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Design And Analysis Of Automotive Powertrain Using Static, Model, Thermal And Transient Structure Analysis Techniques

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Abstract: **In a motor vehicle, the term power train describes the main components that generate power and deliver it to the road surface, water, or air. This includes the engine, transmission, drive shafts, differentials, and the final drive (drive wheels, continuous track as in military tanks or caterpillar tractors, propeller, etc.). Sometimes "power train" is used to refer to simply the engine and transmission, including the other components only if they are integral to the transmission.**

This project aim is to explain how components function and then represent their behavior through mathematical models based on the physics of their operation. Then, the components can be combined together as a complete power train system and the resulting model should provide an important tool to contribute to vehicle design. The design process was done in SOLIDWORKS 2015 and it includes parts such as flywheel, clutch and gearbox. Assembly model was imported into ANSYS WORKBENCH 14.5 to analyze on structural parts. It includes static, model and harmonic analyses are performed on power train. Then we concluded that which material is suitable for the design of Power train depends on the analysis results.

I. INTRODUCTION

The term power train refers to the group of components that generate power and deliver it to the driving wheels. It includes the energy generating engine, the clutch, the transmission, the various drive shafts and the differential. The driveline is the portion of a vehicle after the transmission which changes depending on whether the vehicle is front-wheel drive, rear wheel drive, or four-wheel drive.

The components in the powertrain are to improve their performance efficiency, emissions control, refinement as well as their overall cost effectiveness. The most recent trends in powertrain component engineering are summarized below.

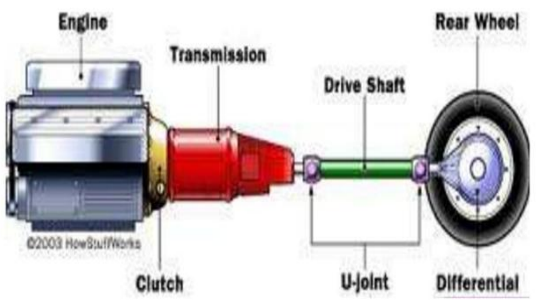


Figure: Powertrain components

II. COMPARISONBETWEENMANUALTRANSMISSIONANDAUTOMATIC TRANSMISSION

Manual transmission	Automatic transmission
Vehicles with manual transmission are usually cheaper.	Vehicles with automatic transmission are costlier than those of manual transmission.
Manual transmission has better fuel economy. This is because manual transmission has better mechanical and gear train efficiency.	Automatic transmission has not better fuel economy. This is because automatic transmission has not better mechanical and gear train efficiency as compare to those of automatic transmission
Manual transmission offers the driver more control of the vehicle.	Automatic transmission does not offer the driver more control of the vehicle as compare to that of automatic transmission system.

Table: Comparison between manual transmission and automatic transmission

III. MATERIALS USED IN POWERTRAIN

Most of the aluminium which is supplied today to the automotive market is used in the power train.

On average, the power train of the cars produced in Europe contains about 80 kg aluminium. This corresponds to 55-60% of the average total aluminium content of the automobiles produced in Europe. For cars produced in North America and in Southeast Asia, the proportion of the aluminium applications in the power train is with 65-70% even higher.

The majority of the aluminium power train components are cast parts (80-85%), produced by different casting technologies. The applied casting alloys typically have an alloy concentration of up to 20%, mostly silicon, magnesium and copper. Many aluminium casting alloys are produced from recycled aluminium, i.e. post-consumer aluminium scrap, often from end-of-life vehicles. The share of the power train components produced from wrought alloys is relatively small (approx. 10% rolled, approx. 5% extruded and about 1% forged aluminium).

In different power train applications, aluminium is the material of choice and has reached complete market penetration. For example, aluminium has displaced copper or brass as the preferred heat exchanger material more than 50 years ago and is today the exclusively used material for these applications. Aluminium is also practically the only material used for pistons. For cylinder heads, transmission housings and many ancillary aggregates, full market penetration is approaching very fast. Lately, engine blocks have been the largest driver of aluminium growth, first for gasoline engines, but now for diesel engines too.

The significant growth of the aluminium share in the engine occurred mainly at the expense of cast iron. However further growth potential in the power train is limited. In fact, there are applications where other lightweight solutions are starting to replace aluminium castings. Today the main material competitors for aluminium in power train applications are high performance plastics, which offer the possibility of a cost efficient part fabrication in areas not subjected to high temperature impacts, and cast magnesium solutions. In the future, the absolute volume of aluminium used in power train components (engine, transmission and driveline parts) may decline due a gradual shift to smaller and more fuel efficient vehicles using smaller power train components.

IV. LITERATURE REVIEW

In 1999, AVL Company proposed a hybrid system that used a 50 cc carburetted lean-burn two-stroke engine with a 0.75 kW electric motor mounted on the engine crankshaft mainly to provide increased torque during acceleration.

Su-Hau et al (2004) focused on the highly efficient energy usage of the battery energy and proposed an integrated management system for electric motor. This integrated management system includes the power-saving controller, energy management subsystem and some hardware protection strategies. The energy management system acts as a supervisor to manage all the events about the battery energy, including the residual capacity estimation and regenerative braking operation.

David and Sheng-Chung (2004) proposed new parallel-type hybrid-electric-power system comprises an engine's energy distribution and a torque-integrated mechanism (specifically including an engine, a motor/alternator, a CVT device, and PCM as well as a 3-helical gear set). To let the engine achieve maximum thermo-efficiency with minimum emissions, the servomotors adjust the diameter size of the pulley to control the engine output for the final power-output axle and the alternator. The system is applied with a stable engine-load to maximize operating performance. The vehicle is driven by the motor alone in the light-duty mode. Meanwhile, in the medium-duty mode, power comes from the engine, with extra energy being used for battery charging. Finally, in the heavy duty mode, both the engine and motor together power the vehicle. The engine output is fixed, but the motor output power can be controlled.

Wenguang et al (2005) presented an approach to control powertrain of series hybrid electric vehicles. A formulation of the system equations and controller design procedure were proposed by them. They also proposed a new switching algorithm for the power converter for motor torque and motor flux control. The sliding mode method is applied to excitation winding control in synchronous generator to achieve the desired current distribution in powertrain.

Yimin and Mehrdad (2006) introduced a speed and torque coupling hybrid drivetrain. In this drivetrain, a planetary gear unit and a generator/motor decouple the engine speed from thevehicle wheel speed. Also, another shaft-fixed gear unit and traction motor decouple the engine torque from the vehicle wheel torque. Thus, the engine can operate within its optimal speed and torque region, and at the same time, can directly deliver its torque to the driven wheels. They also discussed the fundamentals architecture, design, control, and simulation of the drivetrain. Simulations show that the fuel economy in urban and highway driving cycles can be greatly improved.

Kuen-Bao and Tsung-Hua (2006) incorporated a mechanical type rubber V-belt, continuously-variable transmission (CVT) and chain drives to combine power of the two power sources, a gasoline engine and an electric motor in hybrid power system. The system uses four different modes in order to maximize the performance and reduce emissions: electric-motor mode; engine mode; engine/charging mode; and power mode. The main advantages of this new transmission include the use of only one electric motor/generator and the shift of the operating mode accomplished by the mechanical-type clutches for easy control and low cost. Kinematic analyses and design are achieved to obtain the size of each component of this system. A design example is fabricated and tested.

V. MODELLING OF POWERTRAIN

Solidworks Corporation was founded in December 1993 by Massachusetts Institute of Technology graduate Jon Hirschtick. Hirschtick used $1 million he had made while a member of the MIT Blackjack Team to set up the company. Initially based in Waltham, Massachusetts, USA, Hirschtick recruited a team of engineers with the goal of building 3D CAD software that was easy-to-use, affordable, and available on the Windows desktop. Operating later from Concord, Massachusetts, Solidworks released its first product Solidworks*95*, in 1995. In 1997 Dassault, best known for its CATIA CAD software, acquired SolidWorks for $310 million in stock.

SolidWorks currently markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product.

SolidWorks was headed by John McEleney from 2001 to July 2007 and Jeff Ray from 2007 to January 2011. The current CEO is Gian Paolo Bassi from Jan 2015. Gian Paolo Bassi replaces Bertrand Sicot, who is promoted Vice President Sales of Dassault Systems Value Solutions sales channel.

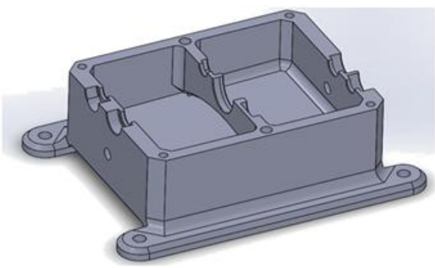


Figure: Design of Horizontal Casing

VI. ASSEMBLY OF POWERTRAIN

Constraints allow you to position mechanical components correctly in relation to the other components of the assembly. You just need to specify the type of constraints you wish to set up between two components, and the system will place the components exactly the way you want. You can also use constraints to indicate the mechanical relationship between components.

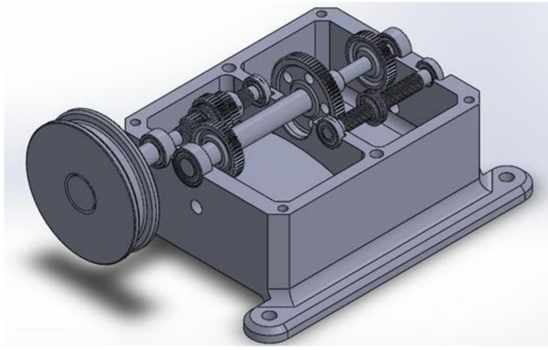


Figure: Main Assembly of Powertrain

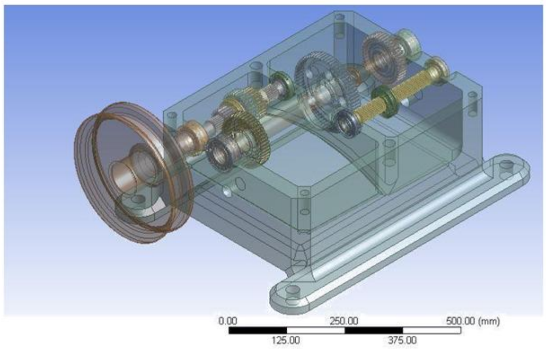
VII. COMPUTATIONAL ANALYSIS

Static analysis is used to determine the displacement, stresses, strains and forces in structures or components due to loads that do not include significant inertia and damping effects. Steady loading and response conditions are assumed. The kind of loading that can be applied in static analysis include externally applied forces and pressures, steady state inertia forces such as gravity of rotational velocity imposed (non-zero) displacements, temperatures (for thermal strain).

A static analysis can be either linear or non-linear. In our present work, we are going to consider linear static analysis.

The procedure for static analysis consists of these minimum steps:

1. Building the model
2. Obtaining the solution
3. Reviewing the results



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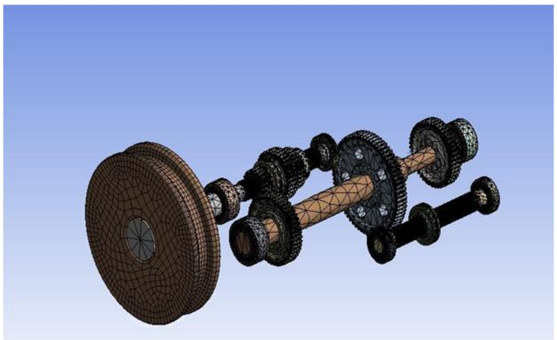
MESHING:



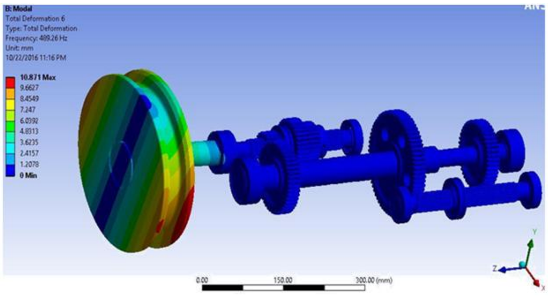


Figure: Sixth mode of Powertrain (Structural Steel)

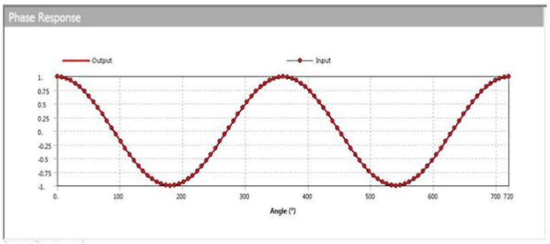


Figure : Strain Phase response of powertrain (Structural steel)

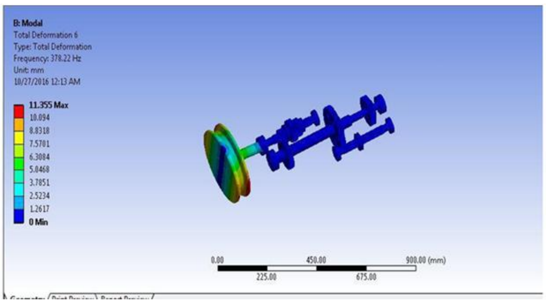


Figure : Sixth mode of powertrain (Cast iron)

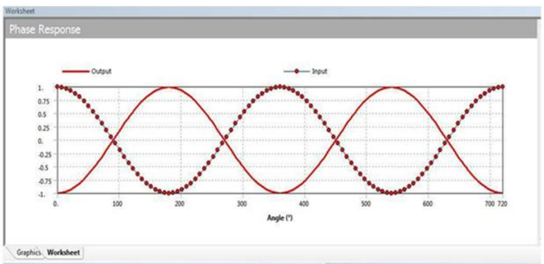


Figure: Strain Frequency response of Powertrain (Cast iron)

VIII. RESULTS & DISCUSSION

Structural analysis, modal and Harmonic analysis of powertrain was successfully performed using ANSYS WORKBENCH 14.5. Here, we used two different types of materials such as structural steel and Cast Iron. For each material we got output parameters related to deformation, stresses, strains and Natural frequencies. These are shown in below table.

Material / Parameter	Deformation (mm)	Equivalent Stress (MPa)	Normal stress (MPa)	Equivalent elastic Strain	Normal elastic Strain
Structural steel	5.3e-5	0.267	0.22	1.36e-6	1.9e-6
Cast Iron	9.76 e-5	0.264	0.213	2.45e-6	1.9e-6

Structural Output parameters from analysis results

Material / Parameter	Minimum Frequency (Hz)	Maximum Frequency (Hz)
Structural steel	80.21	62.12
Cast Iron	489.26	378.2

Table : Frequency output parameters from analysis results

IX. CONCLUSION

- From the results we can conclude that both materials Structural steel & Cast iron has almost same output parameters expect deformation.
- The deformation value for cast iron is higher than structural steel. But in terms of quality of material, we should select Cast Iron as a material to manufacture the Powertrain.
- This project helped in understanding various software's and analyzing it under various conditions and different stresses.
- The meshing of a complex part is made simple by keenly observing and applying the known dimensions, which is a tricky job.
- Through the project the applications of the tools present in the software has become easy and all

the complex parts are being made appropriately with ease.

X. FUTURE SCOPE

- There is many more method that can use to formulate to know about whether design and mechanism will work properly or not such as six-sigma, optimization techniques with vibration, linear and nonlinear buckling and fatigue analysis etc. So these methods can be used to improve the other factors of car powertrain.
- There is always an improving technology arising in the field of automotive. The main Powertrain concept is also one such idea where the design gets changing frequently to improve the performance of the vehicle.
- The extension of the project may be done by applying or using various materials for the Powertrain. By introducing various materials and performing various tests the strength of the each material or composite is known and is applied to the Powertrain.
- The future Powertrain for design aircraft poses many new challenges in configuration design, use of materials, design and analysis methods. These challenges can be met, while adhering to all regulatory requirements of safety, by employing advanced technologies, materials, analysis methods, processes and production methods. By applying functional simulation and developing design tools, the development time and cost reduced considerably.

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