Balance Design and Multi Condition Dynamics Simulation Study of Internal Combustion Air Compressor of Horizontal Moving

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Abstract

The paper is based on the relevant parameters of the 178F diesel engine crankshaft system. Though the balance theory, internal combustion air compressor of horizontal moving is balanced and designed. On one hand, the right counterbalance can be installed at the end of a crank, which can cancel out the rotating inertia force which is produced by the crank to realize the balance of the rotation inertia force; on the other hand, by designing the overall symmetrical structure, it's realized to balance off the reciprocating inertia force or moment along the center of the cylinder.

Keywords

Internal combustion; Horizontal moving; Air compressor; Balance; Inertia.

1. Introduction

At present, the existing internal combustion air compressor remain unbalanced, so that the vibration and noise in the working process is larger, leading to reducing the working efficiency and service life of the compressor[1]. Aiming at the problems above, this paper proposes a level of internal combustion air compressor which is a simpler, more efficient and more convenient new type of pneumatic device which can convert heat energy to gas pressure. First of all, the crankshaft is made up of two shaft heads, main journals, and each cylinder crank, and its unbalance mass is mainly produced by the crank. The right counterbalance can be installed at the end of a crankshaft crank, which can cancel out the rotating inertia force which is produced by the crank to realize the balance of the rotation inertia force. Then, a group of crank connecting rod mechanism of the drive power piston and two groups of crank connecting rod mechanism of the pneumatic piston are arranged by using the symmetrical way, and the size of the components and quality are completely symmetrical, which requires that the length of the connecting rod is same and the quality of a group of crank connecting rod mechanism of the power piston is equal to the sum of the quality of two groups of the crank connecting rod mechanism of the pneumatic piston. This structure can not only achieve the balance of the main vector, and can effectively solve the problem of the main moment balance[2].

2. Balance of the rotating inertia force

The rotating inertia force is produced owing to the rotation of the crankshaft crank and the big end of the connecting rod around the main journal of the crankshaft. The force is proportional to the rotating quality and the rotating radius, and is directly proportional to the square of the rotating angular velocity. Formula is as follows.

$$F = m\omega^2 R \tag{1}$$

F——the centrifugal force

m——the quality of the crank pin and the big end of the connecting rod

ω——rotating angular velocity

R——radius of the crankshaft

Every crank on the crankshaft will produce a rotating inertia force whose direction is the same to the crank arm. When the rotation inertia force vector sum is not equal to zero, the right counterbalance can be installed at the end of a crank, which can cancel out the rotating inertia force which is produced by the crank to realize the balance of the rotation inertia force. Schematic diagram is shown in figure 1.

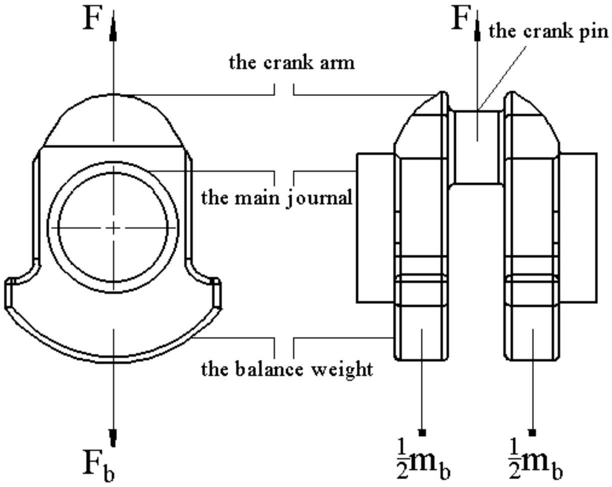

Figure 1 Balance of the single-throw crankshaft

In Scheme 1, one group of crank connecting rod mechanism of the drive power piston and one group of crank connecting rod mechanism of the pneumatic piston adopt horizontal symmetrical layout. The 3D model is shown in figure 2. For the structure of the crankshaft, the rotation inertial force of the crank pin and crank arm can offset each other to achieve the static balance inherent in the crankshaft. However, only extending the lateral crank arm to the opposite position of the main journal can offset a pair of couple of the crank pin and the crank arm. The installation of the counterbalance at the end of a crankshaft crank can achieve the dynamic balance of the crankshaft.

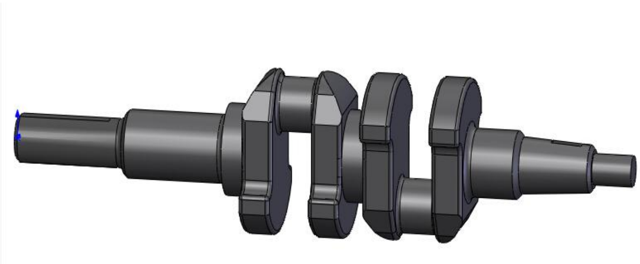

Figure 2 3D model of the crankshaft in Scheme 1

The rotation quality of the crankshaft basically consists of the crank and the connecting rod big end. The quality of the connecting rod usually is divided into two parts which include the rotation quality and the reciprocating motion quality. The rotation quality of the connecting rod will be subject to the quality of the connecting rod big end, and the reciprocating motion quality will be subject to the connecting rod small end. According to the experience, about two-thirds of the total quality of the connecting rod is the rotation quality and one-third of the total quality of the connecting rod is the reciprocating motion quality[3]. The quality of the crankshaft is made of the crank pin and the crank arm. Because not all of the crankshaft crank arms locate at the top of the main journal, itself can offset some parts so that the quality of the crank arm can be negligible and only the quality of the crank pin is considered. The quality formula of the crank pin is as follows.

$$m_j = \rho_j V_j \tag{2}$$

m_j——the quality of the crank pin

V_j——the volume of the crank pin

The mass formula of the connecting rod rotating is as follows.

$$m_c = 2/3C = 2/3\rho_c V_c \tag{3}$$

m_c——the quality of the connecting rod rotation

C——the total quality of the connecting rod

V_c——the volume of the connecting rod

Therefore, it can come to that the formula of the overall rotational quality is as follows.

$$m = m_j + m_c = \rho_j V_j + 2/3\rho_c V_c \tag{4}$$

In SolidWorks Analysis, it can be concluded that, the eccentricity of the crank pin is 25.3m and the volume of the crank pin is 8.968×103mm^3. The material of the crankshaft is nodular cast iron crankshaft and its density is 7.16×10^{-6}kg/mm^3. The volume of the connecting rod is 5.739×10^{4}mm^3. The material of the connecting rod is alloy steel and its density is 7.87×10^{-6}kg/mm^3. The data above will be into the formula 4 and we can get the result that the overall rotational quality is 0.365kg.

Because the rotation inertia force is balanced through two counterweights which are respectively decorated in the opposite direction of the crank arm , the product of the quality of two counterweights and its eccentricity is equal to the product of the product of the quality of the crank pin and the connecting rod big end and their eccentricity.

$$m_b R_b = mR \tag{5}$$

The overall rotational quality and the eccentricity of the crank pin will be into the formula 5 and we can get the result that $m_b R_b$ is equal to 9.23kgmm.

It can be seen through the formula that, if one of m_b and R_B is given, we can determine the another quantity. If we take the crankshaft m_b=0.531kg, we can get R_b=17.38mm.

In Scheme 2, one group of crank connecting rod mechanism of the drive power piston and two group of crank connecting rod mechanism of the pneumatic piston adopt horizontal symmetrical layout. The 3D model is shown in figure 3. Among them, the crank connecting rod mechanism of the power piston group in Scheme 2 is the same to the one in Scheme 1. The total quality of the crank connecting rod mechanism of the pneumatic piston group in Scheme 2 is equal to the quality of the crank connecting rod of the pneumatic piston group in Scheme 1. In another version, the quality of the crank of the pneumatic piston group in Scheme 2 should be half of the one in Scheme 1, and the quality of the connecting rod in Scheme 2 should also be half of the one in Scheme 2. It's required that the center of mass of the improved crank and connecting rod will remain unchanged.

Figure 3 3D model of the crankshaft in Scheme 2

The overall rotational quality and the eccentricity of the crank pin will be into the formula 5 and we can get the result that $m_b R_b$ is equal to 4.465kgmm. If we take the crankshaft m_b=0.274kg, we can get R_b=16.29mm.

3. Balance of the reciprocating inertia force

The reciprocating inertia force is produced as to the reciprocating movement of the piston group and the connecting rod small end structure. The movement direction of the piston group has been along the direction of the center line of the cylinder. In order to balance the inertial force, it's required that the inertial force of the balance mechanism has been along the direction of the center line of the cylinder and the direction of the inertial force is opposite to the direction of the reciprocating inertia force constantly. On the other hand, the size of them must keep the same constantly[4-5].

The reciprocating inertia force of the internal combustion air compressor is also associated with the distribution of the crank. In theory, the two cranks in Scheme 1 keeps a symmetrical arrangement. It just realizes the balance of the reciprocating inertia force and does not achieve the balance of the reciprocating inertia moment. In other words, it does not implement dynamic balance. Its 3D model is shown in figure 4. Relatively speaking, the total quality of the crank connecting rod mechanism of the pneumatic piston group in Scheme 2 is equal to the quality of the crank connecting rod of the pneumatic piston group in Scheme 1, which not only can realize the balance of reciprocating inertia force, but also realize the balance of the reciprocating inertia moment. Its 3D model is shown in figure 5.

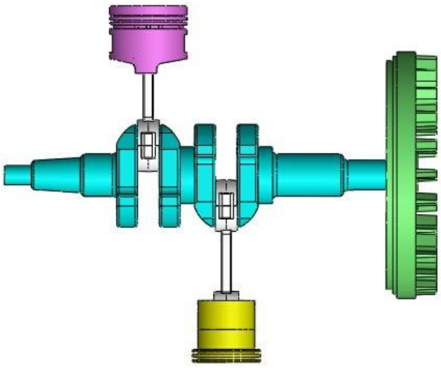

Figure 4 3D model of the crankshaft system in Scheme 1

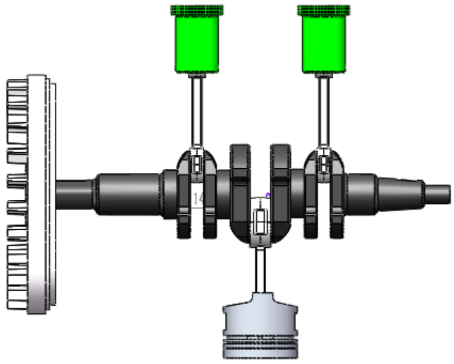

Figure 5 3D model of the crankshaft system in Scheme 2

4. Conclusion

By comparison with two kinds of scheme design, it can be found that the crankshaft in Scheme 1 and Scheme 2 can both realize the balance of the rotation inertia force and the rotation inertia moment. However, the crankshaft system in Scheme 1 can only achieve the reciprocating inertia force balance and not realize the reciprocating inertia moment. Therefore, on the whole, the balance effect of the crankshaft system in Scheme 2 is higher than one in Scheme 1.

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