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The influence of the guide vane angle of the turbocharger on the turbine mechanical properties and flow field characteristics

The influence of the guide vane angle of the turbocharger on the turbine mechanical properties and flow field characteristics

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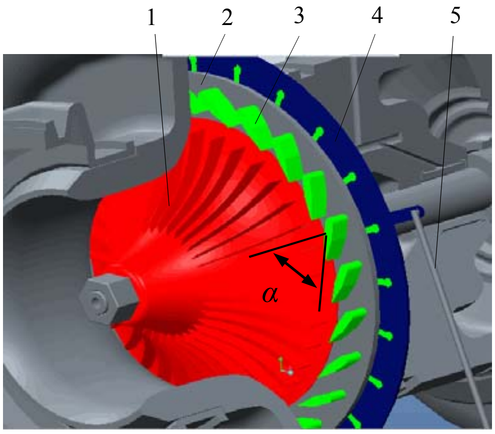
Abstract. Turbocharged gasoline engines produce less exhaust gas when running at a low speed, which is not enough to make the turbine rotor run at a high speed and press in enough air. By changing the cross-section area of the exhaust gas inlet and controlling the gas flow velocity, the turbine can achieve a larger rotation speed with less exhaust gas. Croe2.0 3D software was used to build the 3D model of the adjustable turbine device. ANSYS software is used to analyze the stress of turbocharger turbine. By adjusting the gas flow rate, the adjustable turbine device can significantly change the numerical value of the turbine force, which improves the problems faced by turbocharging engine at low speed and provides theoretical basis for the adjustable turbocharging technology.

1. Introduction

Turbocharging control technology has been applied in engine intake system [1-3]. In order to improve its performance, many scholars have done extensive research on relevant technologies. Fei Wang matched small displacement gasoline engine with turbocharger [4]. Huan Chen established a gas path prediction model for turbocharged gasoline engines [5]. Zucheng Li studied the numerical simulation method of turbocharging performance matching of direct injection gasoline engine in three-line working conditions [6]. In fact, reducing the size of turbocharged turbine can improve the hysteresis of turbocharged engine. A small turbine will have a small moment of inertia. Therefore, when the engine is running at a low speed, the turbine can reach the optimal working speed. Thus, turbine hysteresis can be effectively improved. However, when the engine is at a high speed, the exhaust resistance of small turbines will increase due to the small exhaust cross section. The maximum power and torque of the engine will be affected to some extent. However, for large turbines with low backpressure, although the pressurization effect is better at high speed, the engine will have a stronger dynamic performance. However, it is difficult to drive the turbine at low speed, and the turbine hysteresis is obvious. The turbocharger with variable cross-section can guarantee the optimal charging efficiency under different engine speed conditions, thus improving the low-speed intervention performance of the turbocharger and its responsiveness to engine speed, effectively improving the reliability and service life of the turbocharger and improving the engine emissions. This paper studies the influence of different angle of supercharger flow guide blade on turbine stress, and discusses the pressure and velocity change of turbine flow field when supercharger flow guide blade has different angle.

2. Variable Section Turbocharging Mechanism

Figure 1 shows the variable section turbocharging mechanism, which mainly includes turbine, guide vane control rod, fixed plate, guide vane, control disc and so on. The blade control rod and the control disk cooperate with each other through clamping slots on the disk, and the disk can drive the control rod to rotate. Therefore, the control rod can drive the guide vane to rotate and change the angle, so as to realize the control of exhaust gas velocity. When the system works, the control disc drives the blade control rod to rotate, and the blade control rod drives the guide blade to rotate. The exhaust gas will be sent to the turbine blade along the guide blade. The flow rate and velocity of the gas flowing through the turbine blade are controlled by adjusting the angle of the guide blade, so as to control the turbine speed. When the engine speed is low, low exhaust pressure, the guide vane opening angle is small. According to the principle of hydrodynamics, the flow rate of air entering the turbine will speed up at this time, increasing the pressure at the turbine and making it easier to push the turbine to rotate, thus effectively reducing the hysteresis of the turbine and improving the response time and acceleration ability at low speed of the engine. With the increase of rotating speed and exhaust pressure, the angle of guide vane increases gradually. Under full load, the guide vane remains fully open, reducing the exhaust back pressure, which is equivalent to the supercharging effect of large turbines.At the same time, the turbine speed can be effectively controlled by changing the guide vane angle α.



1- Turbine, 2- fixed plate, 3- guide vane, 4- control disc, 5- control rod

Figure 1. Variable section turbocharging mechanism

3. Static Analysis

Figure 2 shows the three-dimensional model of the turbine, which is relatively simple, because some process structures are processed in the modeling process, and rounded corners and chamfering angles are omitted. Grid partitioning is shown in figure 3. The turbine is made of aluminum alloy. The modulus of elasticity is 0.71×10^5 MPa. Poisson's ratio is 0.33. Density is 2.81×10^3 kg•m^{-3}. When the guide vane Angle of 30°, 40°, 50°, 60°, the equivalent stress is shown in figure 4. The maximum equivalent stress is 98.8Mpa. The allowable stress of aluminum alloy is about 350Mpa, and the safety coefficient is 3.5, which meets the strength requirements.

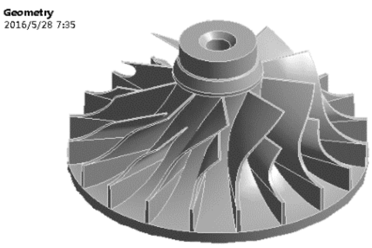


Figure 2. 3D model

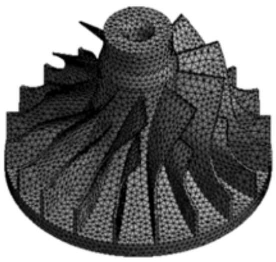
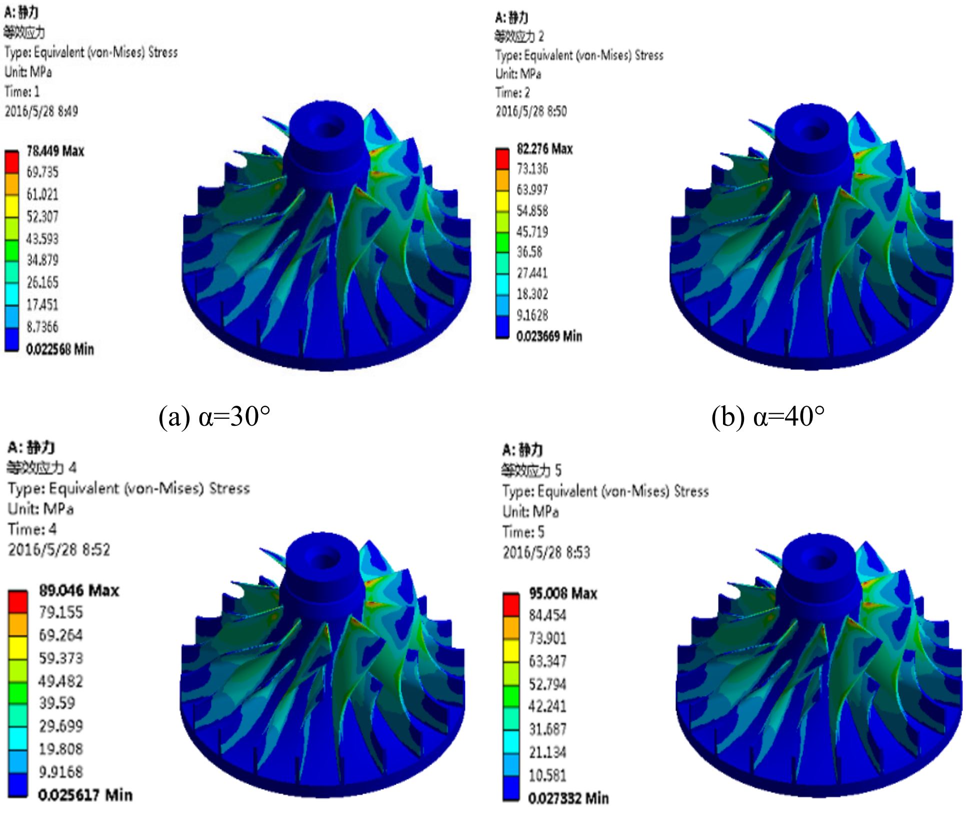


Figure 3. Mesh division



(a) α=30° (b) α=40°

(c) α=50° (d) α=60°

Figure 4. Stress diagram

4. Fluid Analysis

4.1. Gas Model

Because the actual gas model has four sharp edges, which is not conducive to mesh division and calculation, the gas model is simplified. According to the turbine inlet size, the inlet length of the gas model is taken as the length of the gas model. The front side of the gas model is the internal wall of the volute; the convex side is inside the gas model; the back side of the gas model is the hub of the turbine; and the concave side is inside the gas model. By adjusting the angle of the guide vane, the cross-sectional area of the gas entering the turbine can be adjusted, so as to control the speed of the impeller. In order to reduce the calculation amount, only one gas model with nozzle was selected for analysis, as shown in figure 5. Grid partitioning is shown in figure 6.

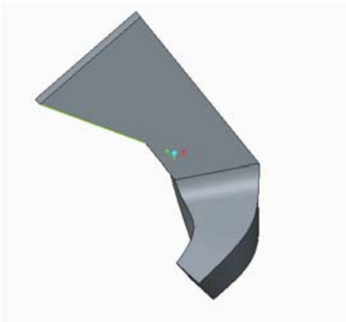


Figure 5. Gas model with nozzle

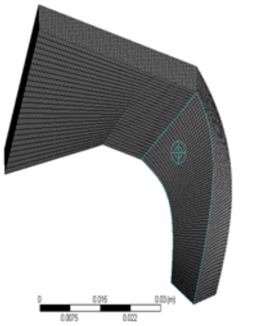
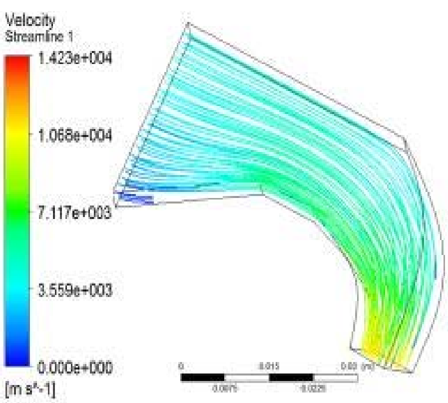


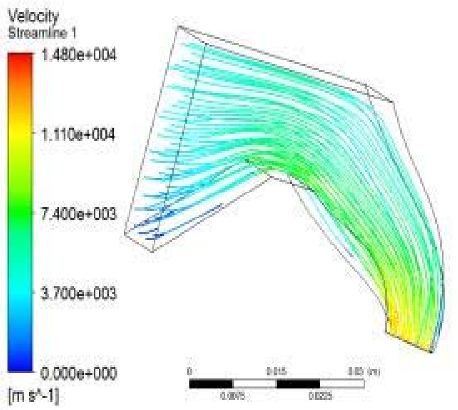
Figure 6. Mesh division

4.2. Result and Discussion

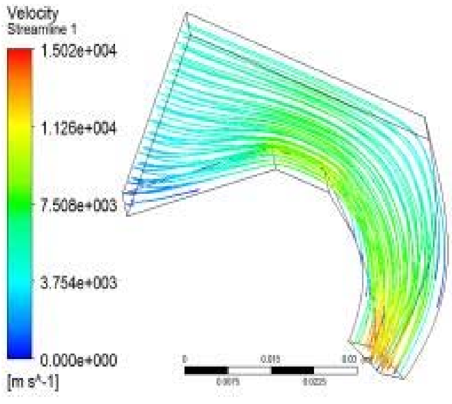
Figure 7 shows the flow velocity diagram obtained after analysis. Figure 7 (a) show peak flow rate is 1.423×10^4 m•s-1 when the guide vane angle is 30°. Figure 7 (b) show peak flow rate is 1.48×10^4 m•s^{-1} when the guide vane angle is 40°. Figure 7 (c) show peak flow rate is 1.502×10^4 m•s^{-1} when the guide vane angle is 50°. Figure 7 (d) show peak flow rate is 1.666×104 m•s^{-1} when the guide vane angle is 60°. Therefore, as the angle of guide blade increases, the maximum velocity of gas flow increases and the impact force on the right blade increases.



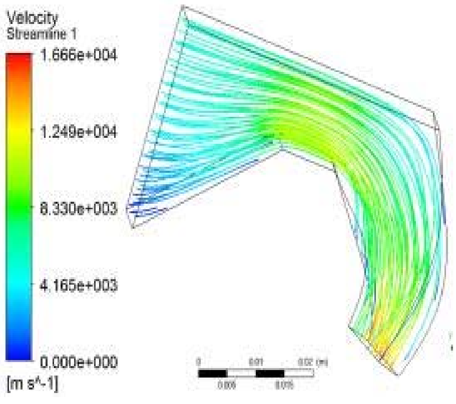
(a) α=30°



(b) α=40°



(c) α=50°



(d) α=60°

Figure 7. Gas velocity diagram

Figure 8 shows the pressure cloud diagram obtained after analysis. Figure 8 (a) show maximum pressure is 1.08×10^{8} Pa when the guide vane angle is 30°. Figure 8 (b) show maximum pressure is 1.061×10^{8} Pa when the guide vane angle is 40°. Figure 8 (c) show maximum pressure is 1.062×10^{8} Pa when the guide vane angle is 50°. Figure 8 (d) show maximum pressure is 1.062×10^{8} Pa when the guide vane angle is 60°. Therefore, as the angle of the guide vane increases, the maximum pressure of the flow increases. As the allowable stress of aluminum alloy is about 350Mpa, the safety factor calculated according to the highest air flow pressure 1.063×10^{8}Pa is 3.3, which meets the strength requirements.

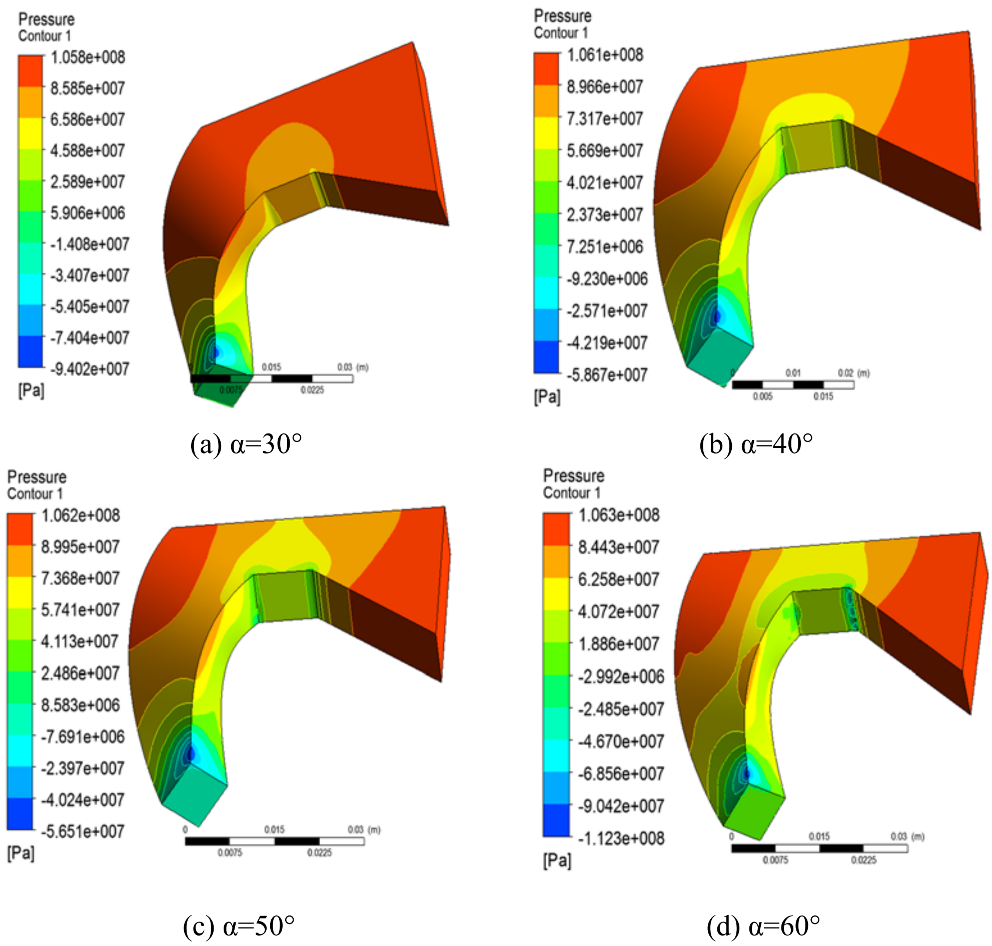


Figure 8. Pressure cloud diagram

5. Conclusion

ANSYS finite element analysis shows that the turbine stress meets the mechanical performance requirements. The gas flowing through the guide vane and turbine blade is modeled. Flunt software was used to simulate the flow of the gas model. The velocity and pressure distribution of gas through nozzle ring and turbine are analyzed. The results show that the regulating angle of the guide vane increases, the gas velocity increases, and the gas pressure increases. The gas pressure is used for strength check to meet the mechanical requirements, which is basically consistent with the static analysis results.

Acknowledgments

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