APPENDIX 1

A1.1 Photograph on overview of testing laboratory

A1.2 Photograph of test setup
A1.3 Photograph of the impeller

A1. 4 Photograph of the bowl
A1.5 Photograph pump outlet of the front view

A1.6 Photograph pump outlet of the top view
A1.7 Photograph pump inlet of the front view

A1.8 Photograph pump inlet of the top view
## APPENDIX 2

**HARI INDUSTRIES, COIMBATORE – 06.**

**SUBMERSIBLE PUMPSET PERFORMANCE TEST REPORT AS PER IS 8034: 2002**

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Frequency (HZ)</th>
<th>Pump Speed (rpm)</th>
<th>Delivery Head (m)</th>
<th>V.H (m)</th>
<th>Total Head (m)</th>
<th>Flow meter Reading</th>
<th>Discharge (lps)</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Motor Input (kW)</th>
<th>Discharge (lps)</th>
<th>Total Head (m)</th>
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Hydrostatic Pressure Test
1) 1.5 times shut-off Pressure = 9.15 kg/cm²
Casing withstood a pressure of 91.50 m of water

Date: 30.01.2010  
Test by [Signature]  
Approved by [Signature]

A2.1 Company data of the pump
APPENDIX 3

CFD STEPS

1. Pre processing

A3.1 Importing the CAD model into ANSA tool
A3.2 Checking the geometry topology in ANSA

A3.3 Setting the part names in ANSA
A3.4 Checking the part names in ANSA

A3.5 Stages of impellers in ANSA
A3.6 Setting the MRF surfaces for impellers in ANSA

A3.7 Setting surface mesh parameters in ANSA
A3.8 Choosing best method in ANSA

A3.9 Setting surface mesh quality in ANSA
A3.10 Surface mesh with preferred quality

A3.11 Setting the volume mesh parameters in T-GRID
A3.12 MRF fluid zones

A3.13 Quality checking (equiangle deviation) in T-GRID
A3.14 Quality checking (equilateral deviation) in T-GRID

A3.15 Importing volume mesh in Fluent
A3.16 Scaling the geometry in fluent

A3.17 Selecting turbulence model and non-equilibrium wall functions
A3.18 Selecting material properties in fluent

A3.19 Setting the stationary fluid zone
A3.20 Setting the moving fluid zone (MRF technique)

A3.21 Setting inlet boundary condition
A3.22 Setting outlet boundary condition

A3.23 Setting moving wall boundary condition
A3.24 Creating the surface monitors

A3.25 Convergence
APPENDIX 4

SUMMARY OF CFD PROCEDURE

Fluent
Version: 3d, dp, pbns, rke (3d, double precision, pressure-based, realizable k-epsilon)
Release: 14.5.0
Title:

Models

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<td>Time</td>
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<tr>
<td>Viscous</td>
<td>Realizable k-epsilon turbulence model</td>
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Material Properties

---

Material: water-liquid (fluid)

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<th>Units</th>
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<td>Thermal Expansion Coefficient</td>
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<tr>
<td>Speed of Sound</td>
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<td>#f</td>
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Material: aluminum (solid)

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<th>Method</th>
<th>Value(s)</th>
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</thead>
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Cell Zone Conditions

Zones

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Setup Conditions

mrf-fluid-2

Condition Value

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<th>Source Terms</th>
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<th>Fixed Values</th>
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<th>Relative To Cell Zone</th>
<th>Reference Frame Rotation Speed (rpm)</th>
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<th>Reference Frame Z-Velocity Of Zone (m/s)</th>
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<th>Reference Frame Y-Origin of Rotation-Axis (m)</th>
<th>Reference Frame Z-Origin of Rotation-Axis (m)</th>
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<td>0.062917003</td>
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<th>Reference Frame Y-Component of Rotation-Axis</th>
<th>Reference Frame Z-Component of Rotation-Axis</th>
<th>Reference Frame User Defined Zone Motion Function</th>
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<table>
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<th>Relative To Cell Zone</th>
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<th>Moving Mesh Y-Velocity Of Zone (m/s)</th>
<th>Moving Mesh Z-Velocity Of Zone (m/s)</th>
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<th>Moving Mesh Y-Origin of Rotation-Axis (m)</th>
<th>Moving Mesh Z-Origin of Rotation-Axis (m)</th>
<th>Moving Mesh X-Component of Rotation-Axis</th>
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<td>-1</td>
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<td>0</td>
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Moving Mesh User Defined Zone Motion Function: none
Deactivated Thread: no
Laminar zone?: no
Set Turbulent Viscosity to zero within laminar zone?: yes
Embedded Subgrid Scale Model: 0
Momentum Spatial Discretization: 0
Cwale: 0.325
Cs: 0.1
Porous zone?: no
Conical porous zone?: no
X-Component of Direction-1 Vector: 1
Y-Component of Direction-1 Vector: 0
Z-Component of Direction-1 Vector: 0
X-Component of Direction-2 Vector: 0
Y-Component of Direction-2 Vector: 0
Z-Component of Direction-2 Vector: 1
X-Component of Cone Axis Vector: 1
Y-Component of Cone Axis Vector: 0
Z-Component of Cone Axis Vector: 0
X-Coordinate of Point on Cone Axis (m): 1
Y-Coordinate of Point on Cone Axis (m): 0
Z-Coordinate of Point on Cone Axis (m): 0
Half Angle of Cone Relative to its Axis (deg): 0
Relative Velocity Resistance Formulation?: yes
Direction-1 Viscous Resistance (1/m²): 0
Direction-2 Viscous Resistance (1/m²): 0
Direction-3 Viscous Resistance (1/m²): 0
Choose alternative formulation for inertial resistance?: no
Direction-1 Inertial Resistance (1/m): 0
Direction-2 Inertial Resistance (1/m): 0
Direction-3 Inertial Resistance (1/m): 0
C0 Coefficient for Power-Law: 0
C1 Coefficient for Power-Law: 0
Porosity: 1
Interfacial Area Density (1/m): 1
Heat Transfer Coefficient (W/m²-k): 1

mrf-fluid-6

Condition Value

-------------------------------------------
Material Name: water-liquid
 Specify source terms?: no
 Source Terms: ((mass) (x-momentum) (y-momentum) (z-momentum) (k) (epsilon))
 Specify fixed values?: no
 Local Coordinate System for Fixed Velocities: no
 Fixed Values: ((x-velocity (inactive . #) (constant . 0) (profile )) (y-velocity (inactive . #) (constant . 0) (profile )) (z-velocity (inactive . #) (constant . 0) (profile )) (k (inactive . #) (constant . 0) (profile )) (epsilon (inactive . #) (constant . 0) (profile )))
 Frame Motion?: yes
 Relative To Cell Zone: -1
 Reference Frame Rotation Speed (rpm): 2880.0001
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**mrf-fluid1**

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Specify source terms? no

Source Terms

((mass) (x-momentum) (y-momentum) (z-momentum) (k) (epsilon))

Specify fixed values? no

Local Coordinate System for Fixed Velocities

((x-velocity (inactive . #) (constant . 0) (profile )) (y-velocity (inactive . #) (constant . 0) (profile )) (z-velocity (inactive . #) (constant . 0) (profile )) (k (inactive . #) (constant . 0) (profile )) (epsilon (inactive . #) (constant . 0) (profile )))

Frame Motion? yes

Relative To Cell Zone -1

Reference Frame Rotation Speed (rpm) 2880.0001

Reference Frame X-Velocity Of Zone (m/s) 0

Reference Frame Y-Velocity Of Zone (m/s) 0

Reference Frame Z-Velocity Of Zone (m/s) 0

Reference Frame X-Origin of Rotation-Axis (m) 0.064846003

Reference Frame Y-Origin of Rotation-Axis (m) 0.062917003

Reference Frame Z-Origin of Rotation-Axis (m) 0.006090003

Reference Frame X-Component of Rotation-Axis 0

Reference Frame Y-Component of Rotation-Axis 0

Reference Frame Z-Component of Rotation-Axis -1

Reference Frame User Defined Zone Motion Function none

Mesh Motion? no

Relative To Cell Zone -1

Moving Mesh Rotation Speed (rpm) 0

Moving Mesh X-Velocity Of Zone (m/s) 0

Moving Mesh Y-Velocity Of Zone (m/s) 0

Moving Mesh Z-Velocity Of Zone (m/s) 0

Moving Mesh X-Origin of Rotation-Axis (m) 0

Moving Mesh Y-Origin of Rotation-Axis (m) 0

Moving Mesh Z-Origin of Rotation-Axis (m) 0
Moving Mesh X-Component of Rotation Axis 0
Moving Mesh Y-Component of Rotation Axis 0
Moving Mesh Z-Component of Rotation Axis 1
Moving Mesh User Defined Zone Motion Function none
Deactivated Thread no
Laminar zone? no
Set Turbulent Viscosity to zero within laminar zone? yes
Embedded Subgrid-Scale Model 0
Momentum Spatial Discretization 0
Cwale 0.325
Gs 0.1
Porous zone? no
Conical porous zone? no
X-Component of Direction 1 Vector 1
Y-Component of Direction 1 Vector 0
Z-Component of Direction 1 Vector 0
X-Component of Direction 2 Vector 0
Y-Component of Direction 2 Vector 1
Z-Component of Direction 2 Vector 0
X-Component of Cone Axis Vector 1
Y-Component of Cone Axis Vector 0
Z-Component of Cone Axis Vector 0
X-Coordinate of Point on Cone Axis (m) 1
Y-Coordinate of Point on Cone Axis (m) 0
Z-Coordinate of Point on Cone Axis (m) 0
Half Angle of Cone Relative to its Axis (deg) 0
Relative Viscosity Resistance Formulation? yes
Direction-1 Viscous Resistance (1/m^2) 0
Direction-2 Viscous Resistance (1/m^2) 0
Direction-3 Viscous Resistance (1/m^2) 0
Choose alternative formulation for inertial resistance? no
Direction-1 Inertial Resistance (1/m) 0
Direction-2 Inertial Resistance (1/m) 0
Direction-3 Inertial Resistance (1/m) 0
C0 Coefficient for Power-Law 0
C1 Coefficient for Power-Law 0
Porosity 1
Interfacial Area Density (1/m) 1
Heat Transfer Coefficient (W/m^2-k) 1

mrf-fluid-4

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Reference Frame Z-Velocity Of Zone (m/s) 0
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Reference Frame Y-Origin of Rotation-Axis (m) 0.062917003
Reference Frame Z-Origin of Rotation-Axis (m) -0.26704001
Reference Frame X-Component of Rotation-Axis 0
Reference Frame Y-Component of Rotation-Axis 0
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Reference Frame User Defined Zone Motion Function none
Mesh Motion? no
Relative To Cell Zone -1
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Moving Mesh Z-Component of Rotation-Axis 1
Moving Mesh User Defined Zone Motion Function none
Deactivated Thread no
Laminar zone? no
Set Turbulent Viscosity to zero within laminar zone? yes
Embedded Subgrid-Scale Model 0
Momentum Spatial Discretization 0
Cwale 0.325
Cs 0.1
Porous zone? no
Conical porous zone? no
X-Component of Direction-1 Vector 1
Y-Component of Direction-1 Vector 0
Z-Component of Direction-1 Vector 0
X-Component of Direction-2 Vector 0
Y-Component of Direction-2 Vector 1
Z-Component of Direction-2 Vector 0
X-Component of Cone Axis Vector 1
Y-Component of Cone Axis Vector 0
Z-Component of Cone Axis Vector 0
X-Coordinate of Point on Cone Axis (m) 1
Y-Coordinate of Point on Cone Axis (m) 0
Z-Coordinate of Point on Cone Axis (m) 0
Half Angle of Cone Relative to its Axis (deg) 0
Relative Velocity Resistance Formulation? yes
Direction-1 Viscous Resistance (1/m2) 0
Direction-2 Viscous Resistance (1/m2) 0
Direction-3 Viscous Resistance (1/m2) 0
Choose alternative formulation for inertial resistance? no
Direction-1 Inertial Resistance (1/m) 0
Direction-2 Inertial Resistance (1/m) 0
Direction-3 Inertial Resistance (1/m) 0
C0 Coefficient for Power-Law 0
C1 Coefficient for Power-Law 0
Porosity 1
Interfacial Area Density (1/m) 1
Heat Transfer Coefficient (W/m2-k) 1
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stationary-fluid

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Set Turbulent Viscosity to zero within laminar zone? yes
Embedded Subgrid-Scale Model 0
Momentum Spatial Discretization 0
Cwale 0.325
Cs 0.1
Porous zone? no
Conical porous zone? no
X-Component of Direction-1 Vector 1
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Z-Component of Cone Axis Vector 0
X-Coordinate of Point on Cone Axis (m) 1
Y-Coordinate of Point on Cone Axis (m) 0
Z-Coordinate of Point on Cone Axis (m) 0
Half Angle of Cone Relative to its Axis (deg) 0
Relative Velocity Resistance Formulation? yes
Direction-1 Viscous Resistance (1/m²) 0
Direction-2 Viscous Resistance (1/m²) 0
Direction-3 Viscous Resistance (1/m²) 0
Choose alternative formulation for inertial resistance? no
Direction-1 Inertial Resistance (1/m) 0
Direction-2 Inertial Resistance (1/m) 0
Direction-3 Inertial Resistance (1/m) 0
CD Coefficient for Power-Law 0
CL Coefficient for Power-Law 0
Porosity 1
Interfacial Area Density (1/m) 1
Heat Transfer Coefficient (W/m²-k) 1

Boundary Conditions

Zones

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<td>pressure-inlet</td>
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<td>blocking-wall-diffuser-side</td>
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<td>coupling-sandbed-assembly</td>
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<td>s-1-stage-bowl</td>
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<td>s-1-stage-wall-sep</td>
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### s - 5 - stage - impeller
58 wall

### s - 6 - stage - impeller
59 wall

### shaft
61 wall

### wall - new y - created
63 wall

### prism side - 5
5 wall

### outlet - sec: 142
142 wall

### prism side - 145
145 wall

### s - 1 - stage - impeller: 009
9 wall

### s - 2 - stage = impeller: 012
12 wall

### s - 3 - stage - impeller: 016
16 wall

### s - 4 - stage - impeller: 019
19 wall

### s - 5 - stage - impeller: 022
22 wall

### s - 6 - stage - impeller: 035
35 wall

### shaft: 066
66 wall

### shaft: 067
67 wall

### shaft: 068
68 wall

### shaft: 069
69 wall

### shaft: 070
70 wall

### shaft: 071
71 wall

#### Setup Conditions

**outlet - sec**

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<tr>
<td>Apply a rotational velocity to this wall?</td>
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<td>Z-Component of Wall Translation</td>
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<tr>
<td>Define wall velocity components?</td>
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<td>Eslip constant</td>
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**inlet - sec**

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<td>Shear Boundary Condition</td>
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Define wall motion relative to adjacent cell zone? yes
Apply a rotational velocity to this wall? no

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<th>Velocity Magnitude (m/s)</th>
<th>X-Component of Wall Translation</th>
<th>Y-Component of Wall Translation</th>
<th>Z-Component of Wall Translation</th>
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Define wall velocity components? no

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Wall Roughness Height (m) 0
Wall Roughness Constant 0.5
Rotation Speed (rpm) 0

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<th>X-Position of Rotation-Axis Origin (m)</th>
<th>Y-Position of Rotation-Axis Origin (m)</th>
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X-component of shear stress (pascal) 0
Y-component of shear stress (pascal) 0
Z-component of shear stress (pascal) 0
Fslip constant 0
Eslip constant 0
Specularity Coefficient 0

**inlet-ext**

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<td>Turbulent Viscosity Ratio</td>
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<td>is zone used in mixing-plane model?</td>
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**outlet-ext**

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<td>Backflow Direction Specification Method</td>
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- Y-Component of Flow Direction: 0
- Z-Component of Flow Direction: 0
- X-Component of Axis Direction: 0
- Y-Component of Axis Direction: 0
- Z-Component of Axis Direction: 1
- X-Coordinate of Axis Origin (m): 0
- Y-Coordinate of Axis Origin (m): 0
- Z-Coordinate of Axis Origin (m): 0

**Turbulent Specification Method**
- Backflow Turbulent Kinetic Energy (m^2/s^2): 1
- Backflow Turbulent Dissipation Rate (m^2/s^3): 1
- Backflow Turbulent Intensity (%): 10
- Backflow Turbulent Length Scale (m): 1
- Backflow Hydraulic Diameter (m): 1

**is zone used in mixing-plane model?**
- no

**Radial Equilibrium Pressure Distribution**
- no

**Specify Average Pressure Specification**
- no

**Specify targeted mass flow rate**
- no

**Targeted mass flow (kg/s)**
- 1

**Upper Limit of Absolute Pressure Value (pascal)**
- 5000000

**Lower Limit of Absolute Pressure Value (pascal)**
- 1

**blocking-wall-diffuser-side**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
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</thead>
<tbody>
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<td>Define wall motion relative to adjacent cell zone?</td>
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<td>Apply a rotational velocity to this wall?</td>
<td>no</td>
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<tr>
<td>Velocity Magnitude (m/s)</td>
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<td>X-Component of Wall Translation</td>
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<td>Z-Component of Wall Translation</td>
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<td>Wall Roughness Constant</td>
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**coupling-sandbed-assembly**

<table>
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s-1-stage-bowl
### inlet-wall-sep

<table>
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### s-2-stage-bowl1

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Eslip constant 0
Specularity Coefficient 0

s-5-stage-bowl

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s-6-stage-bowl

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Z-component of shear stress (pascal) 0
Fslip constant 0
Eslip constant 0
Specularity Coefficient 0

s-1-stage-impeller

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Eslip constant 0
Specularity Coefficient 0

s-2-stage-impeller

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Y-Position of Rotation-Axis Origin (m)            0.062916783
Z-Position of Rotation-Axis Origin (m)            -0.084938624
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Y-Component of Rotation-Axis Direction             0
Z-Component of Rotation-Axis Direction             -1
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Z-component of shear stress (pascal)                0
Fslip constant                                      0
Eslip constant                                      0
Specularity Coefficient                              0

s-3-stage-impeller

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<td>Rotation Speed (rpm)</td>
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s-4-stage-impeller

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Wall Roughness Constant 0.5
Rotation Speed (rpm) 0
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Y- Position of Rotation-Axis Origin (m) 0.062916783
Z- Position of Rotation-Axis Origin (m) -0.26704501
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Y- Component of Rotation-Axis Direction 0
Z- Component of Rotation-Axis Direction -1
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Y-component of shear stress (pascal) 0
Z-component of shear stress (pascal) 0
Fslip constant 0
Eslip constant 0
Specularity Coefficient 0
s- 5-stage-impeller

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s- 6-stage-impeller

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prism side-5
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prism side 145

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### s-4-stage-impeller: 019

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s-5-stage-impeller:022

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s-6-stage-impeller:035

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shaft: 066
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Fslip constant                                       0
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Specularity Coefficient                              0

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Solver Settings
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Body Forces                  1  
Momentum                     0.7  
Turbulent Kinetic Energy     0.8  
Turbulent Dissipation Rate   0.8  
Turbulent Viscosity          1  

Linear Solver

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Pressure-Velocity Coupling

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Discretization Scheme

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Solution Limits

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