Research on Vehicle Hydrodynamic Turbine Atomization System Based on Single Chip Microcomputer Technology

Guoqing Zhu

Jilin University, Changchun, China

599054887@qq.com

Abstract. A new type of mass flow detection technology for vehicle twin turbines with swirl correction characteristics is introduced. The basic structure, the principle of the moment of momentum and the realization process of the technology are introduced. The improved scheme of the second turbine under unsteady flow condition is presented. According to the principles of fluid dynamics and turbomachinery, the vehicle turbine atomizer is optimized by using Concepts NREC software. Using this scheme can not only save the development cost, shorten the development period, but also improve the stability and reliability of the equipment.

Keywords: MCU, Vehicle Fluid Mechanics, Turbine System, Numerical Simulation, Impeller Design.

1. Introduction

The direct mass flow measurement method for momentum-torque dual turbines proposed in the 1960s is based on the basic theory of fluid mechanics. The mass flow is measured by the gap between the two turbines, the torque difference and the elastic action of the spring. It has the advantages of simple structure and low cost, but it has not been commercialized because of the large error of repeated measurement. Up to now, the theoretical model of vehicle turbine mass flowmeter has not received enough attention [1]. In the 1990s, people proposed a inertial navigation mass flowmeter with two impelers connected, and carried out theoretical analysis based on the cascade theory. The repeated measurement accuracy of the instrument is above 1%.

The flow network method transforms the complex flow path into a network structure with multiple units. A set of flow path equations is established by associating them with characteristic elements. The flow rate, pressure, temperature and other parameters along the path are obtained. It can be used in the design and calculation of vehicle turbine cooling system. Some scholars use the flow grid method to numerically simulate the air cooling system of internal combustion engine. Researchers have modeled the aerodynamic systems of internal combustion engines [2]. The chamber pressure and the cooling flow under dynamic and static cooling methods are compared with the experimental results. Some scholars have numerically simulated the flow field and heat transfer performance of the inner cooling section of vehicle turbine guide blades. The flow field and heat transfer performance of the inner cooling section of the blade were studied. Firstly, the pressure and flow rate inside the burner are analyzed, and then the heat transfer process inside the burner is analyzed, but the influence of rotation on the inside of the vehicle turbine is not considered in theory and experiment. The fluid in vehicle turbine cylinder is regarded as one-dimensional homogeneous flow field, and the influence of flow field characteristics on the dynamic characteristics of vehicle turbine is considered. The Angle between the relative velocity of the fluid at the exit of the blade and the axis is no longer simply regarded as equal to the spiral Angle of the blade.

2. Vehicle turbine design method

The expansion ratio, work amount, speed and turbine inlet condition of the vehicle turbine are all determined by the overall performance analysis software of the gas turbine to ensure that the designed turbine matches other parts, at least to ensure that the turbine can provide sufficient power for the compressor drive. The working characteristics and stability of the compressor have a more significant impact on the rotation speed, so the size of the rotation speed generally depends on the structural parameters of the compressor [3]. After determining the overall characteristics and design requirements of the vehicle turbine, the average streamline method is used for the preliminary design of the vehicle turbine. In the thermodynamic analysis, the load parameters, flow coefficient and reaction degree of the stage should be selected first, and the efficiency of the stage should be determined by Smith curve. After the above points are determined, the average velocity of the blade and the velocity of the inlet can be obtained by using the basic aerodynamic thermodynamic equation. In the design of uniformly distributed flow line, only one-dimensional analysis of "meridian flow" is carried out. Two-dimensional numerical simulation is used to solve the problem of axial flow field parameter allocation [4]. The existing flow structure is assumed to be axial, without considering the change of flow field between different impellers. In the initial design, if the selected reactivity is large, the moving blades will be subjected to a large load, resulting in a large number of blades, and then the reactivity should be re-selected for the thermodynamic calculation of the average flow line. If the flow coefficient is too small, it will lead to increased pressure on the blade root, and it is necessary to adjust the velocity triangle on the mean flow line and increase the meridian speed. After the design of its strength and structure is completed, it can be put into use. FIG. 1 shows the aerodynamic design process of vehicle turbines. The triangular value of the design speed calculated by the Axial module in the ConceptsNREC software is shown in FIG. 2 (the picture is quoted in Energies 2022, 15(17), 6240).

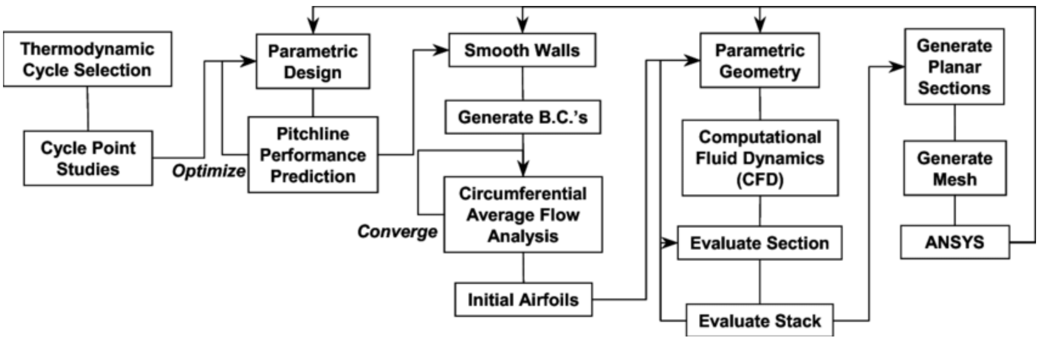

Fig. 1 Aerodynamic design process of vehicle turbine

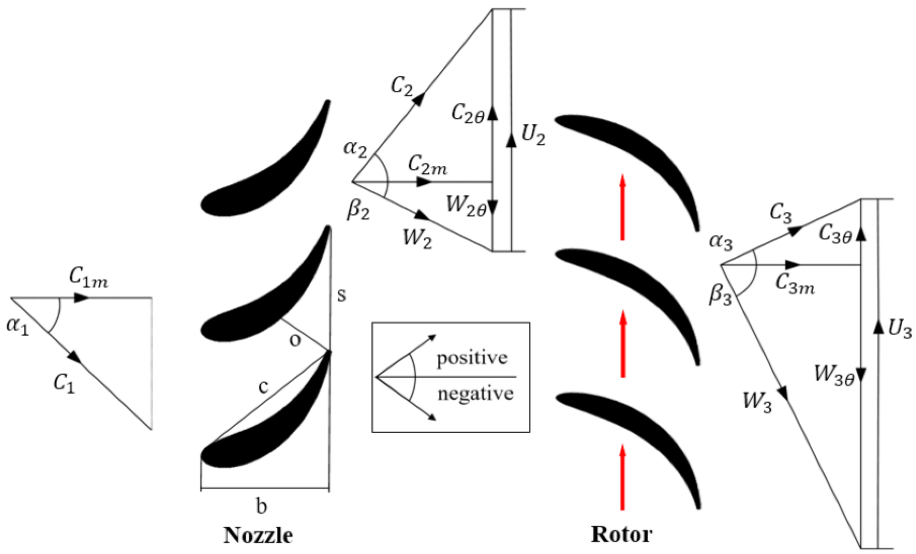

Fig. 2 Triangle diagram of preliminary design speed of vehicle turbine

3. Structure and mathematical model

The basic structure of the turbine mass flowmeter is designed according to the principle of moment of momentum, as shown in Figure 3 (the picture is quoted in the basic of Flow Measurement Technique). It is composed of shell, impeller, bracket, bearing, torsion spring, magnetic sensor and so on. The two turbines are installed at different angles. The turbines are installed in an elastic body, and the elastic body is equipped with two signal detection transducers. As the fluid passes through the turbines, the Angle at which the two turbines are installed changes, causing a change in the torque required for both turbines [5]. The displacement difference caused by the torque Angle is proportional to the mass flow rate. Through the signal of the secondary instrument, the sensor can detect different displacement values and convert them into different material flow values. A small piece of permanent magnet is inserted into the blade of a turbine, and the magnetic sensor is attached to the blade. The magnetic field is located just below the blade as it rotates, creating a pulse. Through the analysis of these two pulses, we can get the two turbine speeds and the phase difference between the two turbine blades. The volume flow rate of the blade is proportional to the rotation speed of the blade, and the phase difference between the blades is proportional to the mass flow rate of the blade. When the turbine of the twin-turbine flowmeter rotates at A constant angular velocity θ, the various torques acting on the turbine blades are balanced. Among them, the torque balance equation of turbine 1 is:

$$F_s = F_a + F_c + F_f + F_\theta + F_e \tag{1}$$

F_s is the driving torque acting on the turbine. F_a is the surface resistance moment of the turbine hub. F_c is the bearing resistance moment. F_f is the resistance moment of blade pre-clearance. F_θ is the resistance moment of turbine hub end face. F_e is the torque of the spring [6]. The resistance torque generated by the signal reading device is generally very low and is not accounted for in the above formula. The surface resistance moment of turbine hub, bearing resistance moment, blade pre-clearance resistance moment and turbine hub end resistance moment of turbine 1 and turbine 2 can be considered to be equal, while the torsional moment of spring is equal and their direction is opposite. It can be obtained by formula (1) and (2) :

$$F_e = \frac{F_s - F_s^{'}}{2} \tag{2}$$

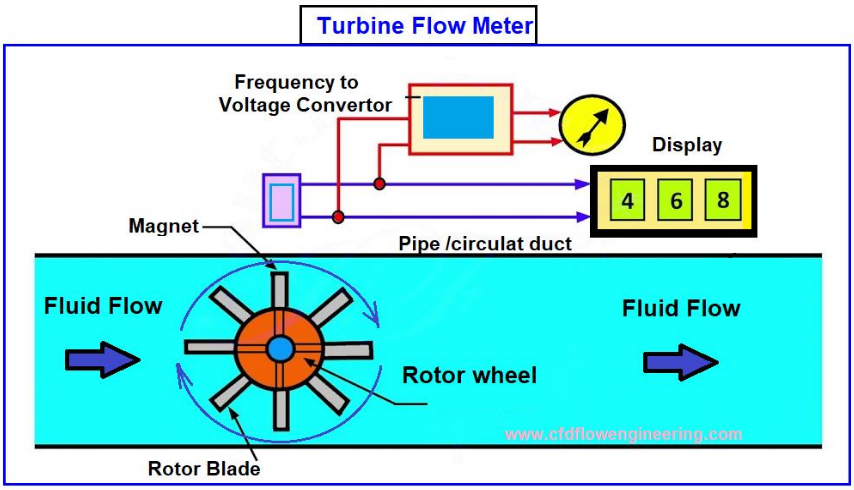

Fig. 3 The basic structure of the turbine mass flowmeter is designed according to the principle of moment of momentum

In order to obtain F_s, annular elements with a height of sl at turbine radius l are investigated. V_a is the axial velocity, U_1 and U_2 are the relative velocities of the inlet and outlet respectively, σ_1 and σ_2 are the angles between and and the axial velocity respectively, D is the chord length of the blade, ε is the exit Angle of the blade, L is the pitch of the spiral blade, φ is the blade thickness, θ is the turbine angular velocity, R is the blade spacing at the radius r of the turbine, $R = 2\pi_l / N$. Where N is the number of blades.

Using the moment theorem of dynamic force, the driving moment acting on the area of the microelement can be written:

$sF_s = \rho N l V_a^2 R(\tan\sigma_2 - \tan\sigma_1) sl$

ρ is the fluid density. By integrating the above formula along the full length of the blade, the driving torque of the turbine can be obtained as follows:

$$F_s = \rho N \int_{l_a}^{l_f} l V_a^2 R(\tan\sigma_2 - \tan\sigma_1) sl \qquad (3)$$

Where: l_f is the radius of the tip of the blade. l_a is the radius of blade root

$\tan\sigma_1 = l\theta / V_a; \tan\sigma_2$ can be determined by referring to the research results of turbomachinery boundary layer theory and making necessary amendments. $\tan\sigma_2$ can be expressed as:

$\tan\sigma_2 = (1 + \Delta^* - \theta)\tan\varepsilon$

θ, Δ^* is the dimensionless momentum thickness and dimensionless displacement thickness, respectively. They can be calculated respectively by the following formula:

$$\theta = \frac{\theta_{FR} + \theta_{FP}}{R\cos\varepsilon} \qquad (4)$$

$$\Delta^* = \frac{\varphi_{FR}^* + \varphi_{FP}^* + k\varphi}{R\cos\varepsilon} \qquad (5)$$

θ_F and φ_F^* are the momentum thickness and displacement thickness at the trailing edge of the impeller, and subscripts R and P represent the suction surface and pressure surface, respectively. Both θ_F and φ_F^* are functions of the Reynolds number and are dependent on the flow state.

4. Fluid network model

According to the characteristics of the low-temperature airflow path, the flow network structure of the low-temperature airflow path is constructed by selecting appropriate components (Figure 4 cited in Appl.Sci. 2020, 10(16), 5635). (1) The pressure source elements are used to set the boundary conditions of import and export. (2) The flow field and heat transfer process in the internal flow passage are obtained by combining the elements of the internal flow passage with the characteristic parameters such as the friction resistance coefficient and the convective heat transfer coefficient. (3) The loss element comprises a bending element and a hole element. The resistance coefficient of the device is calculated and experimentally studied. The bending element can simulate the heat transfer process, and the hole element does not consider heat transfer.

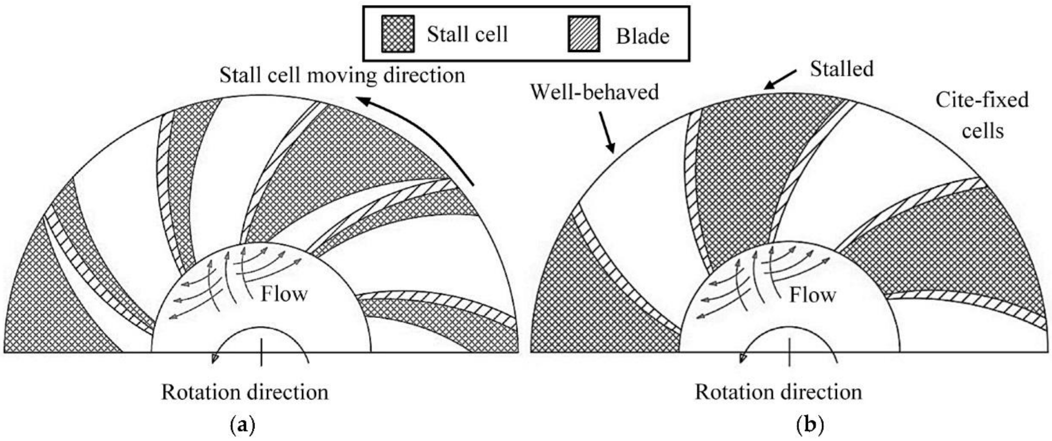

Fig. 4 High pressure air flow network with rotating blades

5. Model calculation and result analysis

The impeller speed at A given fluid physical property parameter, incoming flow velocity or flow rate and instrument geometry parameter can be calculated by numerical method, and then the corresponding instrument coefficient K can be obtained [7]. The meter coefficient of twin-turbine mass flowmeter is calculated to determine the quantitative relationship between meter coefficient K and q_m. By using Romberg algorithm, the author compiled a D language program to calculate the instrument coefficient K of the double turbine mass flowmeter $Dg50$ under the condition of different inclination angles of the two impellers. The calculation results are shown in Figure 5.

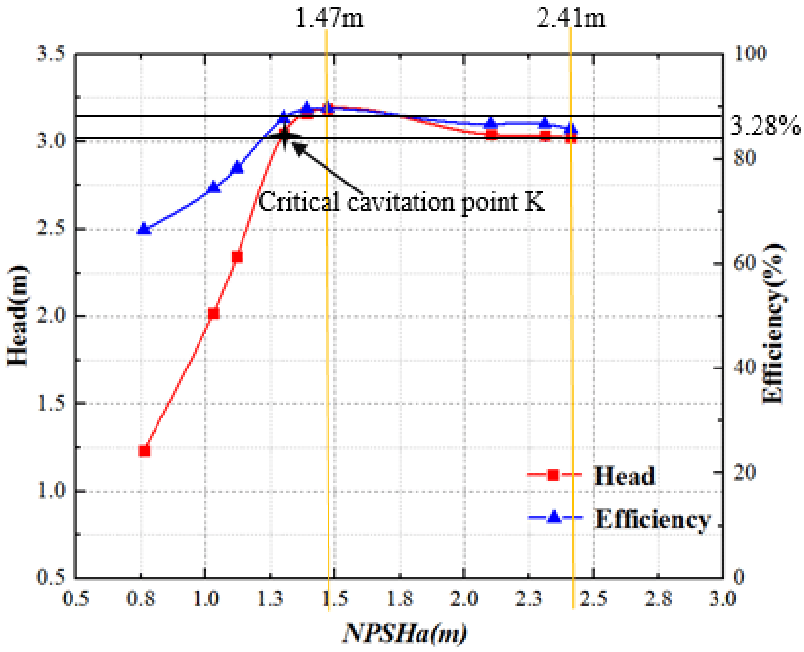

Fig. 5 Application of K theory to the calculation of characteristic curves at different blade tilt angles

When the flow rate is greater than (12 kg/s), the meter's measurement factor K is essentially constant; When the liquid flow is very small, the measurement factor K will change with the liquid flow. The K-nonlinearity of the low flow zone, in addition to being affected by the initial flow rate and drag torque, is the same as that of conventional turbine flowmeters, and the torsion spring in the low flow zone also shows obvious nonlinearity due to its low driving torque (Table 1). From Figure 6, it can be seen that in the range of 1 to 10 ms, the electronic circuit can be used to measure the time difference of the signal with high accuracy.

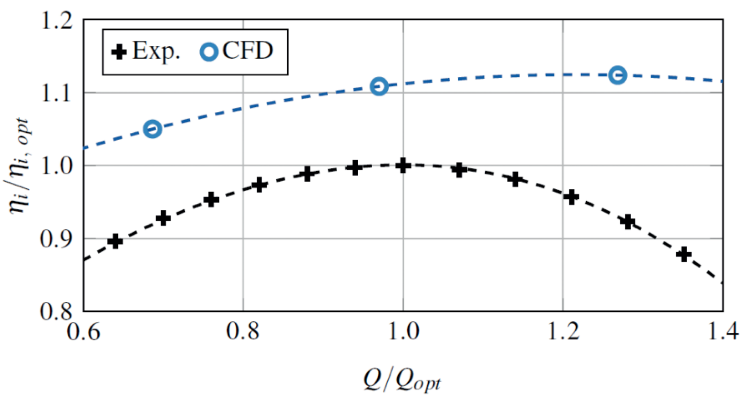

Fig. 6 Theoretical calculation of flow and signal characteristic curve with 55° impeller inclination Angle

Table 1. Quality signal test data of flowmeter

serial number	Flow point $q_m(10^3 kg/h)$	Quality signal $\Delta t(ms)$	$K\Delta t/q_m$	Repeatability (%)
1	4.281	0.011	0.220	2.698
2	5.271	0.078	0.197	0.198
3	7.656	0.210	0.188	0.104
4	15.927	1.712	0.172	0.083
5	26.917	2.744	0.167	0.031
6	37.906	4.068	0.169	0.052
7	44.073	4.922	0.166	0.104
8	51.521	5.455	0.168	0.073
9	59.490	6.726	0.166	0.052

6. Conclusion

In this project, a new approximate analysis algorithm for vehicle turbine fluid is proposed, which can accurately predict the characteristic curve of flowmeter under larger flow rate (Reynolds number). In this paper, some innovations have been made in the theoretical analysis of vehicle turbine fluid mass flow sensors, especially in the rear turbine.

References

[1] Feng Chao, Xu Huajing, Huang Jian, et al. Structural parameter optimization and fluid simulation of turbine hydraulic oscillator. Science Technology and Engineering, Vol. 22(2022) No. 9, p.72-77.

[2] Li Wei, Wang Qiang, ZHANG Hailei, Ren Yang, HE Jiawei, Men Rixiu. Axial force and its formation mechanism in the switching process of turbocharger. Journal of Fluid Machinery, Vol. 50(2020) No. 5, p.76-84.

[3] Sun Dongning, LIU Huixiang, Zhu Yi, et al. Research on an ultra-high speed Tesla turbo-kerosene generator. Missiles and Space Launch Vehicles, Vol. 10(2022) No. 4, p.65-69.

[4] Yang Baofeng, Jin Lu, Wang Xiaofeng, et al. Vibration characteristics of turbopump housing under two fluid transfer paths. Rocket Propulsion, Vol. 49(2021) No. 1, p.72-79.

[5] Song Yang, Wang Wei, Geng Rui, et al. Blade strength analysis technology based on turbine guide vane composite structure design platform. Steam Turbine Technology, Vol. 65(2022) No. 2, p.81-86.

[6] Jia Qian, Ruan Qi, Cui Zhan, et al. Theoretical analysis and experimental study on the breaking speed of spiral groove mechanical seal under extreme working conditions. Journal of Fluid Machinery, Vol. 049(2021) No. 10, p.1-6.

[7] Jiang Jingjun, Yang Feng, Liu Zezhong, Bin Guangfu. Influence of texture depth of internal thread on dynamic characteristics of oil film of turbocharger floating ring bearing. Lubrication and Sealing, Vol. 47(2022) No. 10, p.78-83.