
Using ADAMS/Engine For Analyzing Crankshaft Loads And Torsion Vibration.

2004-40

Ignacio Manzo, MSc.

Author

Email: Ignacio.manzo@exatec.itesm.mx

Dr. Noel León-Rovira.

Co-author

Center for Product Design and Innovation,

Tel.: +52 81 81582012, Email: noel.leon@itesm.mx

Instituto Tecnológico y de Estudios Superiores de Monterrey, Mexico.

The Monterrey Tech System has developed into an institution recognized — both nationally and internationally — for its academic excellence. Monterrey Tech students are pioneers in the use of Computer Aided Engineering tools. MSC.ADAMS is used at several engineering and graduate courses. MSC.ADAMS has been implemented also in several master program theses to gain a better insight in its different modules. The present paper shows an example of a thesis of the master program Manufacturing Engineering using ADAMS/Engine.

During this project, a virtual prototype of an internal combustion engine with four cylinders and 1600 cc was simulated with the objective of analyzing the loads applied on the crankshaft and its dynamic behavior.

Starting from the gas forces acting on the pistons, the torsion vibration and the reaction forces of the crankshaft supports were generated.

This work was the continuation of a previous master thesis where Working Model 3D had been used to simulate the dynamic behavior of a similar four cylinder engine. However, in that former work the reaction forces and torsion vibrations of the crankshaft could not be simulated.

The focus on crankshaft simulation is a first step toward the creation of specific knowledge for supporting local enterprises that manufacture forged crankshafts for car and truck engines.

Keywords: ADAMS/Engine, crankshaft engine, torsion vibration, main bearings forces,

Introduction

At Monterrey Tech System, research work is being held to give support to the local industries. This master thesis has been pioneer in the use of ADAMS/Engine for virtual prototyping and simulation of engines. During the design process, design engineers apply a variety of techniques and scientific principles with the purpose to define a device with enough detail to complete the manufacturing process. During the design process engineers develop new products or innovate the actual one, using tools to facilitate the required analysis, save time and costs and in general to increment the efficiency to reach the target.

3D-CAD parametric modeling has become one of the principal tools during the design process of machinery. Using 3D-CAD tools it is possible to create more complex

models in less time and with lower costs, obtaining at the end a virtual geometric model. For further analysis, new capabilities are added to the 3D virtual models as multi body systems. ADAMS/Engine is a multi body system that gives the possibility, of adding movement, and analyzing the dynamic behavior of engine models and its components.

Scope

The main target of this thesis is to analyze the dynamical stresses acting in the crankshaft of four-cylinder inline engine starting from the dynamic torque generated by the gas combustion.

The process of building templates in ADAMS/Engine in order to model virtual functional prototypes has been applied in this project. This analysis is then performed

by simulation with ADAMS/Engine, which is then validated with one simpler analytical model.

Development of Virtual Functional Prototypes.

The entire crank train was first modeled using Mechanical Desktop. This parametric model was then transferred to Adams/View as step files for building the virtual functional prototype. Later, using ADAMS/AutoFlex a finite element analysis of the crankshaft was performed, and first partial results of this module were found. After that, the use of ADAMS/Engine was implemented to build a template of a model dynamically similar to the 4 cylinders and 1600 cc engine selected. The crank train subsystem was analyzed, consisting of the crankshaft, conrods and pistons. The model is dynamically equivalent to the real engine selected. The objective was to obtain the loads acting at the main bearing during engine functioning and to analyze them for understanding its behavior and sources. The use of ADAMS/Engine was implemented based on a self learning process of its user interface. At first the idea was to complete the model using Mechanical desktop, but then, as new tools were discovered in ADAMS/Engine and after completing the learn process of its standard interface, the total crank train was created in ADAMS/Engine.

Methodology:

The methodology consisted in building a virtual functional prototype of the four cylinder engine based on the software's template builder. The virtual functional prototype, created is dynamically equivalent to the real engine. It was simulated using ADAMS/Engine Powered by FEV. This way it was possible to obtain the main forces acting on all the

bearings as also the torque at the crankshaft.

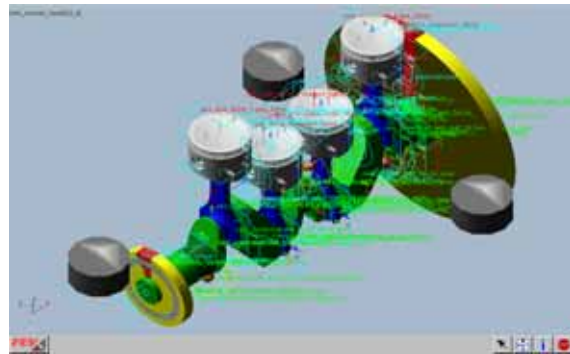


Fig. 1. General View of the template.

Results Considering One Value of the Angular Velocity

A simplified analytical model for a one cylinder engine was used for comparing the simulations results with the analytical ones.

Analytical calculus for the simplified one cylinder engine, were obtained using TK Solver as shown in the figure 2. [4]

Comparison chart: Analytically vs Adams

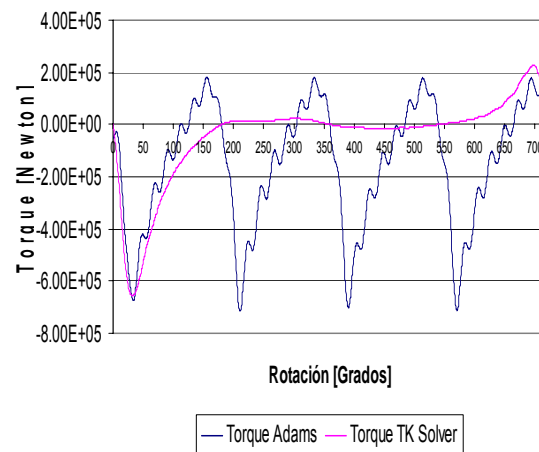


Fig. 2. Analytical model in TK Solver.

$$Tg21 = Fg \cdot r \cdot \text{SIND}(\omega \cdot t) \cdot \left[1 + \left[\frac{r}{l} \right] \cdot \text{COSD}(\omega \cdot t) \right]$$

Results obtained in ADAMS/ Engine show the behavior of the forces acting in the main crankshaft bearings. In Fig. 3 are shown the values of the forces acting in the direction of the piston axis race (x axis). Here it is possible to identify how these forces are transferred to the bearing at specific times of the combustion cycle. The red line is the force in Newton acting upon the front bearing (#1), the purple line is the force acting upon bearing # 3. It is possible to see that during the maximum force value acting upon bearing # 1 the force in bearing # 3 has its minimal value. Flexibility of the crankshaft and the flexibility of the bushings result in interconnections of the forces acting in the bearings in dependence of time.

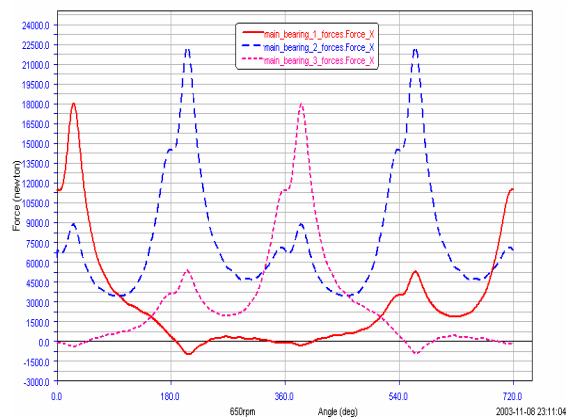


Fig. 3. Main bearing forces at 650 rpm

Considering Different Values of the Angular Velocity

In order to analyze the behavior of the torque at different angular velocities, simulations were performed from 650 rpm to 4500 rpm. The results are shown in fig 4. Taking as reference a similar work made with a ship engine shaft [7], it is possible to conclude, based on this result, where the maximum torque in the system is obtained at the resonance frequency of the system. The torque obtained at 2500 rpm (15000 degrees/sec) is smaller than at 3500 rpm (21,000 degrees/sec) due to the reduction of the differential between the excitation frequency and the natural frequency of the system. The maximal resulting torque in

the system is given at 3100 rpm (18,600 degrees/sec) this is because the differential between the excitation frequency and natural frequency of the system is at its minimum value. It is possible to conclude that at this speed the system is under main resonance.

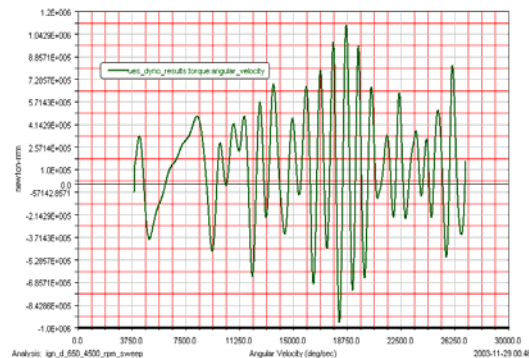


Fig. 4. Torque from 650 to 4500 rpm in ADAMS/Engine.

In fig. 4 is shown the torque behavior across the angular velocity of the crankshaft.

Conclusions and Recommendation.

The research and self-learning process of the ADAMS/Engine module allowed identifying the required steps for the templates creation and simulation. The procedures to generate a crank train subsystem that includes: crankshaft, conrods, piston pin, and piston may be performed with much less effort and in much less time than creating a model in a 3D CAD system and transferring it to ADAMS/VIEW for simulation.

The results obtained in ADAMS/Engine as well as the analytical results obtained in TKSolver offers a perspective of the internal function, forces and torque of the engine, which help in better understanding the relationships among the parameters of the entire system. The results obtained in ADAMS/Engine show effects that are not identifiable with the analytical model, as more details as higher harmonics vibrations

appear during the simulation. The simplified analytical model for only one cylinder engine does not consider the higher harmonics effects.

It is recommended to continue exploring the creation of the entire engine in ADAMS/Engine as also to further understand the possibility of completing the templates using CAD models as also ADAMS/Autoflex to get the finite elements model combined with ADAMS/Engine

In this case, only a comparison between the analytical model of torque and the results of the simulation were made, as no other data were available for comparing the forces acting upon the bearings.

For a thorough understanding, it is recommended to develop an experimental measurement of the forces acting in the main bearings and comparing these results with the obtained in ADAMS/Engine.

References.

1. MSC.ADAMS, Power train Dynamics Applications using "ADAMS/Engine powered by FEV", ADAMS/AutoFlex User Manual V12
 2. Edward F. Obert. Internal Combustion Engines, Publisher Compaia Editorial Continental; 1996.
 3. Fundamentals of machine components design / Robert C. Juvinall, Kurt M. Marshek. Publisher Wiley Text Books
 4. NORTON Robert L. Design of Machinery, McGraw Hill, 1995 México.
 5. Alejandro Roque, Simulación de un motor de combustión interna, 2002.
 6. Autodesk Mechanical Desktop V6, Users Manual.
 7. Preliminary torsional vibration analysis of the propulsion system, CADEA CO.
-