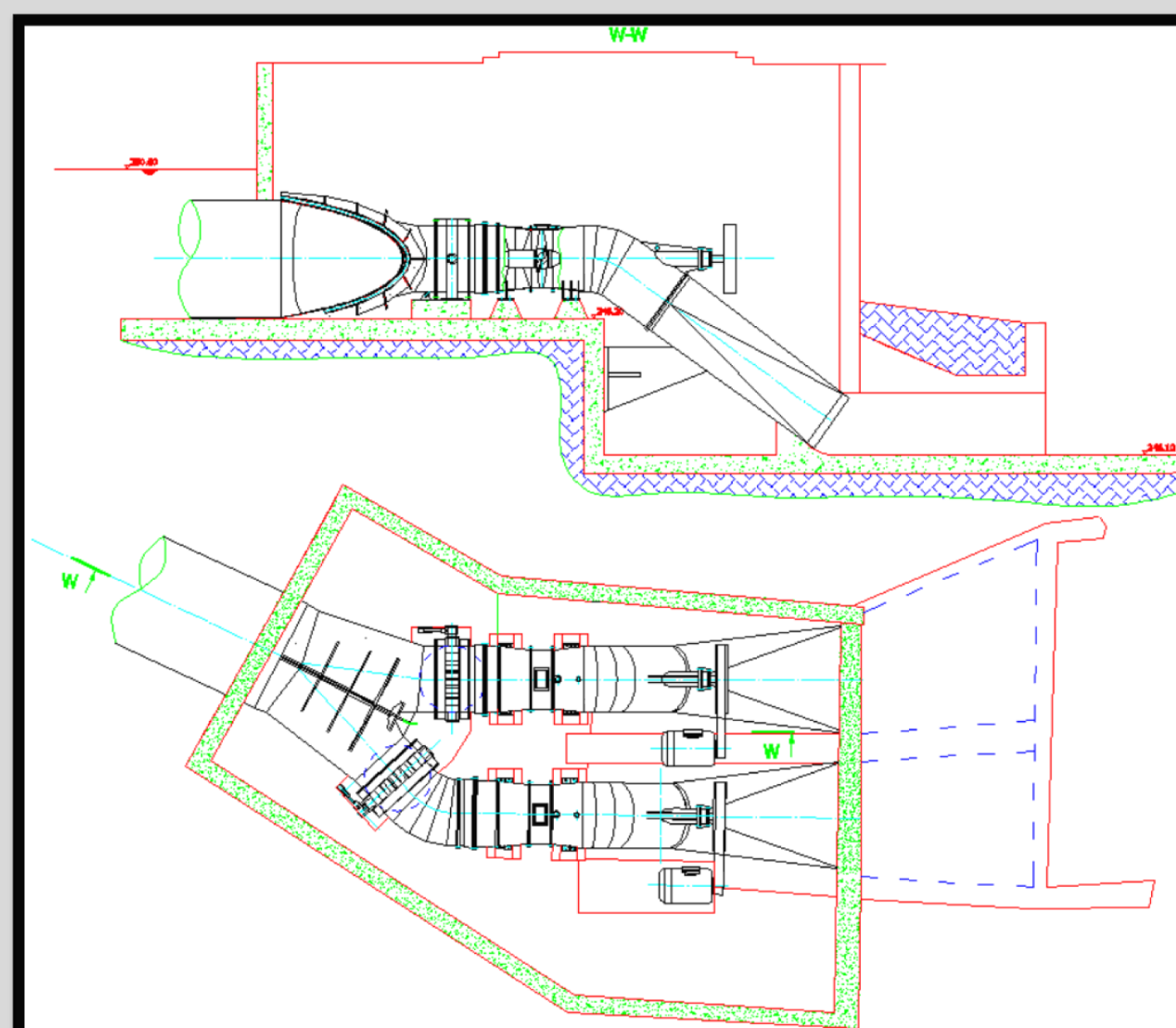
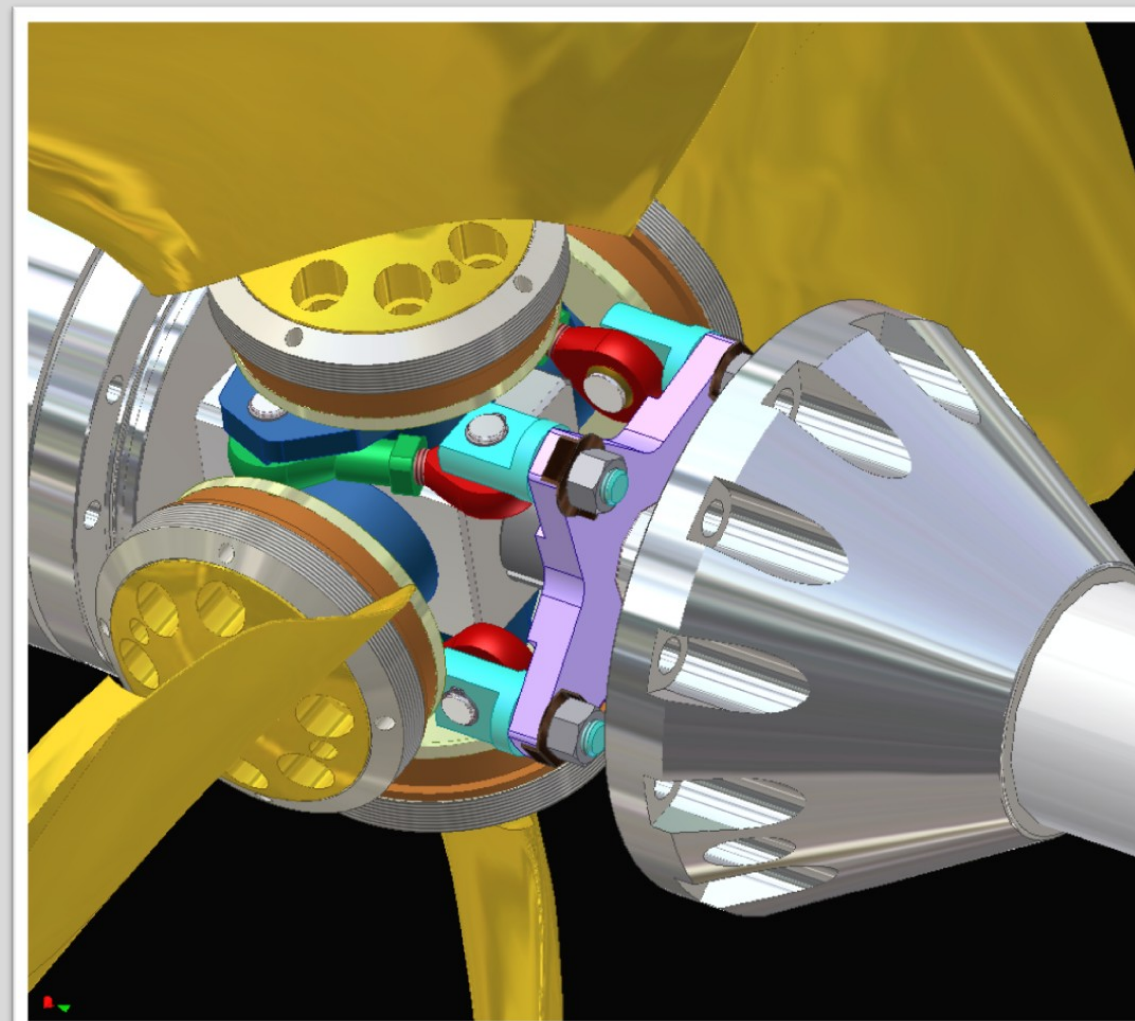


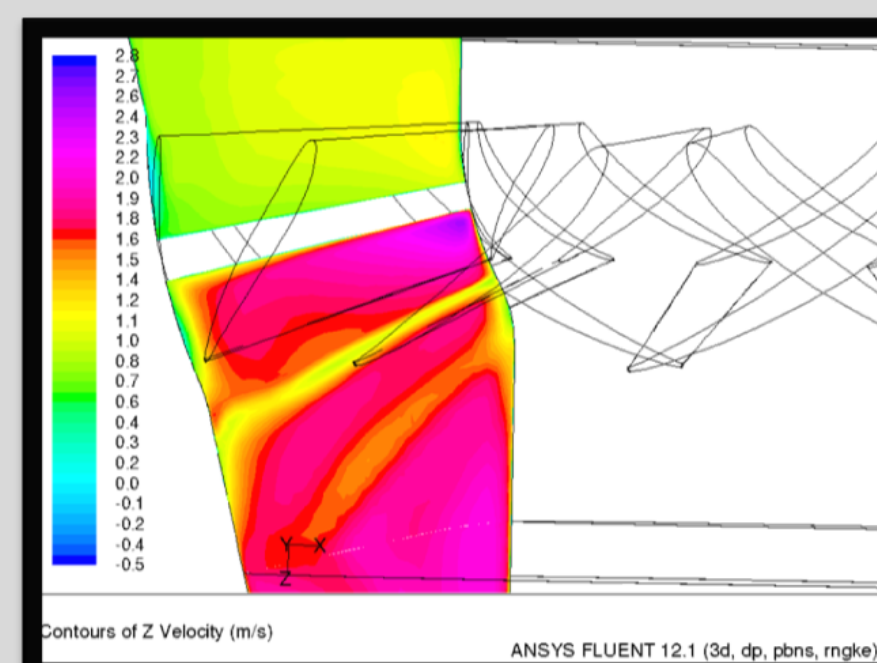
Fig. 2. Example of TSPu turbine installation layout.



TSPu 900 turbine operating and geometrical parameters:

- net head: 2.1 m
- rotational speed: 240 rpm
- discharge: 2.53 m³/s
- output: 44 kW
- runner diameter: 0.9 m

2. Numerical computations for the model hydraulic turbine tested at the Gdańsk University of Technology – comparison with experiment



Tab. 1. Experimental and computational results for different turbulence models.

Turbulence model	Output	Discharge	Efficiency	Efficiency relative difference (experiment vs. computations)
-	W	l/s	-	%
Experiment	1763	74.32	0.887	-
Spalart-Allmaras	1750	74.16	0.885	0.28
k-ε RNG Standard WF	1666	74.10	0.844	4.96
k-ε RNG Enhanced WF	1712	73.81	0.872	1.78
k-ω SST	1754	74.38	0.885	0.25

Model hydraulic turbine operating and geometrical parameters:

- net head: 2.726 m
- rotational speed: 650 rpm
- runner diameter: 0.265 m
- discharge: 74.32 l/s

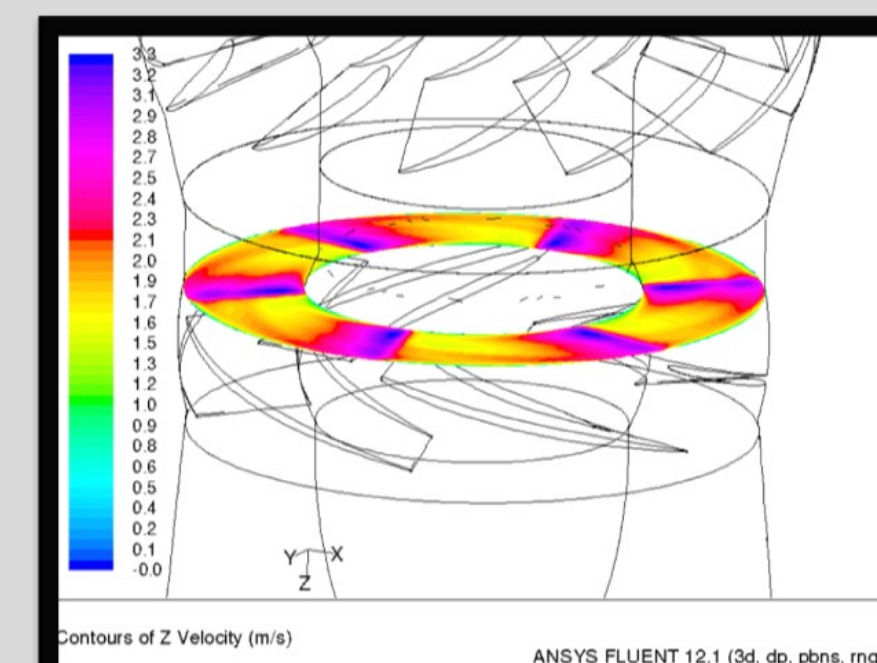
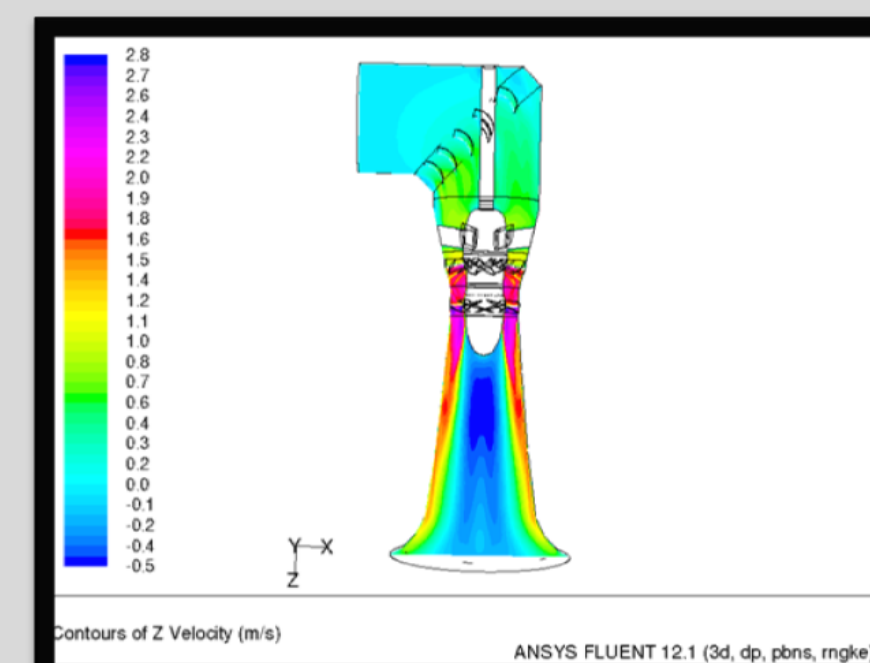


Fig. 3. Computational results obtained by the means of Fluent™.

3. Numerical investigations of the CAM curve

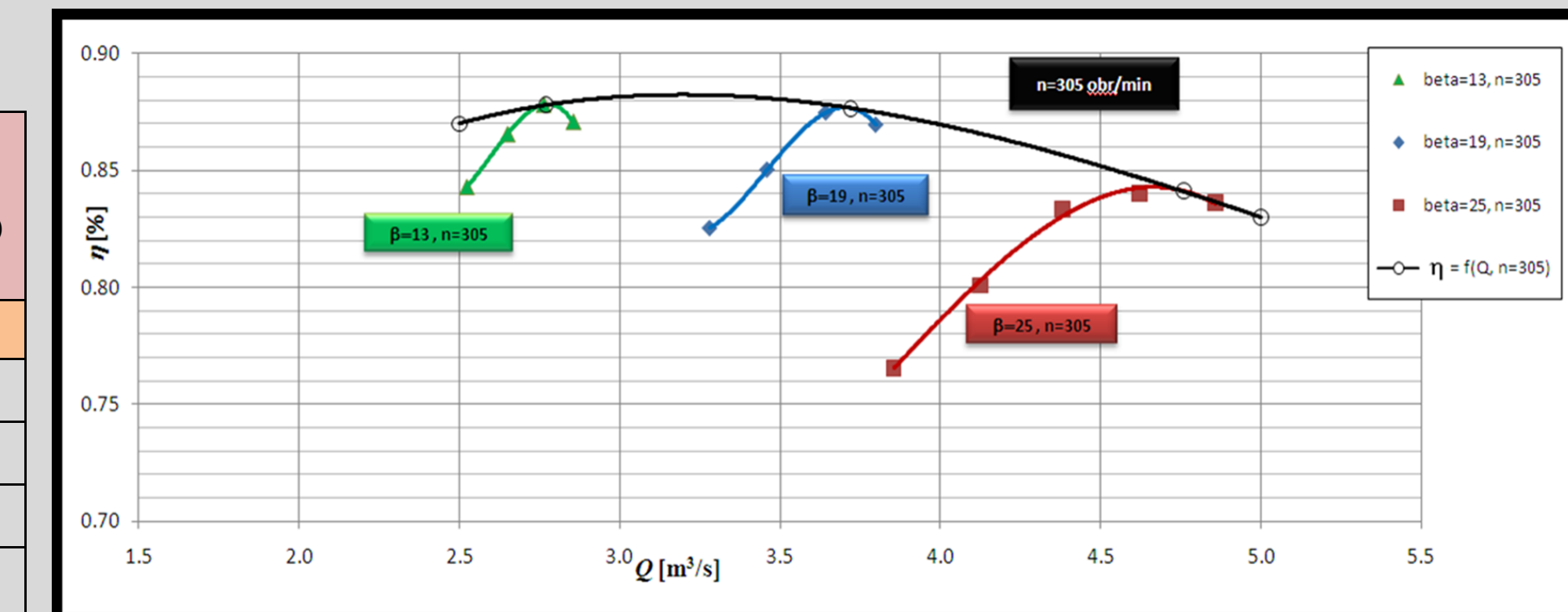


Fig. 4. Numerical investigated cam curve for different guide vanes and runner angles.

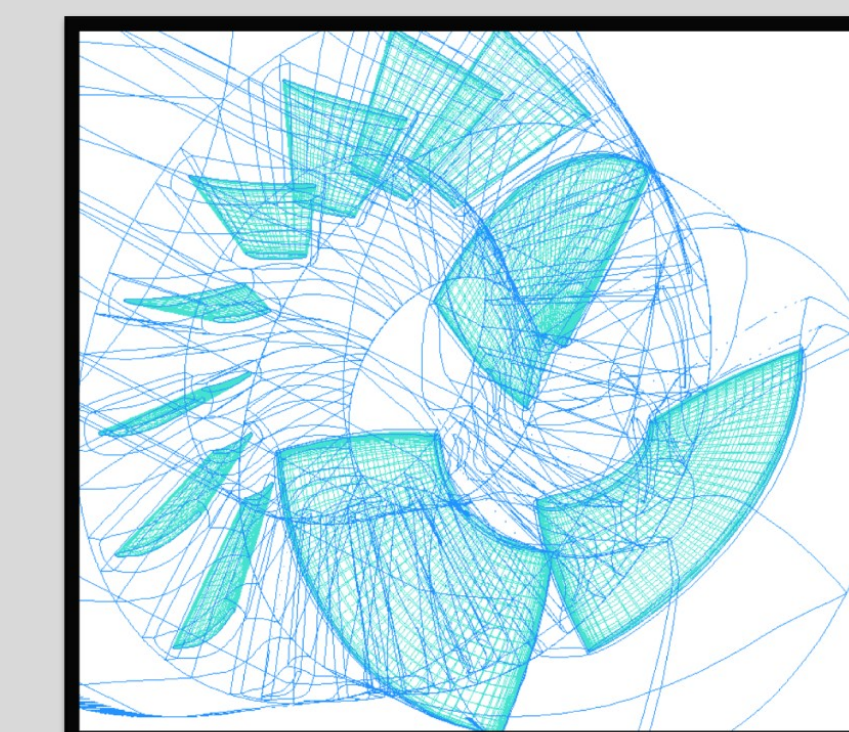


Fig. 5. Computational mesh example.

Axial flow turbine D=1090 operating and geometrical parameters:

- the investigated range of guide vanes opening angle α : 49°-79°
- the investigated range of runner opening angle β : 13°-25°
- net head: ~3.1 m
- rotational speed: 305 rpm
- runner diameter: 1.09 m

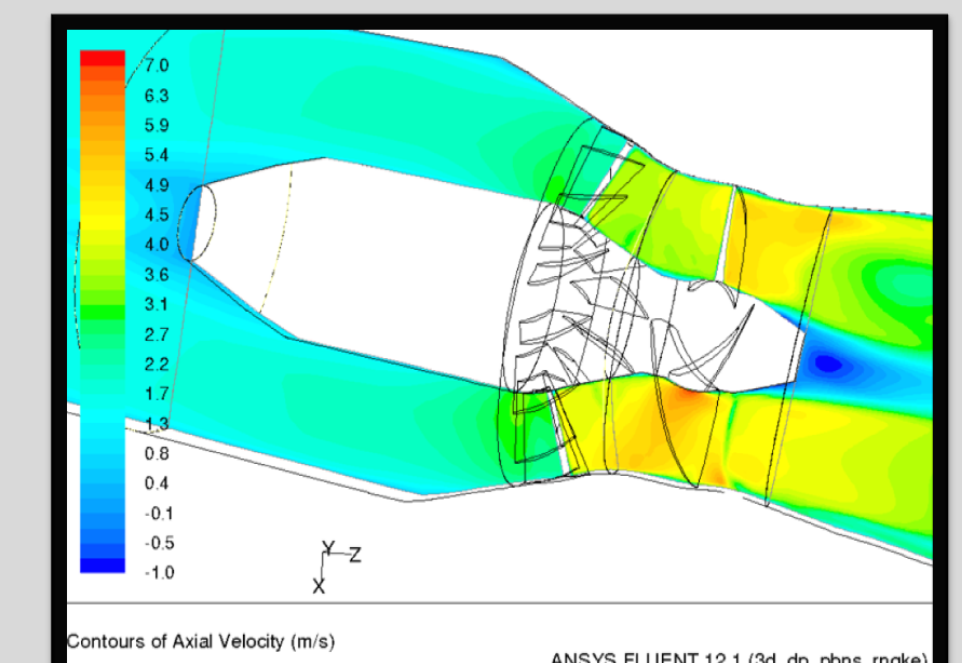
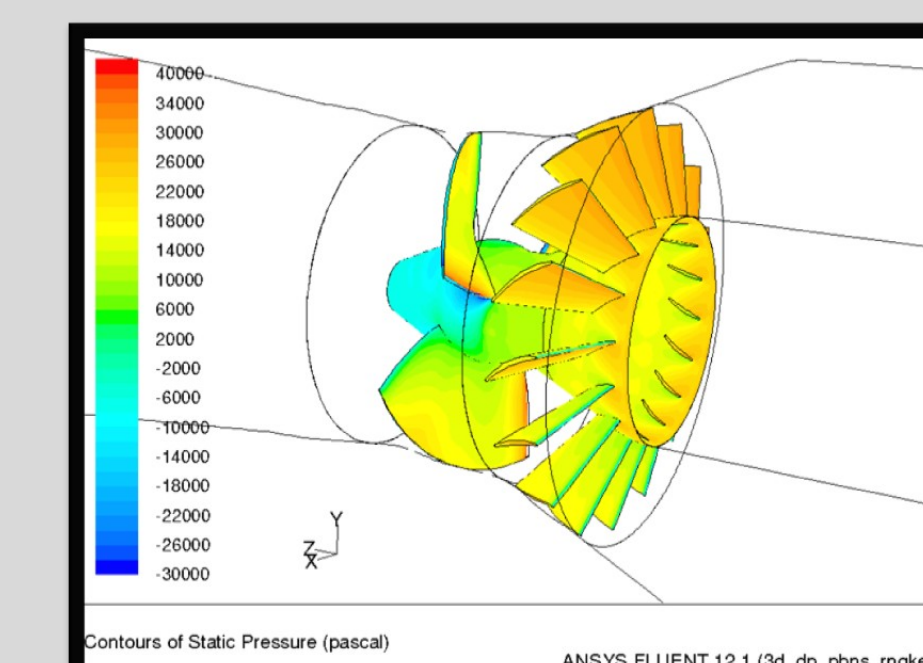


Fig. 6. Computational results obtained by the means of Fluent™.

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