



School of Engineering

Motion Simulation and FEA

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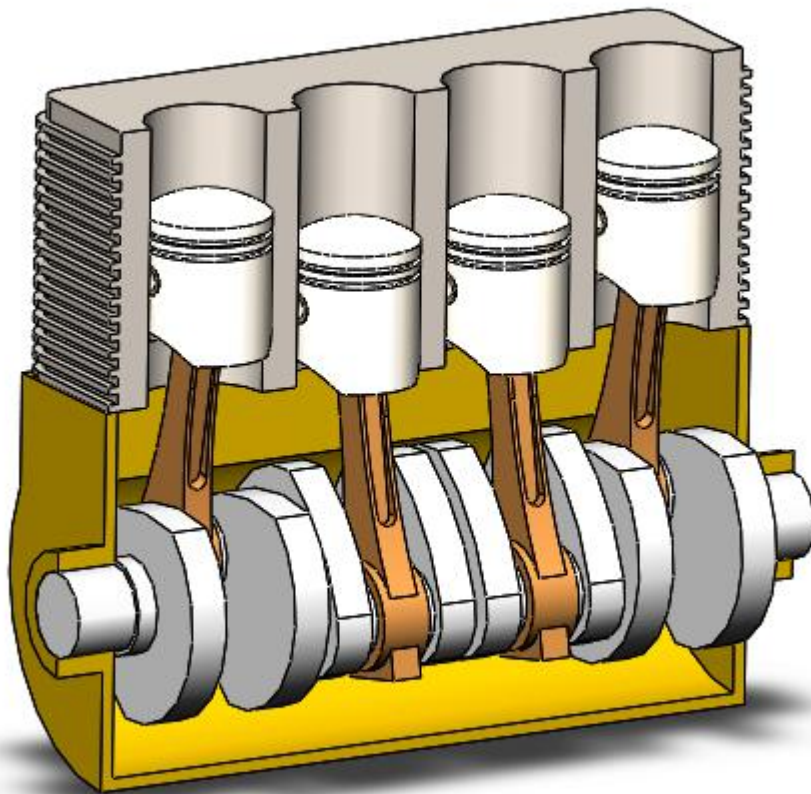
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Introduction

In this study, author demonstrate the methods and techniques that have learned to review, consolidate, extend and apply knowledge and understanding, and to initiate and carry out projects. Author modeling an assembly of engine which is 3068.79 grams in total and do the finite element analysis about it with Solidworks 2019. The piston type internal combustion engine mixes fuel and air burns in its cylinder. The heat energy released causes the cylinder to generate high pressure and high temperature gas. The gas expansion pushes the piston to perform work, and then outputs mechanical work through a crank link mechanism to drive the driven machinery to work. With the PC, and the rapid development of CAD technology, in the past only in workstation environments, UNIX platform 3D design software application, it is now the ordinary PC platform and the use of the Windows environment, become ordinary of designers, engineers design tools. In this report author demonstrate the steps of how to modeling the assembly of engine from single parts. After the modeling, finite element analysis would be applicated for modifying the engine.

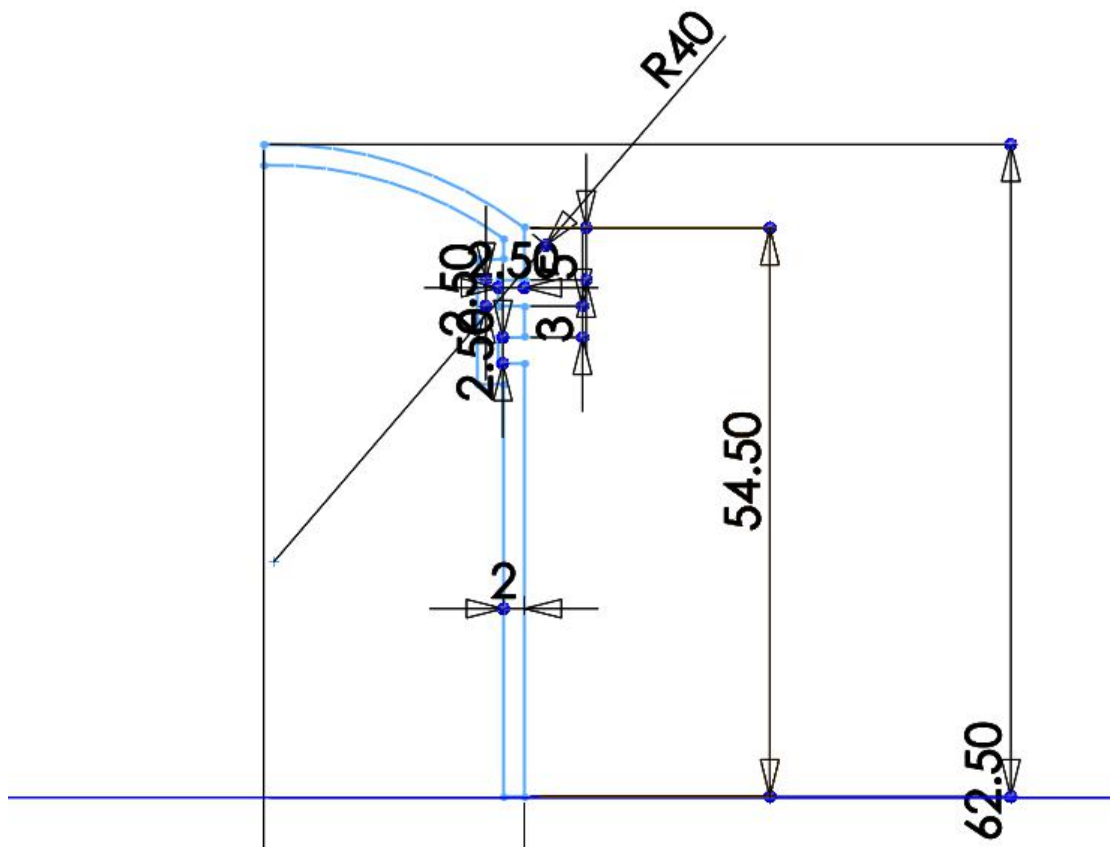
1. Modeling the parts separately

There are 15 individual parts but 6 different parts for the engine, so author will separately model the piston, piston pin, connecting rod, crankshaft, upper and lower blocks. The whole model as the below picture show:

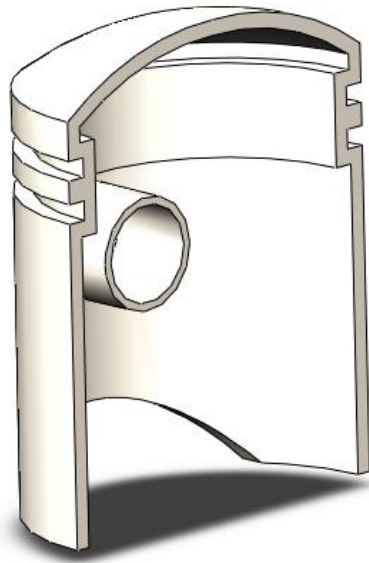


a) The part of piston model

The piston is a reciprocating mechanism in the cylinder block of an automobile engine. It was basically revolved by a simple stretch as the graph show

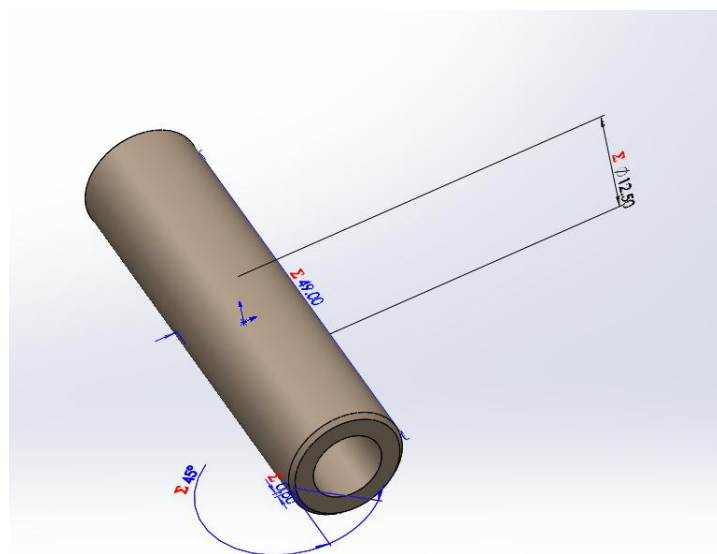


After revolving it, extrude a circle and cut a part of it. As the cross sections view show below



b) The part of piston pin model

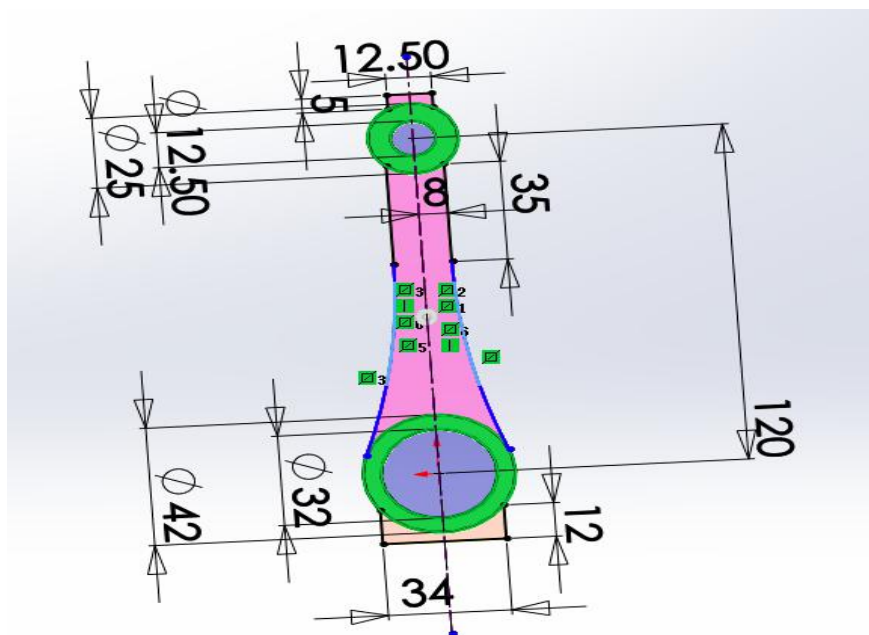
The piston pins are cylindrical pins mounted on the piston skirt. And it is a simple extrude model with a circle as the picture show and its thickness is 2.50mm. Finally get a fillet in 45 degrees with 0.5mm.



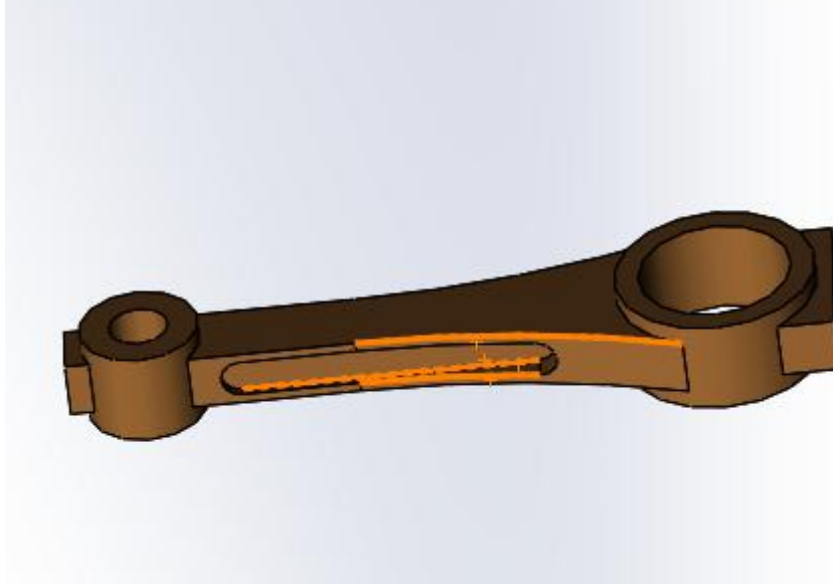
名称	数值/方程式	估算到	评论
全局变量			
添加整体变量			
特征			
添加特征压缩			
方程式			
"D1@草图1"	= 12.5	12.5mm	
"D1@拉伸-薄壁1"	= 49	49mm	
"D2@倒角1"	= 45	45度	
"D1@倒角1"	= 0.5	0.5mm	
添加方程式			

c) The part of connecting rod model

The piston and the crankshaft are connected, and the force received by the piston is transmitted to the crankshaft, and the reciprocating motion of the piston is converted into a rotary motion of the crankshaft. The connecting rod model is extruded by two stretches as the graph whose dimension is indicated show



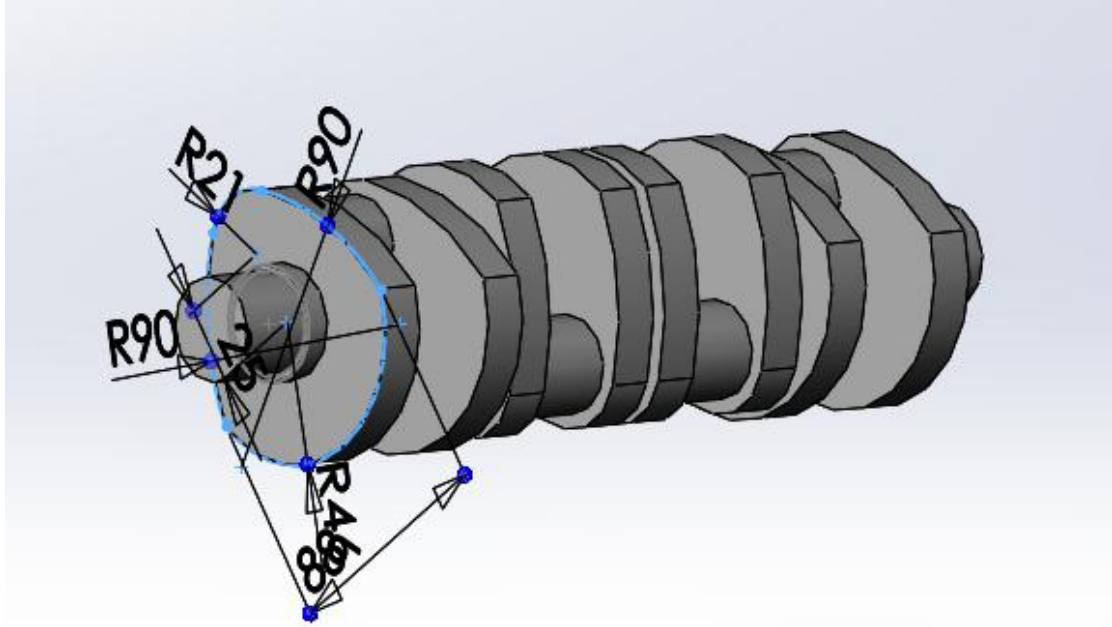
Ultimately the connecting rod is done after the two circles are cut.



d) The part of crankshaft model

The crankshaft is the most important component in the engine. It receives the force from the connecting rod and converts it into torque that is output through the crankshaft and drives other accessories on the engine work. The crankshaft is subject to the combined effects of centrifugal force of the rotating inertial force, so that the crankshaft is subject to bending and torsional loads. Therefore, the crankshaft is required to have sufficient strength and rigidity, and the surface of the journal needs to be wear-resistant, uniform in work and good in balance. The

crankshaft is symmetry and modelling by 19 extrudes part and 9 of them was mirrored.



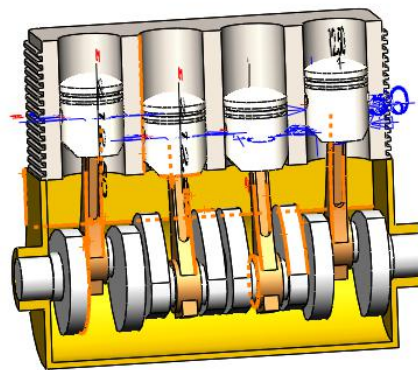
e) The part of upper block model

Cylindrical metal parts that guide the piston in a linear reciprocating motion in the cylinder. The upper block is also symmetry and it was modelling by a simple stretch:

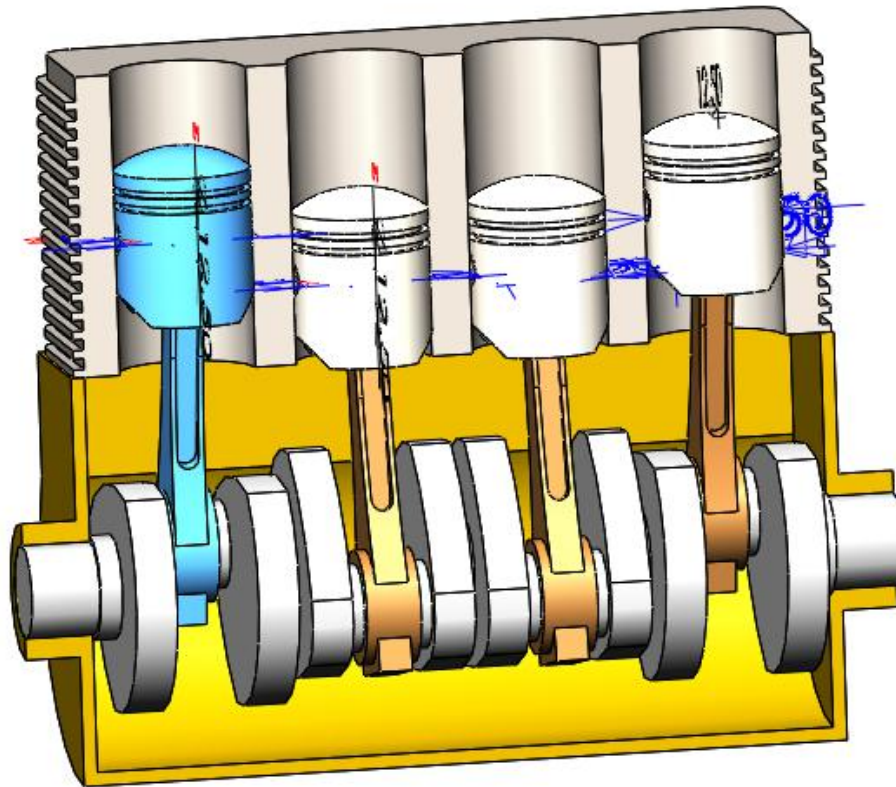
A 3D model of a mechanical part, likely a bracket or support, shown in a perspective view. The part is olive green. Key dimensions are indicated: a vertical dimension of 65, a horizontal dimension of 52, and a curved surface with a radius of R72.50. The part features a central cutout and a smaller circular feature on the right side.

2. Assemble the separate parts of the engine

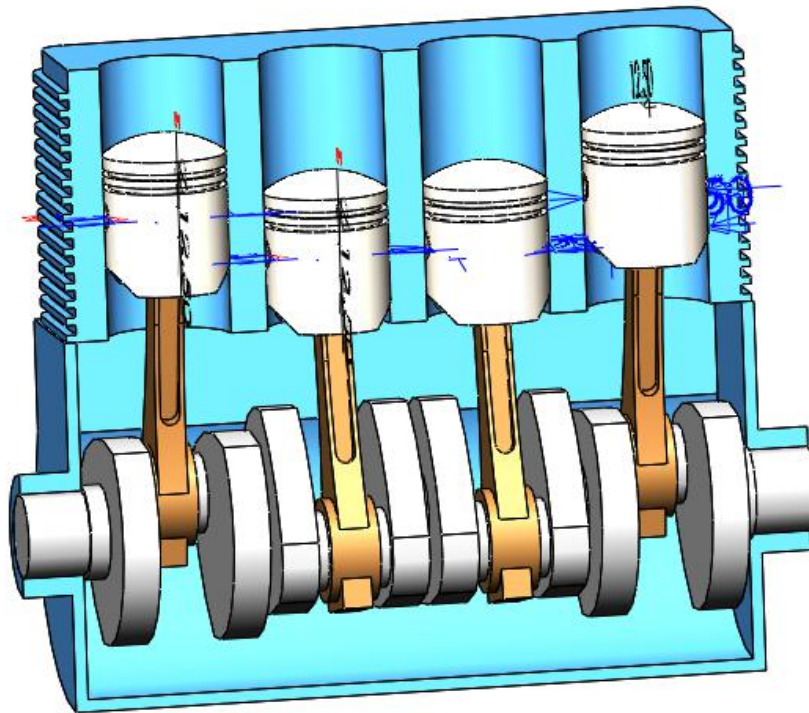
After modelling all the parts of the engine, assembly of it should be done for the motion simulation and finite element analysis.



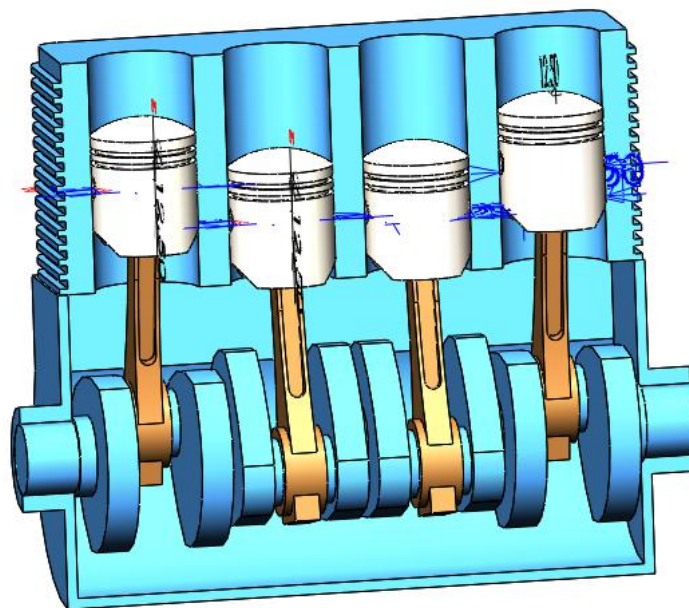
Firstly, author assemble the piston, piston pin and the connecting rod. Piston, connecting rod and piston pin are all concentric and then mate the outer surface of piston with the piston pin. The upper connecting rod is mated with the piston pin and make them symmetry.



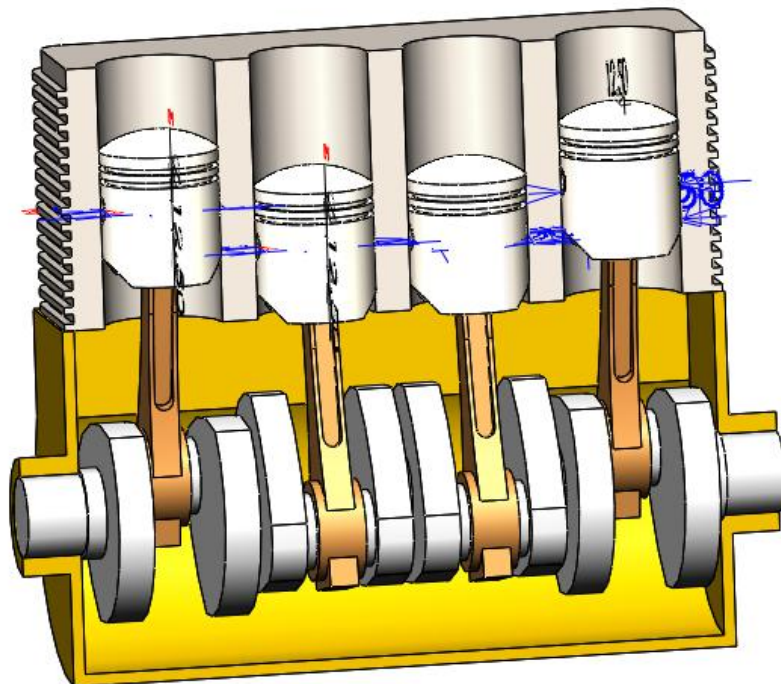
Secondly, the upper block should mate with the lower block which is simple the lower face of upper block to the upper face of the lower block and make them symmetry.



Thirdly, author should mate the crankshaft with the lower block, which is concentric with the hole of the lower block. Then make the crankshaft and the lower block symmetry.



Then connecting rod should mate with the crankshaft. Obviously the middle two are symmetry and the other two are also symmetry separately. Only two of them should be mated with crankshaft by the lower connecting rod, then mirror the accomplished two with mates.



3. The assembly engine motion simulation

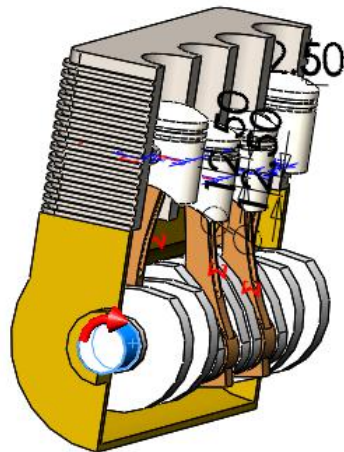
(Schroff, 2019) SOLIDWORKS Motion is a computer software tool that Supports engineers to analyse and design mechanisms. It is a module of SOLIDWORKS product family developed by Dassault Systemes SOLIDWORKS corporation. This software

supports users to create virtual mechanisms that answer general questions in product design as describe next.

After accomplishing the parts and assembly of the engine, author demonstrate the SOLIDWORKS Motion about the engine model.

a) Create a motor for the engine motion

Obviously, it is an engine and it is complex to make four motor for four cylinder which is totally different to drive the piston, connecting rod and the crankshaft. Then in turn author drive the crankshaft which is a rotating body. Finally, the rotating motor which is 100RPM and clockwise is created as the picture show:

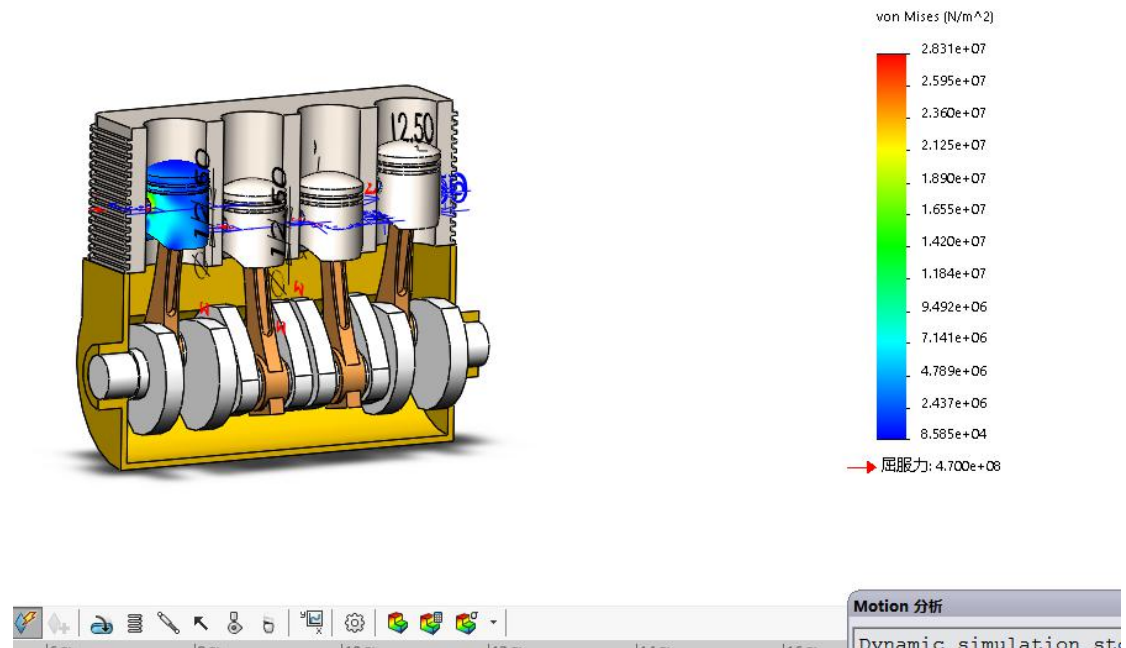


b) Motion action

After adding the damping between the cylinder and the piston, author calculate the action. The reserve real engine motion can be demonstrated.

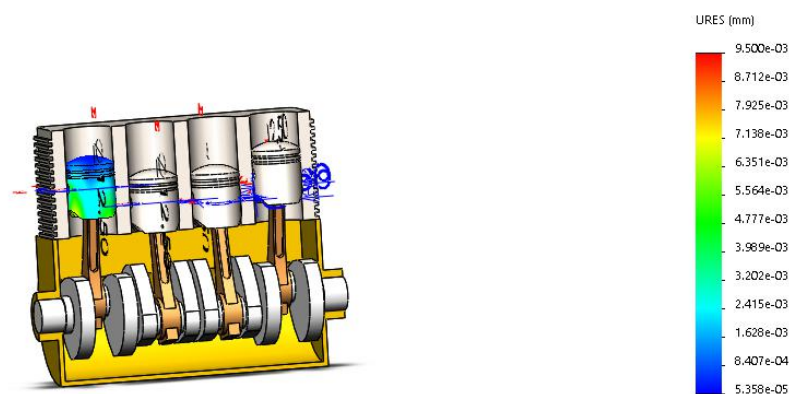
c) Motion simulation of the piston

The piston connecting rod assembly is an important part in the internal combustion engine that affects the output power and working life. The piston bears the pressure of the chemical reaction of the fuel and outputs the power of the engine. Due to the high working speed of the piston assembly, the mechanical and thermal loads are loads, and the working environment is harsh. Its working ability has a significant impact in the performance and reliable of the engine. When accomplishing the motion action which has set the motor and motion manager, the motion simulation could be done when applying the material to the piston and create a proper mesh. Then here is the stress analysis below:



The graph shows the greatest stress in the piston pin. The main area causing piston damage is also an important consideration for optimal design.

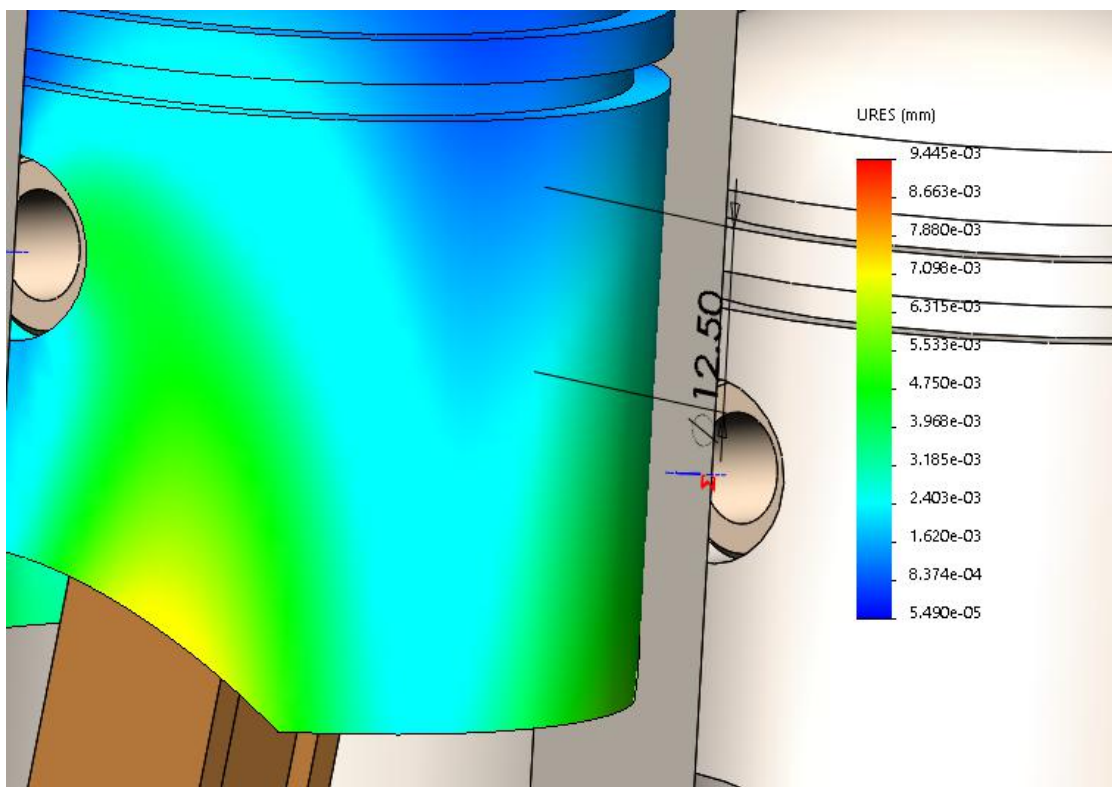
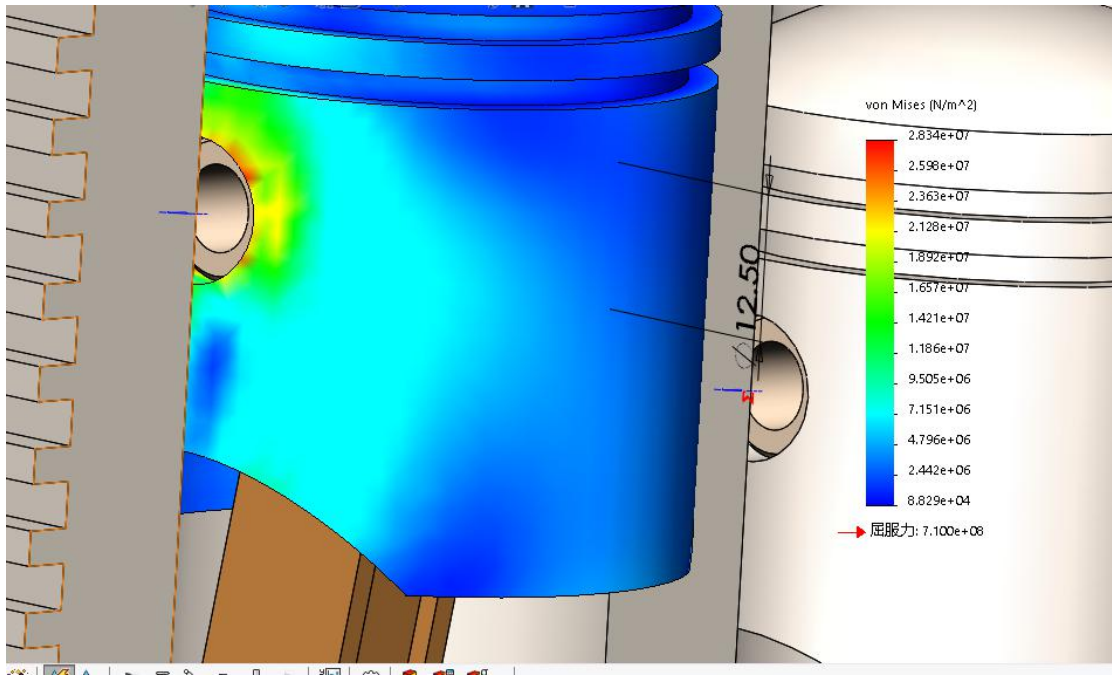
The static placement graph is following by it.



in which the biggest placement can be demonstrated in the piston skirt. Piston skirt refers to the part below the lower end of the oil ring groove. Its role is to guide the piston in a reciprocating linear motion in the cylinder and to receive side pressure. Therefore, the skirt must have the necessary length and sufficient area to ensure reliable guidance and reduce wear.

d) Modify the piston part

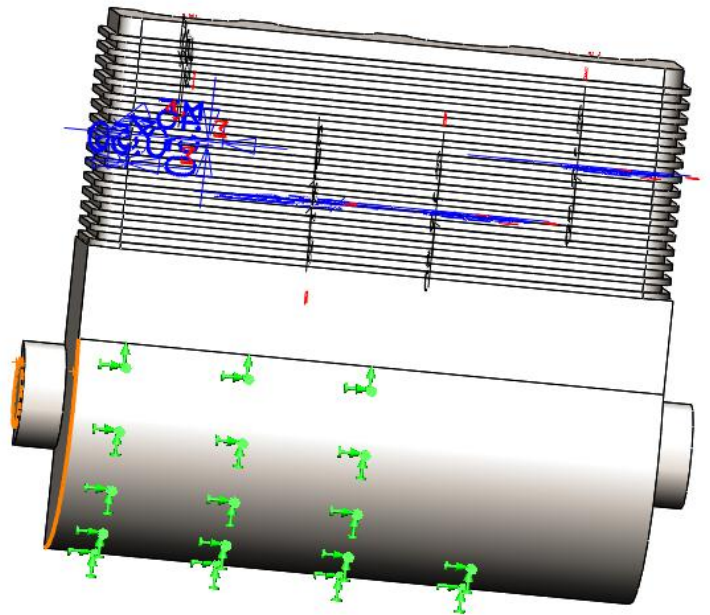
After analysing the motion simulation of the piston, there is a way to modify the piston by change the material of the piston to steel 4030normalizing whose yield strength is 710000000N per Square meter. By changing the material, the yield strength becomes greater and the modified results as the graph show:



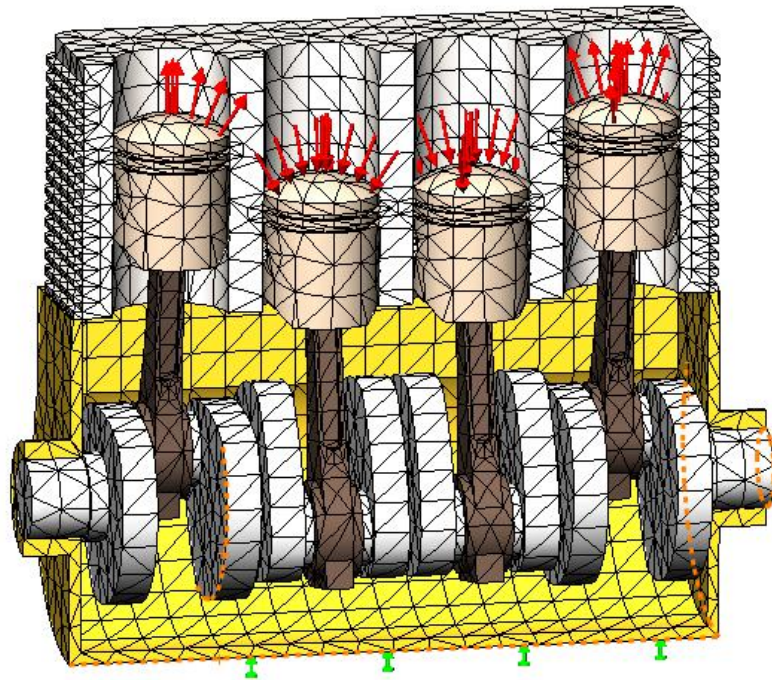
4. The finite element analysis

Finite element analysis (FEA) uses mathematical approximation to simulate real physical systems (geometry and load conditions)

Here author create a static analysis about the engine, then applying steel 4030 (annealing) to all the parts. After applying the material, the lower block is fixed.



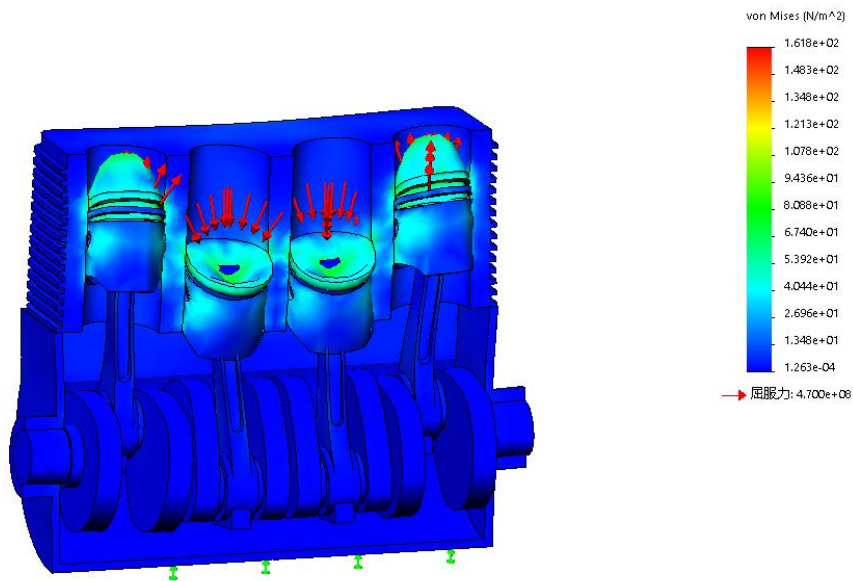
Secondly, author create a high solid quality mesh whose Jacobian is 4 and the total number is 27448.



In order to simulate the gas force of real engine, author put four pressure on the piston with tow different direction but they all are 5N per Mm.

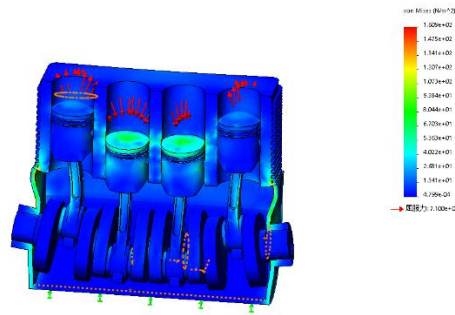
Finally, the result could be calculating and shown as a picture

below:



As the graph shows, the deformation of the piston is huge and the engine could not work. Then the author changed the material of the piston to steel 4030 (Normalizing) and the result did not make a big difference. And the author changed all four pressures to 1 N per Mm, but the result still did not make a big difference.

Finally, the author changed the middle two pressures to 1 N per Mm, while the other two remained at 5 N per Mm. Then the result became better.



Then it is easy to be found that the piston is stronger when it is tensile. The four pistons are in the same condition when the engine work. As a result, all the cylinders should bear the greatest tensile force.

5. Conclusion

This report is mainly divided to three parts – assembly modelling, motion study and the static study in finite element analysis. In the first part, author demonstrate the methodology within modelling and use the equation to modelling the piston pin and connecting rod. The assembly is accurately modelling and the data is on the graph. The total masses inputted for the simulation is 3068.79 grams. Motion study is done after the assembly accomplishing, in order to imitate to the real engine, the torque is on the crankshaft and it is 100RPM. Then the reverse engine motion is shown, cylinder motion could be analysed.

Finally, author does the finite element analysis to investigate the engine. The piston which in tensile is stronger than pressure. The great pressure should be considered when people design the piston.

6. Reference

Schroff, S. (2019). Motion Simulation and Mechanism Design Using SLIDERWORKS MOTION 2019. *SDC Publication*, 1-1.