Basic Designing of Mechanical Vapor Compressor in Multi-Effect Distillation for Fresh Water Production

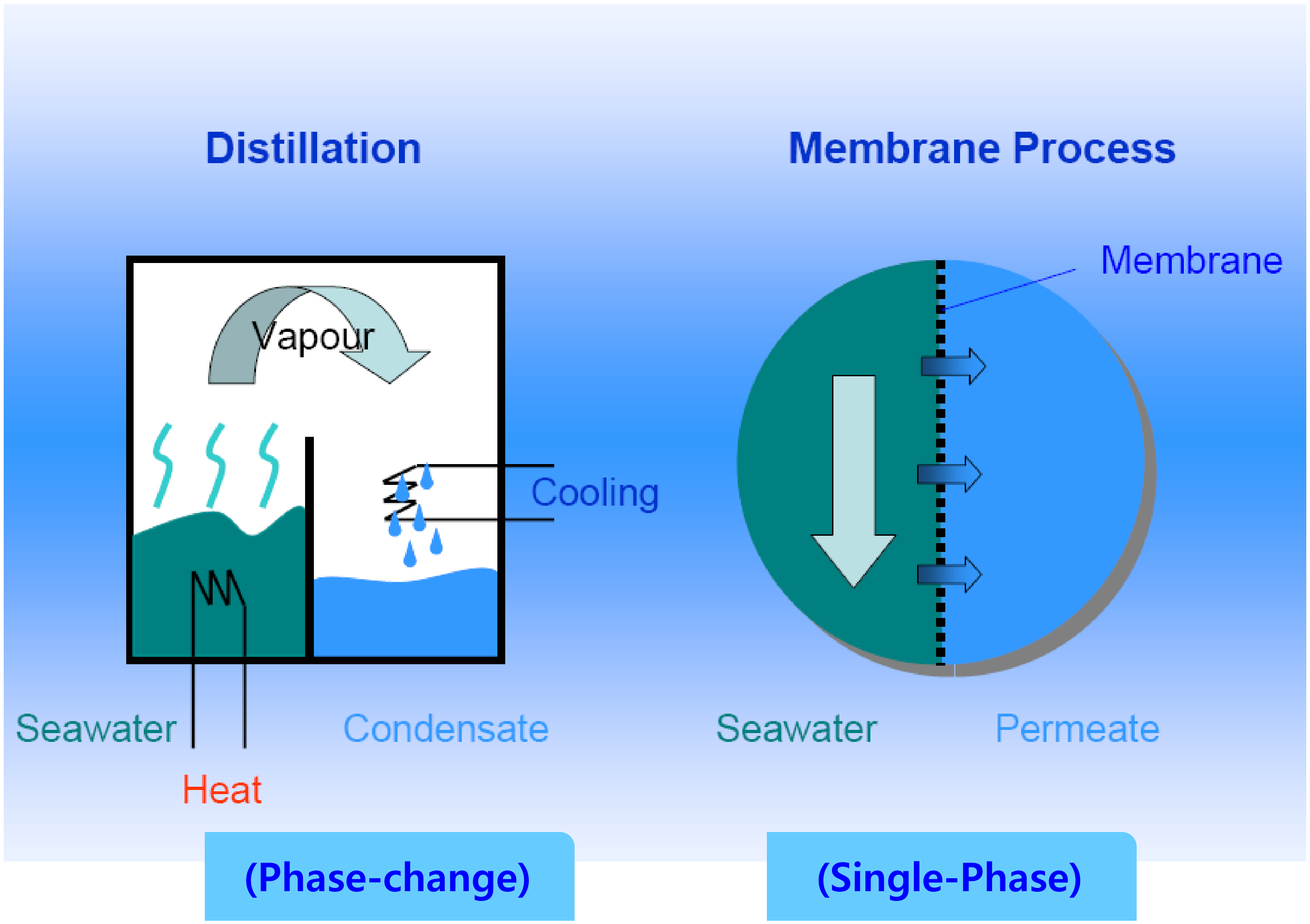
Gyeongsang National University
Hanshik Chung

Thermal and Fluid Research Group
Department of Mechanical and Precision Engineering, GNU

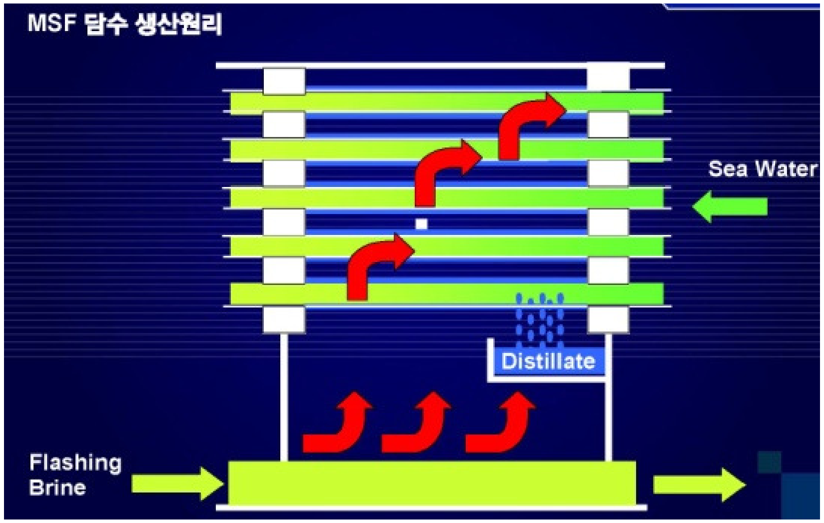
CONTENTS

- Background of Study
- Introduction & Objective
- Results and discussion
- Conclusions

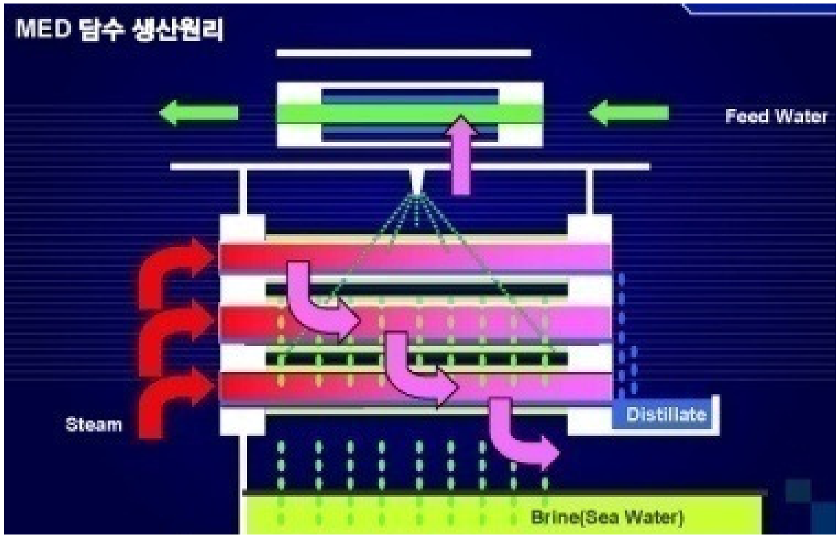
Fresh Water Generation System ;



Why and What is MED ?



• **MSF**
(Multi Stage Flash Desalination)

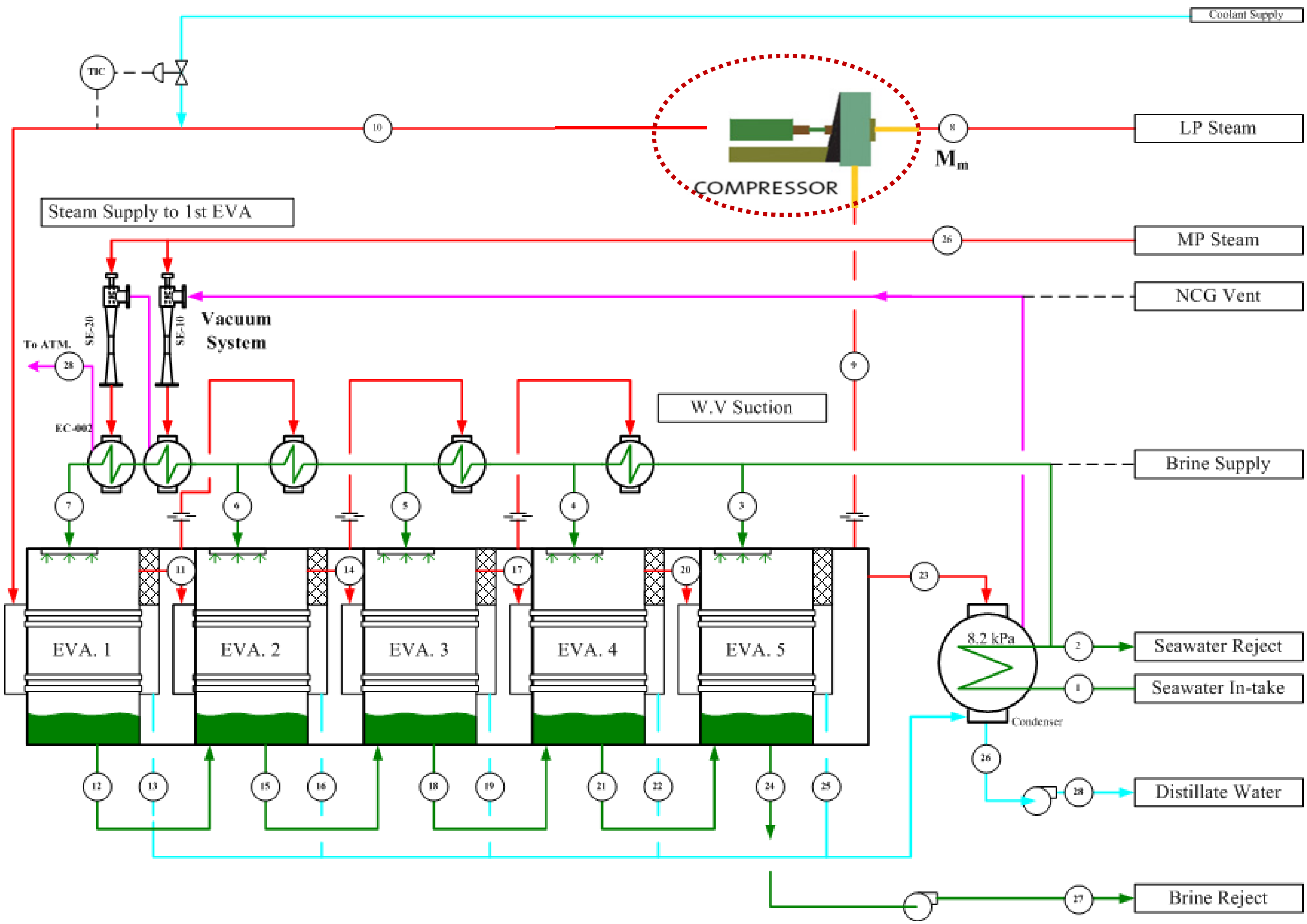


•**MED**
(Multi Effect Desalination)

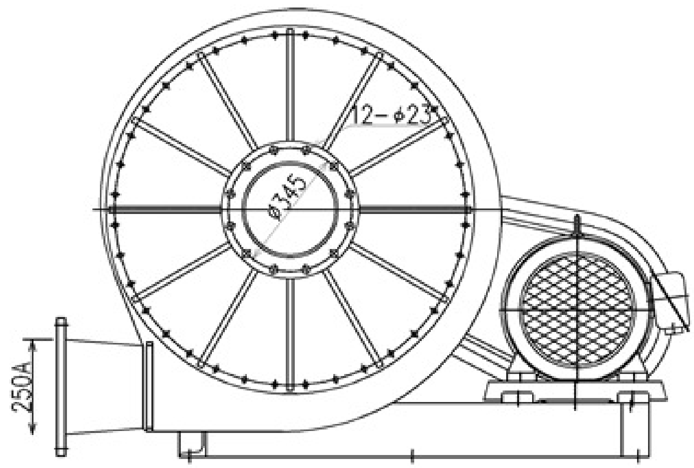
(1) **MED-TVC : MED by TVC (Thermo Vapor Compressor)**

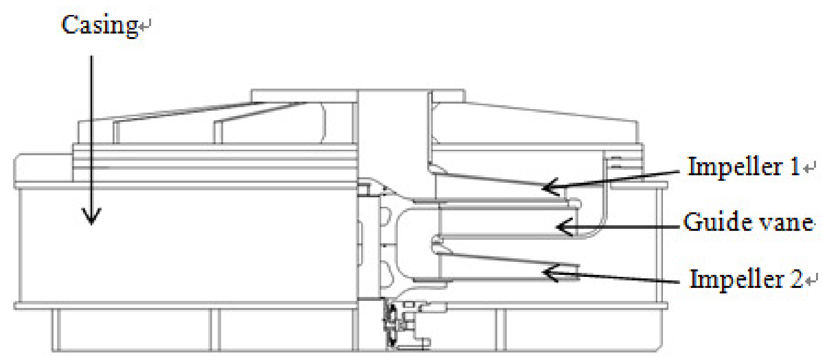
(2) **MED-MVC : MED by MVC**
(Mechanical Vapor Compressor)

MVC and MED System



Mechanical vapor compressor design.





Assumptions and Simulation Conditions

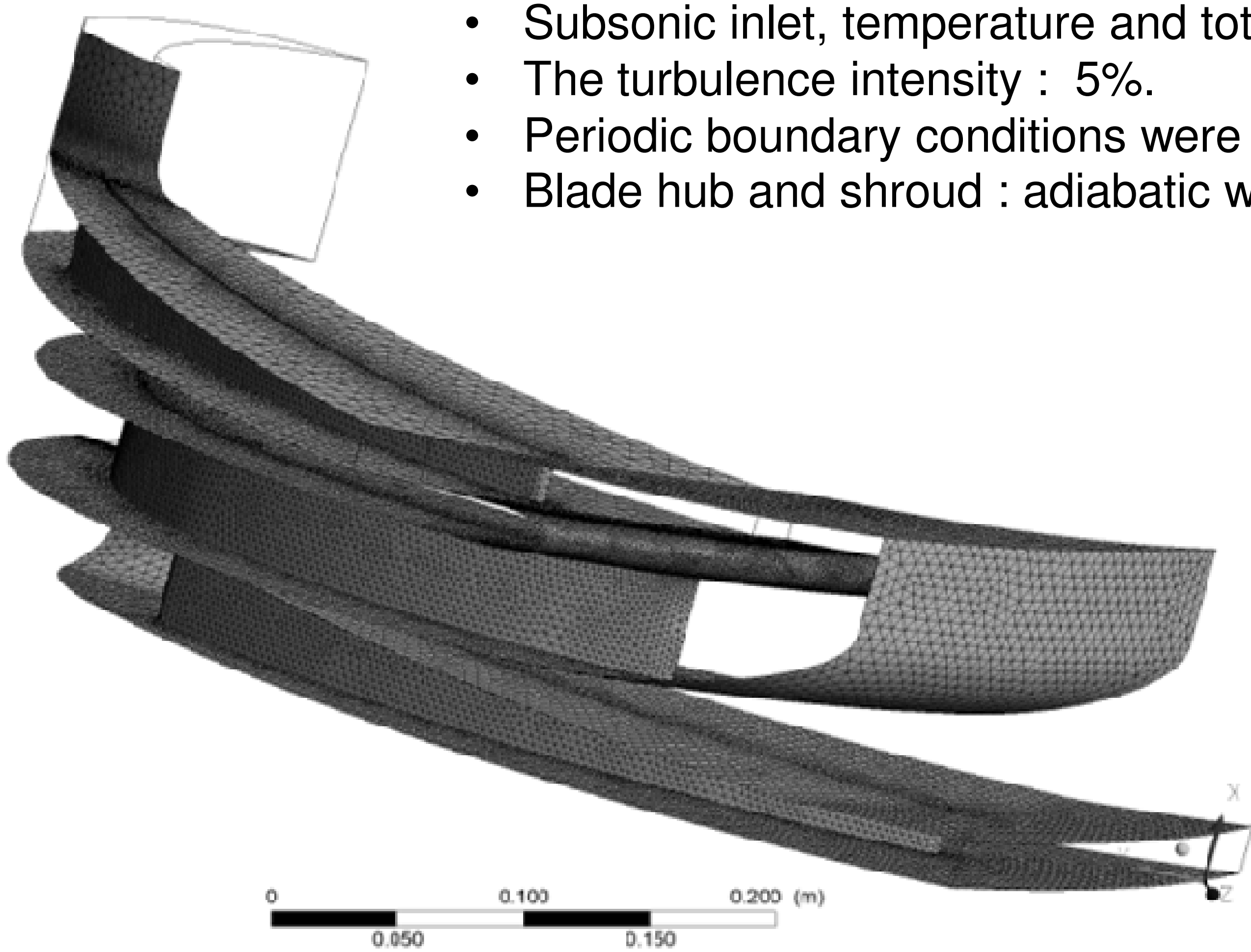
- Steady state conditions
- 3D periodic model with CFD software package (CFX 12)
- To reduce the computational cost, only single passage
- 119,291 nodes and 613,893 elements

NUMERICAL MODELING

3-Grid computational domain

The inlet boundary conditions;

- Subsonic inlet, temperature and total pressure
- The turbulence intensity : 5%.
- Periodic boundary conditions were applied
- Blade hub and shroud : adiabatic walls.



Governing Equation

- 3-D Reynolds averaged compressible Navier-Stokes equations
- SST k-ω turbulence model

Mass and momentum conservation equations

$$\frac{\partial}{\partial x_i}(\rho u_i) = 0 \quad (1)$$

$$\frac{\partial}{\partial x_i}(\rho u_i u_j) = -\frac{\partial p}{\partial x_i} + \frac{\partial p}{\partial x_j}\left[\mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} - \frac{2}{3}\delta_{ij}\frac{\partial u_l}{\partial x_l}\right)\right] + \frac{\partial}{\partial x_j}\left[\mu_t\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\left(\rho k + \mu_t\frac{\partial u_l}{\partial x_l}\right)\delta_{ij}\right] \quad (2)$$

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho U_j k) = \tau_{ij}\frac{\partial u_i}{\partial x_j} - \beta^* \rho \omega k + \frac{\partial}{\partial x_j}[(\mu + \sigma_k \mu_t)\frac{\partial k}{\partial x_j}] \quad (3)$$

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho U_j k) = \tau_{ij}\frac{\partial u_i}{\partial x_j} - \beta^* \rho \omega k + \frac{\partial}{\partial x_j}[(\mu + \sigma_k \mu_t)\frac{\partial k}{\partial x_j}] + 2\rho(1 - F_1)\sigma_\omega \frac{1}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial \omega}{\partial x_j} \quad (4)$$

Details of geometry and flow condition in inlet

Number of rotor blades @ each stage	14
Number of stator blades	15
Diameter impeller 1	Inside : 282 mm
	Outside : 750 mm
Diameter impeller 2	Inside: 298 mm
	Outside : 792 mm
Diameter guide vane	Inside : 298 mm
	Outside : 792 mm
Basic rotating speed	3650 rpm
Total pressure @ inlet	24.1 kPa
Specific enthalpy @ inlet	2.62×10^{6}J /kg
Specific entropy @ inlet	7.84×10^{3} J /kg.K
Static temperature @ inlet	64.1^{o}C

Fluid properties

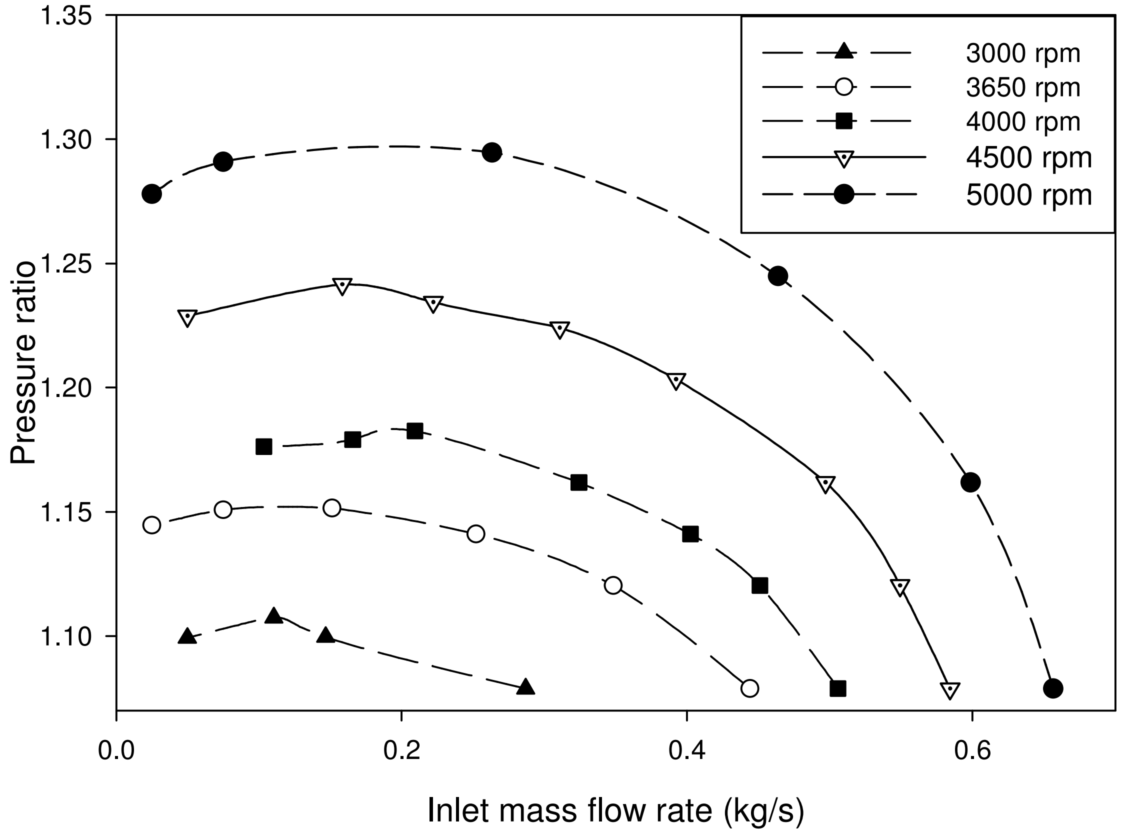
Properties of saturated steam.

PROPERTY	VALUE
Molar mass	18.015 kg/kmol
Critical Volume	55.95 cm^3/mol
Critical Temperature	647.14 K
Critical Pressure	220.64 bar
Boiling temperature	64.1^{o} C
Acentric Factor	0.344

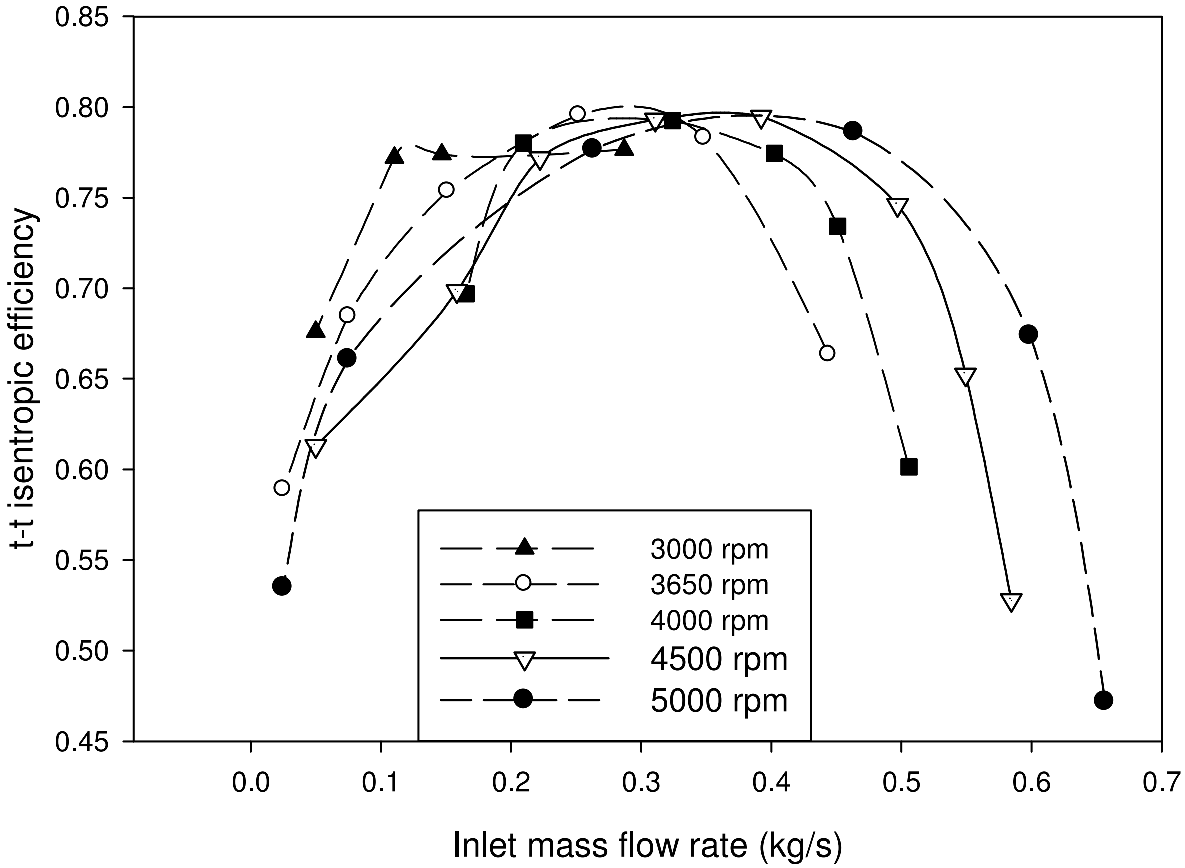
Boundary conditions.

SETTING	TYPE	
Inlet	Total pressure, total temperature	
Outlet	Average static pressure Mass flow out	
Interface Models	Frozen Rotor	
Blade	Heat transfer	adiabatic
	Mass and Momentum	no slip wall
	Wall roughness	smooth wall

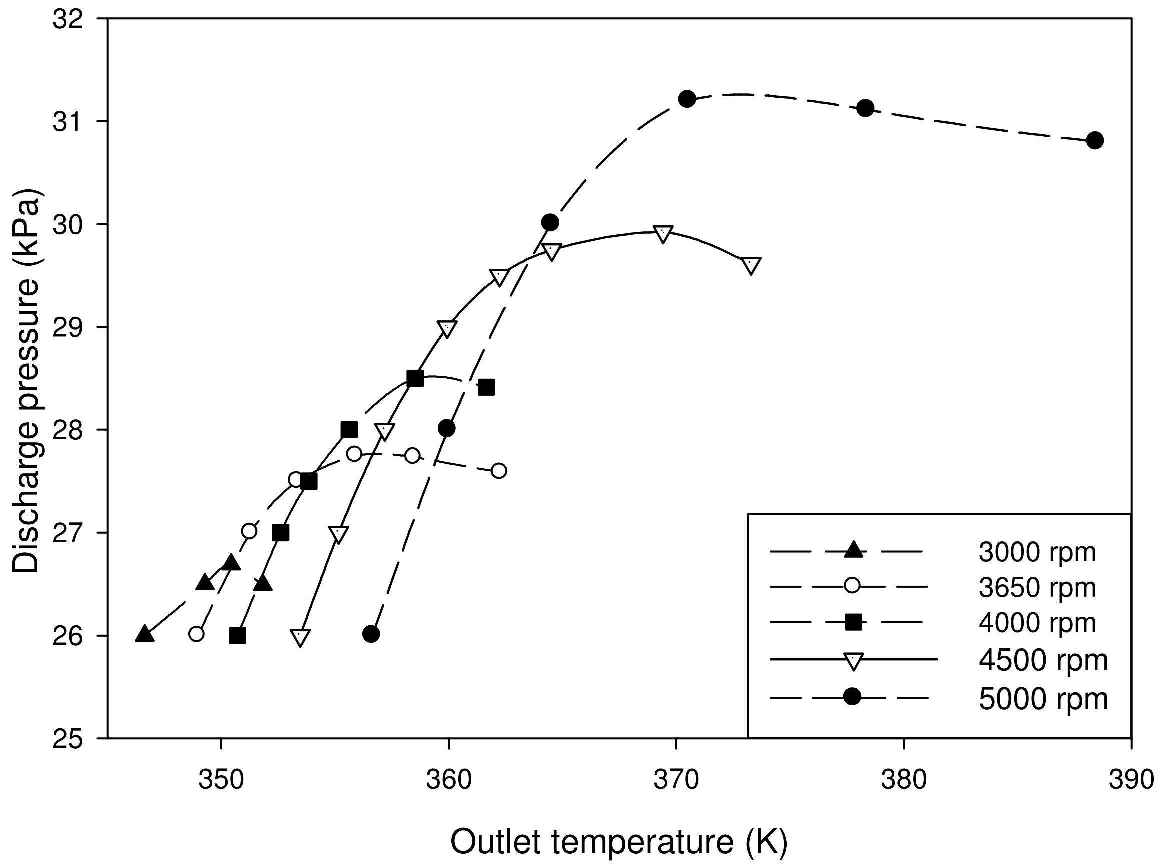
RESULTS AND DISCUSSION



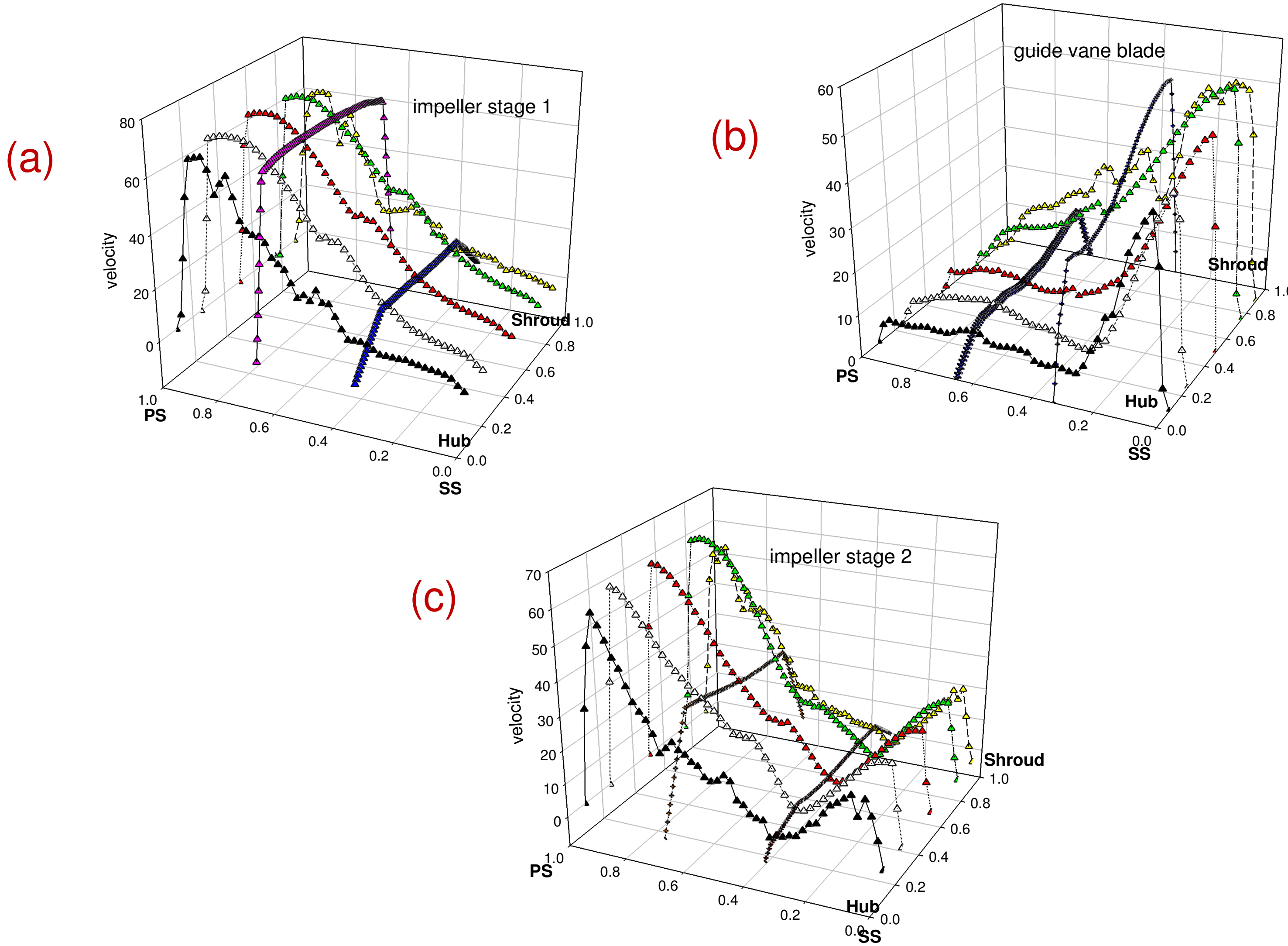
Compressors performance map at various rotational speeds.



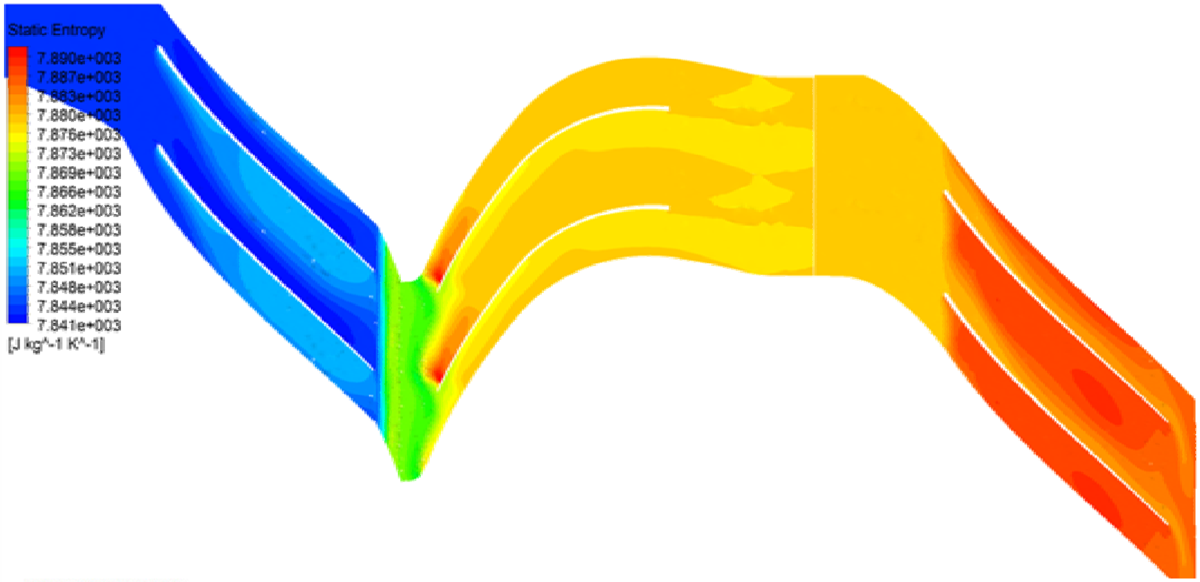
Mass flow rates and efficiencies for various Rotational speeds.

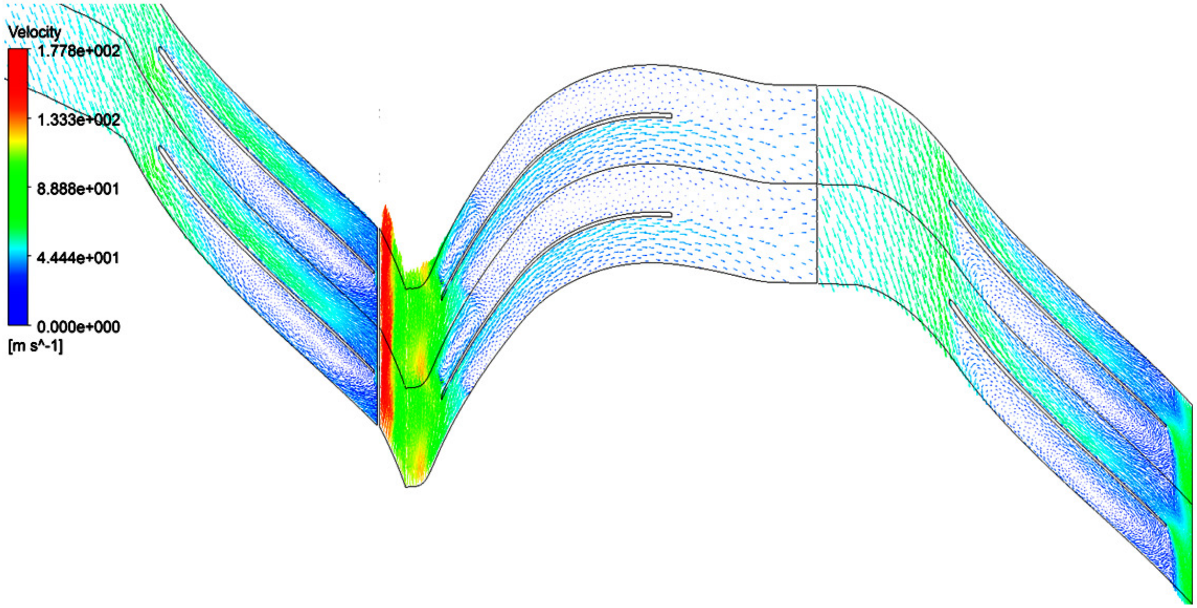


.Temperature and discharge pressure at various rotational speeds.

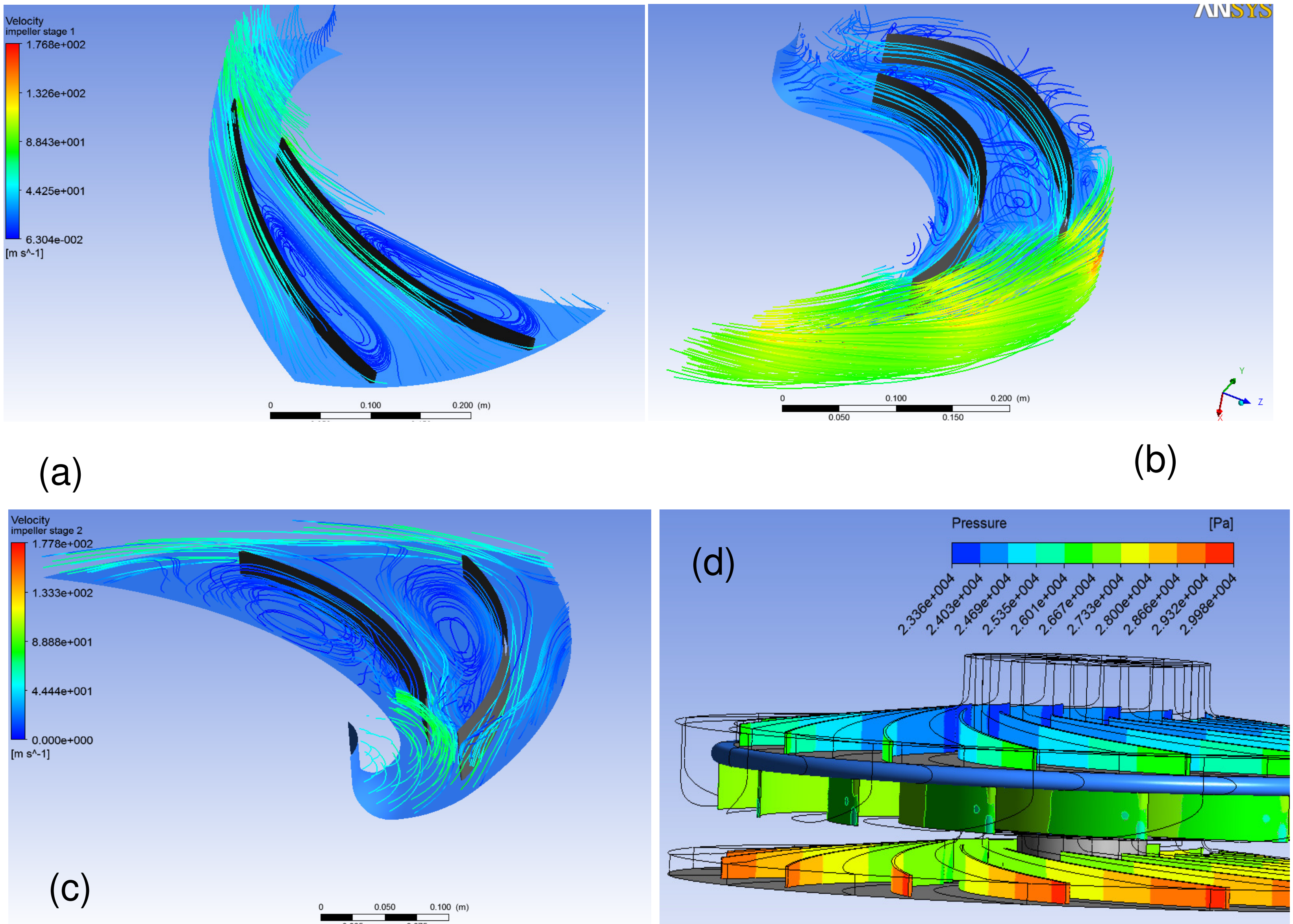


Flow field at blade in blade passage at (a) 16.6%, (b) 50%, and (c) 83.3%





Contour of static entropy and plot of velocity vector for 4500 rpm rotational speed at low suction mass flow rate.



Three-dimensional flow structure in flow passage (a, b, and c) and blade loading at rotor and stator at low suction mass flow rate.

CONCLUSION

- The effects of various operating conditions on the compressor performance have been investigated.

  At a high discharge pressure, the blockage effect was very dominant, restricting the flow rate.
- A detailed flow analysis was performed in this simulation, along with an examination of secondary phenomena.
- The results clearly show the flow characteristics inside the compressor under different operating conditions.
- This simulation showed that the widest stable operating zone was located at a high rotational speed.

THANK YOU!

Do You Have
Any Questions?