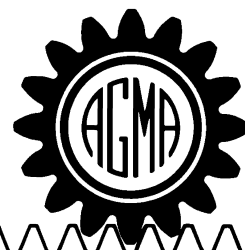


Simulation Model for the Emulation of the Dynamic Behavior of Bevel Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

Simulation Model for the Emulation of the Dynamic Behavior of Bevel Gears

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[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

Starting point: Today the impact of bevel gear deviations on the noise excitation behaviour can only be examined insufficiently under varying working conditions such as different rotational speed and torque. The vibration excitation of bevel gears resulting from the tooth contact is primarily determined by the contact conditions and the stiffness properties of the gears. By the use of a detailed tooth contact analysis the geometry based gear properties can be developed and provided for a dynamical analysis of the tooth mesh.

Research objective: A model has been developed for the simulation of the dynamic behaviour of bevel gears. With the aid of a load-free tooth contact analysis the geometry-based part of the path excitation is determined at first. With a tooth contact analysis under load the path excitation caused by deflections can be calculated. The geometry based part of the path excitation and a characteristic surface of the excitation values is created and provided for dynamic simulation. The behaviour of the model has been verified with a set of hypoid gears by describing the tooth contact force depending on the rotary speed.

This dynamic model is able to consider every deviation of the micro- and macrogeometry from the ideal flank topography, i.e. waves and/or groves in the surface structure in combination with two and three dimensional flank deviations like profile deviations, helix deviations and twists. It is also possible to consider the influence of friction and the contact impact caused by load and/or manufacturing. errors with a test rig to verify the calculations.

Results: The result of the study is the investigation of the complex influence of surface structures which result from manufacturing processes, manufacturing deviations and flank corrections on the noise excitation of bevel gears. The resulting noise excitation can be rated in form of the excitation level with the aid of this dynamic model.

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Introduction

Due to their high efficiency, bevel gear sets are widely used in industry to transmit torque, generate high rotational speeds and change rotation directions. Mostly studies on bevel gear dynamics are based on experiments or simple formulations considering only the torsional vibrations. In this paper a precise dynamic simulation model of bevel gear pairs is developed. The method combines a finite element based tooth contact approach with a multi body dynamic simulation to provide a more accurate and comprehensive analysis of the excitation in the tooth mesh. The tooth mesh is modelled as a spring-damper set. The spring-damper set is able to consider all six degrees of freedom. The varying characteristic mesh forces of the spring and the damper are calculated using a detailed, finite element based tooth contact analysis. The forces are multidimensional functions of the rotational transmission error under load, the pinion displacement, the rolling position and if necessary additionally the sliding speed. The considered excitations in the tooth mesh are transmission errors due to profile deviations, the changing stiffness of the meshing teeth as the number of teeth in contact changes and the varying sliding friction. Finally, a basic transmis-

sion with a bevel gear pair is analyzed for different operating speeds.

Excitation mechanisms in the tooth mesh

The main source for the dynamic excitation of bevel gears is the tooth mesh [1]. In the tooth contact different excitation mechanisms are combined to a complex resulting excitation. The three most significant terms are the unloaded transmission error, the changing stiffness of the meshing teeth and the premature tooth contact, Figure 1.

The load-free transmission error is caused by gear deviations which lead to a path excitation [3]. The most important gear deviations influencing the excitation behaviour under load-free operating condition are pitch, flank and profile variations [4], [5], [6]. But path excitations can also be caused by deviations of 3rd order, as e.g., generated cut deviations and even of 4th order, as e.g., roughness describing tooth flank surface structures [7]. All deviations lead to changing operating conditions, i.e., changing rotational speeds and different load carrying torques. In numerous practical tests it is shown that for operation conditions of low specific loads deviations have the main influence on the excitation in the tooth mesh and on the noise.

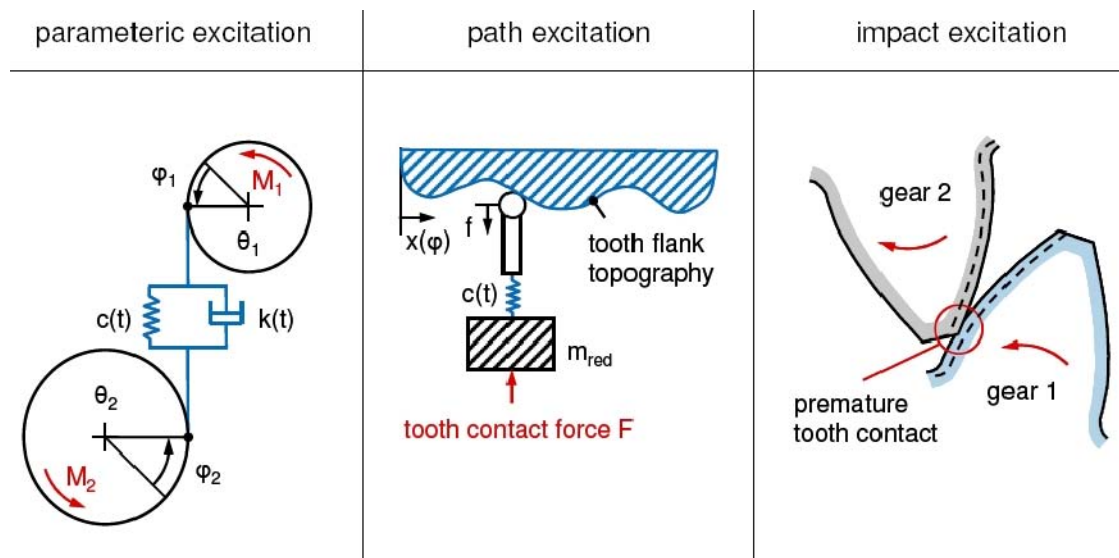


Figure 1. Excitation mechanisms [2]