



American
Gear Manufacturers
Association

Technical Resources

09FTM10

AGMA Technical Paper

The Effect of Flexible Components on the Durability, Whine, Rattle, and Efficiency of an Automotive Transaxle Geartrain System

by A. Korde and B.K. Wilson,
Romax Technology, Inc.

The Effect of Flexible Components on the Durability, Whine, Rattle, and Efficiency of an Automotive Transaxle Geartrain System

Amol Korde and Brian K. Wilson, Romax Technology, Inc.

[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Gear engineers have long recognized the importance of considering system factors when analyzing a single pair of gears in mesh. These factors include important considerations such as load sharing in multi-mesh geartrains and bearing clearances, in addition to the effects of flexible components, such as housings, gear blanks, shafts, and carriers for planetary geartrains. However, in recent years transmission systems have become increasingly complex, with higher numbers of gears and components, while the quality requirements and expectations in terms of durability, gear whine, rattle and efficiency have increased accordingly. With increased complexity and quality requirements, a gear engineer must use advanced system design tools to ensure a robust geartrain is delivered on time, meeting all attribute, cost and weight requirements. As a standard practice, finite element models have traditionally been used for analyzing transmission system deflections, but this modeling environment does not always include provisions for analysis of rattle, efficiency, nor considerations for attribute variation, which often require many runs to be completed in a short timeframe. An advanced software tool is available for the analysis of transmission system durability, whine, rattle and efficiency, all within a single programming environment, including the effects of flexible components such as housings, gear blanks, and shafting, while also allowing manufacturing variation studies to be performed. An example transaxle case study is examined in detail.

Copyright © 2009

American Gear Manufacturers Association
500 Montgomery Street, Suite 350
Alexandria, Virginia, 22314

September 2009

ISBN: 978-1-55589-963-9

The Effect of Flexible Components on the Durability, Whine, Rattle, and Efficiency of an Automotive Transaxle Geartrain System

Amol Korde, Brian K. Wilson, Romax Technology, Inc.

Introduction

Throughout the gearing industry, the natural progression of higher consumer expectations requires that gear design engineers be tasked with creating quieter, more durable and efficient designs while at the same time reducing costs and development time. Previous accepted practices of optimizing a gear pair independently of the intended application, or “system”, performing expensive and time consuming durability and noise/vibration testing of system prototypes, then adjusting the gear designs accordingly before repeating the testing cycle, is quickly becoming not only impractical, but unaffordable. Companies simply do not have the resources, especially during an economic downturn, to rely on prototype testing to drive the geartrain design; testing should only be utilized as a final verification of a design optimized using various statistical methodologies in conjunction with state-of-the-art geartrain system CAE analysis tools [1, 2].

These advanced CAE tools have been previously shown to allow the prediction of the system gear whine performance of a complex automatic transmission used in an automotive application [3, 4]. The predictions included static transmission error of a planetary gearset factoring in the effects of time-varying factors such as load sharing and carrier deflections, mode shapes and natural frequencies, absolute levels of vibration due to the gear mesh forces, and manufacturing variation due to microgeometry variation.

Additional studies using the advanced geartrain system CAE tools included analysis of the high-mileage gear whine performance of an automatic transmission, as well as microgeometry inspection methods used to accurately represent the actual planetary gearset hardware [5]. Predictions of high mileage performance is important to several industries for varying reasons: for automotive applications, the residual value of previously-owned vehicles can be negatively affected by the presence of passenger compartment gear whine, even if the

noise itself is not indicative of an impending gear failure; for aerospace applications, the rate of gear wear due to geartrain system effects can be critical to designing a robust gearset beyond just following basic gear standards.

Further studies using the same geartrain system CAE tools have shown the importance of including representative boundary conditions, such as the driveline downstream inertia and gearbox housing loads, and the resulting effect on noise, vibration and durability predictions [6]. Clearly, the flexible housing containing the geartrain was a critical component enabling the correct mesh misalignment to be predicted as part of the total system, therefore allowing a more robust non-linear gear contact study to be performed. Additional investigations also showed that the downstream effects of the durability rig (inertia, dynamics) can inadvertently effect the outcome of the durability testing itself, compared to how the geartrain would perform in the actual vehicle. The study demonstrated that durability rig testing, without proper analysis, may provide an incorrect indication of actual durability performance, possibly leading to unexpected failures in the field.

An issue not clearly demonstrated for geartrain systems such as transmissions and transaxles used in various industrial applications is the need for including flexible components as part of the system analysis, specifically for analysis of performance attributes such as gear durability, whine, rattle, and total system efficiency with predictions for individual component efficiency contributions. For transmissions with rigid housings, explicitly designed to not deflect significantly even under high geartrain loads, perhaps the flexibility of the housing is not so critical for the making accurate gear mesh misalignment predictions for instance. However, for applications where the gearbox housing is optimized for weight, using materials such as aluminum and magnesium with thin-walled designs, housing flexibility becomes exceedingly important when analyzing geartrain deflections not only for high

loads, but across a wide range of loading conditions.

This paper will investigate the housing flexibility issue using a generic manual transaxle used in an automotive as an example. The transaxle was modeled using the advanced CAE tool previously referenced [1–6], both with and without the housing as shown in Figure 1. All gear, bearing and shafting details were the same, except that the outer bearing race connections to the condensed finite element model of the housing were set to ground for the configuration without the housing. Therefore, the

differences between the performance attributes analyzed and presented below represent the effect of the housing. Additional capabilities inherent to the inclusion of the housing as part of the geartrain system analysis will also be demonstrated.

Mesh misalignment

For the purposes of the mesh misalignment investigation, the aforementioned transaxle was analyzed with the powerflow of the system set through first gear only, predicting the alignment effects at the first gear and final drive mesh locations, as indicated in Figure 2.

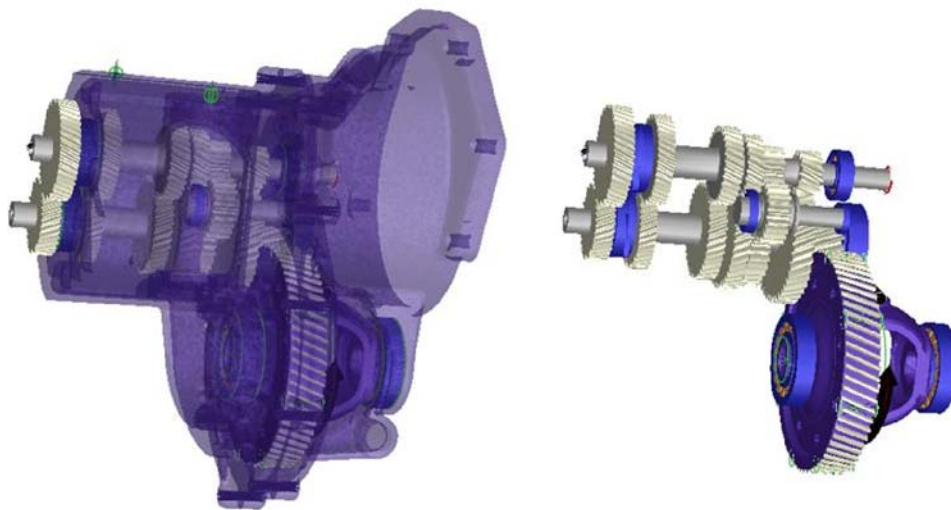


Figure 1. Advanced CAE transaxle system model, with and without the housing

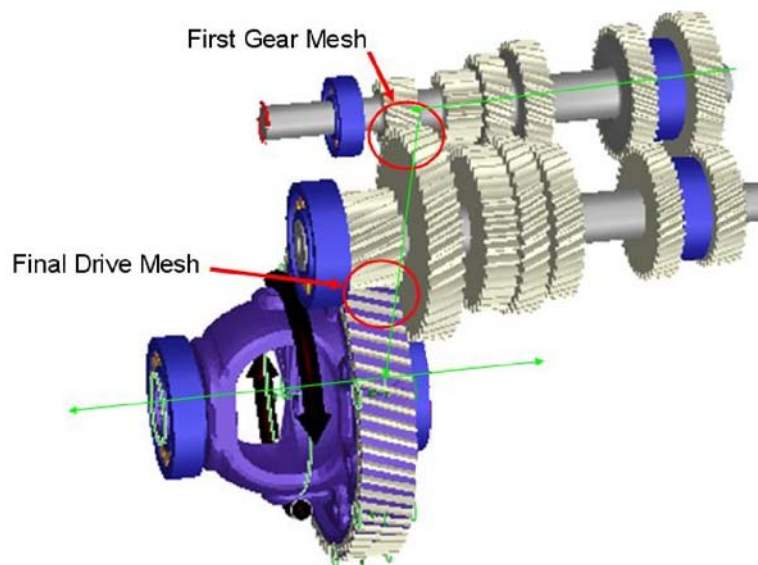


Figure 2. First gear powerflow (green) and mesh locations (red) for transaxle system model
The geartrain was subjected to loading conditions covering light to heavy throttle in an automotive application, both with and without the housing. The