The design of the crankshaft and connecting rod mechanism based on P-V diagram

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Abstract: The design of good performance and long service life, crankshaft affects the engine performance and fuel economy. It can reduce the consumption of materials and manufacturing cost. Thermodynamic calculation of mixed gas cylinder is analysised based on P-V diagram drawing, It compared with theory and practice to optimize the design of the crankshaft and connecting rod mechanism of engine crank connecting rod mechanism.The paper comes up with the overall design of the crankshaft connecting rod mechanism through the analysis of force on the calculation and selection of the structure and size of the crankshaft.

Introduction

The crankshaft is responsible for the inertial rotation transformation of the reciprocating motion of the piston and the flywheel to circular motion itself, which supplies power to the engine, also the source of the whole mechanical system. The structure of automobile crankshaft is very complex. It is related to automobile general layout and engine parameters. Therefore, in the design of whole manufacturing process, the crankshaft design is particularly important.In addition, each parameter and vehicle performance matching is an important content of the crankshaft structure design. This gives us how to design a high quality crankshaft research topic.

Analysis and calculation of parameters

The main initial parameters of the engine table as follows Table1.

Table1:initial parameters of the engine

Maximum power	63kw	The number of stroke	4
Engine speed	5000r/min	The mean effective pressure	0.8～1.2MPa
Engine Displacement	1388ml	The number of cylinders	4

Selection of the mean effective pressure.

According to the basic calculation formula of internal combustion engine design:

$$P_0 = P_{me} * V_S * i * n/(30 * \tau)$$ （formula 1）

in which：

P_0 is the ratedpower.Its value is 63kw.

P_{me} is the average effective pressure.The unit is Mpa (1Mpa=10 bar)

V_s is the volume of the cylinder.Its value is 1.39/4L.

i is the number of cylinders of the engine. Its value is 4.

n is the speed of the engine.Its value is 5000r/min.

τ is the number of engine strokes.Its value is 4.

According to the formula 1, it can be calculated $P_{me} = 1.09Mpa$.

Calculation of cylinder diameter and piston stroke.

$$V_S = \pi * D^2 * S/4000000$$ （formula 2）

in which：S is engine piston stroke and its unit is mm.

D is engine cylinder diamete and its unit is mm.

According to the references, gasoline engine piston stroke and the cylinder diameter ratio S/D is between 0.8 to 1.0.Set S/D equal to 0.9.According to the formula 2, it can be calculated D=78.93mm,S=0.9and D=71.04mm.Mean piston speed can be calculated according to the formula2: $V_m = S * n/30000$ = 11.84m/s.

Thermodynamic calculation

Mixed gas cylinder volume is composed of a carburetor to quantitative regulation. The purpose of doing so is to adapt to changes in load engine. The design of the crankshaft is four stroke engine. The working cycle includes four processes such as intake stroke, compression stroke, expansion stroke and exhaust stroke. In this design process, the first step is to determine the engine cycle parameters. Then the cylinder compression and expansion processes are calculated. Finally is to draw the isochoric heating cycle P-V map, paving the way for the analysis of the piston rod of the crankshaft stress condition.

Determination of basic parameters of thermodynamic cycle. According to the references, the following parameters can be selected.The compression process of adiabatic exponent $n_1 = 1.32 \sim 1.38$, set $n_1 = 1.32$.The expansion process of adiabatic exponent $n_2 = 1.23 \sim 1.28$, set $n_2 = 1.28$.The compression ratio of gasoline engine $\varepsilon = 7 \sim 12$, set $\varepsilon = 9$.The Pressure rise ratio $\lambda_p = 6 \sim 9$, set $\lambda_p = 7$.

Drawing P-V diagram

Compressed air inlet pressure starting point is as the local atmospheric pressure. According to the references, namely the internal combustion engine. Then the cylinder compression process is approximately regarded as adiabatic process adiabatic index, compression process, utilization. The calculated total cylinder volume is substituted into the formula.And then use EXCEL to draw the compression process line.

Mixed gas from the cylinder end point to the top of the cylinder is compressed.after, This is isochoric heating because of unchanged the cylinder volume. When the piston reaching TDC, ignited by a spark plug, the use of pressure elevation ratio of λp can be calculated by the theoretical maximum explosion pressure. The expansion process and the compression process are both parabola. According to the index of the expansion process, the expansion line and theory P-V diagram can be drawn by using EXCEL.

Calculation parameters of P-V diagram

$$V_a/V_c = \varepsilon \qquad \text{(formula 3)} \qquad V_a = V_s + V_c \qquad \text{(formula 4)}$$

in which:

V_a is the total volume of the cylinder and its unit is L.

V_c is the volume of the combustion chamber and its unit is L.

According to the formula 3 and formula 4: $V_c = 0.043\text{L}$, $V_a = 0.39\text{L}$。

$$p_a * V_a^{1.32} = p_c * V_c^{1.32} \qquad \text{(formula 5)}$$

in which:

p_a is the Inlet pressure and its value is 0.09Mpa.

p_c is the compression end ppressure.The unit is Mpa.

According to the formula 5: $p_c = 1.65\text{Mpa}$.And the relationship between expansion pressure and expansion end pressure is as following.

p_z = λp * p_c=11.56Mpa. so $p_z * V_c^{1.28} = p_b * V_a^{1.28}$.

So it can be calculated $p_b = 0.68\text{Mpa}$.

Simplification of actual engine working process.

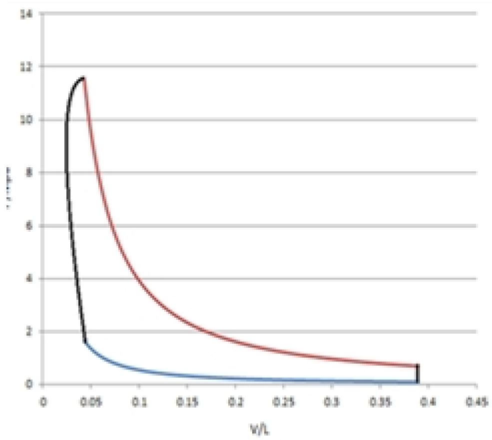
1) The continous reciprocating cycle is simplified as a closed loop.

2) The compression and expansion strokes are adiabatic process.

3) Exhaust process is simplified as a constant volume heat release process.

4) assuming the refrigerant to the ideal gas, a gas engine working process composition does not change . Based on the above data, obtains the theory P-V diagram in Fig1 .

There are some differences between the practice P-V diagram and the theory P-V diagram. This is caused by the ignition advance angle and gas distribution phase. The following is some adjustment to the engine theory P-V diagram as the practice P-V diagramin Fig2.This value in the longitudinal direction and theory of coordinate P-V diagram intersection, then the original values of this X direction above parts removed, the remaining part finishing. The actual situation, the maximum explosion pressure is unlikely to stop in, but after the TDC. This design decision will be maximum explosion pressure design top end point.According to the above adjustment, it can be obtained after finishing the actual P-V diagram as following.



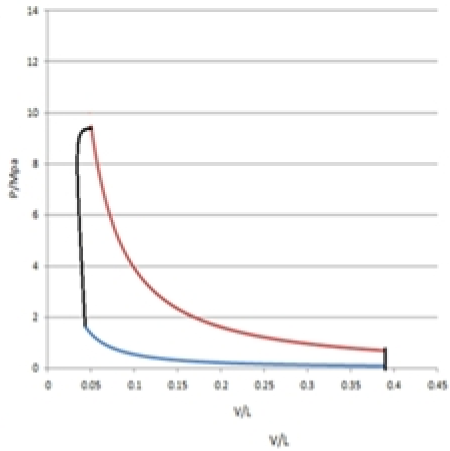
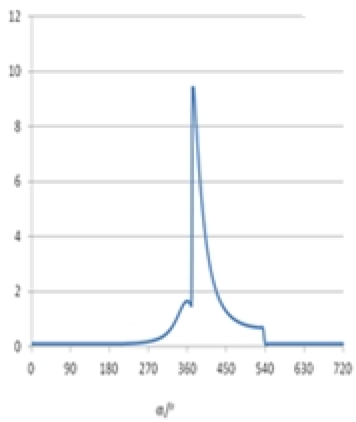


Fig1: the theory P-V diagram

Fig2: the practice P-V diagram

P - V diagram to P - α graph

According to the relationship between the crank angle and displacement of piston, the total cylinder volume of the corresponding crank angle can be obtained using Excel in Fig3.The P-α diagram can be drawn according the calculation of the parametersEvery 5 ° from the point of P-V diagram in Fig4.



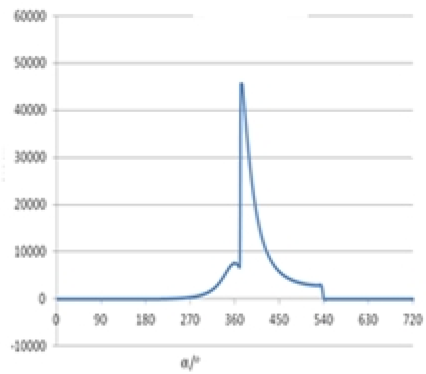


Fig3: cylinderabsolute pressure

Fig4: Cylinder pressure

Ignore the little friction between the piston and the cylinder and the connecting rod, the design as long as the research and analysis of gas pressure and inertia force.

Structure design

Crankshaft observing from the integral structure is divided into integral type and combination, this design decision is integral crankshaft. Structure design and the determination of main dimensions of crankshaft details including includes 6 aspects.

To determine the size of the crankpin.Crank pin diameter.$D_2 = (0.60\sim0.65) * \mathrm{D}$,Select the diameter$D_2 = 0.6 * 78.93 = 47.36\mathrm{mm}$.The length of the crank pin $L_2 = (0.35\sim0.45) * \mathrm{D}$,Select the $L_2 = 0.39 * 78.93 = 30.78\mathrm{mm}$.In order to crank and connecting rod side as far as possible not to have a little friction, clearance and between them,select the $L_2 = 31\mathrm{mm}$.Crank pin diameter $d_2 = (0.4\sim0.6) * D_2$, select the $d_2 = 0.5 * 47.36 = 23.68\mathrm{mm}$.

To determine the spindle neck size.

Under normal circumstances,$D_1 = (0.65\sim0.75) * \mathrm{D}$, select the $D_1 = 0.7 * 78.93 = 55.251\mathrm{mm}$.Spindle neck length $L_1 = (0.35\sim0.45) * \mathrm{D}$, select the $L_1 = 0.36 * 78.93 = 28.41\mathrm{mm}$.

Conclusion

Manufacturers found that the fatigue failure of crankshaft is almost occurred in the transition fillet through long-term observation and research. The whole crankshaft type of fatigue failure results in the fracture reason is fatigue crack and spreading to crank down in most cases at the transition fillet. Therefore it is very necessary to calculate fatigue strength corresponding to two of maximal amplitude of crankshaft fillet stress in this design.

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