Effect and Flow Analysis of Turbine Blades in the Engine Turbocharger

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Abstract - *Turbocharger is a eminent component in automobile vehicle to increase their efficiency. Turbocharger forces compressed the air into engine. The Turbine wheel and Compressor wheel are designed in CATIA and fluid flow analysis is carried out to investigate pressure, velocity and turbulence for Wrought Aluminum Alloy and Mar-m-246 in ANSYS.*

Key Words*: *ANSYS, Blades, Computational Fluid dynamics, Compressor, flow analysis, Fluent, Turbocharger

1. INTRODUCTION

A Turbocharger is invented in 1905 by Alfred Buchi, a Swiss engineer working at Gebruder Sulzer. The engine needs more oxygen and fuel for efficient combustion. Before the invention of the turbocharger, the efficiency of the engine is less because the displacement of oxygen from the environmental air to the cylindrical engine chamber is less. So the combustion of the fuel is not much good.so the large-size engines are trying to use, but the replacement of the engine is not possible.

In 1905, AlfredBuchi had invented a component which is capable of compressing air, before getting into the inlet of the engine. When the aircraft is flying above the sea level the horsepower of the craft engine is reduced. To attain the same horse at the sea level while fly above the sea level, it is called turbo normalizing. When the horsepower is increased above the normal level (horsepower at the sea level) is called turbocharging.

After the combustion gets completed, the exhaust gas is used to rotate the impeller of the turbine. Due to this rotation of the turbine, the compressor also rotates. Since, both the impeller and turbine are coupled together. Hence this kinetic energy is used for the suction of atmospheric air in the environment. Therefore, it increases the efficiency of the engine.

1.1 TYPES OF TURBOCHARGER

There are many different types of turbocharger used within the automotive industry:

1. Single-Turbo.
2. Sequential -Turbo.
3. Twin-Scroll Turbo.
4. Variable Geometry Turbo.
5. Variable Twin Scroll Turbo.
6. Electric Turbo.

2. Material Consideration

The most common material for turbocharger compressor wheels has been aluminum alloys. Other materials, introduced since the 1990s, include titanium alloys, as well as magnesium and stainless steel alloys. As by the process, four major compositions were detailed Mar-M246, Air, CO2, and Wrought Aluminium Alloy 2011. The turbine doesn't require any contact seals. Therefore, the process of the turbine with non-lubricated compressed air is free from wear. Continuous-flow machines optimally utilize the energy of the compressed air so the air requirement of a turbine motor is 1/3rd less when compared to a pneumatic vane motor. The power to weight ratio [kg/kW] is only half. Mar-M246 and Mar-M247 are considered for the wheels exposed to high temperatures which are used in the turbine wheels to withstand the high-temperature exhaust gas. Mar-M247 is often chosen for the very high-temperature applications where temperatures briefly exceed 1080oC. Mar-M246 is suitable for intermediate applications.

Turbocharger turbine blades have to withstand high temperatures, especially in gasoline applications. Common turbine wheel materials include nickel-based superalloys and titanium alloys.

3. CAD Modelling

In modeling the component for the analysis, the turbine wheel and compressor wheel are modeled as per the standard specifications.

3.1 Modelling of Compressor Wheel

The solid model is designed in the CAD software CATIA, which is owned by the Dassault System. The impeller of the turbocharger we designed is a shaft outer diameter of 8.084mm, an inner diameter of 4.46mm and the total length is 32.4mm, and each impeller blade thickness is 0.81mm 11 blades equally aligned. These impeller blades were designed to withstand the density, thermal conductivity, viscosity, and specific heat capacity.

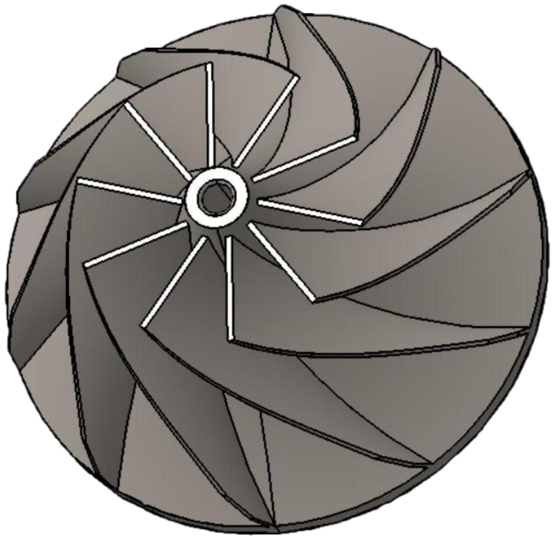

Fig1. Compressor Wheel

3.2 Modelling of Turbine Wheel

The impeller of the turbocharger we designed is a shaft outer diameter of 31mm, the inner diameter of 15.8mm, and the total length is 68mm, and each impeller blade thickness is 0.86mm total of 11 blades equally aligned. These impeller blades were designed to withstand the density, thermal conductivity, viscosity, and specific heat capacity.

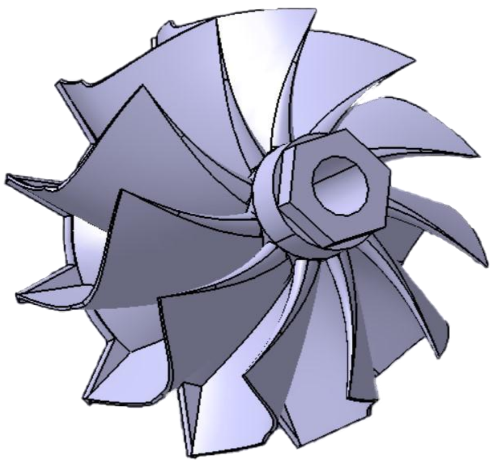

Fig2. Turbine Wheel

4. Fluid Flow Analysis

The finished model is converted into a suitable format for the analysis software like (stp, igs, step). Here the analysis is carried out in the ANSYS Fluent (Fluid flow analysis)

4.1 Analysis of Compressor Wheel

The IGS format of the turbocharger compressor wheel is imported into ANSYS Fluid Flow (Fluent) as shown in figure 3. After importing, the design file was open from Geometry Design Modeller. After that the enclosure type is defined, in this analysis box type is used.

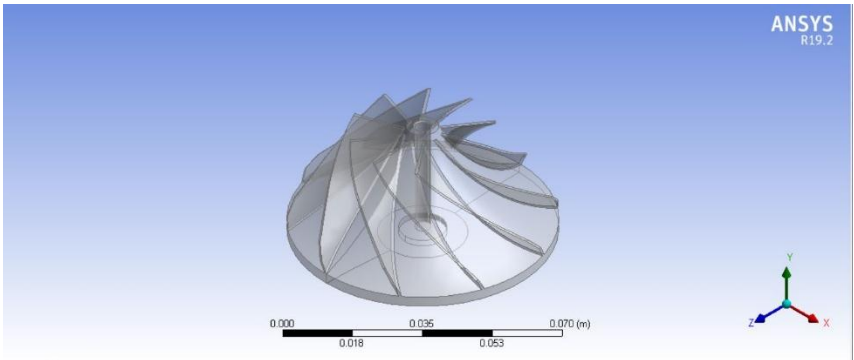

Fig3. Model imported in the ANSYS

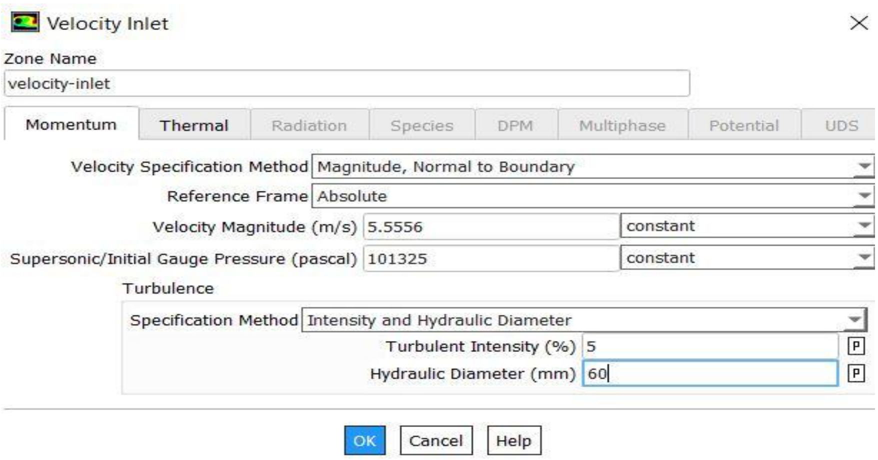

Fig4. Velocity conditions at the inlet

After the enclosure, meshing is performed. Here the mesh size is about 2mm and an adaptive mesh sizing. Then, the boundary conditions are given the faces to be exposed to velocity inlet and outlet, Pressure inlet, and outlet.

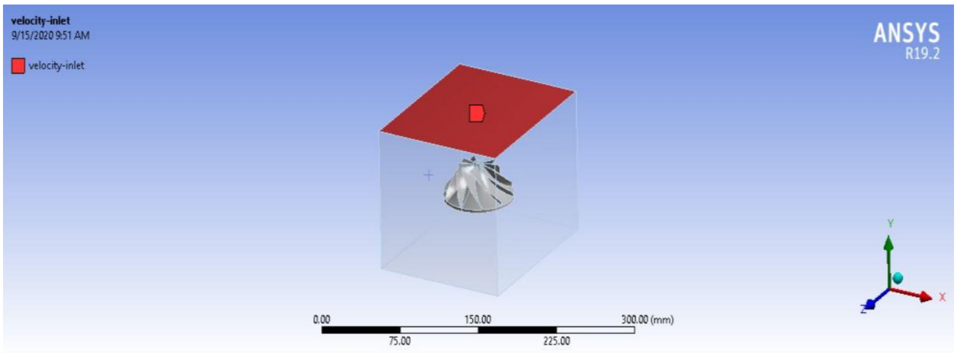

Fig6. Velocity at the inlet

Here the flow type is of laminar to turbulence by Reynolds number formula. The initial value is assumed ad the 20Km/hr as the car speed and the pressure is about 1 bar, the inlet temperature is of 300K. Finally the material is applied like fluid and solid.

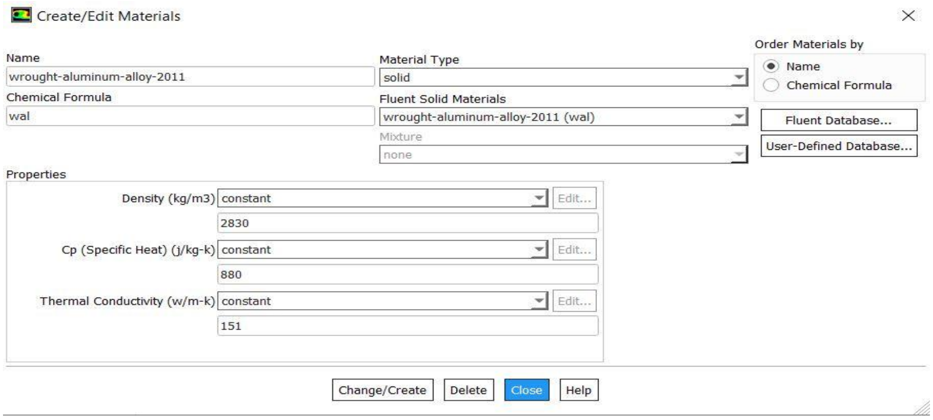

Fig7. Material Properties of Wrought Aluminum alloy

4.2 Analysis of Compressor Wheel

The analysis for the turbine wheel procedure is the same as the compressor wheel procedure above shown. The things change after in turbine wheel in solution setup. The condition of the turbine wheel is the same as the boundary conditions of the compressor wheel above seen.

In that velocity bar, the velocity value was given as 3.375 m/s because now we considering the car moving speed of 20 km/hr according to the unit consistency of the compressor wheel to the turbine wheel. The atmospheric pressure of air is given in pressure bar 101325 Pascal then inlet temperature is taken as 693k in the thermal bar and close it. As same in the velocity-outlet dialogue box there you can just give outlet pressure that is the same as atmospheric pressure.

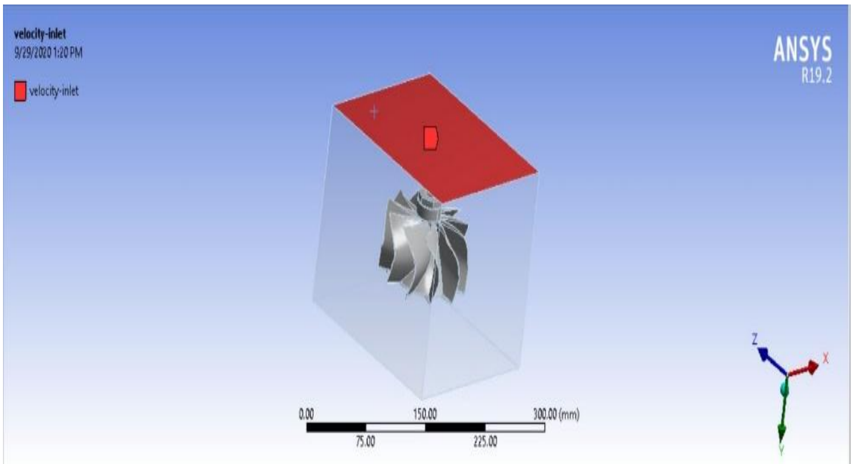

Fig8. Velocity at the inlet of the compressor

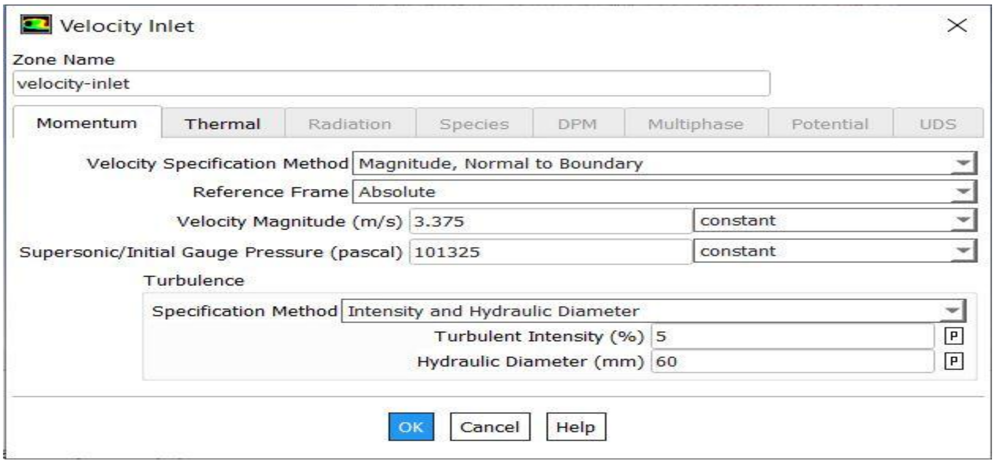

Fig9. Velocity conditions at the inlet for the compressor

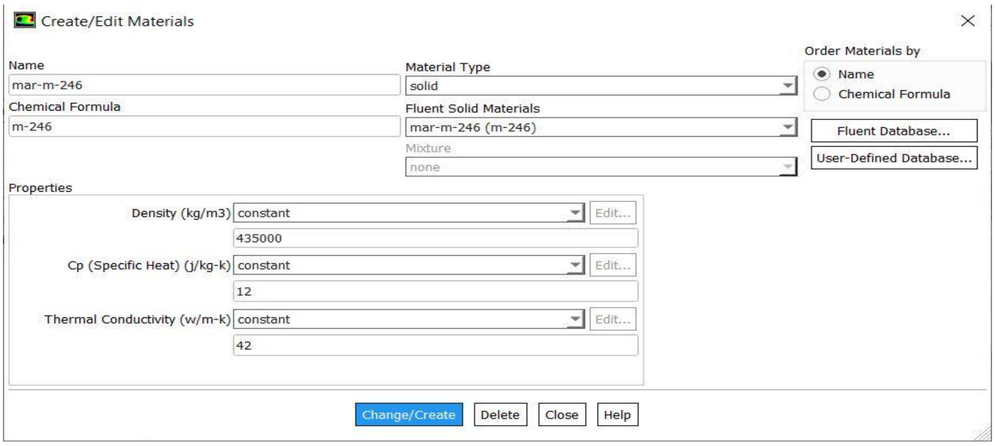

Fig7. Material Properties of Mar-m-246

5. Result and Discussion

5.1Compressor Wheel

After the analysis is completed, post-processing is done. The output values are obtained compared with each other. The figure shows a comparison between the values.

5.1.1 Scaled Residuals

Fig shows the scaled residuals on the turbocharger compressor wheel for Computational fluid dynamics and for the material wrought aluminium alloy 2011.

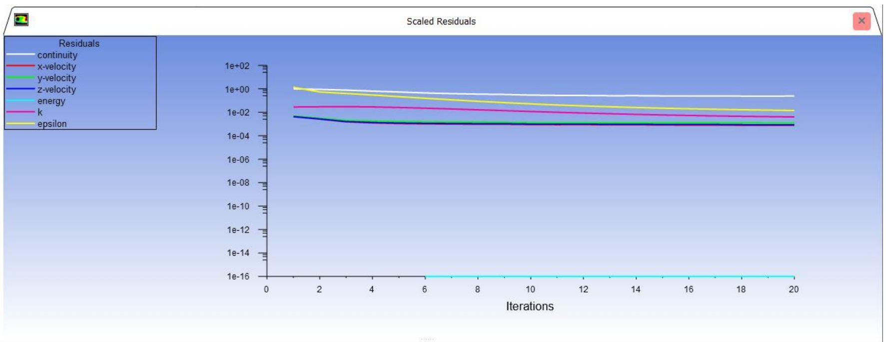

Fig8. Scaled Residuals of Wrought aluminum alloy

5.1.2 Pressure Contours

Figure shows pressure contour on the turbocharger compressor wheel for Computational fluid dynamics and for the material wrought aluminium alloy 2011.

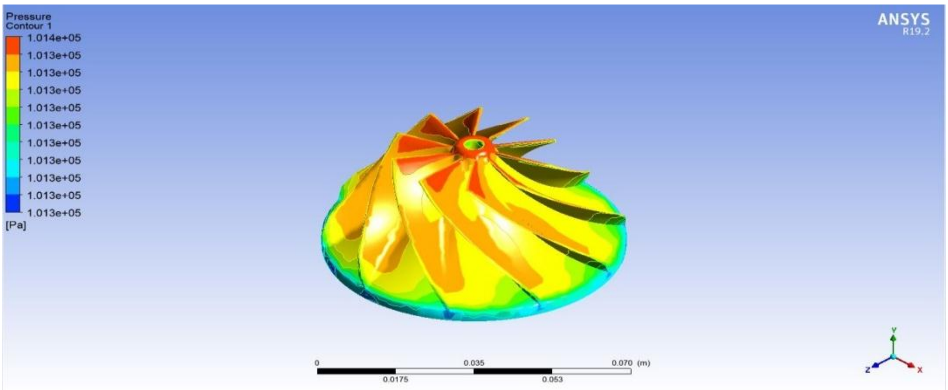

Fig9. Pressure contour

5.1.3 Velocity Contours

Figure shows the velocity contour on the turbocharger compressor wheel for Computational fluid dynamics and for the material wrought aluminium alloy 2011

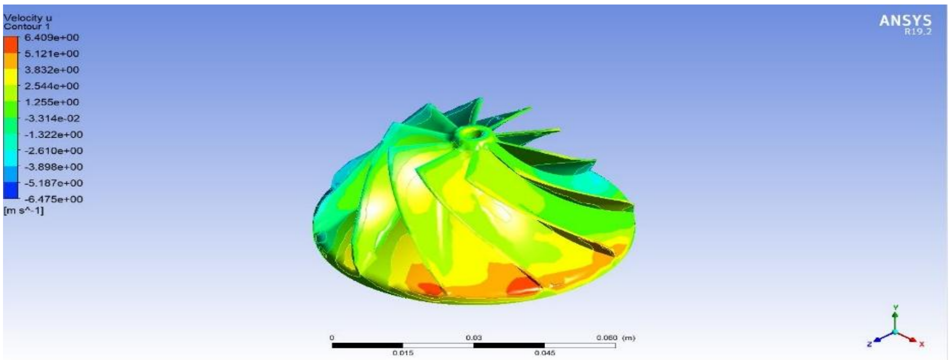

Fig10. Pressure contour

5.1.4 Turbulence Kinetic energy

Figure shows the turbulence kinetic energy on the turbocharger compressor wheel for Computational fluid dynamics and for the material wrought aluminium alloy 2011.

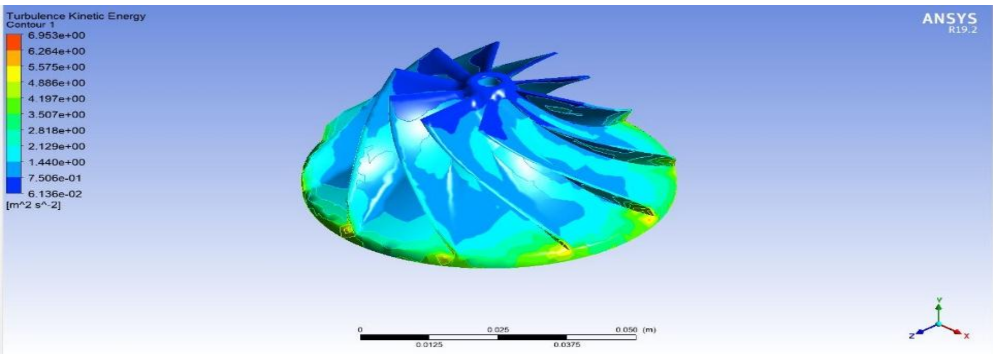

Fig11. Kinetic Energy

5.2 Turbine Wheel

After the analysis is completed, post-processing is done. The output values are obtained compared with each other.

5.2.1 Scaled Residuals

Figure shows the scaled residuals on the turbocharger turbine wheel for Computational fluid dynamics and for the material Mar-m-246.

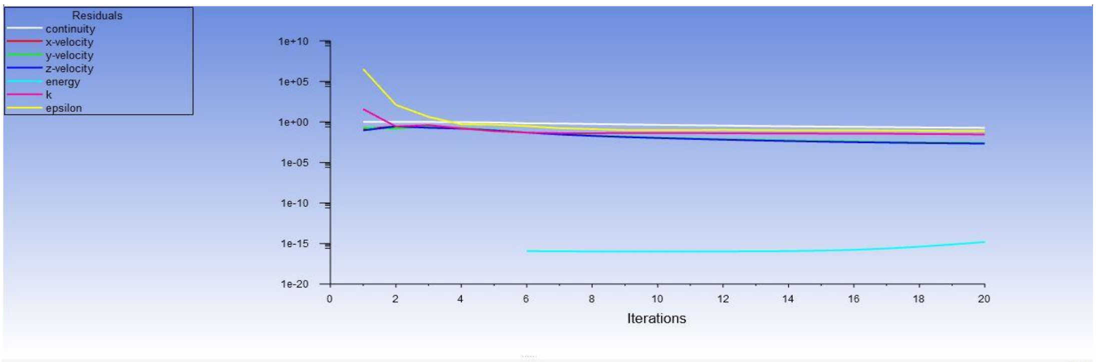

Fig12. Scaled Residuals of Mar-m-246

5.2.1 Pressure Contour

Figure shows pressure contour on the turbocharger turbine wheel for Computational fluid dynamics and for the material Mar-m-246.

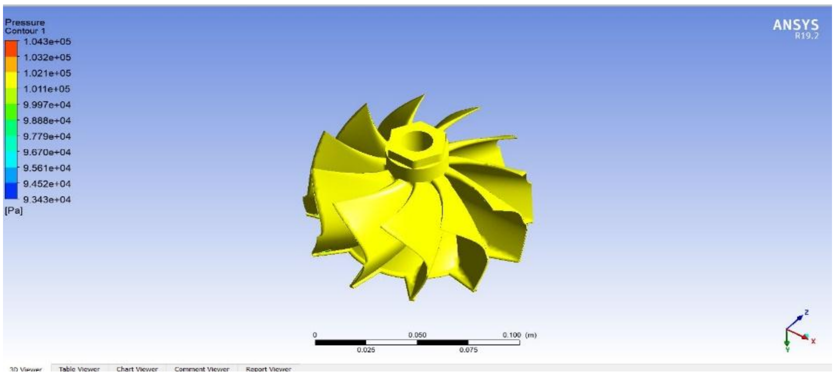

Fig13. Pressure Contour of Mar-m-246

5.2.2 Velocity Contour

Figure shows the velocity contour on the turbocharger turbine wheel for Computational fluid dynamics and for the material Mar-m-246.

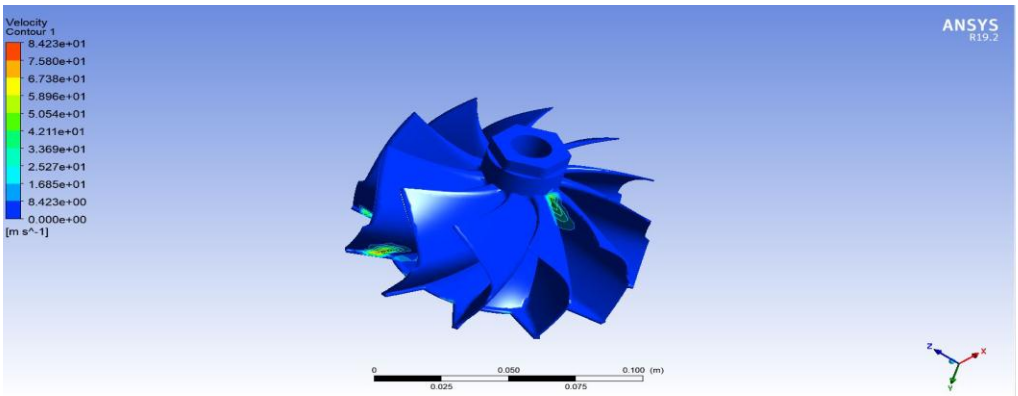

Fig13. Velocity Contour of Mar-m-246

5.2.3 Turbulence Kinetic energy

Fig shows the turbulence kinetic energy on the turbocharger compressor wheel for Computational fluid dynamics and for the material Mar-m-246.

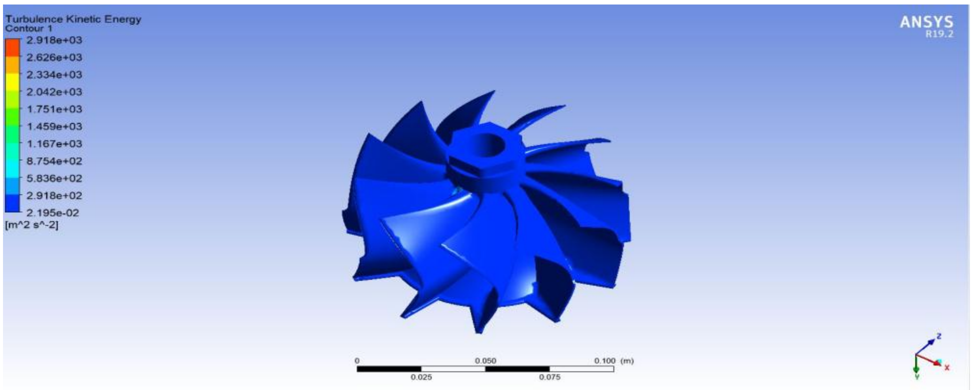

Fig14. Kinetic Energy

Table -1. Comparison between the results

Parameters	Wrought Aluminum Alloy	Mar-m-246
Pressure	101356 Pa	104326 Pa
Velocity	9.56254 m/s	84.2255 m/s
Velocity U	6.40907 m/s	71.6254 m/s
Velocity V	2.95743 m/s	43.0648 m/s
Velocity W	6.29250 m/s	26.5760 m/s
Turbulence Kinetic Energy	6.9533 m^2/s^2	2917.81 $^2/s^2$

6. Conclusion

From the above analysis, the outcome acquired is evident that materials wrought aluminum alloy 2011, Mar-m-246 are best to use in the turbocharger compressor wheel and turbine wheel respectively. The study is carried out in the Ansys fluent software, and the modeling is done by the Catia software. The analysis provides that it is the best combination to apply the material.

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