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Review Paper on Automotive Gear Rattle Phenomena

Tejaswini Kulkarni*[1], Sudhir Takalkar[2], Digambar Chaudhari[3]

[1]Mechanical Engineering, R.H.S.C.O.E., Nashik, India
[2]Engineering Department, Mahindra Sona Ltd, Nashik, India
[3]Mechanical Engineering, R.H.S.C.O.E., Nashik, India

ABSTRACT

Acoustic comfort is an important criterion for sales of automobile manufacturers. For many years, research efforts led to reduction of acoustic levels. Consequently, noise sources that were previously masked emerge. Specifically, gear rattle noise due to impacts between teeth of unloaded gears is particularly audible at low speed regime of the engine. Gear rattling noise is one of the major problems facing the industry, and the car industry in particular, because cars spend so much time idling under no load or very light loads.[11]

Many researchers had given their contribution in field of gear rattle its causes and effect. Driveline contains many components, thus it has multiple degrees of freedom. Therefore, review of past literature helps in understanding and resolving complicated problem and will be helpful in future work. This paper is the study of researchers work on gear rattle phenomena, and vehicle noise, causes and effects of gear rattle, Experimental analysis and conclusion by researchers, various techniques to reduce gear rattle, simulation etc.

Keywords: Gear rattle, Vehicle noise, Driveline, Backlash, Techniques to reduce gear rattle

I. INTRODUCTION

The gearbox is a system of gearings that allows the variation of the gear ratio between its input and output, which can be made manually or automatically. The main function of this component is to make the best use of the power provided by the engine. Besides, in order to make a perfect gear mesh (without friction), there must be a clearance between the gear teeth. Impacts between these teeth generate several kinds of noise, usually known as rattle and clunking. [4]

The term gear rattle makes reference to the sound induced by collisions between the unloaded gear mesh pairs in the transmission. It can be noticed on manual transmissionvehicles in neutral condition (idle rattle) related to the engine firing frequency. These collisions result from torque fluctuations transmitted from the engine. The impact force on a driven gear during a collision changes its speed so that a relative motion develops between the mating gears. Rattle is also described in literature referring to a condition where high levels of vibrations are found in the transmission (drive rattle).

Gear rattle is due to the presence of dead spaces and backlashes. Moreover angular backlashes are generally variable with the relative angular rotation and this periodic fluctuation constitutes itself a cause of gear rattle [11].

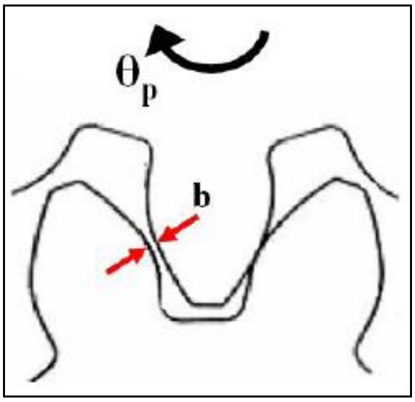

Figure 1. Gears in meshing vibrate due to backlash (b) [6]

Gear rattle risk is becoming more relevant nowadays because of :

- A trend towards downsized engines with reduced cylinder count
- Increased amplitude and reduced frequency of torsional vibration
- Better level of vehicle refinement (i.e. less 'masking noise')

II. LITERATURE REVIEW

Brancati, et al., (2015), analysed gear rattle induced by multi-harmonic excitation by an experimental point of view. Many analysts consider a sinusoidal law of speed, but a multi harmonic excitation, as a sum of two harmonic components was adopted during the analysis. An interesting behaviour was observed in the gears when variation in the second order harmonic amplitude of the excitation was done. The dynamic behaviour had been evaluated by the use of a test rig for unloaded gear pairs and results of experimental tests, in the time and frequency domain, well agreed with some numerical simulations. The analysis conducted on an unloaded gear pair subjected to a multi-harmonic excitation had evidenced interesting aspects in relation to the gear rattle phenomenon by examining the gear relative angular motion, both in time and frequency domains. The rattle frequency, initially equal to that of the fundamental component of the speed fluctuation, becomes equal to that of the second harmonic component, when the amplitude of the second order excitation component assumes a value equal to about 70-80% of the first component.

From above literature review conducted, gear rattle phenomenon and various techniques for reducing gear rattle are understood. Also, various methods used for modelling of gear rattle problem are studied. These methods will help in developing a model of neutral gear rattle problem. The main work done till now is in modification of gear geometry, or modifying flywheel i.e., by using a dual mass flywheel. It has also been seen that various clutch parameters do influence gear rattling. Study of induced fluctuation in drive line is done, which is helpful for modeling of real world rattling problem. [1]

Laihang Li et al., (2015), studied the transient vibration phenomenon in a vehicle power-train system during the start-up (or shutdown) process with a focus on the nonlinear characteristics of a multi- staged clutch damper. First, a four-degree-of-freedom torsional model with multiple discontinuous non linearities under flywheel motion input was developed, and the power- train transient event was validated with a vehicle start-up experiment. Second, the role of the nonlinear torsional path on the transient event was investigated in the time and frequency domains; interactions between the clutch damper and the transmission transients were estimated by using two metrics. Third, the harmonic balance method was applied to examine the non linear characteristics of clutch damper during a slowly varying non-stationary process in a simplified and validated single-degree-of-freedom power-train system model. Finally, analytical formulas were successfully developed and verified to approximate the nonlinear amplification level for a rapidly varying process. [2]

Brandon,et al., (2014**),** Noise produced by components in a diesel affect the quality of the engine noise. One component source related to consumer complaints is gear rattle. Gear rattle is caused by gear tooth impacts resulting from fluctuations indifferential torsional acceleration of the driving gears. Previous work in this area has focused on rating the overall sound quality of diesel engines without specifically focusing on models for predicting the perception of gear rattle. Here, a method to generate sounds having different levels of gear rattle is described. First, diesel engine noise recordings were analysed to determine the engine speed time histories; they were then used to guide gear impact timing and to generate gear noise components. The gear noise transfer paths were then tuned to improve the quality of the gear noise predictions. The gear noise simulation tool is presently being used to generate sounds for subjective tests designed to quantify the detestability, perception of growth, and annoyance of gear rattle. The noise prediction coupled with the sound quality models based on the analysis of the subjective data will provide a way to predict how people perceive gear rattle so that component noise targets can be set directly related to human perception.

This simulation method has proven successful at creating realistic sounding time histories with varying levels of gear rattle. The independent control of the level of the gear rattle events will be a useful tool in determining thresholds at which gear rattle may be detected and for understanding, the way people perceive growth of gear rattle. Gear rattle simulations created as described here were used in a subjective test designed to quantify detectable levels of gear rattle; the results of that test will be reported later. Decisions that were made during the development of the method that improved the sound of the simulations from a listening perspective but degraded the sound quality metric comparison between the simulated and real signals highlight the importance of listening to the sounds and not relying solely on sound quality metrics during the simulation process. The understanding gained from the development of this simulation process may help to guide the development of a gear rattle metric using noise measurements. In recent work, it has been observed that gear rattle might affect the operation of the engine. It was previously mentioned that the presence of gear rattle tends to amplify the ‘background’ noise (engine noise not related to gear rattle impact events). An improved simulation might implement feedback that more accurately simulates how gear rattle affects the operation of the engine. [3]

Heirichs and Bodden (1999) described gear rattle as an air borne sound, occurring when torsional vibrations of the gearbox are transmitted to its housing through the bearings. It also have a structure borne parcel, originated when the gearbox mounting system interacts with the vehicle frame. In some cases, the shifting system can contribute transmitting vibrations directly to the passenger cavity. In recent years a device called dual mass flywheel (DMF) has been used to reduce these vibrations, due to its inertial, stiffness, and damping effects (Albers, 1994). Instead of using a single flywheel inertia attached to the crankshaft, when a DMF is installed, the transmission input shaft inertia is increased; allowing better vibration insulation in both idle and drive rattle condition.

Simionatto, et al., (2013), performed numerical investigation in order to understand how the parameters of the pre-damper affect dynamics of power train concerning two of the NVH phenomena are the Shuffle and the Clunk. A model with 12 degrees of freedom was built, considering nonlinearities on the clutch disk, on the driving gear pairs of the transmission and also on the differential gear. The clutch disk was modeled as a multi-stage stiffness combined with different levels of dry friction. Then, 18 clutch disks with different pre-damper specifications were modeled and simulated in the same dynamic model of power train in order to evaluate the sensibility of the Clunk phenomenon to each parameter, and estimated in which driving gear pair the impacts were more severe.

Results showed that the input gear pair of the gearbox was more likely to present high acceleration when subjected to sudden torque reversals. The variation of hysteresis levels on the pre-damper showed the expected results, as the time that the system takes to cease vibration increases with the increase of hysteresis. However, changes in the width of the pre-damper showed that, concerning teeth impacts, too wide or too thick pre-dampers tend to make the system more prone to more intense impacts.[4]

Kadmiri et al., (2012), reported an experimental investigation of a conventional manual automotive gearbox designed by Renault under rattle conditions. First, the gearbox was instrumented and assembled on a test bench which replicates an automobile power train. Driving and loose gears angular displacements were measured with two optical encoders. Stereo-mechanical impacts were characterized by a coefficient of restitution defined from the generalized impact theory. Its value depended on materials, contact geometry, operating conditions and the presence of lubricant. Identification of key parameters was considered in detail. A dimensionless parameter describing rattle excitation level was proposed. It combines excitation frequency and amplitude, inertia and drag torque. The input data were updated from experimental measurements. Nonlinear dynamic response was computed and compared with experiments performed within various ranges of neutral and drive operating conditions. Experiments had also validated models describing the different contributions to drag torque applied to the loose gear. The other parameters governing rattle noise depend on gearbox design (inertia, gear backlash, eccentricity, etc.). Experiments performed confirm that the equivalent excitation level can be described using the dimensionless parameter L. From this work, it can be inferred that a numerical model can be prepared to predict the characteristics of the nonlinear dynamics of gear, whatever the gearbox configuration. Characterization of gear rattle may be considered, for any loose gear, any gearbox and any operating conditions.[5]

Miyasato, (2011), has analyzed idle rattle with a systemic approach. Natural frequencies of a linearized system in idle was calculated and compared to the order content of the engine input torque. Then, a nonlinear model with piecewise linear stiffness and hysteresis representing the clutch and time-varying stiffness with backlash for the gears, was subjected to alterations in clutch, gears and its inertial parameters in order to compare the gear rattle response in terms of vibration intensity. The hysteresis seems to have an optimum range of values, resulting in vibration level increment when it was over dimensioned. Modifications on the stage transition angle resulted in greater level of vibration when the clutch worked on both idle and drive stages. Varying parameters such as the helix angle and gear width had small influence on the resultant impacts, which were much more related to the gear pair chosen. Increasing the clutch hub inertia resulted in reduction of the rattle index (RI) level, showing the effectiveness of using a dual mass flywheel device on the system.

From this work it can be seen that clutch parameters do influence rattle index. Also, modifications on the clutch stiffness parameter had strong influence on the gear rattle intensity. [6]

Bozcaet al.,(2010), the optimization of gearbox geometric design parameters to reduce rattle noise in an automotive transmission based on a torsional vibration model approach is studied. Rattle noise is calculated and simulated based on the design parameters of a 5-speed gearbox, and all pinion gears and wheel gears are helical. The effect of the design parameters on rattle noise is analysed. The observed rattle noise profiles are obtained depending on the design parameters.

Optimized geometric design parameters lower the rattle noise by 10% compared to the calculated rattle noise values for the sample gearbox. All optimized geometric design parameters also satisfy all constraints. Optimizing the geometric design parameters not only reduces the rattle noise but also increases the desirable bending stress and contact stress level. While geometric parameters, such as the module, number of teeth, helix angle, face width, backlash and axial clearance are optimized, the operational parameters, such as angular acceleration and excitation frequency are not optimized because these operational parameters are given by the automotive manufacturer as input values. [7]

S. Theodossiade et al., (2009), introduced a new approach for understanding the interactions between the transmission gears during engine idle conditions by taking into account the effect of lubrication. Gear impacting surfaces were treated as lubricated conjunctions rather than the usually reported dry impacting solids. Depending on load and speed of entraining motion of the lubricant into the contact domains, the regime of lubrication alters. In this paper, the influence of lubricant in torsional vibration of lightly loaded idling gears was examined which promotes iso-viscous hydrodynamic conditions. It was shown that the lubricant film under these conditions behaves as a time-varying nonlinear spring–damper element. Spectral analysis of the system response is compared to the findings of the linearised system. In the overall response, the engine orders are dominant, while in the microscopic fluctuations the natural frequencies of the system have the strongest presence. The lubricant behaves like a nonlinear spring damper, which significantly affects the response of idle gears during the meshing cycle. The examination of the linearised system revealed that the system response was strongly affected by the lubricant properties. Particularly the viscosity was one of the main factors, which governs the overall system behavior, affecting the drag torque and inertia of the idle gears, promoting rattle. This was an observation, which can contribute to root cause solutions of this NVH concern. [8]

Padmanabhan et al., (2002), presented a state of the art in the modeling of transmission rattle. Specifically they have developed a step-by-step approach to address the rattle problem. Although the overall problem solving procedure was broken up into three key steps, it is essential to remember that each of these was inter-dependent on the other two steps. Current research and future plans focus on the development of new or improved semi-analytical and computational methods, impact damping mechanisms, sound perception metrics, and optimization of driveline parameters for rattle-free conditions. [9]

Michael Yu Wang et al.,(2002), this paper describes a research work on modeling and numerical analysis of torsional vibration in automotive manual transmissions. The focus of the effort is on a decoupling procedure for the numerical analysis of gear rattle. The power train model is specified into a linear subsystem and a non-linear subsystem that includes the strong nonlinearities of gear backlash and multistage clutch stiffness. The weak coupling of the subsystems is then exploited for efficient numerical analysis. It is shown that the decoupled model yields an acceptable accuracy with a significant gain in computational efficiency when using an algorithm of numerical integration of stiff differential equations or a finite element in time algorithm. Numerical simulation results for a Daimler-Chrysler vehicle power train are given to illustrate the effectiveness of the proposed scheme. [10]

S¨ureyya et al., (1999), the cause of rattling and clattering noise is torsional vibration of transmission components that are not under load, that move backwards and forwards within their functional clearances. This noise is perceived as distinct from other sources of noise, and is intrusive because of its undesirable character. The transmission parameters backlash, axial clearance and main centre distance were varied by experimental analyses in test stand trials, showing the effect on the propensity to rattle and clatter. By optimizing these parameters, it was possible to minimize the rattling and clattering noise. Measures internal to the transmission to reduce loose part vibration in vehicle transmissions were also considered. The effectiveness, in terms of minimizing clattering and rattling proneness, of making the axial thrust collars elastic with and without pre-compression of the elastomer was considered. All internal transmission measures discerned as effective in reducing rattling and clattering noise need to be examined in terms of service life and possible side effects in all the operating states arising in a vehicle transmission. The calculated noise level with the EKMS imulation program correlates with the measured noise level. Parameter studies with the EKMS imulation program, which contains all relevant parameters for the excitation of rattling noise caused by idle gears, shows the significant parameters for the investigated transmissions. [11]

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III CONCLUSION AND FUTURE SCOPE

From above literature review conducted, gear rattle phenomenon and various techniques for reducing gear rattle are understood. Also, various methods used for modeling of gear rattle problem are studied. These methods will help in developing a model of neutral gear rattle problem. Literature presents study of gear rattle simulation and analysis. Design modifications are made in components like flywheel and gear box. In driveline, flywheel and gear box are major components whose design cannot be modification is critical, costly and difficult. One of the most flexible parts of the power train, in terms of design, is the clutch disk, because it is much less expensive than the engine, the gearbox and the differential gear and a fine tuning of its parameters may reduce the severity of many NVH phenomena [3]. Not much work has been done on clutch design with regard to this problem. Therefore, there is an opportunity to find out modification in clutch design so that engine vibrations are isolated from gear box.

III. REFERENCES

[1] Renato Brancati, Ernesto Rocca, Sergio Savino, Francesco Timpone, Experimental Analysis of the Relative Motion of a Gear Pair under Rattle Conditions Induced by Multi-harmonic Excitation, Proceedings of the World Congress on Engineering 2015 Vol. II WCE 2015, PP 1 - 3.

[2] Laihang Li & Rajendra Singh, Analysis of start-up transient for a power-train system with a nonlinear clutch damper, Elsevier, Mechanical Systems and Signal Processing 62-63, 2015,PP 4(60–479).

[3] Brandon Sobecki; Patricia Davies; J. Stuart Bolton, Simulation of gear rattle to aid in the development of sound quality, metrics for diesel engine component specification, Purdue University,USA2014.

[4] Vinicius Gabriel Segala Simionatto, Hugo Heidy Miyasato, and Milton Dias Junior, On the Influence of the Clutch Disk's Pre-Damper Parameters on Shuffle and Clunk Phenomena in Power trains, DINAME 2013 - Proceedings of the XV International Symposium on Dynamic Problems of Mechanics M.A. Savi (Editor),

ABCM, Buzios, RJ, Brazil, February, 2013,PP 17-22.

[5] Younes Kadmiri, Emmanuel Rigaud, Joel Perret-Liaudet, Laurence Vary, Experimental and numerical analysis of automotive gearbox rattle noise, Elsevier, Journal of Sound & Vibration, 2012 , PP 3144–3157.

[6] Heidy Miyasato, Study of the gear rattle phenomena in automotive power-train systems, 21st International Congress of Mechanical Engineering, October 24-28, 2011.

[7] Mehmet Bozca, Torsional vibration model based optimization of gearbox geometric design parameters to reduce rattle noise in an automotive transmission, Yildiz Technical University, Mechanical Engineering Faculty, Machine Design Division,24 July 2010 , Yildiz, Istanbul, Turkey, PP34349

[8] S. Theodossiades, O. Tangasawi, H. Rahnejat., 2009, Gear teeth impacts in hydrodynamic conjunctions promoting idle gear rattle, Journal of Sound andVibration, 303 (2007) ,PP 632–658.

[9] Chandramouli Padmanabhan, Todd E. Rook, and Rajendra Singh, Modeling of Automotive Gear Rattle Phenomenon: State of the Art, SAE International, 2000, PP 951316.

[10] Michal Yu Wang, Numerical Modelling and Analysis of Automotive Transmission Rattle, Depatment of automation and comuter-aided Engineering, Chinese university of Hong Kong, Shatin, NT Hong Kong,Martch 2002,PP921–943.

[11] Sureyya Nejat, Loose part vibration in vehicle transmissions - Gear rattle, 25.02.1999,University of Stuttgart, Institut Maschinenelemente, Paffenwaldring 9, D-70569, Stuttgart-ALMANYA.

[12] Laihang Li & Rajendra Singh, Analysis of start-up transient for a power-train system with a nonlinear clutch damper, Elsevier, Mechanical Systems and Signal Processing 62-63, 2015,PP4(60–479)

[13] Chengwu Duan, Rajendra Singh, Super-harmonics in a torsional system with dry friction path subject to harmonic excitation under a mean torque, Elsevier, Journal of Sound and Vibration 285, 2005 (pp 803–834)

[14] Literature on Vibration and the Human Body,study which demonstrates of why shiatsu massage systems are better than vibration systems

[15] R singh, H Xie and R. J. Comparin, Analysis of Automotive Neutral Gear Rattle ,the Ohio State University, Department of Mechanical Engineering, Columbus, USA,1998,PP 43210-1107,

[16] Renato Brancati, Ernesto Rocca, Sergio Savino, Francesco Timpone, “Experimental Analysis of the Relative Motion of a Gear Pair under Rattle Conditions Induced by Multi-harmonic Excitation”, Proceedings of the World Congress on Engineering 2015 Vol. II WCE 2015, July 1 - 3.

[17] S.B. Shim, Y.J. Park, K.U. Kim, “Reduction of PTO rattle noise of an agricultural tractor using an anti-backlash gear”, Elsevier, Bio system Engineering, 2008 PP 346 – 354.

[18] Steel Wire For Mechanical Springs, Specification Part 2 Oil Hardened And Tempered Steel Wire,IS4454(part 2):2001

[19] Tejaswini Kulkarni, Sudhir Takalkar, Digambr Chaudhari, Transmission Noise and Gear Rettle in Automotive Driveline, International Journal of Modern Trends in Engineering and Research, e-ISSN No.:2349-9745, 28-30 April, 2016.