IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	**Dynamic analysis of epicyclic power transmission systems in hybrid electrical vehicles**	
Project Number	**IMURA0605**	
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Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?
(*Feel free to nominate more than one. For more information, see www.iitbmonash.org)*

1. **Advanced computational engineering, simulation and manufacture**
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research
7. Humanities and Social Sciences

The research problem

Define the problem

There is a growing socioeconomic and environmental concern about the climate change, pollution, and fossil fuel crisis in the scientific community and the public. Recent researches show that transportation is a major source of pollutants and ecological disruption, and has significant impacts on the health of people. The US Environmental Protection Agency estimates that motor vehicles are responsible for 75 percent of carbon monoxide emissions, nearly one half of smog-forming volatile organic compounds (VOCs), more than half of the nitrogen oxide (NOx)

emissions, and about half of the toxic air pollutant emissions in the United States.

Hybrid electric vehicles (HEV) present a great potential for significant fuel economy improvement. The amount of fuel energy that a vehicle consumes depends on the following factors: the thermodynamic efficiency of the heat engine; the forces of friction within the mechanical system that delivers engine output to the wheels; the forces of friction in the wheels and between the road and the wheels (rolling friction); internal forces that the engine works against devices such as electrical generator, air conditioner etc.; external forces that resist motion; non-regenerative braking force. Hybrid electric vehicles are able to combine gasoline and a relatively small battery by using hybrid functions such as engine-off at idle, a moderate level of coast down or braking regeneration and possibly acceleration assist [1].

Epicyclic gear train is the core of the power transmission in hybrid electrical vehicles. An epicyclic system consists of at least one planet gear mounted on a planet carrier, which rotates about a central axis. Due to the advantage of high power density, compact structure, and large payload capacity, epicyclic gear trains have broad applications in automobile, aerospace, manufacturing, and automation industries. For example, complex compound epicyclic trains have been studied and developed for power split transmission in most hybrid electric vehicles. Advanced low-noise differential spiral-bevel gear system was developed for NASA Glenn 500-hp Helicopter [2].

One of the key challenges in developing epicyclic gear trains lies in accurate estimation of the losses. Traditionally it is believed that internal power flow is the fundamental problem ie the input power is amplified by the system and a big portion of the amplified power keeps circulating inside the system without doing any work. Consequently, the internal circulating power results in huge power losses. Preventing circulating power in epicyclic systems has been adopted as an industrial standard in developing such systems.

In our recent work [3,4], we have introduced a new method of modelling epicyclic gear trains based on gear meshing losses and kinematic constraints. Estimates of power losses using this method shows that there is no need for assuming losses due to internal power circulation. This new method also has the advantage that it allows power losses in large complicated epicyclic gear trains to be estimated. The results have been validated with experiments conducted on a simple gear train. However, more theoretical and experimental studies - particularly on gear trains of greater complexity - must be conducted to fully understand this phenomenon. This is the main focus of the present study. Due to the complexity of the power flow, no design and analysis tool is available for determining the power flow pattern inside a complex epicyclic system.

References

1. K. C. Oh, D. H. Kim, T. C. Kim, C. S. Kim, and H. S. Kim. Efficiency measurement and energy analysis for a HEV bench tester and development of performance simulator. International Journal of Automotive Technology, 6(5):537–544, 2005.

2. Litvin, F. L., Fuentes, A., Vecchiato, D., and Gonzalez-Perez, I., 2004, “New Design and Improvement of Planetary Gear Trains,” NASA Glenn Research Center Technical Reports.

3. Chen, C. and J. Angeles, Virtual-power flow and mechanical gear-mesh power losses of epicyclic gear trains. Journal of Mechanical Design, 2007. 129(1): p. 107-113.

4. Chen, C., Power Flow Analysis of Compound Epicyclic Gear Transmission: Simpson Gear Train. Journal of Mechanical Design, 2011. 133(9).

Project aims

Define the aims of the project

The aim of this project is to develop a unified framework for the dynamic analysis of epicyclic power transmissions in hybrid electrical vehicles. The framework can be used to analyse power flow in complex epicyclic systems. In this project, an interactive tool for design and analysis of complex epicyclic systems will also be developed to compute the internal and external power flow for any given epicyclic system, provide the range of optimum operation, and optimize a given system by modifying the design parameters for the highest efficiency. With the help of this tool, many novel compound epicyclic transmissions enumerated in the past can be evaluated and some may find their applications in the real world. It could also lead to sufficient insights for synthesizing new designs.

Expected outcomes

Highlight the expected outcomes of the project

Primary outcome: A unified framework for the dynamic analysis of power transmissions in hybrid electrical vehicles.

Other outcomes: A computational tool for estimating the important performance parameters of an epicyclic gear train. It will consist of an interactive user interface and functional modules. With the inputs from a user, the important performance parameters of an epicyclic system will be computed and displayed.

Along the course of this project, a number of conference and journal papers will be published.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

This project will develop a unified theoretical framework and a simulation tool with potential application in design optimization and optimal control of epicyclic gear trains with applications in automobile and aerospace industry.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

One student is required for this project. This student is required to have a good knowledge of mechanical systems, mechanics, and dynamics and excellent skills in programming.

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Prof. P. Seshu, and Prof. A. Guha

Please provide a few key words relating to this project to make it easier for the students to apply.

hybrid electric vehicle, power transmission. efficiency, power flow, epicyclic gear train, simulation