RESEARCH ARTICLE OPEN ACCESS

Kinematic and Dynamic Modeling and Simulation of Four Stroke Petrol Engine

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Abstract
This paper presents the kinematic and dynamic modeling and simulation of an internal combustion engine. The study aims to conduct the kinematic and dynamic simulation of the four stroke engine in ADAMS/view software. The thermodynamic cycle (Otto cycle) of a standard four stroke engine is calculated by MATLAB 11.0 and is implemented in ADAMS/view to study the dynamic behavior. All the parts of the engine are modeled in Pro-E according to the original dimension of engine. The assembly from Pro-E is imported in ADAMS/view and proper joints are applied to it. The gas force acting on the piston according to the Otto cycle is applied as a single component force. ADAMS/view help to perform the kinematic and dynamic analysis of the engine easily as the inputs required for the analysis are very less and results can be obtained in terms of position, velocity, acceleration and force acting on the parts and at joints of the mechanism.
Keywords: Kinematic, dynamics, four stroke petrol engine, ADAMS/view.

I. INTRODUCTION

The Internal combustion petrol engine are those that burn their fuel which is mixture of air and petrol from carburetor inside the cylinder. These engine convert the chemical energy stored in their fuel into heat energy during the power stroke of piston. The heat energy produced from burning of fuel is used for motion of piston

The working of a four stroke petrol engine is based on simple slider crank mechanism. The kinematic of engine is similar to slider crank mechanism. [3]

II. MODELING OF ENGINE PARTS

The modeling of parts of an internal combustion engine namely piston, connecting rod, crankshaft and cylinder are done using the original dimension of a engine in Pro-e 5.0 . The assembly is generated in the assembly module of the CAD software and imported in the parasolid (.x_t) format in ADAMS/view.

The material used for piston is aluminum 2024 with density as 2.78 gm/cm^3.[1]

TABLE No. I PARAMETERS OF THE PISTON

Parameters of Piston	Measured Value (in mm)
Diameter of the piston	50
Thickness of Piston	4.5
Radial Thickness of Groove	2.5
Axial Thickness of Groove	1
Total Length of piston	39
Land b/w ring	2
Distance from top land to the first groove	4
Outer Diameter of pin	13.2
Inner Diameter of pin	9.1
Length of Pin	38.6

TABLE No. II DIMENSION of CONNECTING ROD

S.no	Parameter	Values
1.	Length of connecting rod	94.7mm
2.	Outer Diameter of Big end	39.02mm
3.	Inner Diameter of Big end	30.19mm
4.	Outer Diameter of small end	17.75mm
5.	Inner Diameter of Small end	13.02mm

The material used for connecting rod is cast iron and the density is 7.197e-006 Kg/mm^3. [2]

TABLE No.III DIMENSION of CRANKSHAFT

Parameter of crankshaft	Measured Value (in mm)
Diameter of the crank	89.6
Diameter of the crank pin	30
Distance between outer surfaces of crank	40
Distance between inner surfaces of crank at crank pin side	15
Distance between inner surfaces of crank on lower side	10

The material used for crankshaft has a density of 7800 kg/m^3.

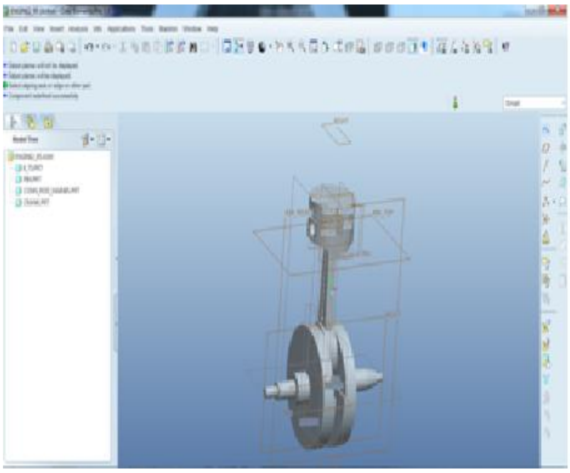

Figure No.1 ASSEMBLY OF ENGINE

III. SIMULATION OF MODEL

1. Appling Joints

The parasolid model from Pro-e is imported in ADAMS/view. Here joints are applied between different parts of the engine so that the desired motion of all the parts is obtained . The mechanism has the following bodies.

- Connecting Rod
- Crankshaft
- Piston
- Pin

Piston and piston pin is connected with the help of a fixed joint so that both act as a single body during the motion of mechanism. The connecting rod and piston is connected with the help of a cylindrical joint which allows it to rotate or slide along the axis. Piston is given translational motion with the help of translational joint between ground and piston. Connecting rod and crankshaft is connected with the help of a spherical joint which allows free rotation about a point. Both the ends of the crankshaft are also connected to ground with the help of a spherical joint.[4]

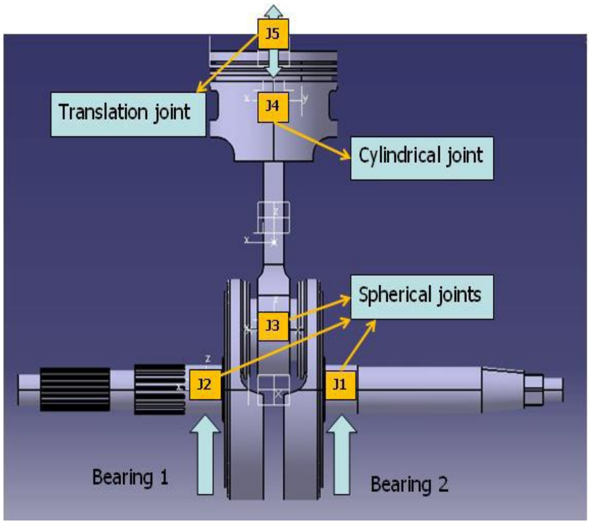

Figure No.2 JOINTS APPLIED IN ENGINE

2. Imposing Motion

The motion to be applied in mechanism is generated from ideal Otto cycle and is applied in the form of force acting on the piston. The gas force acting on the piston is calculated according to the ideal Otto cycle in Matlab. The properties of the ideal cycle are used to calculate the cylinder pressure and the gas force acting on the mechanism in a working cycle.[6] The calculated data is used to make pressure v/s crank angle and pressure v/s volume graph in Matlab.[5] The gas force calculated is applied as a single component force on piston. The data of the gas force is imported in the form of test data in ADAMS and is used in the form of a spline. The single component force is defined as a function which uses the spline as the input data. The spline represent the gas force acting on the piston in a single cycle of the engine.

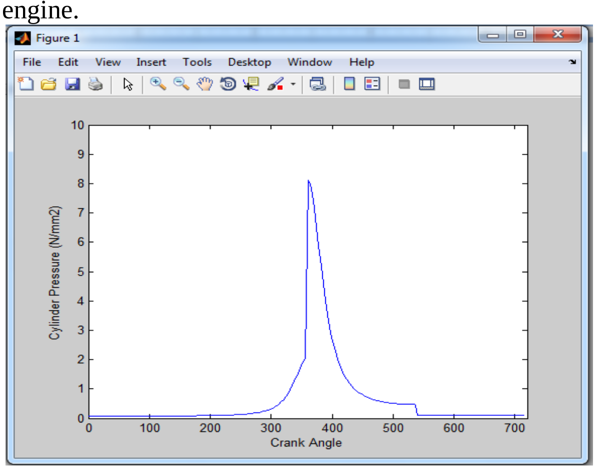

Figure No.3 Pressure v/s crank angle graph

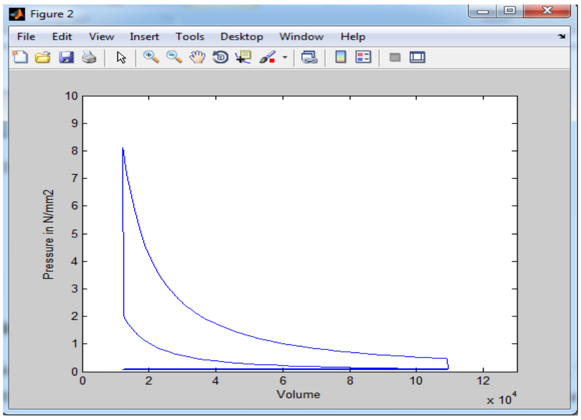

Figure No.4 Pressure v/s volume graph

IV. RESULT & DISCUSSION

The kinematic analysis of any mechanism include the study of it displacement, velocity and acceleration without the consideration of any external forces on it. Here the kinematic analysis of piston is done so as to get the idea of the whole system. The forces acting on the piston governs the motion of the other parts of the mechanism. The gas force acting on the system is not considered in the analysis only the change in position of the parts due to the force acting on them is observed for change in position

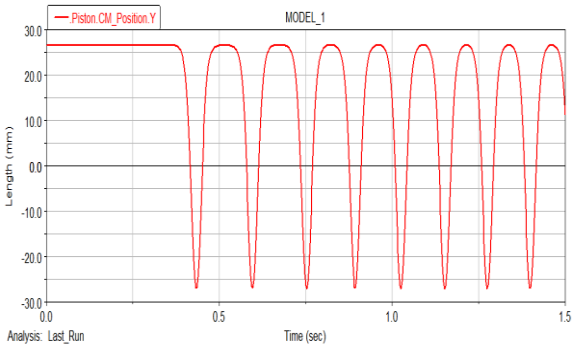

Figure No.5 Position of piston

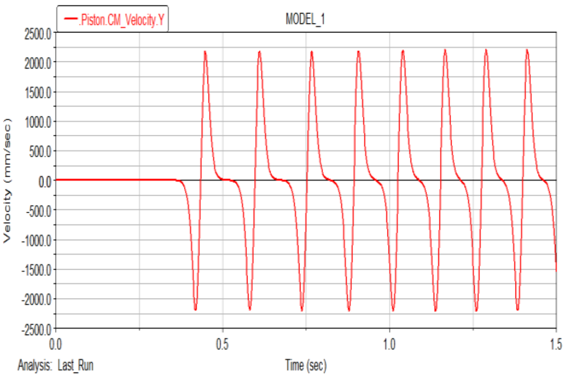

Figure No.6 Velocity of the piston

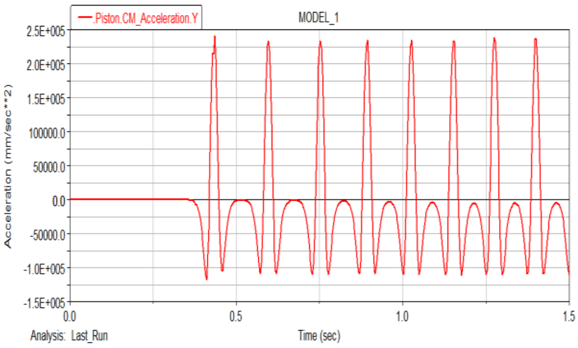

Figure No.7 Acceleration of the piston

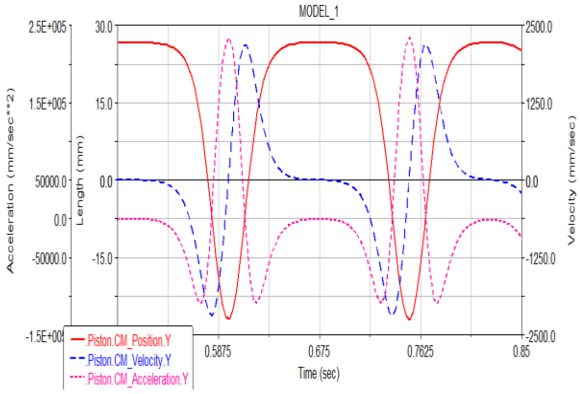

Figure No.8 Position, Velocity and Acceleration for a single Cycle

The dynamic analysis of the mechanism include the consideration of the force acting on it. The dynamic analysis is carried to study the effect of forces of every part of the mechanism, also their effect on other parts of the mechanism.

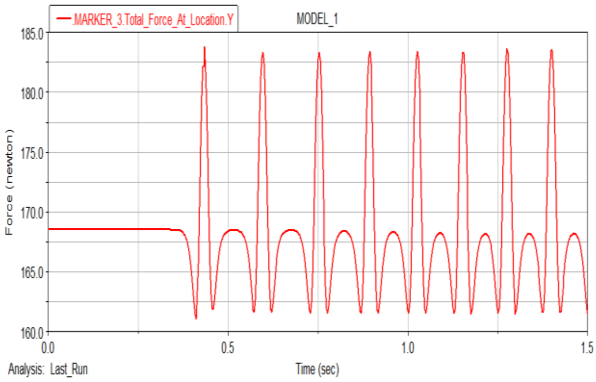

Figure No.9 Force acting on the piston

The total force acting on the piston is important for the further calculations and the power source of the engine. The maximum force acting on the piston is 183.84 N. This force is transmitted to connecting rod and finally to crank which is the output power of the engine.

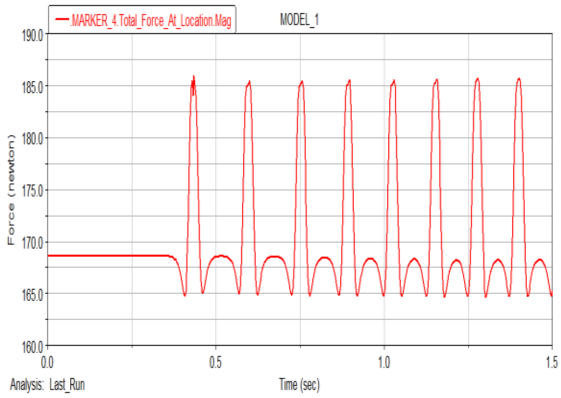

Figure No.10 Force acting on small end of Connecting rod

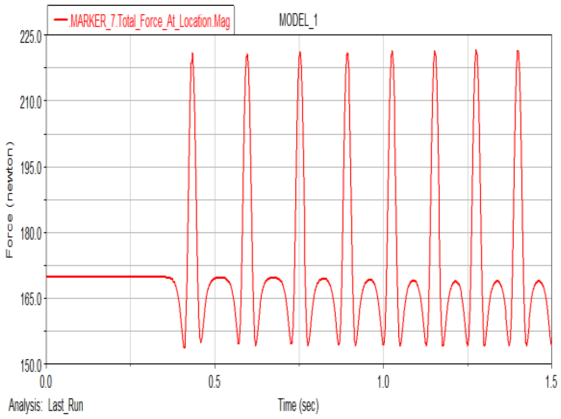

Figure No.11 Force acting on big end of connecting rod

The force acting at the small end of the connecting rod whose value is approximately same as the value of the force acting on the piston. The force acting at the center of gravity of the connecting rod is zero which shows that the mass distribution at the small and big end is suitably done. The force acting on the big end of the connecting rod is 221.78N which is higher than the small end.

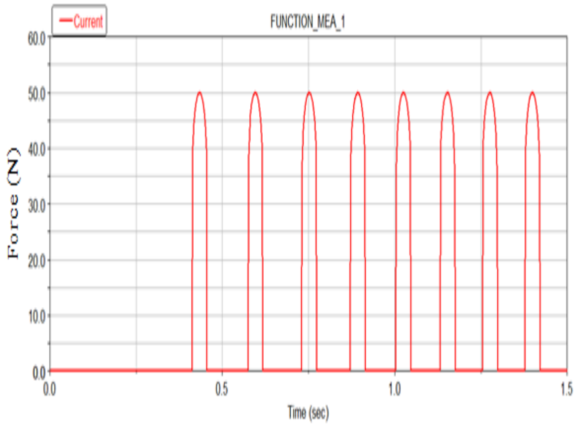

Figure No.12 Side Thrust of the piston

The side thrust is measured with the help of impact function which calculates the value of the force acting on the cylinder walls due to collision of the piston. The impact function has many inputs in terms of displacement and velocity function of the two surface also the stiffness and the damping coefficient of the material is required. The output is in terms of the force acting perpendicular to the surface of the piston on the cylinder walls.

V. CONCLUSION

The study shows that ADAMS can be used as an effective tool for estimation of the dynamic forces on any mechanism. The kinematic analysis of the system can be used to determine the position, velocity and acceleration of the parts of the engine. The dynamic analysis include all the force acting on the system. The input required for the analysis are the forces acting on the system, the mass properties of each part and the proper joints between every member or link of the mechanism. The effect of inertia forces is added to the simulation automatically which saves the calculation time.

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