Modification of design in PL series vacuum pump to enhance performance of pump

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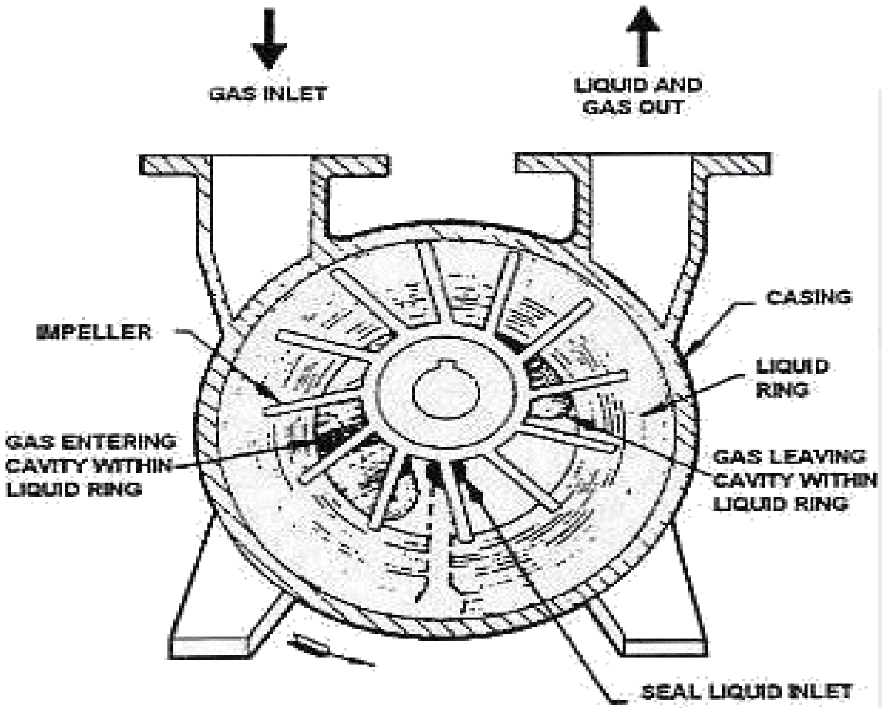
Contents of Project

Introduction

- A pressurized liquid vacuum pump is a rotating positive displacement pump. It is also known as liquid ring vacuum pump.
- They are typically used as a vacuum pump but can also be used as a gas compressor.
- The function of a liquid ring pump is similar to a rotary vane pump the difference being that the vanes are an integral part of the rotor and churn a rotating ring of liquid to form the compression chamber seal.
- Liquid ring pumps are typically powered by an induction motor.

Image of pump



Objective

- Liquid ring vacuum pump encounters severe problems while working on liquid sump. These problems include
  - Leakage in the pump
  - Jamming
  - Reduction in the level of vacuum as time advances
  - cavitations
  - Vibration in the Pump
- Here the objective of the investigation is to increase the performance and reliability of the pump by modifying its design parameters.

Literature Review

A. Shirinov, studied

- On the Tool™ Booster vacuum pump consists of side channel and Holweck pump Stages. This pump achieves 10-3 Pa final pressure and exhausts against Atmosphere. Research is done on side channel pump stages. It shows the ways to Increase the compression and pumping speed while simultaneously reducing size and power consumption. The influences of a backing pump on the power consumption, the form and number of rotor blades on the performance of side channel pump stages have been investigated. It was shown that the power consumption of the pump at final pressure drops from 1150 W to less than 150 W, if a backing pump is used. The properties of double-flow and single-flow side channel stages were compared to each other. It was shown that double-flow stages have a higher pumping speed and a lower compression than single-flow stages.

Jun Fu Zhao studied

- A modified pump-out technique, incorporating a novel pump-out hole sealing process, has been developed that enables a high level of vacuum to be achieved between the panes of a vacuum glazing. The modified pump-out method provides several potential opportunities for the fabrication of a vacuum glazing with improved thermal performance.

Philip C. Eames studied

- Reciprocating and liquid ring vacuum pumps chapter discusses the reciprocating and liquid ring vacuum pump. The best feature of the power pump is its high efficiency. Overall efficiencies normally range from 85% to 94%. The losses of approximately 10% include all those due to belts, gears, bearings, packing, and valves. The direct-acting pump has some of the same advantages as the power pump, plus others. These units are well suited for high-pressure low-flow applications.

Yueping Fang studied

Rotary displacement pump discusses leak-free rotary displacement pumps. These pumps are employed for transport and circulation duties. Nowadays, these pumps are mainly used in the chemical, petrochemical, cosmetic, foodstuff, paper processing, and bitumen processing industries. The interior of the pump must be lubricated, perhaps once a month, with tallow mixed with a tenth part pulverized graphite. This prevents rust formation in the interior of the pump, and ensures a long service life.

A. Shirinov, S. Oberbeck

- The On Tool™ Booster vacuum pump consists of side channel and Holweck pump stages. This pump achieves 10^{-3} Pa final pressure and exhausts against atmosphere. Research is done on side channel pump stages. It shows the ways to increase the compression and pumping speed while simultaneously reducing size and power consumption.

Zeyu Li, Liansheng Li, Yuanyang Zhao, Gaoxuan Bu, Pengcheng Shu

- The rarefied gas flows through suction port, scroll clearance and discharge port are treated as leakage of dry scroll vacuum pump (DSVP). The models for predicting the above-mentioned leakage rate were derived in this paper. The model for predicting the heat transfer rate between rarefied gas and working chamber wall was also developed. Then, a general model for describing the working process of DSVP was set up according to the energy and mass conservation principle. This model can be applied to predict the performance of DSVP. The pumping speed for different suction pressures was obtained. Furthermore, the ultimate pressure and power consumption for different speeds were gotten. A good agreement between the theoretical results and experimental data was obtained. Finally, the volume ratio of prototype was changed and its influence on the performance was studied by experiment.

Project Planning

Finding problem

- Selecting the major problems which are affecting the performance of pump
- Problem definition of selected problems

Solving the problem

- Outcome of investigations
- Analysis of outcome results for feasibility
- Modification of design according to outcome results
- Conclusion

Work progress:

Leakage:

When the water is flowing from inlet side there is leakage from the joint where we couple the motor. In order to reduce the cavitations we removed the splitter but it enhances the leakage problem further. Generally company which manufacture vacuum pump uses glance to reduce leakage. But glancing cannot stop leakage problems properly. So we used seal to prevent this problem instead of using glance. Seal shows excellent result to stop the leakage.

- **Jammed** : Pump jammed because of two reason the first reason is if the alignment of the shaft is not proper or the vane size is not accurate than the friction will be create between body and vane.

- **Cavitations:** when the water flow from the inlet side on that time it create the bubble in the casing of the pump which create the cavitations and effect the rotor and eccentricity of the pump. By changing the blade angle and removing the central splitter we can reduce the cavitations problem. By removing the splitter the generated bubble may not able to burst so we can reduce the cavitations problems to a greater extent.

Corrosion

Improper vacuum: when the material of eccentricity get wear on that time vacuum will not create properly and it also create the noise because of increasing space between rotor and eccentricity.

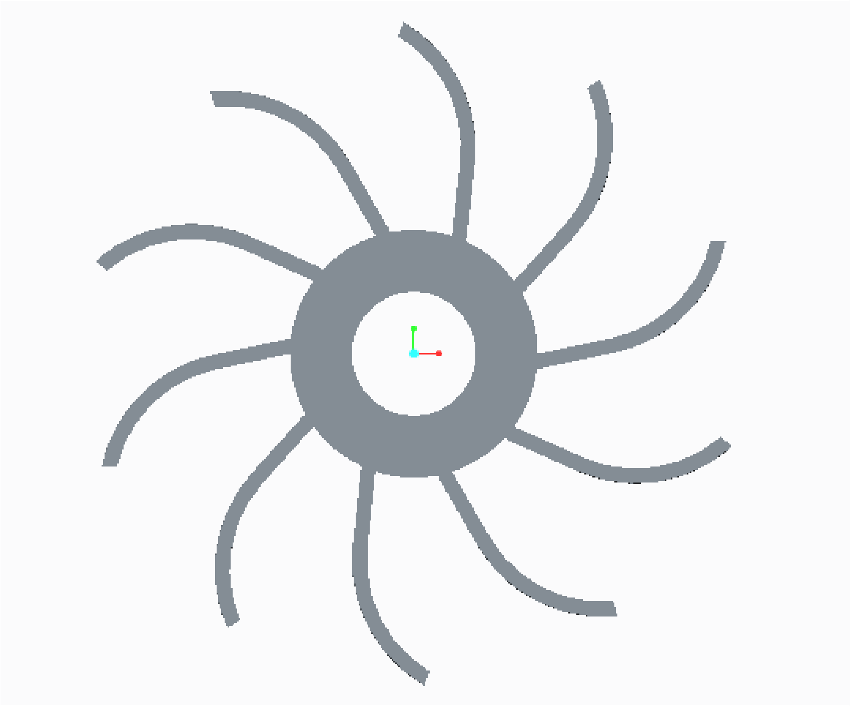
Vibration in the pump: The reason of this vibration is the shape and the size of vane.

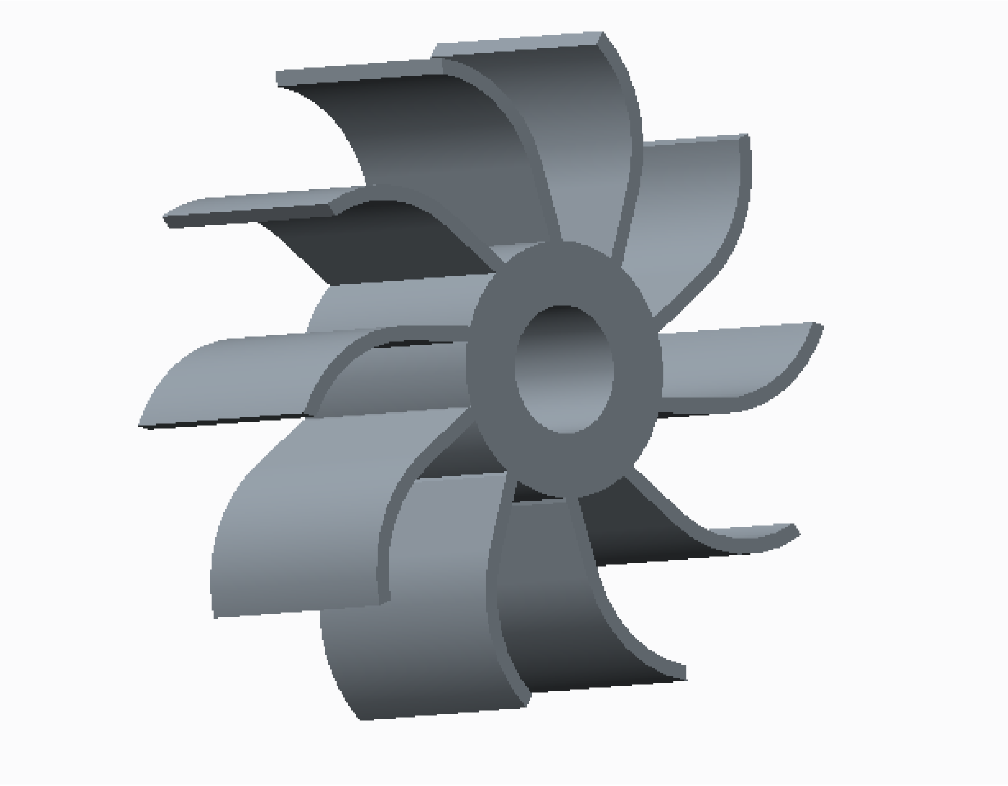
Eccentricity of the pump:− Eccentricity helps to create vacuum in the pump. Which break by high pressure of water and because of corrosion.

Different Parts of Vacuum Pump:-

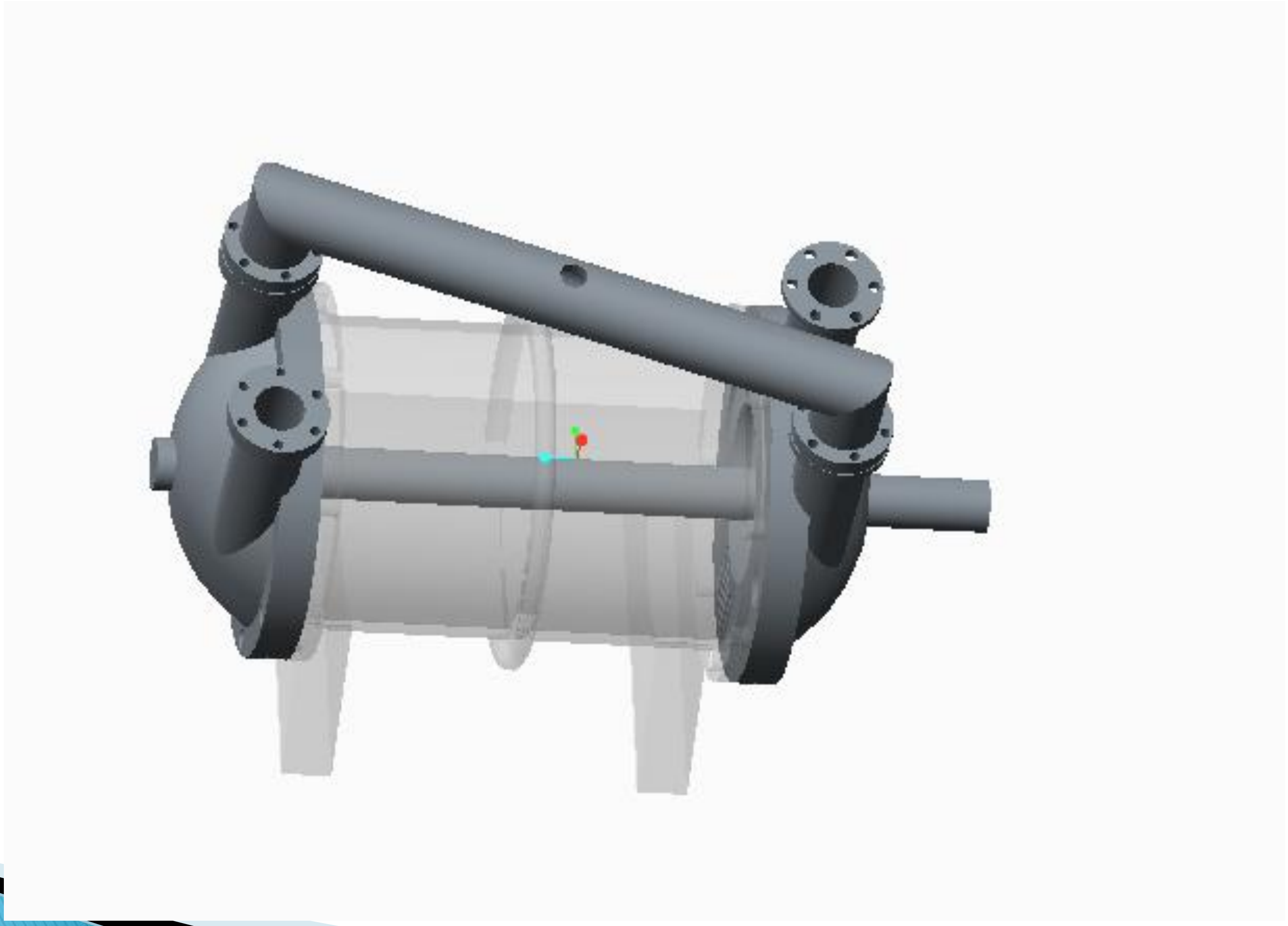
•**MOTOR**: The power source of the pump which drives the shaft. AC motors and DC motors are the most common power sources for pumps, but internal combustion engines (ICEs), hydraulic power, and steam power are other possibilities. Motor is used for generating power for working of the pump. Motor is use to work the vacuum pump which rotates the shaft and which are connected with the shaft of the pump and rotate the impeller so the impeller is run and vacuum create.

•**<u>IMPELLER</u>**: A rotating disk with a set of vanes coupled to a shaft. When the impeller rotates, it imparts energy to the fluid to induce flow. Flow characteristics of the pump vary widely based on the impeller design.

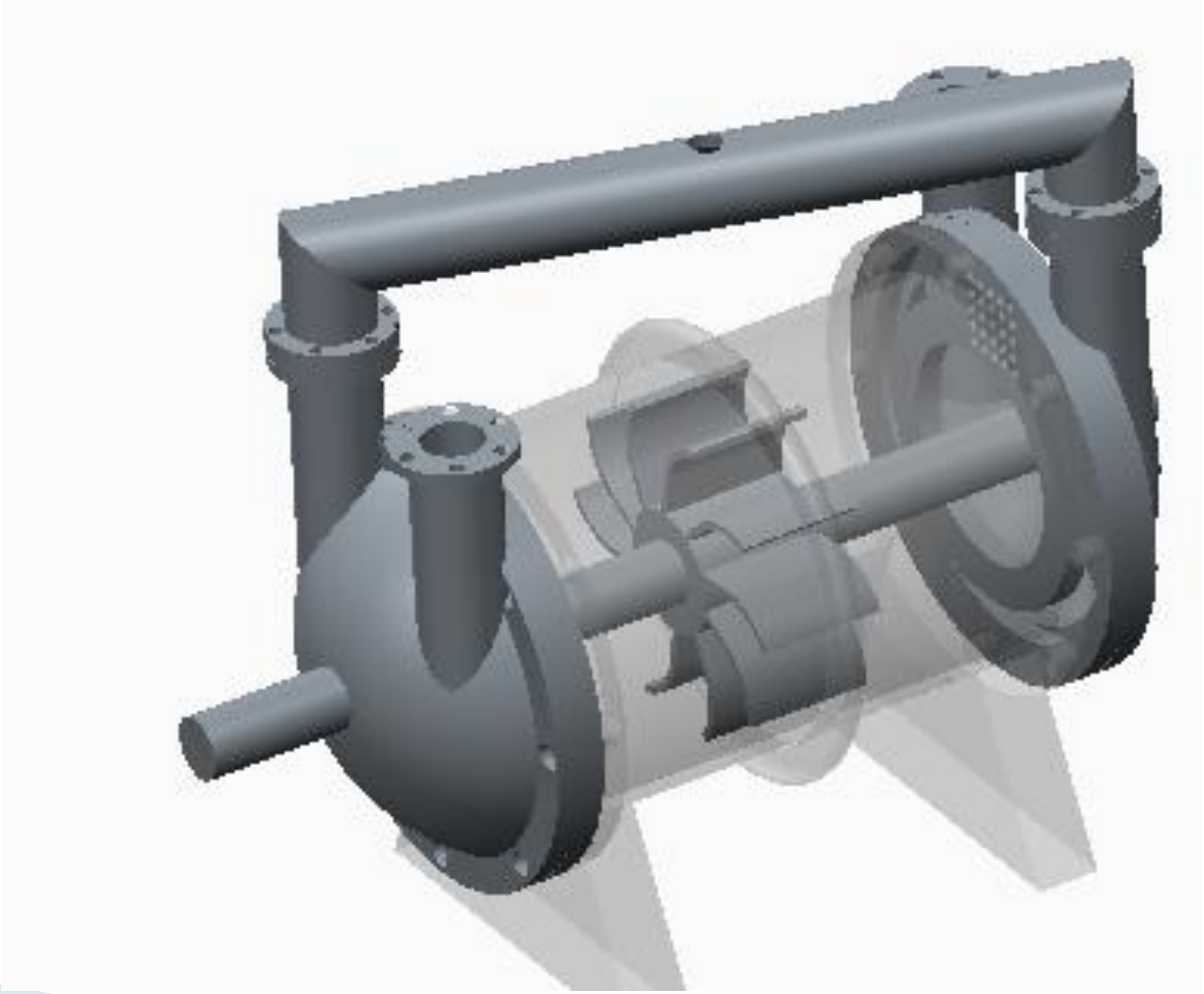




•**PUMP BODY**: It is covered the all parts of the pump and to provide the safety from dust, material, garbage etc. And helps to create the vacuum by preventing the air from leaking inside.



Modified Design of Pump



Calculation:-

1.) Free Air Delivery: - $\{(K\times T1)/P1\}\times\sqrt{H}\times\sqrt{(P_2/T)}\times 3.6$, M^3/Hr.

2.) Suction Capacity: - (F.A.D×100) / (100 - % of Vacuum), M^3 / Hr.

Here, K= Nozzle Constant

T_1= Absolute temp. Of free Air

P_1= Pressure of free air

P_2=Absolute pressure after nozzle

H= Pressure drop across nozzle

T=Absolute temp. Of air after nozzle

1.) **Free Air Delivery:-**

$$F.A.D = \{(K \times T1)/P1\} \times \sqrt{H} \times \sqrt{(P_2/T)} \times 3.6$$

$$= \{(118.41 \times 305.15)/752\} \times \sqrt{207} \times \sqrt{(736.41/298.15)} \times 3.6$$

$$= 3911.81\ M^3 / Hr.$$

2.) **Suction Capacity:-**

$$\text{Suction Capacity} = (F.A.D \times 100) / (100 - \%\text{ of Vacuum})$$

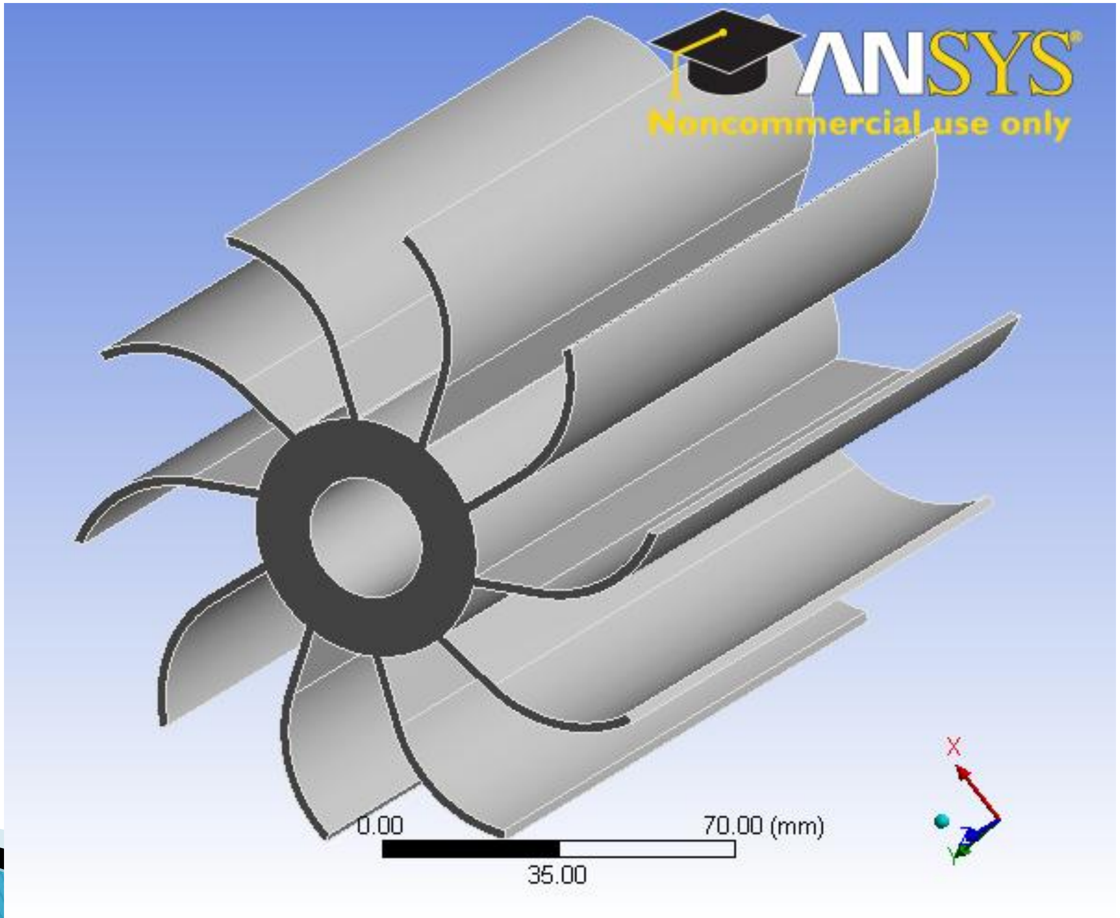
$$= (3911.81 \times 100) / (100 - 7.89)$$

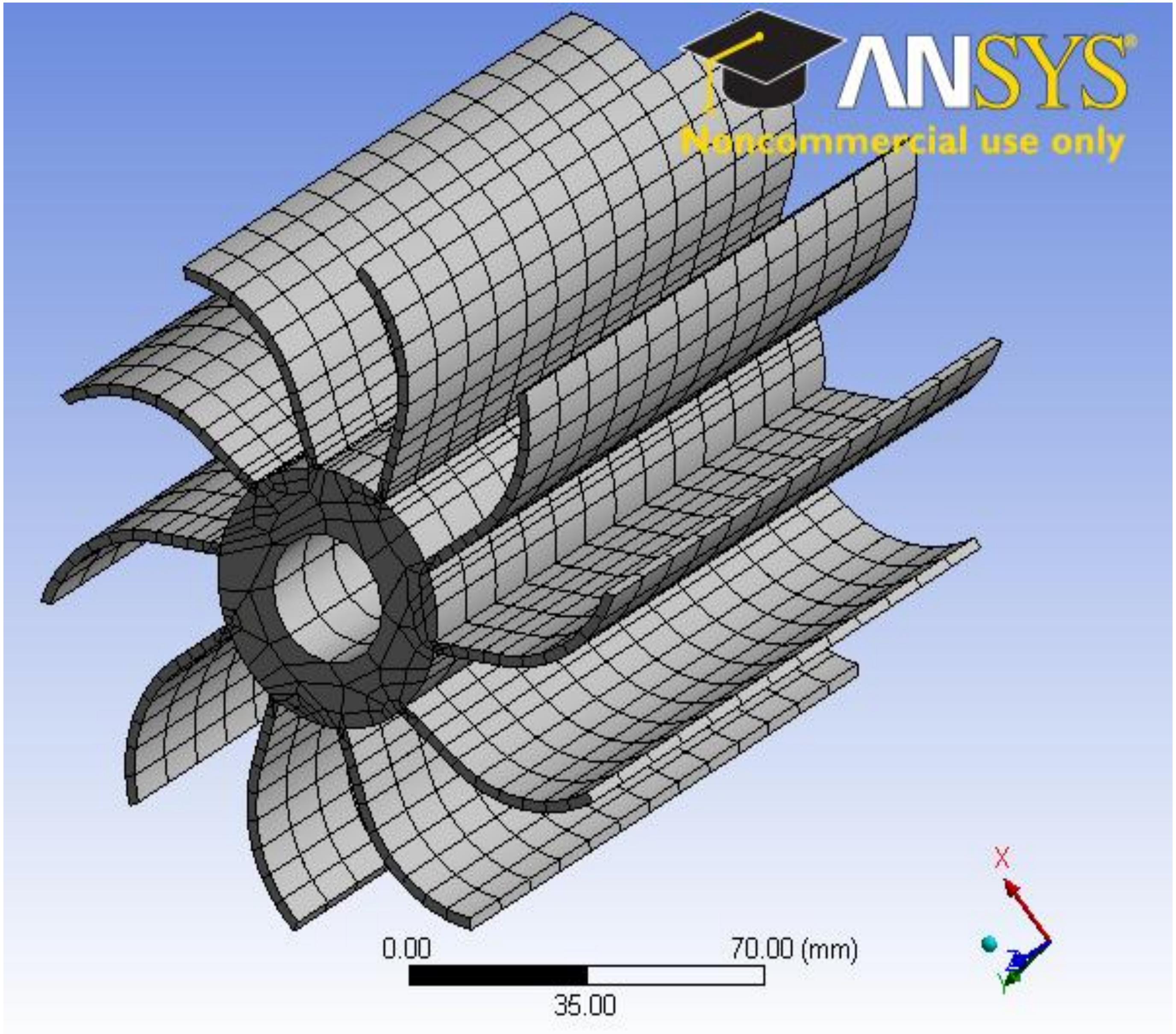
$$= 4246.79,\ M^3 / Hr.$$

Vacuum in MM of HG	Vacuum %	Current A	Volt V	H MM Wg.	h MM Wg.	F.A.D M^3 / Hr.	Capacity M3 / Hr.
60	7.89	120	420	207	212	3911.24	4246.49
100	13.16	138	420	170	175	3551.03	4089.07
200	26.32	160	420	135	138	3170.26	4302.49
500	65.79	272	420	77	80	2401.14	7018.73
700	92.11	262	420	0	0	0.00	0.00

Analysis:-

1. **ANALYSIS OF OLD IMPELLER:-**

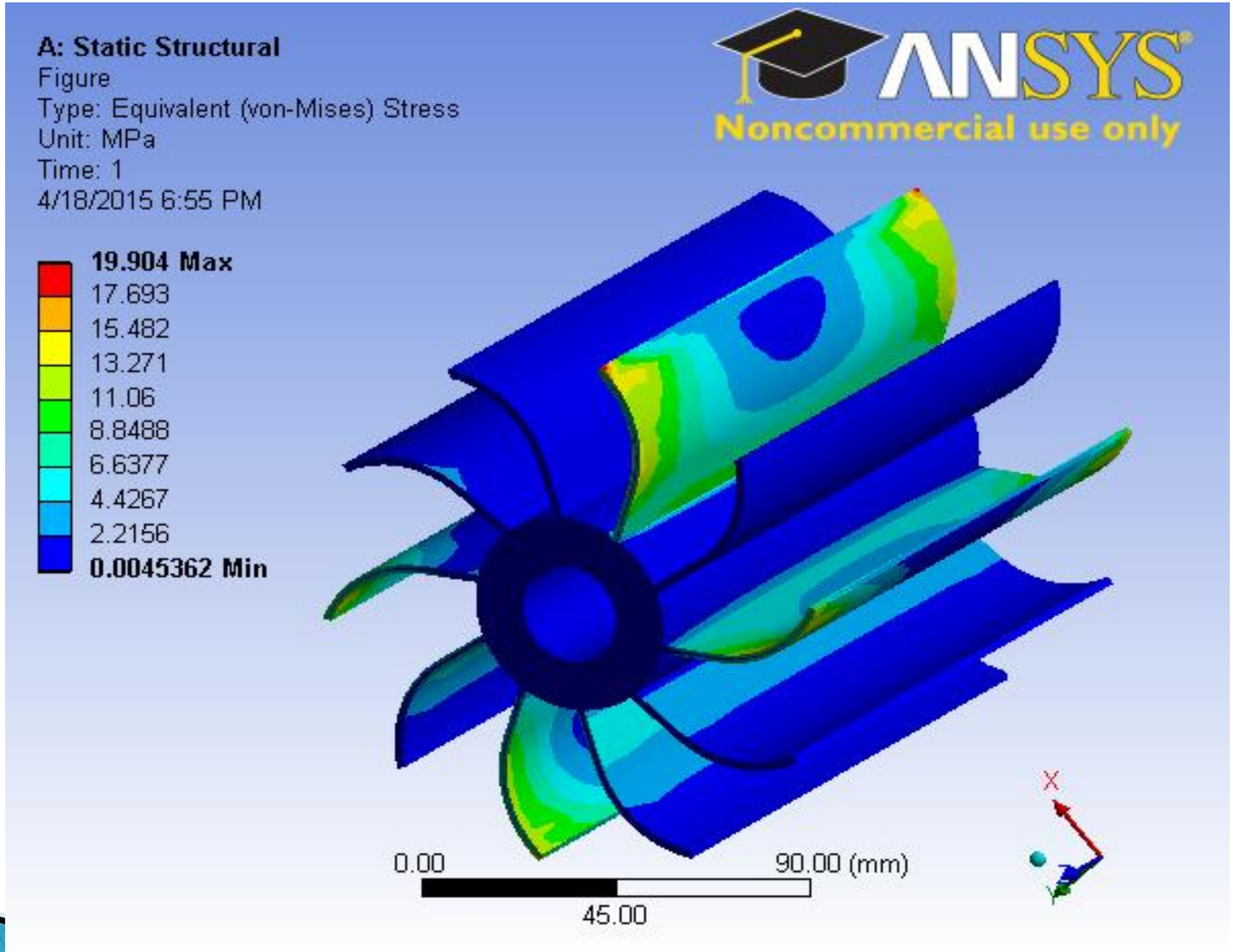




ANSYS
Noncommercial use only
0.00
70.00 (mm)
35.00
X
Y
Z

Static Structural (A5)

Object Name	***Static Structural (A5)***
State	**Solved**
Definition	
Physics Type	**Structural**
Analysis Type	**Static Structural**
Solver Target	**Mechanical APDL**
Options	
Environment Temperature	**22. °C**
Generate Input Only	**No**



A: Static Structural
Figure
Type: Equivalent (von-Mises) Stress
Unit: MPa
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19.904 Max
17.693
15.482
13.271
11.06
8.8488
6.6377
4.4267
2.2156
0.0045362 Min
ANSYS
Noncommercial use only
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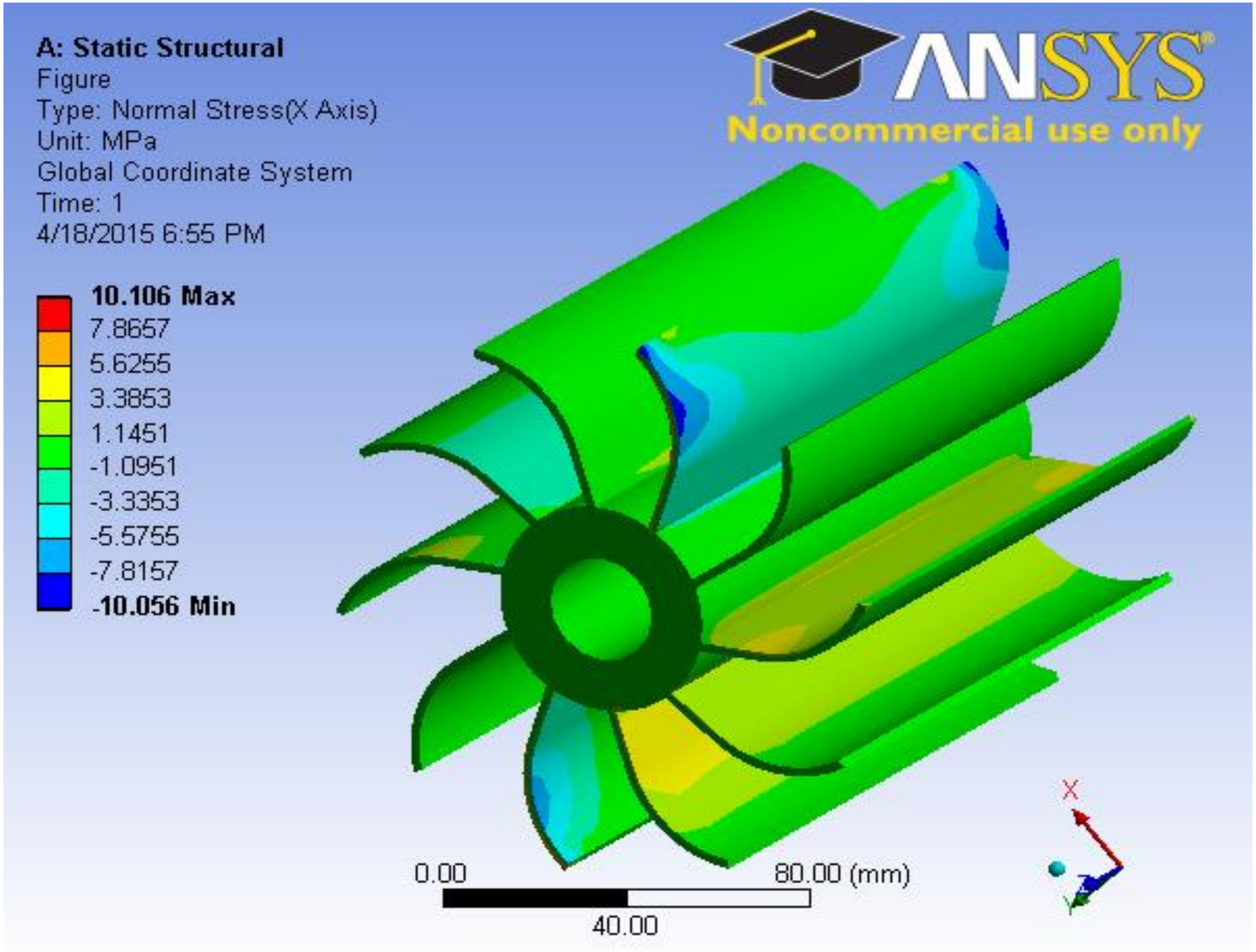
90.00 (mm)
45.00
X
Y


A: Static Structural
Figure
Type: Normal Stress(X Axis)
Unit: MPa
Global Coordinate System
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10.106 Max
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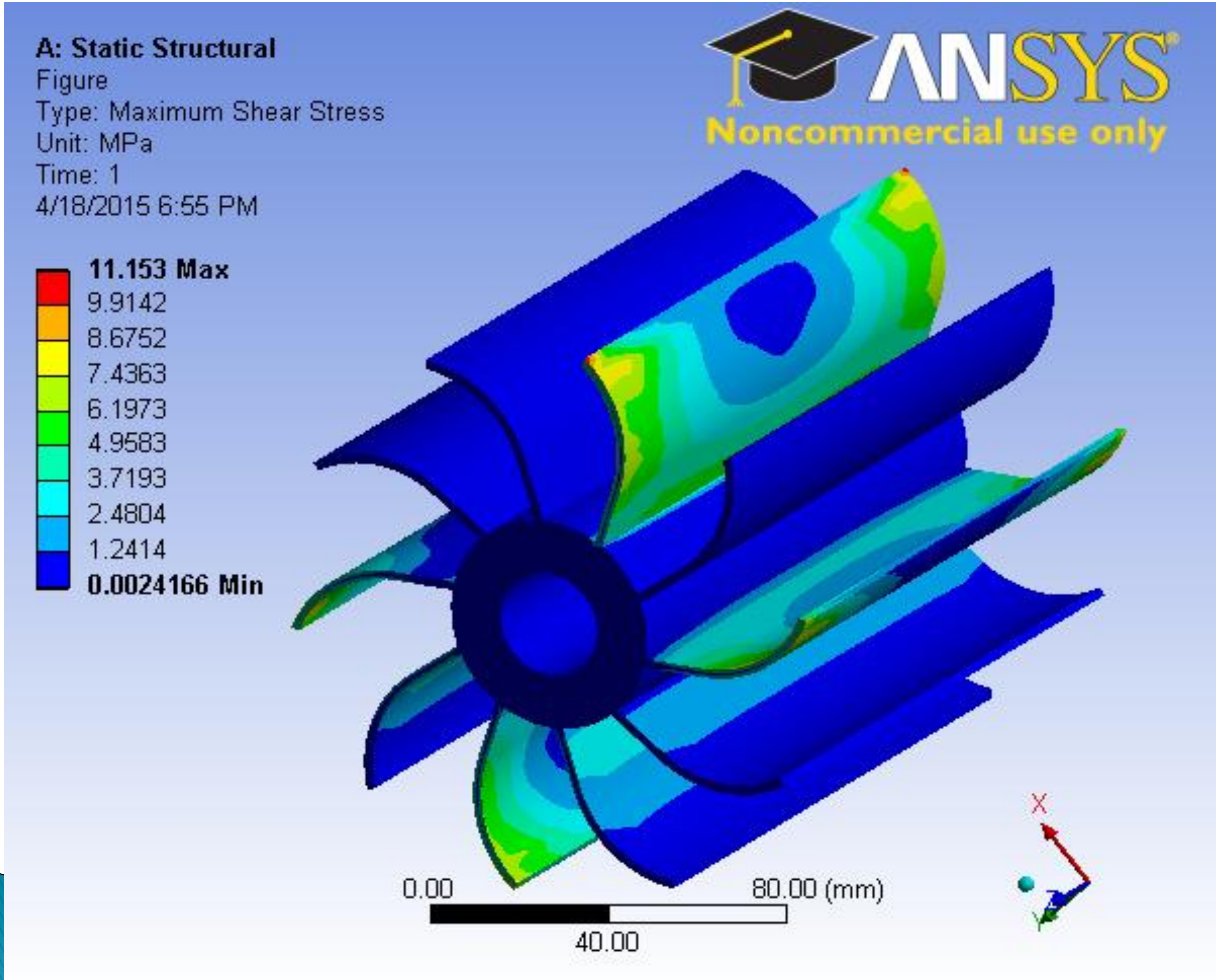
5.6255
3.3853
1.1451
-1.0951
-3.3353
-5.5755
-7.8157
-10.056 Min
ANSYS
Noncommercial use only
0.00
80.00 (mm)
40.00
X
Y


A: Static Structural
Figure
Type: Maximum Shear Stress
Unit: MPa
Time: 1
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4.9583
3.7193
2.4804
1.2414
0.0024166 Min
ANSYS
Noncommercial use only
0.00
80.00 (mm)
40.00
X
Y

Material Data:
Structural Steel

Density	7.85e-006 kg mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

Alternating Stress Mean Stress

Alternating Stress MPa	Cycles	Mean Stress MPa
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

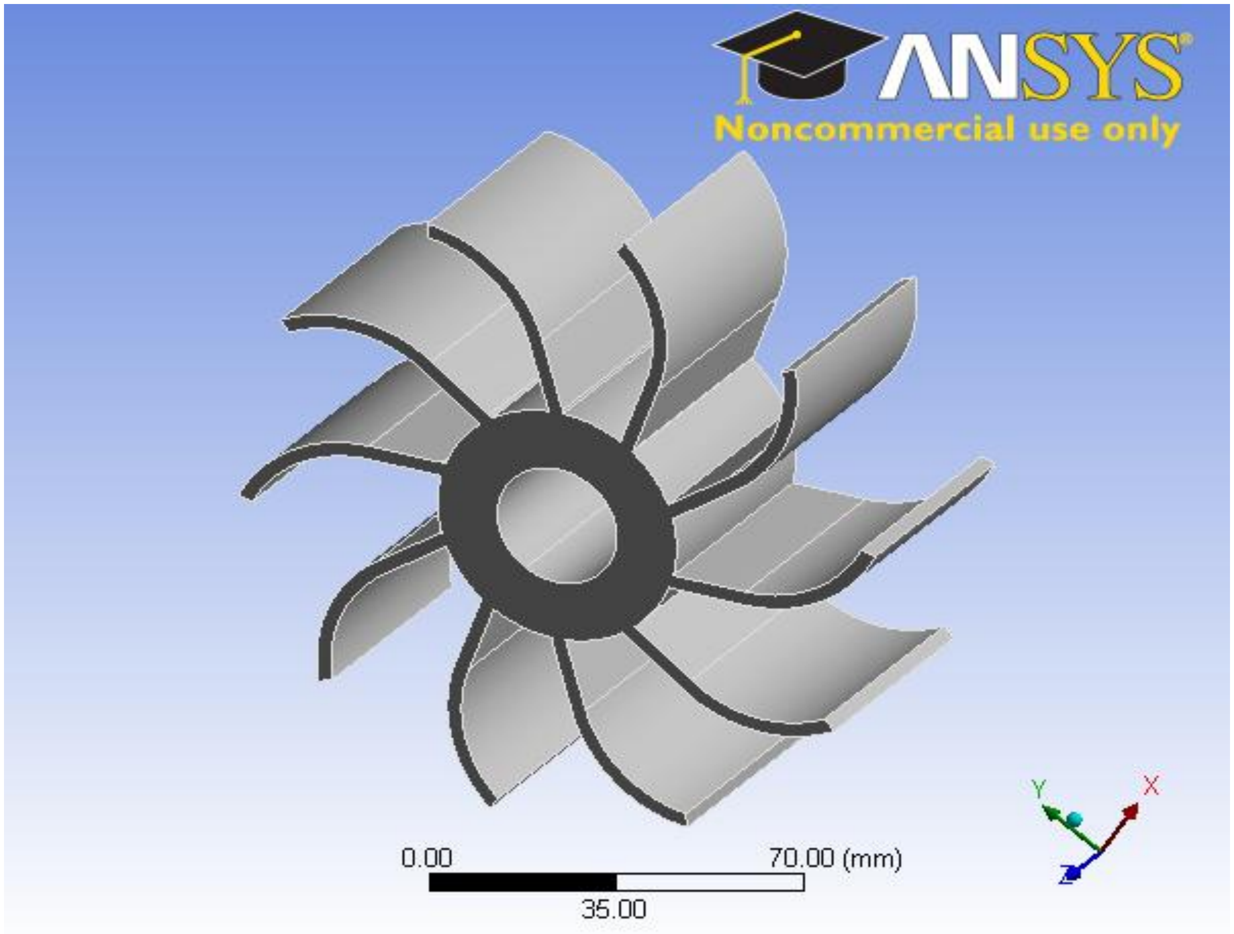
Strain-Life Parameters

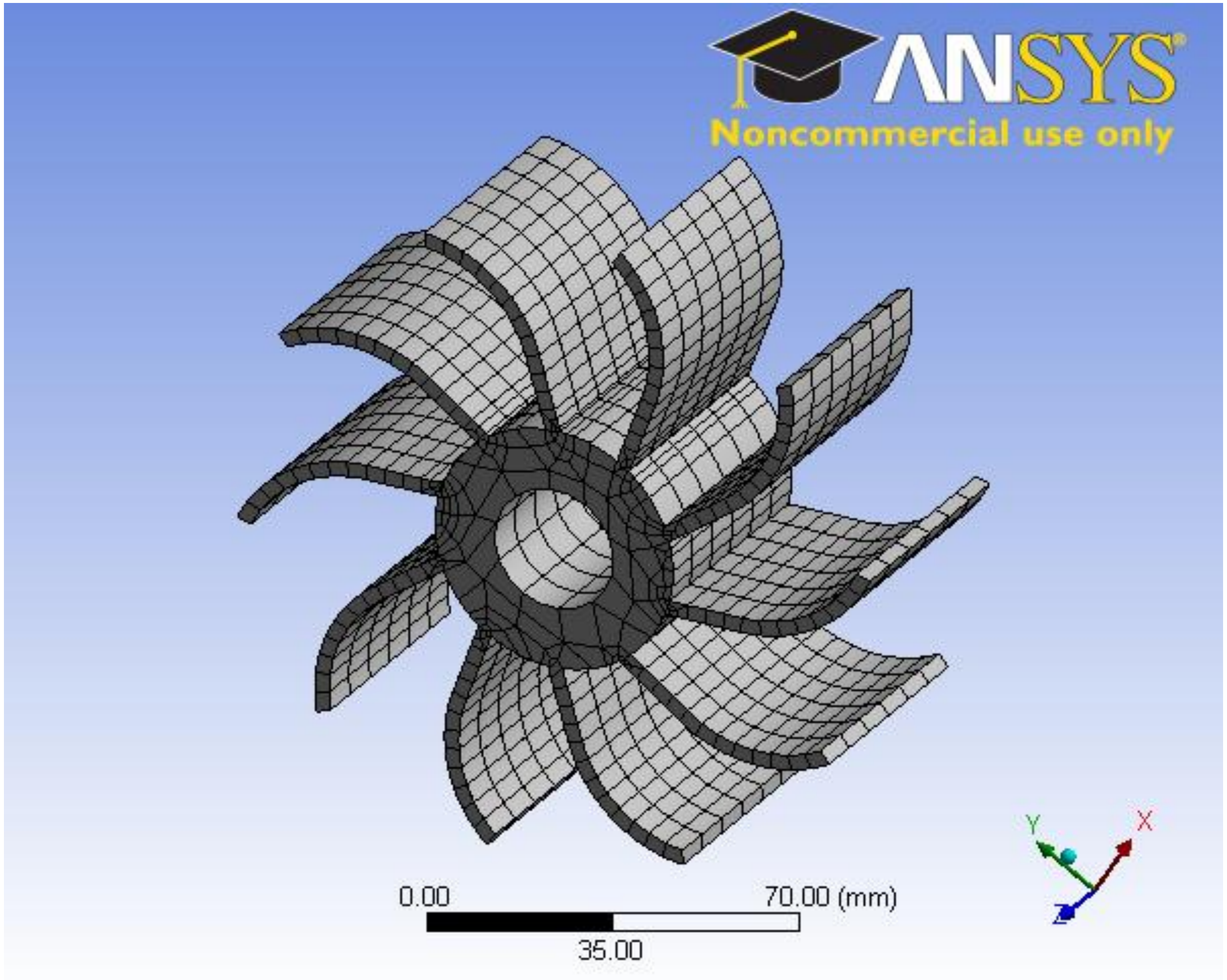
Strength Coefficient MPa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient MPa	Cyclic Strain Hardening Exponent
920	-0.106	0.213	-0.47	1000	0.2

Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	2.e+005	0.3	1.6667e+005	76923

ANALYSIS OF NEW IMPELLER:-




ANSYS
Noncommercial use only
0.00
70.00 (mm)
35.00
Y
X
Z

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Object Name	***Static Structural (A5)***
State	**Solved**
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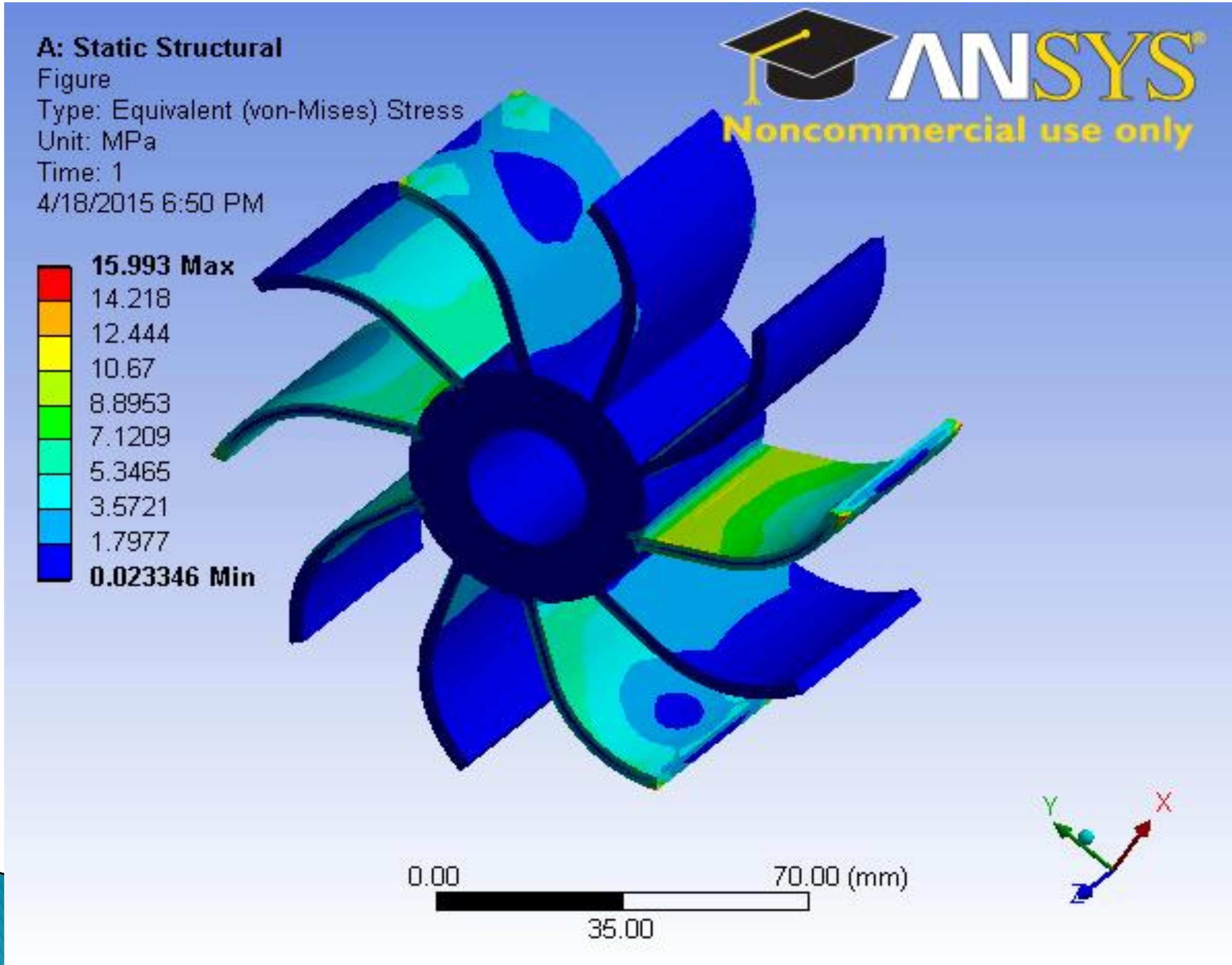

A: Static Structural
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Type: Equivalent (von-Mises) Stress
Unit: MPa
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12.444
10.67
8.8953
7.1209
5.3465
3.5721
1.7977
0.023346 Min
ANSYS
Noncommercial use only
0.00
70.00 (mm)
35.00
Y
X
Z

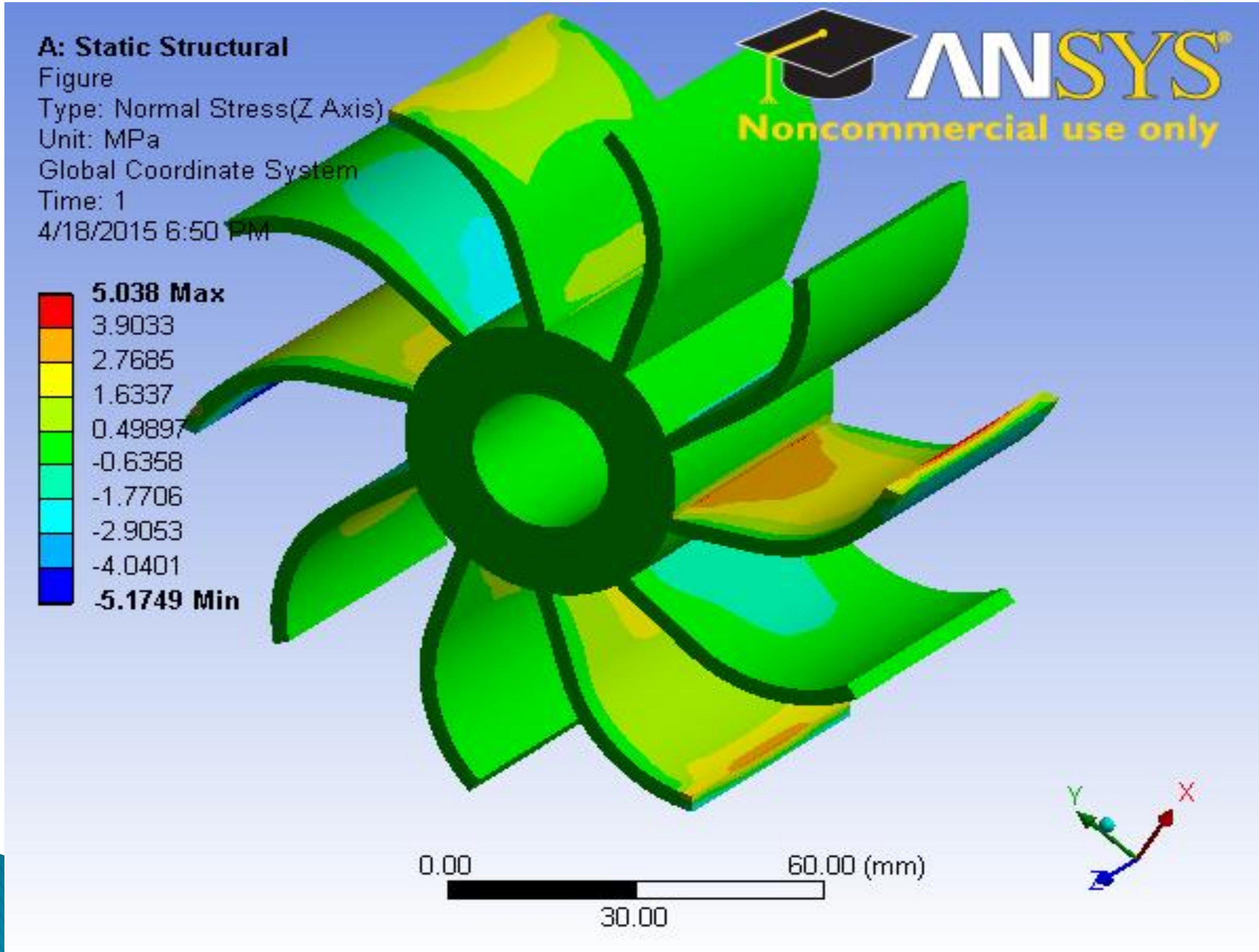
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Figure
Type: Normal Stress(Z Axis)
Unit: MPa
Global Coordinate System
Time: 1
4/18/2015 6:50 PM
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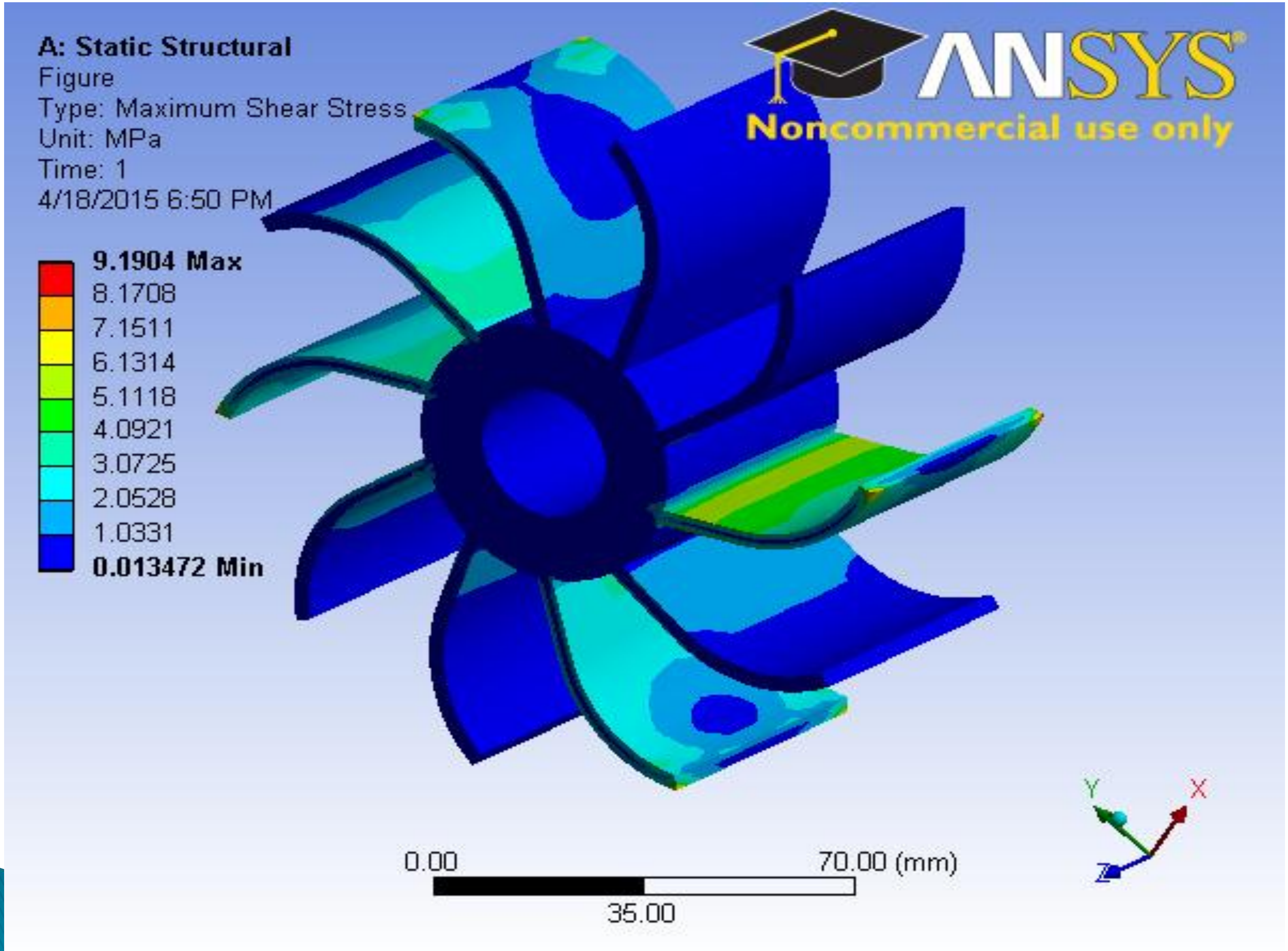
3.9033
2.7685
1.6337
0.49897
-0.6358
-1.7706
-2.9053
-4.0401
-5.1749 Min
ANSYS
Noncommercial use only
0.00
60.00 (mm)
30.00
Y
X
Z


A: Static Structural
Figure
Type: Maximum Shear Stress
Unit: MPa
Time: 1
4/18/2015 6:50 PM
9.1904 Max
8.1708
7.1511
6.1314
5.1118
4.0921
3.0725
2.0528
1.0331
0.013472 Min
ANSYS
Noncommercial use only
0.00
70.00 (mm)
35.00
Y
X
Z

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Conclusion:

- Form the above project we thoroughly studied various factors which affects pump performance. The factors includes Cavitations, Short term creation of vacuum, Leakage and corrosion in the material. We re-designed the pump parameters to increase the performance. By removing the splitter and re-designing the blades we can increase the performance but removing the splitter leads to higher leakage in the pump. In order to remove this cons we are trying to replace the conventional glance to seal. Further in near future we will change the blade material or apply coating to increase the corrosion resistance of eccentricity material and will use some other technique to remove the vacuum problem.

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