The Design and Analysis of the Hydraulic-pressure Seal of the Engine Box

Zhenya Chen\textsuperscript{1,2}, Xingquan Shen\textsuperscript{1,2}, Zhijie Xin\textsuperscript{1,2}, Tingting Guo\textsuperscript{1,2} and Kewei Liao\textsuperscript{1,2}

\textsuperscript{1}School of Mechanical Engineering, North University of China, Taiyuan 030051, China;
\textsuperscript{2}Research Center of Deep-hole Machining Engineering Technology, Taiyuan 030051, China

Abstract: According to the sealing requirements of engine casing, using NX software to establish three-dimensional solid model of the engine box. Designing two seals suppress schemes basing on analyzing the characteristics of the case structure, one of seal is using two pins on one side to localize, the other is using cylinder to top tight and fasten, Clarifying the reasons for the using the former scheme have a lower cost. At the same time analysing the forces and deformation of the former scheme using finite element analysis software and the NX software, results proved that the pressure scheme can meet the actual needs of the program. It illustrated the composition of the basic principles of manual pressure and hydraulic system, verified the feasibility of the seal program using experiment, providing reference for the experimental program of hydrostatic pressure in the future.

1. Introduction
Engine is a kind of can taking other forms of energy into mechanical energy of the machine, and tank of the engine is the base of the transmission parts, with gears and bearing parts in it, equivalent to muscle cavity supporting the heart movement. In the processes of energy conversion, engine tends to produce high pressure and heat, transferring a larger force and torque at the same time, so the cabinet design requires sufficient strength and stiffness; At the same time, in the process of working, the function of gears, the work by cylinders and the rotation of the bearings require lubrication and clean environment to ensure efficient operation system, so box body needs to be sealed well. The hydraulic pressure test of the engine box is an important means of verifying the qualification of sealing, as well as the compactness of the material.

The holes in the engine box are divided into two types: one is the thread hole and the other is the non-threaded hole. Because of its connection, screw holes are tightly sealed by thread through sealing tape. Non-threaded hole, can be sealed by sealing pad on the cylinder to cling to the tank. Connecting the water injection mouth with pump by hose and inject water, the pump the air from the cylinder to loosen seal and release water, by the test bench around the pool should be built to realize the recycling of water. Operation process requires 0.1 Mpa for water pressure which should be maintained for 15 min; if the pressure reading is constant and deformation of tank could be neglected, meanwhile the injection process should be quickly, then the case is on test,; in addition, the exhaust should be reasonable and thorough, fast clip with quick pressure relief is also in need, etc.

2. The analysis and Design of the Tank Structure
There are 25 hole should be sealed on the tank. In this project, the structure design of the cylinder
tightening device is marked. The construction of the cabinet is shown in Figure 1.

(1) Front view: there are 6 holes. Two of them (R116) are on the same plane, whose boss height is 5mm, the radius of the other four with uniform plateau and boss height (5mm) are R120, R118, R65, R50. Exhaust vent is arranged on the upper right of the view; the acreage for sealing of front view is 921.1cm²; the pressure of the outlet should be 921.1kg, according to its hydraulic pressure of 0.1Mpa.

(2) The left view: there are 2 holes, one of them is a hole with radius of 165mm. The acreage for sealing of front view is 283.3cm², the pressure of the outlet should be 283.3kg. What’s more, there is a screw hole of M30x1.5, whose shape are uniform viewed from left and right.

(3) The back view: 7 holes. R117.5 and R31.3 (be covered), both of them are in the same plane; the other five are in another plane, with a threaded hole (M27x2), and another threaded hole (M32), R151.1, as well as R141. The area need to be jam is 99.2cm², while the pressure is 998.2kg. There is a threaded hole which is not shown in the picture.

![Figure 1.](image)

3. The Plan of Pressure Loading
The hole-bracing sealing scheme requires that the supporting poles meet high positioning accuracy and individual freedom movement, which makes it difficult to design, thus the hole-pressing sealing scheme should be adapt.

Based on the characters of the tank, two programs for sealing are put forward:

Pro.1 is to sealing with two pins on one side, shown in Figure 2, which contains three air cylinder, a suit of bed-stand support, a pair of guide rail and support circuit. The over-all structure has been illustrated in picture. Whole process is divided into 5 parts: work locating, workpiece transmitting, cylinder closing and tightening, cylinder withdraw and output.

Pro.1 is made up by two pins on one side to orientate, making use of bottom and mechanical cooperate of short pin and hole. To achieve bottom sealing by its mass, elastic sealing rubber mat is distributed on the supporting surface.

Pro.2, seals suppress schemes of cylinder, includes two conveyer belts, six cylinders, a suit of bed-stand support, as well as support circuit and motor, as is shown in Figure 3. To achieve the function, the device finishes six steps in the test: placing and transferring, identifying the situation, locating the work, closing and tightening, dropping out of cylinder, exportation of products.

Compared with pro.1, pro. 2 is tedious and money-cost. So pro.1 is recommended, and following is analysis.
Figure 2. The structure of two pins on one side  
Figure 3. Structure of cylinder sealing

4. Principle and Project of Hydraulic System
The principle of system of hydraulic pumping test is shown in pic.7. The pressure for tank depends on P1. If the tank is sized. Start the hydraulic pump. Make the electromagnetic commutation valve 1 charge, clamp the cylinder action, will be clamped by the specimen. The pressure oil enters the left cavity of the cylinder and the piston rod goes right. The water in the tank opens a one-way valve to the left cavity of the water cylinder. When the switch is touched, the signal is sent for the electromagnetism valve 1. Then, the pressure oil is transferred to the right cavity of the cylinder, pushing the piston to the left, the pressure water inside the tank, along the pipe to the test piece. If the test valve is not leaking, the contact pressure gauge will show the pressure in the tank and automatically press for one minute. After that, the pressure gauge sends an electrical signal, which opens the unloading valve and sends the pressure water back into the tank. Then press the button to power the reverse valve 2, loosen the cylinder and remove the workpiece. The cycle turns over and over. If the valve is leaking, open the unloading valve immediately and let the pressure water return to the tank, as shown in figure 4.

Figure 4. Hydraulic System Principle Diagram

5. Suppressing the Analysis of the Box Body
Engine cases are usually made of gray cast iron, and gray cast iron has good casting performance and vibration damping performance. But its density is larger caused in the weight of per unit volume is larger, in order to satisfy the use requirement, to realize the lightweight design, this experiment adopts cast aluminum as the material of body, whose density of 2700 kg/m3, thus the body weight is 212 kg.
and at the same time the weight of support is 89 kg, so the total weight is 301 kg.

Using the ANSYS finite element software to simulate, we get the simulation parameters for aluminum alloy, whose density is 2700 kg/m³, 7 e10pa with young's modulus, and Poisson's ratio is 0.33. All constraints are imposed on the casing wall. Putting the pressure (0.45 Mpa) on the side face of box, the simulation results are as follows:

![Figure 5. Displacement diagram of box](image)

![Figure 6. Stress diagram of box](image)

The maximum displacement of the box is 0.09108 mm when the external pressure is 0.45 MPa, and the maximum displacement occurs in the outer edge of the ear, got from figure 5.

The maximum stress of the box in figure 6 is 21.8608 MPa, the maximum stress occurs in the fascia joint.

Taking use of the finite element analysis software NX to simulate the features, the simulation
results are as follows: in the figure 11, when the outer pressure of 0.7 MPa, the maximal displacement of box body is 0.140 mm, the largest displacement occurs in the bearing outer ears.

Conclusion: the results of ANSYS and NX simulation results show that the pressure hole sealing method is very small and does not have a large effect on the seal.

6. Pressure Test of the Tank
The manual test pump is shown in figure 7.

![Figure 7. Manual test pump](image)

The process of the manual test is follow: firstly, open the tap and the valve, casing to the engine with water. When water spilled from the overflow valve, close the overflow valve and water-filling valve;

Start the main motor metering pump and keep pump running, closing circulating valve and open the hydraulic valve as well as pressure valves, then the press rises up .When the pressure rises to 0.45 MPa, servo motor offers small flow rate until pressure to 0.5 MPa, then hold the pressure on .

The circulating valve keeps working by pump to retain the pressure, when the engine body at 0.5 MP and send a signal.

After the test pressure is finished, open the pressure-relief valve firstly and then open the overflow valve.

7. Conclusion
Pressure test could guarantee the airtight of the box .This paper has designed two kinds of box seal testing scheme, the latter adopts positioning method called "two pins on a plane" .The finite element analysis and experiments validation prove that the second method of engine box functions very well.

The hydraulic system can complete the automatic pressure regulation of the system, which has guiding significance to the hydraulic pressure test.

8. Reference
[1] Cheng L J, Zhang J P, Huo W, et al. Power System Analysis and Design of the Six-Cylinder Hydraulic Confined Piston Engine[J]. Advanced Materials Research, 2013, 765-767:57-61.
[2] Wang Z, Zhao J, Zhang Z, et al. Design and Analysis of the Limiting Valve Group of Rotary Pressure for Full Hydraulic Rotary Drill[J]. Machine Tool & Hydraulics, 2016.
[3] Sun M, Zhang Z Y, Kong W J. Design of Sealing Structure and Analysis of the Flow Field in Micro Internal Combustion Swing Engine[J]. Applied Mechanics & Materials, 2014, 670-671(2):930-935.
[4] Liu F, Cai X. Design and Analysis of New Type of Four Equal Pressure Seal Sealing Fixture [J]. New Technology & New Process, 2011.
[5] Shen Z, Li L, Wang P. Analysis on the Effect of External Pressure Function on Internal Pressure Seal of Special Thread Connection[J]. Technology Supervision in Petroleum Industry, 2012.
[6] Zhang S, Zhao Z F, Zhao C, et al. Design Approach and Dimensionless Analysis of a Differential Driving Hydraulic Free Piston Engine[C]// SAE 2016 Commercial Vehicle Engineering Congress. 2016.