Swirling Flow in Annular Diffusers Between Two Counter-Rotating Turbines

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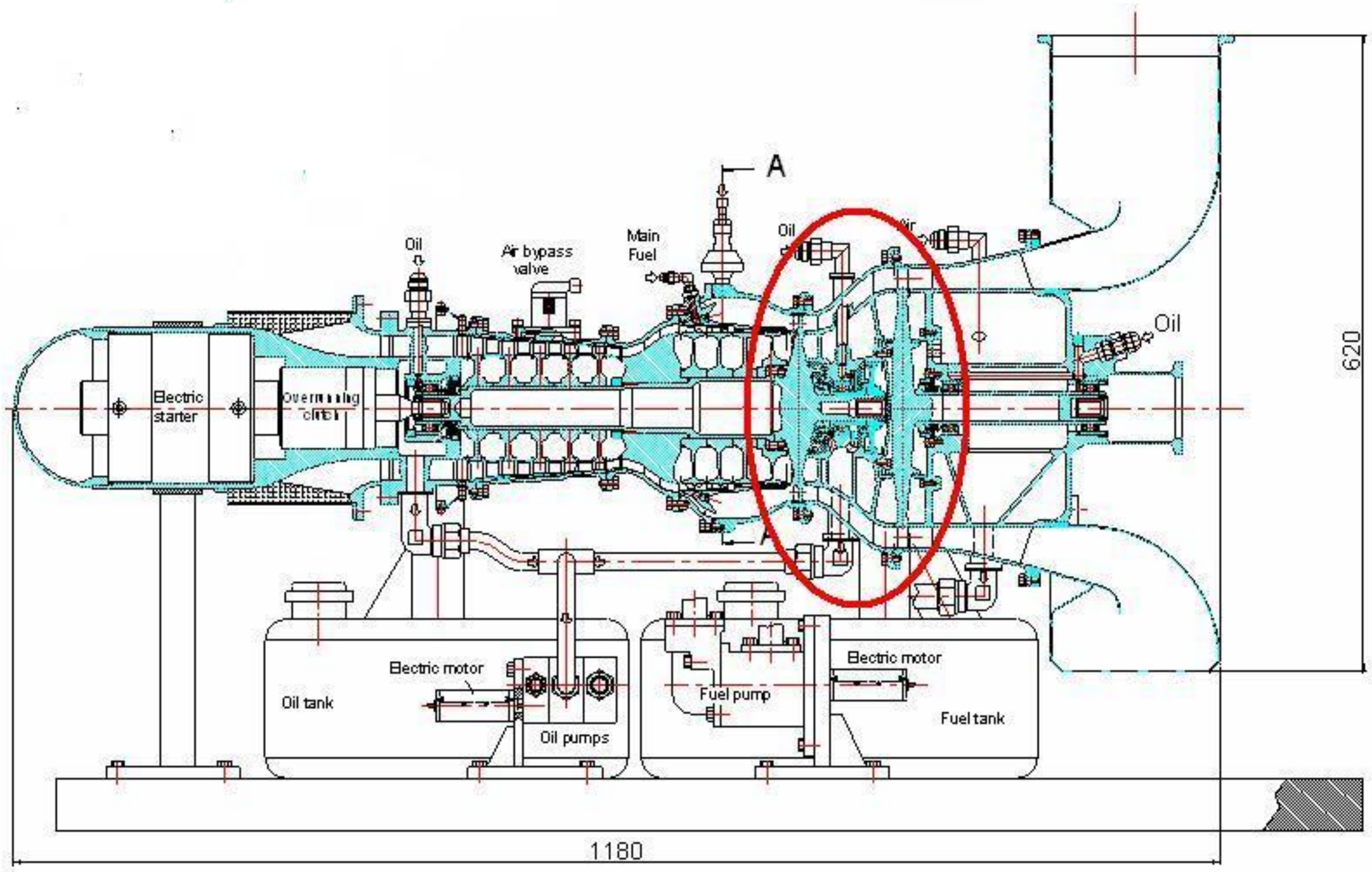
Swirling Flow in Annular Diffuser



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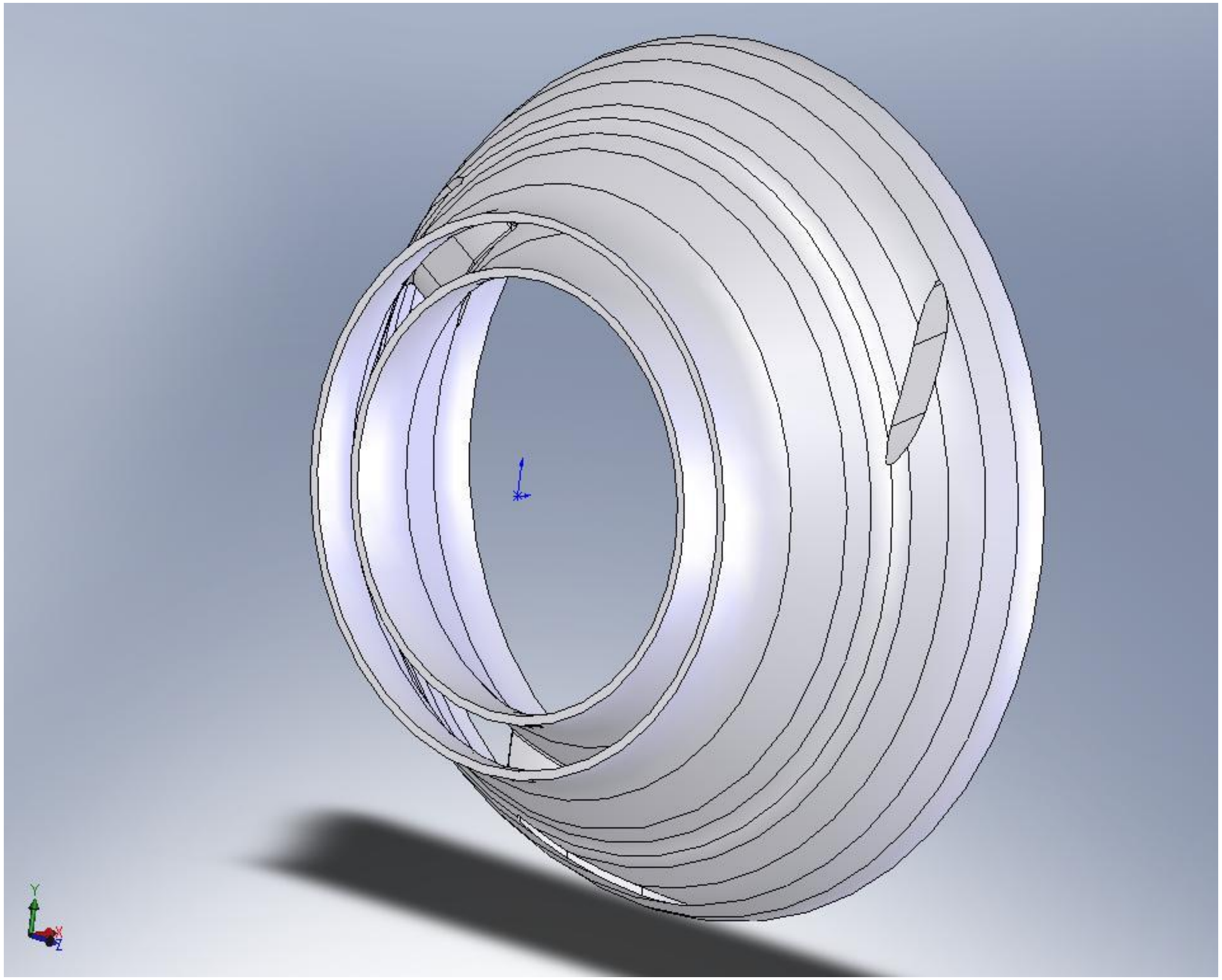
CAD Model



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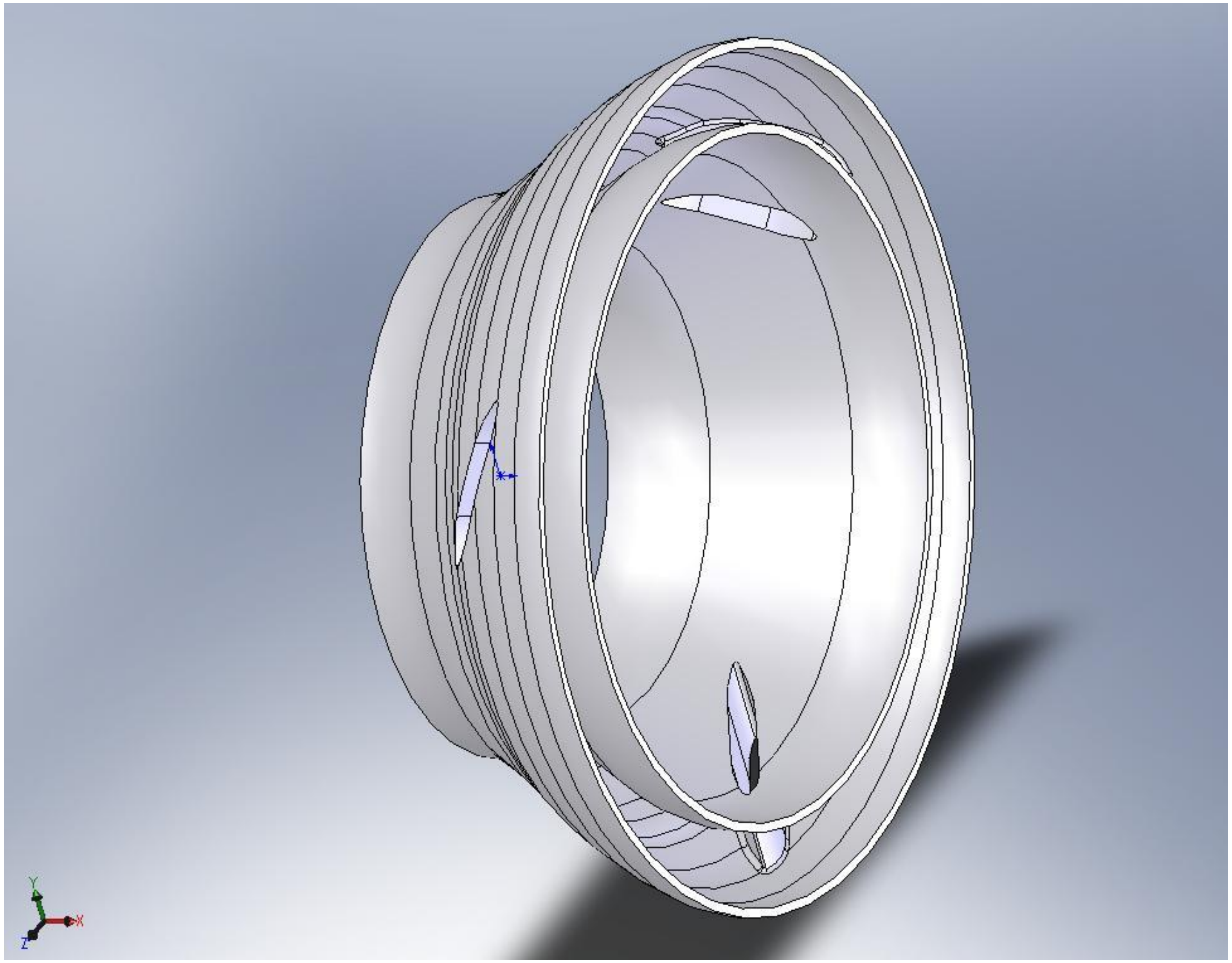
CAD Model



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Calculated Domain and Boundary Conditions

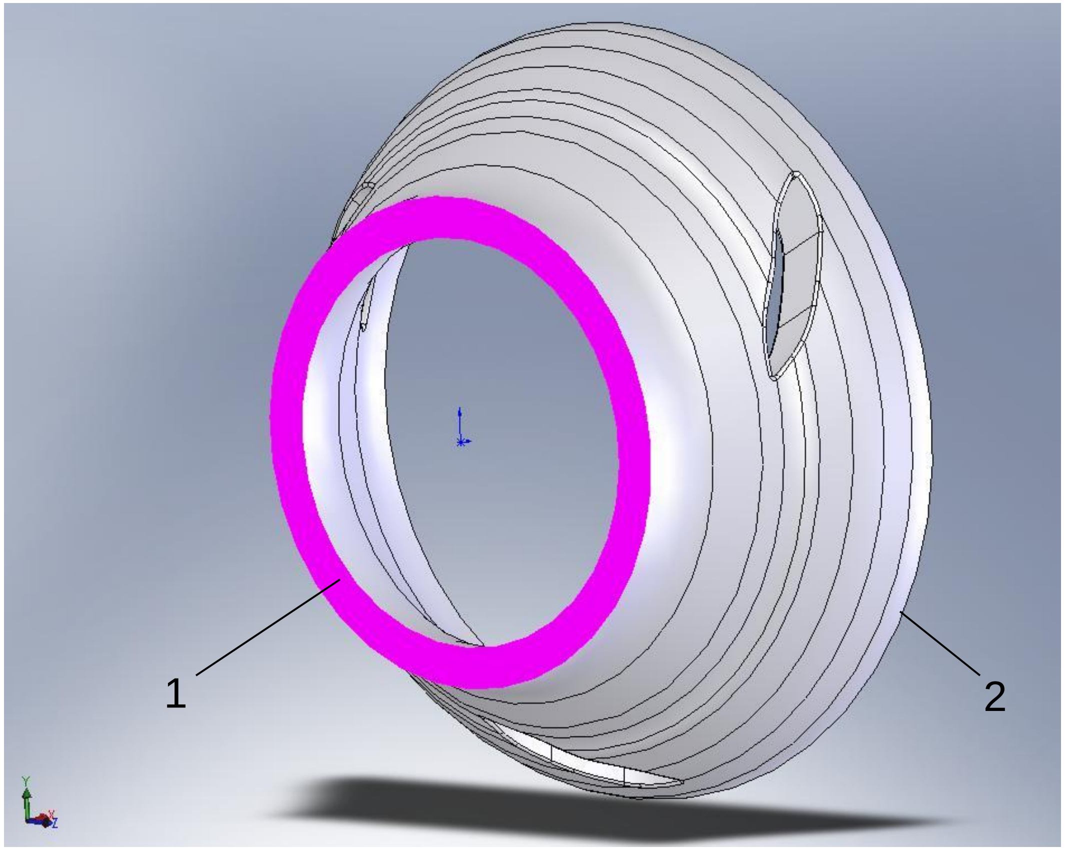

Figure 1. 1 – mass flow inlet, 2 – outlet-vent

Mass-Flow Inlet:

Q=1.528 kg/s

α=58.8°

T_0=1202K

Outlet-Vent:

p_s=const,

ζ=const,

$\zeta = \Delta p/(\rho v^2/2)$ – *loss coefficient*

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Governing Equations

$$\frac{\partial u_i}{\partial t} + \frac{\partial}{\partial x_j}\left(u_i u_j\right) = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\nu\left(\frac{\partial u_i}{\partial x_j} - \frac{2}{3}\frac{\partial u_i}{\partial x_i}\right) - \mu \overline{u}_i' \overline{u}_j'\right) \quad (1)$$

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u_i)}{\partial x_i} = 0 \quad (2)$$

$$\rho\frac{di}{dt} = A\frac{dp}{dt} + \frac{\partial}{\partial x_i}\lambda\frac{\partial T}{\partial x_i} \quad (3)$$

The Models of Turbulence

k-ε models:

Realizable

RNG-based

k-ω standard model

Reynolds Stress Model (RSM)

FLUENT , GAMBIT

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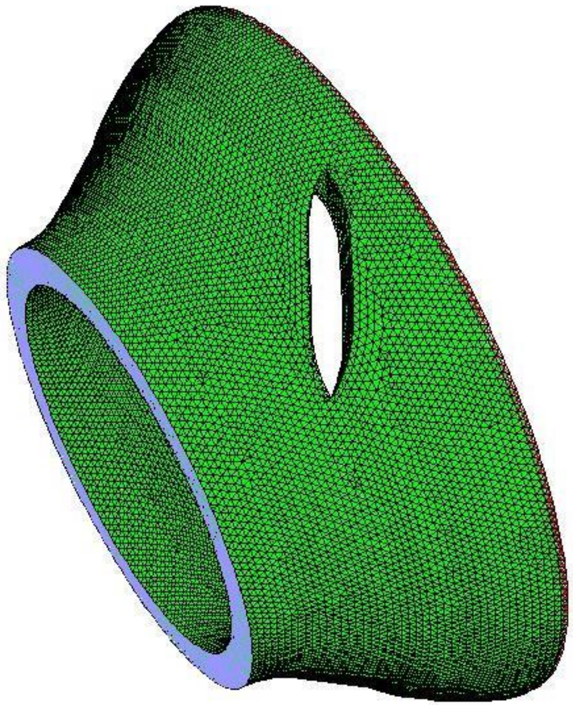
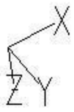
Calculated Grid



<u>Unstructured Tetrahedral Grid</u>

Base grid: ~350,000 cells

Adapted grid:~600,000 cells



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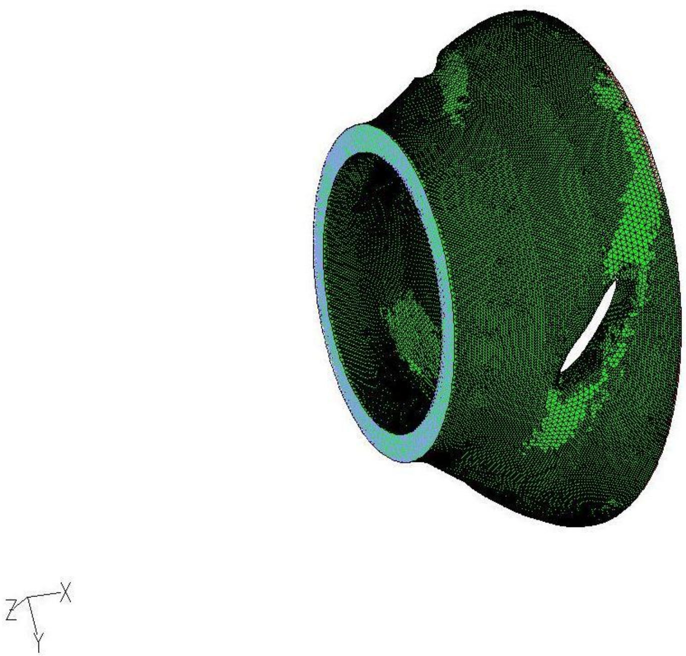
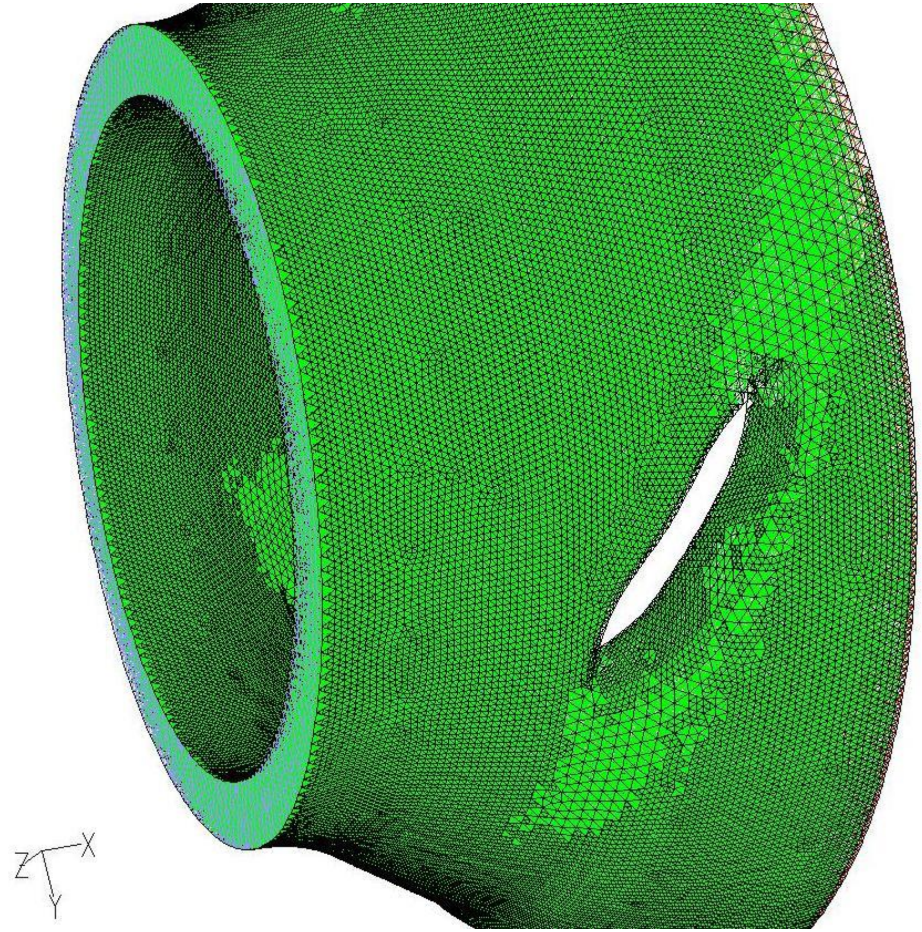
Gradient Adaptation





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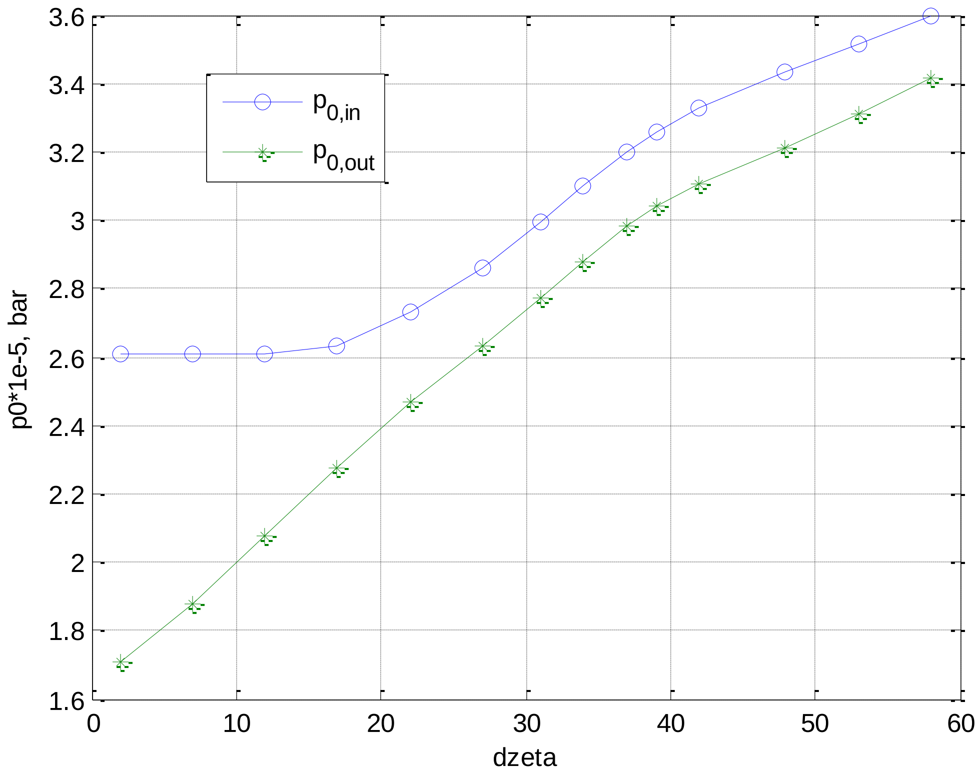

Figure 2. Total pressure at inlet and outlet sections

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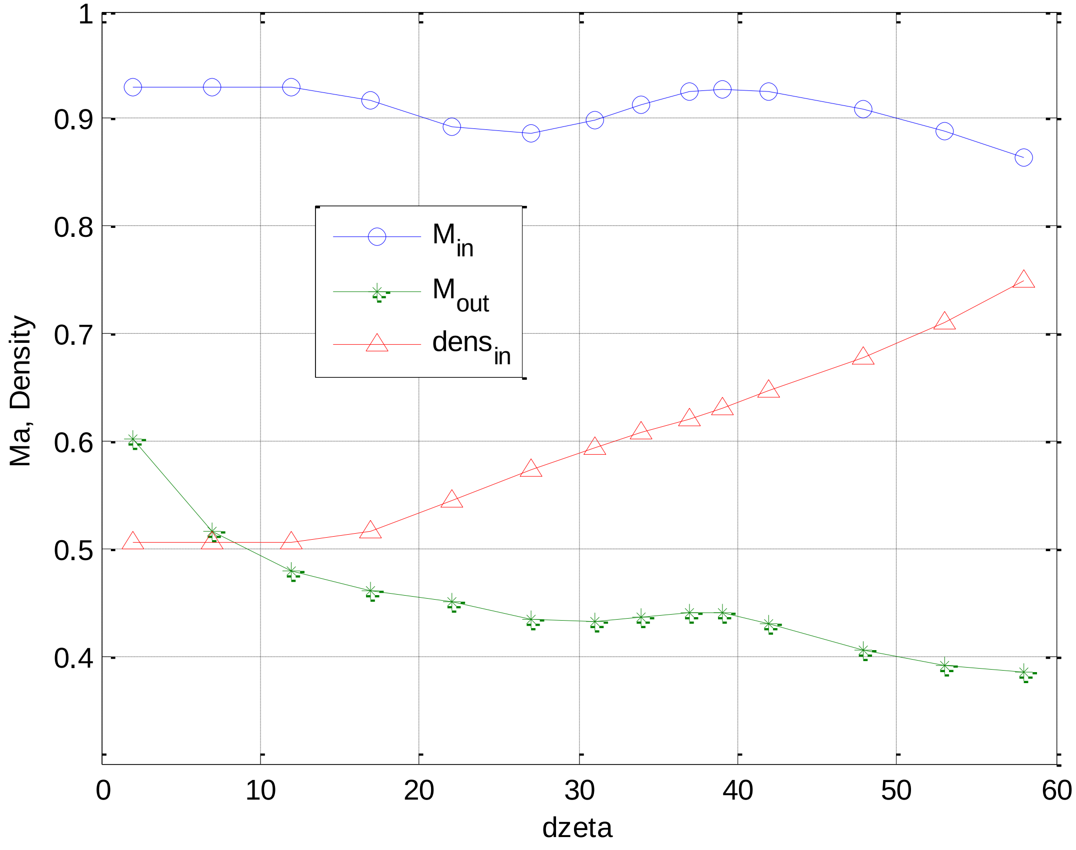

Figure 3. Mach number and density as functions of ζ

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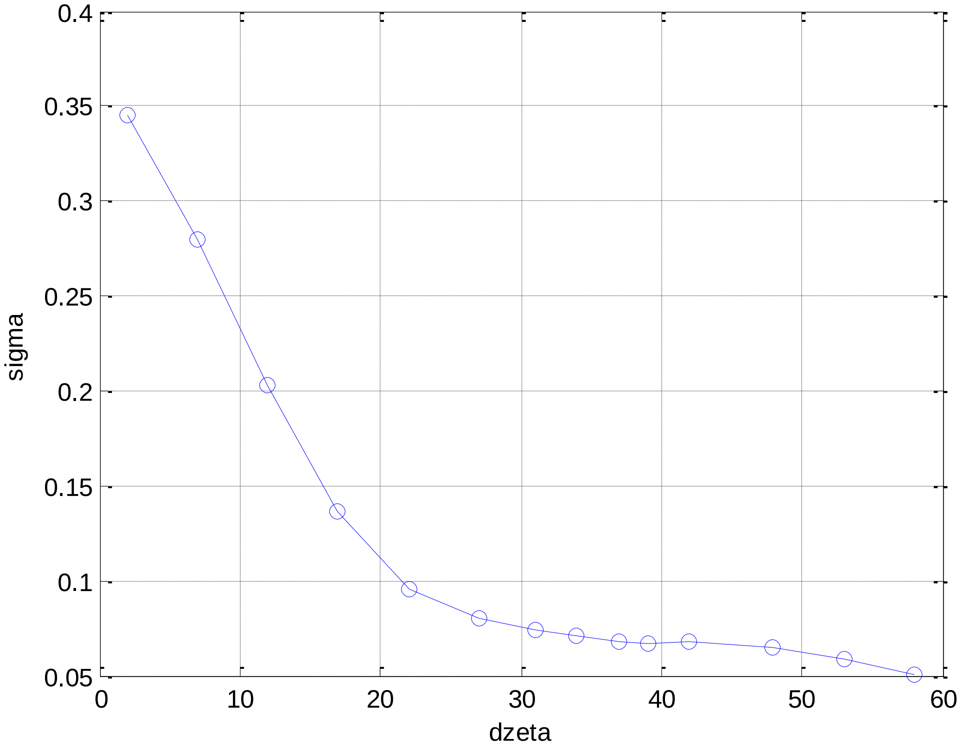

$$\sigma = \frac{p_{0,in} - p_{0,out}}{p_{0,in}}$$

Figure 4. Total pressure losses

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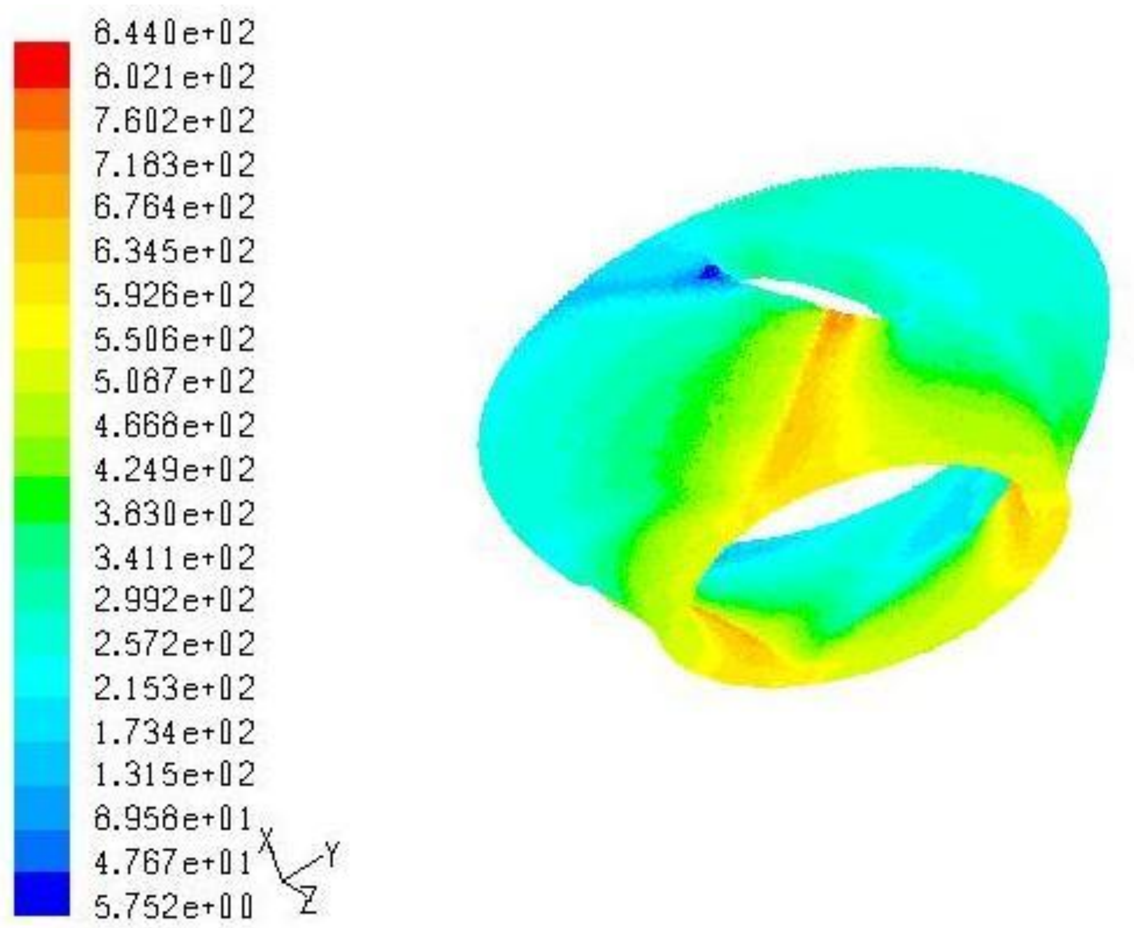

Ma_{in}=0.864

σ=5.1%

Figure 5. Velocity Magnitude, ζ=58

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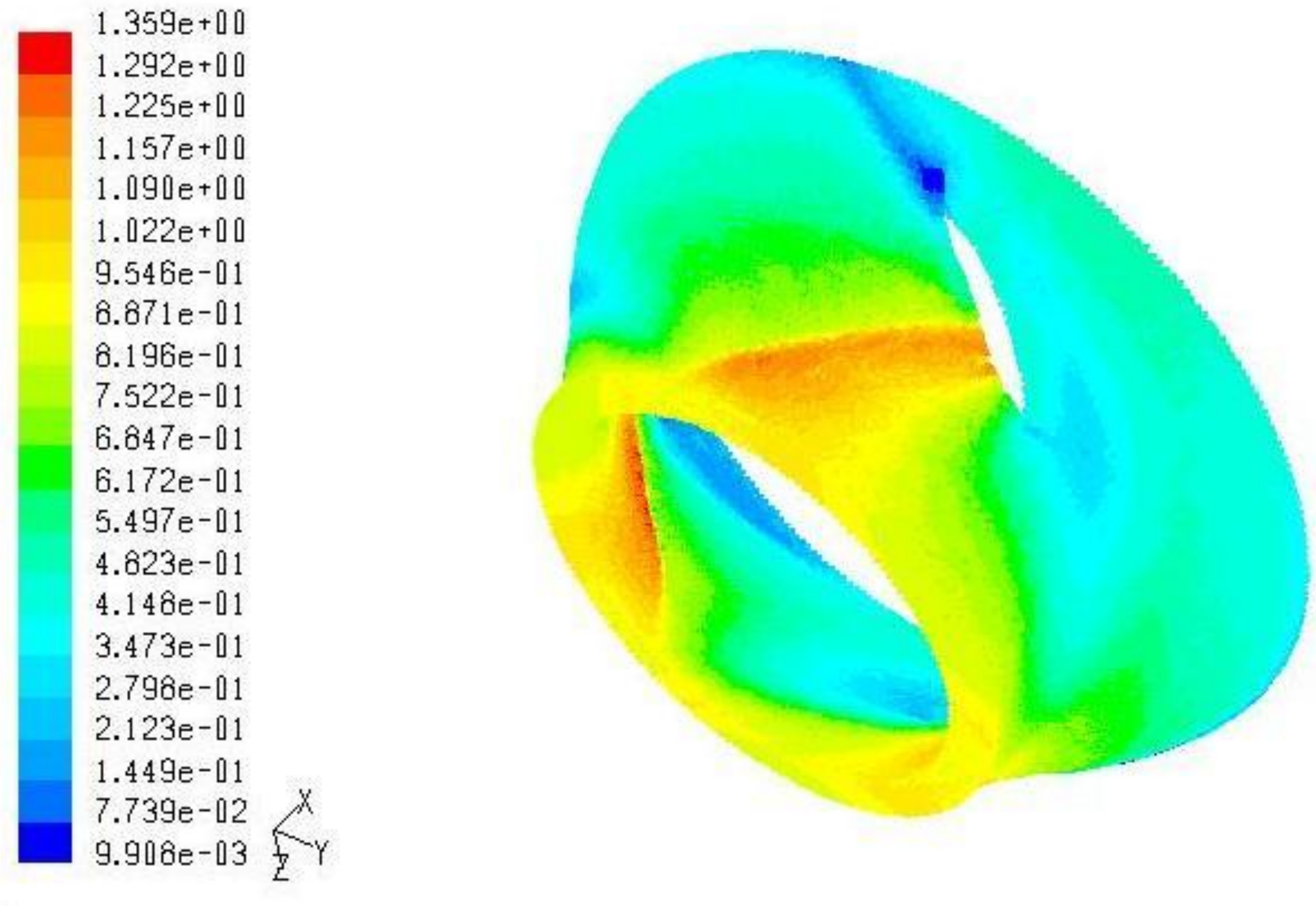

Ma_{in}=0.908

σ=6.5%

Figure 6. Mach number, ζ=47.9

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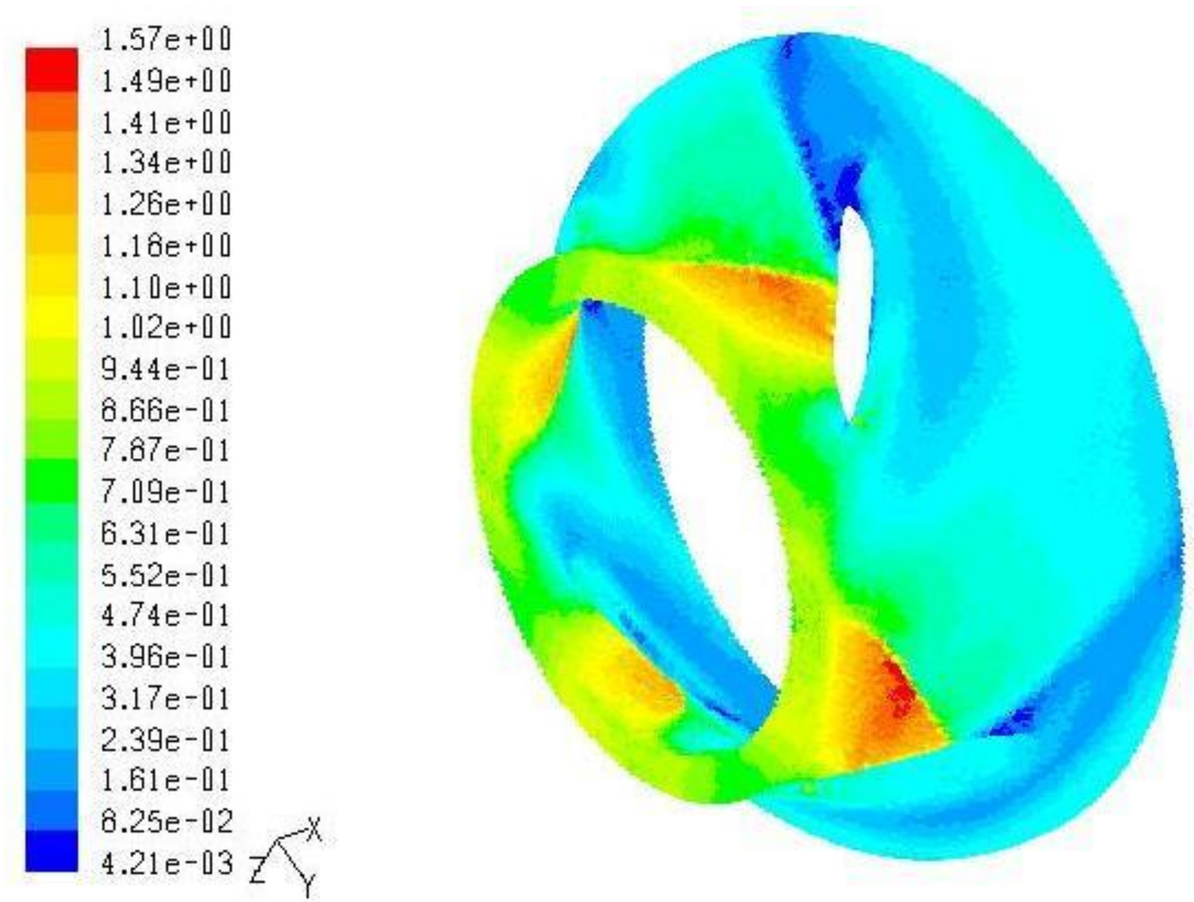

Ma_{in}=0.870

σ=9.8%

Figure 7. Mach number in non-optimal diffuser, ζ=47.9

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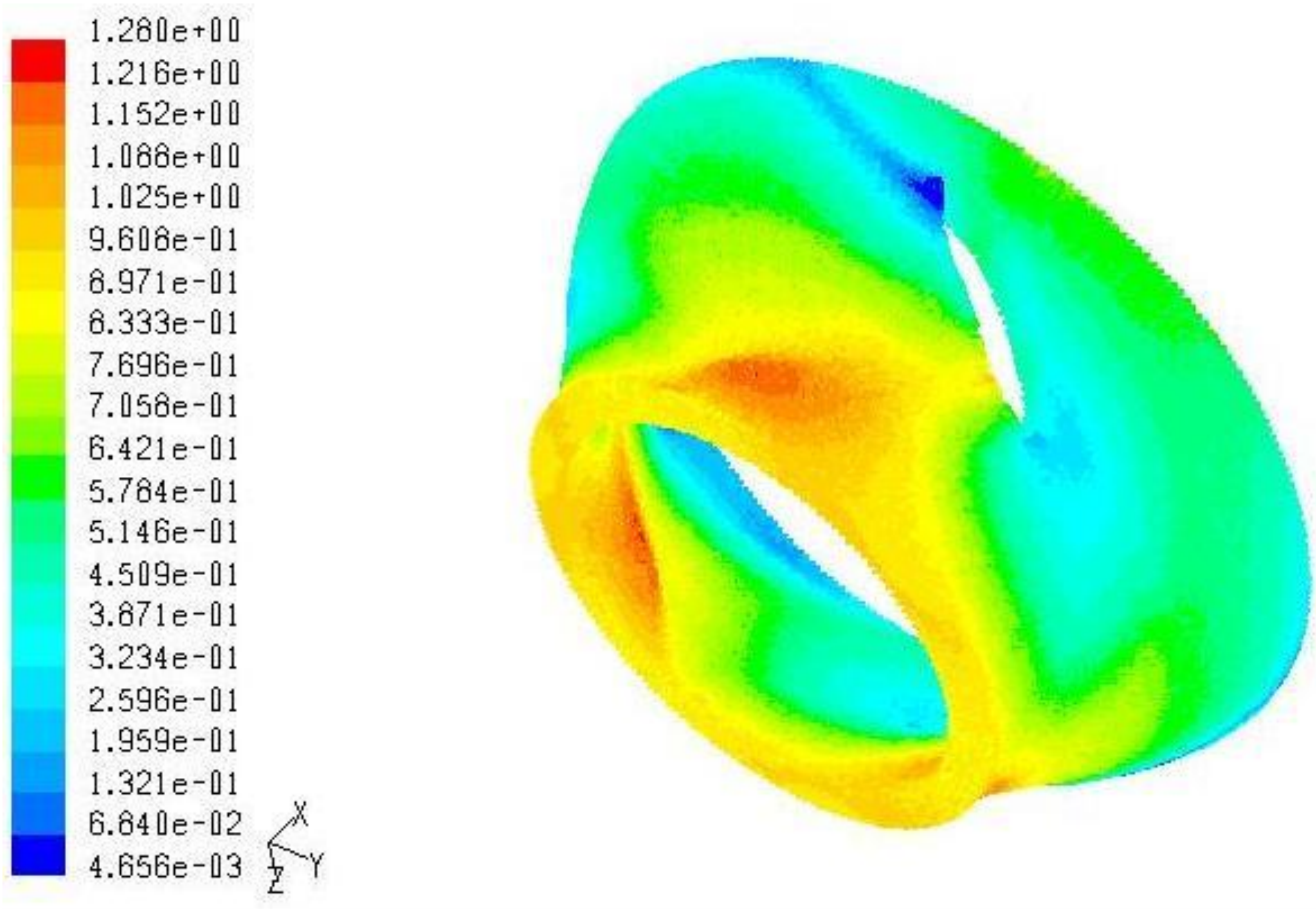

Ma_{in}=0.928

σ=6.7%

Figure 8. Mach number , ζ=39

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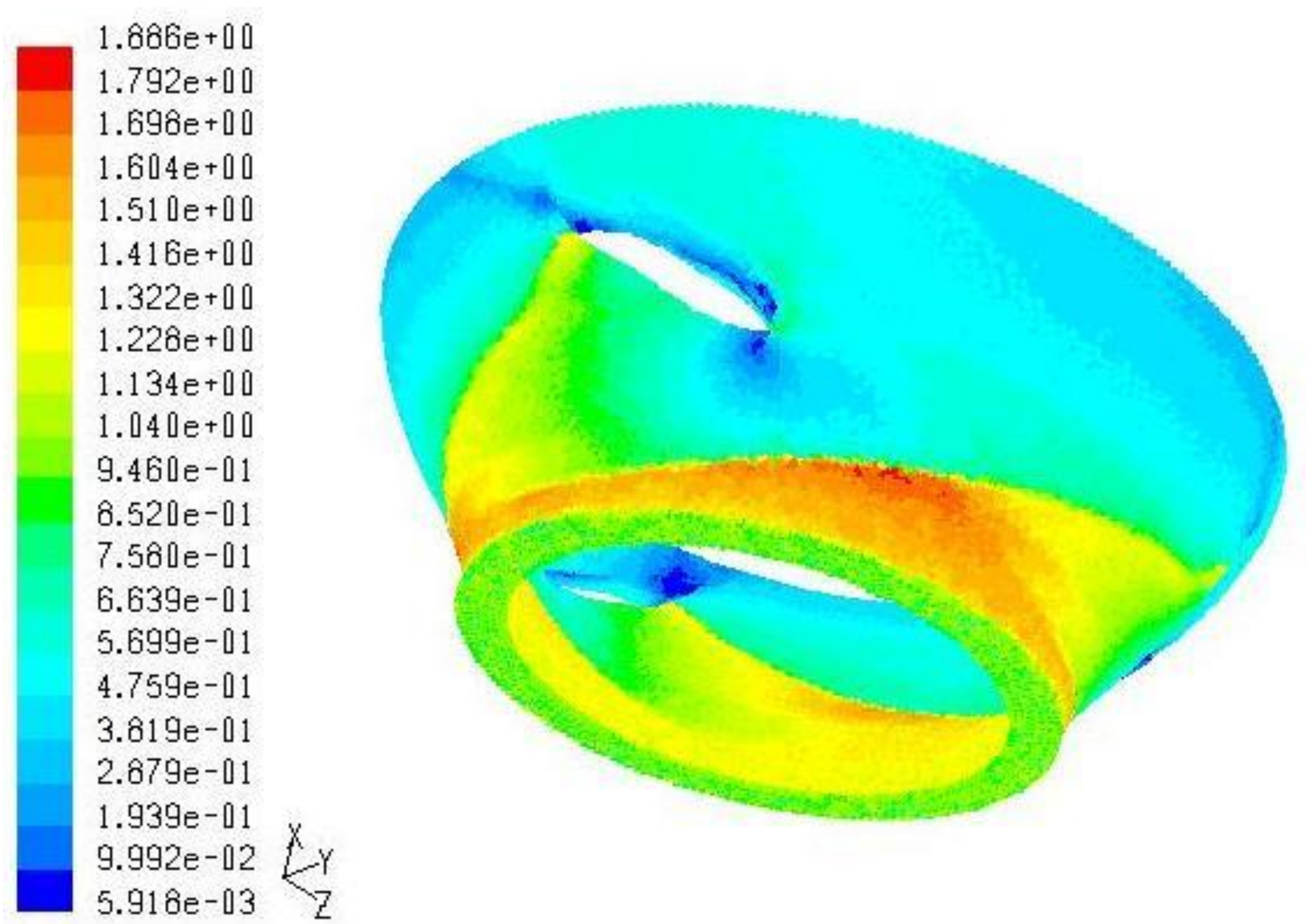

Main=0.930

σ=20.3%

Figure 9. Mach number , ζ=12

Swirling Flow in Annular Diffuser

Effects of the Models of Turbulence

Table 1. Comparison for different models, ζ=47.9

Model	$p_{0,in}$, bar	$p_{0,out}$, bar	Ma_{in}	Ma_{out}	$\|v\|_{,in}$, m/s	σ, %
Realizable	3.436	3.212	0.908	0.405	568.5	6.52
RNG	3.435	3.221	0.907	0.410	567.8	6.23
k-ω	3.490	3.216	0.916	0.410	579.1	7.85
RSM	3.434	3.223	0.907	0.413	572.6	6.14

Effect of Grid Adaption

Table 2. k-ε Realizable Model, ζ=47.9

Grid	$p_{0,in}$, bar	$p_{0,out}$, bar	Ma_{in}	Ma_{out}	$\|v\|_{,in}$, m/s	σ, %
Base	3.436	3.212	0.908	0.405	568.5	6.52
Adapted	3.444	3.214	0.908	0.410	574.5	6.68

Adapted grid,$p_{0,in}$=3.3 bar $\Rightarrow$ ***6.5% $\leq \sigma \leq$ 7.7%***

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CONCLUSIONS

1. It is possible on the base of CFD modeling to optimize configuration of intermediate diffuser to reduce to a minimum pressure losses owing to correct choice of its profile, and number, location and direction of vanes.
2. Failing experimental data we can’t prefer either of considered models of turbulence. Therefore on the base of carried study we suppose that calculated total pressure losses are in the limits from 6.5% to 7.7%