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Experimentation Vibration Damping by Particle Damping in Transmission Gears

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Abstract: *The vibration and noise from gear transmission have great damage on the mechanical equipment and operators. Through inelastic collisions and friction between particles, the energy can be dissipated in gear transmission. A dynamic model of particle dampers in gear transmission was put forward in this project. The vibration from gear engagement is the main source of the noise and vibration of reducers under heavy load and high speed. In order to dissipate the energy as well as suppress the vibration, we introduce the particle damping technology into gear transmission. In this project, the model of the particle dampers is built in the inherent lighting holes of the gear. Then we use the discrete element method to analyze the kinematics and dynamics of the damping particles and determine the relationship between energy dissipation and friction coefficient (surface roughness) of the particles at different rotational speed and load. We come to the conclusion from simulation results that at low rotational speed, smoother particles have better damping effect, while at high speed, rougher particles are better. There is no evident relation between the load and the coefficient of static friction. Finally, the simulation results are verified by experimental results. This conclusion will provide a theoretical basis for engineering practice.*

Keywords: Vibration and Noise, Inelastic Collisions, Gear Transmission, etc.

I. INTRODUCTION

Particle damping technology is a form of an auxiliary□mass type vibration damper, where many metal, tungsten carbide, ceramic or other types of small particles are placed within the cavities of the vibrating structure, or the enclosures attached to the vibrating structure in order to mitigate the response of the primary structure. The primary structure vibrates; kinetic energy is significantly absorbed through the combined effects of particle□to□particle and particle□to□wall inelastic collisions and frictional losses, producing considerable damping to the primary structure. Particle damping technology has been widely used due to its simplicity, moderate cost, good durability, and temperature insensitivity. Particle dampers are also suitable for employment in long□term harsh environments, such as high temperature, severe cold, and oil contamination, where other types of damping devices are no longer suitable or efficient, thus making the use of particle dampers a low□maintenance damping methodology.

II. LITERATURE SURVEY

[1] Particle dampers are devices that work by a combination of impact and friction damping. They dissipate the energy of a system by transferring it to a bed of particles. This bed is geometrically constrained to remain inside a container fixed to the vibrating system. As such, the motion-caused interaction occurring inside the container damps the absorbed energy. The main dissipative mechanisms involved are: collisions between the container walls and the particles and between the particles themselves; sliding friction between the same; and, rolling friction between the same. For collisions between the particles and the cavity walls to occur, both should be out-of-phase with each other.

Design examples, analytical formulations, numerical models, and experimental setups for such dampers are gathered. Modelling approaches are presented both for particle interaction and for systems equipped with particle dampers. The consequences of the nonlinear behaviour of particle dampers are brought to attention. As such, the apparent contradictions of the conclusions and approaches presented in the literature are highlighted. A list of particle simulation software and their use in the literature is provided. Most importantly, a suggested approach to create a sound numerical simulation of a particle damper and the accompanying experimental tests is given.

[2] Gears are one of the most common mechanisms for transmitting power and motion and their usage can be found in numerous applications. Studies on gear teeth contacts have been considered as one of the most complicated applications in tribology. The changes in operating conditions such as increase in temperature, load, reduction in viscosity result decrease in lubricant film thickness and degradation of lubricating oil thereby triggering several types of failures on tooth surfaces viz. pitting, scuffing, micro pitting, scoring, and spalling, these faults influence changes in vibration signals. Author presents the results of experimental investigations carried out to assess wear in spur gears of single stage spur gear box under fatigue test conditions.
The studies considered the lubricant film thickness analysis, wear mechanism studies on gear tooth surfaces, oil degradation analysis using Fourier transform infrared radiation (FTIR) method along with vibration signal analysis. The work presented in this paper author was aimed to assess the development of surface fatigue wear in a spur geared system. A single stage spur gear box was used to conduct fatigue test experiments. In the fatigue test experiments, the gearbox was allowed to operate over a period of 1200 h. Experimental studies include lubricant film thickness analysis in conjunction with oil degradation measurement and analysis.

[3] In this research paper the modal analysis of involute spur gear pair is carried out using finite element analysis tool ANSYS14.5. Gear noise and vibration is a major problem in many power transmission applications this problem becomes more significant in applications with higher operating speeds, where there is vibratory excitation which is related to the gear transmission error. The goal of modal analysis in this research paper is to determine the natural mode shapes and frequencies of the present spur gear pair and to comparatively analyze with frequencies of the geometrically modified involutes spur gear pair during free vibration as well as in pre-stress condition. The modal analysis is carried out on both the present spur gear as well as geometrically modified involutes spur gear in two conditions i.e., Natural frequency and Forced frequency in pre-stress loading.

[4] As a passive means of vibration reduction, particle damping is mainly applied to the horizontal or vertical steady field. However, it is seldom applied to centrifugal fields. Under high speed and heavy loading, the vibration of tooth surfaces of gear transmissions becomes more severe shortening gear service life and augmenting noise. Under centrifugal loading, the particle system exhibits different characteristics, for example, particles are extruded at the end farthest from the centre. We investigated gears with drilled via holes filled with damping particles. Using the discrete-element method, we developed an energy dissipation model for the particle system accounting for friction and inelastic collisions. Energy dissipation and damping characteristics of this system were analysed. Experiments were also conducted with the gear system having different particle filling rates. The results show that this filling rate is an important parameter associated with particle damping in a centrifugal field. An unsuitable filling rate would significantly reduce damping effectiveness. With changes in rotation speed and load, the gear transmission system has different optimal filling rates. The results provide guidelines for the application of particle damping in centrifugal fields of gear transmissions. Experiments demonstrated that particle damping under centrifugal field could effectively reduce the vibration in gear transmission. Particle filling rate is an important parameter in particle damping in centrifugal fields. Inappropriate filling rates would reduce the total energy loss and therefore damping effectiveness in gear transmission. For different rotation speeds and loadings, we need to choose an optimal particle filling rate to effectively reduce the vibration of the primary gear system. The results may provide theoretical basis for the application of particle damping under a centrifugal field in gear transmission.

[5] Gears are used for a wide range of industrial applications. They have varied application starting from textile to aviation industries. They are the most common means of transmitting power. They change the rate of rotation of machinery shaft and also the axis of rotation. For high-speed machinery, such as an automobile transmission, they are the optimal medium for low energy loss and high accuracy. During operation, meshed gears‟ teeth flanks are submitted to high contact pressures and due to the repeated stresses, damage on the teeth flanks in addition to tooth breakage at the root of the tooth is one of the most frequent causes of gear failure. This fatigue failure of the tooth decides the reliability of the gear. In this paper, spur gear made up of EN9 material is designed and mode shape of respective gear is found out. Modal analysis result shows that the frequency value (23611 Hz) of existing gears manufacturing with EN9 steel is much higher as compared to engine frequency value and no resonance condition was found. Further modal analysis of gears made out of EN353 as per the design of existing gears (EN9) was carried out in order to reduce cost with performance at par.

[6] Honeycomb sandwich laminates which are the basic structural element of spacecraft have inherently low damping. In this paper, we propose to improve the damping characteristics of such structures by adding damping particles in the cells of the honeycomb. This paper presents modelling of a cantilever beam constructed with honeycomb structure with the hexagonal honeycomb cells, filled with particles. The beam is subjected to external dynamic loads and the interactions of damping particles with the walls of the cells and its overall effect on the frequency response function (FRF) and the damping of the beam are obtained. The discrete-element-method (DEM) is used to model the dynamics of the particles in conjunction with the governing equations of motion of the beam and the cell- walls.
The particle-particle and particle-wall impact is modelled using Hertz's non-linear dissipative contact model for normal component and Coulomb's laws of friction for tangential component. The effect of the damping particles on the transfer function, damping behaviour and resonance peaks of the honeycomb sandwich beam whose cells near the tip were filled with damping particles was investigated analytically and experimentally. A cell level model of the honeycomb core and its interaction with damping particles, modelled by DEM, was developed.

[7] As one of the most essential mechanical devices, the gear transmission system has been extensively applied in aerospace, marine, vehicle and industrial machinery. Nevertheless, due to the possible factors like material defects, manufacturing errors, overload, inappropriate installation, and insufficient lubrication, gear tooth failure or damage may occur and affect the normal operation of the gear system, and further result in excessive vibrations, noise emissions and undesirable dynamic characteristics. It is necessary to monitor the running status of the gear system and to diagnose the tooth faults in time before a sudden breakage takes place. As a result, the gear tooth fault detection is receiving increasing attentions in recent years.
The nonlinear frequency responses based on several statistical indicators are obtained to assess the vibration behaviors and fault conditions for the gear system. In addition, the vibration responses in time and frequency domains are also analysed. Results show that peak and crest factor are the optimal indicators for tooth crack detection. Whereas, the kurtosis hardly works in most cases due to the presence of clearance nonlinearity. Besides, the vibration response characteristics such as time histories, phase diagrams, Poincare maps, FFT spectrums and sidebands, could present indications reflecting the tooth crack propagation to some extent. Therefore, the developed model is capable of predicting the mesh stiffness and vibration behaviors of a cracked gear system, and the corresponding vibration analysis could provide references aiding the tooth crack detection for researchers and engineers.

[8] The current trend in the construction of gearboxes, regarding the speed increase, favour's the increase of the dynamic loads and, consequentially of the vibration level. Therefore, the vibration reduction of gear transmissions finds a growing interest, representing an element of fight against environmental pollution. The vibration characteristic for the coated gear is low compared with steel gear. Based on increasing the coating thickness up to certain limit and also noise factor for coated gear is very low. Increasing the lifetime of the gear.

[9] A gear is a rotating machine part having cut tooth, which mesh with another toothed part in order to transmit torque. To design the spur gear to study the weight reduction and stress distribution for cast steel and composite materials. Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. The main objective of this research work is to introduce a new gear material for gear. EN32A, EN24 is selected for suitability analysis. Gears are the important part of any machine application like electric overhead travel, machine tool, automobile for power transmission. The main part of this research work is to identify the natural frequency and natural vibration modes of EN32A, EN24 gear and also the effect of change in mass of gear. This project is based on the topology optimization of the existing gear with the reduction of material from the gear and to reduce the total weight of the gear.

F.E. Modelling shall be pursued for deriving analytical solution to the problem while physical experimentation would be done to offer inputs to the work and validate the model at the initial phase of work.

III. IMPLEMENTATION

As we know, gears are used in the industries to change the speed, torque, and the direction of power source. As gear transmission tending to be high speed, heavy duty and high reliability, the performance of the gear transmission needs to be very high. The vibration caused by gear transmission is the main source of the noise for most machinery and equipment. It has been observed that, in running condition vibrations introduced in the transmission gear which generates noise and harshness and adversely affects the performance of the whole gearbox. We will use passive vibration control method to reduce the vibrations i.e., particle damping technology. The particle damping is a combination of the impact and the friction damping. Change in the vibrations generated in the transmission gear can be calculated by analytically and by simulation. We will compare the results of both by doing experimental validation.

IV. CONCLUSION AND DISCUSSION

By analysis of the gear transmission, we got the source of the vibration of the gear pair and the boundary condition of the centrifugal field of the gear transmission the dampers being set in. Through theoretical calculation, simulation analysis and experiment, the particle damper's damping mechanism has been obtained. The conclusions drawn are mentioned as below,

1. The vibration frequency and the excitation frequency derived from the modal analysis of the gear are not relevant, and therefore no resonance occurs.
2. By comparison, the variation of the driving gear's rotational speed and acceleration is far less than that of the driven gear's, which suggests the main source of the vibration is the driven gear.
3. Putting particles into the driven gear can achieve a better damping effect. The optimum particle diameter is 4–5 mm under whatever condition. The optimum diameter in experiment is slightly different from that in simulation. Such discrepancy can be explained by the changed characteristic of the system due to additional apparatuses in experiment.
4. Choosing an optimal particle diameter will help to effectively reduce the vibration of gear system for different rotation speed and loads.

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