Procedure for Optimum Design of a Two-Stage Spur Gear System*

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In this paper, an optimum design of a two-stage spur gear system is performed. The optimization is based on a multicriterion technique consisting of a Min-Max method combined with a direct search technique. The optimum design includes the minimization of seven objective functions. They are the volume of gears, the center distance and five dynamic factors in the input shaft, first-teeth meshing, intermediate shaft, second meshing and the output shaft. The dynamic factors are estimated using a dynamic model of twelve degrees of freedom. The objective functions are governed by eleven design variables, chosen to be the number of teeth and face width of the pinion of each stage, stiffness of the input, intermediate, and output shafts and the inertia of the four gears of the mechanism. The developed optimum design is found to give compact-gear system with quiet running (minimum dynamic factors) compared with the classical design. The angle between the power transmitting directions is found to have an important role on the objective functions and the optimum design. A value of 180° for this angle is found to be the optimal for all functions.

Key Words: Gear Design, Vibration, Multi-Criterion Optimization

1. Introduction

Gear design is a highly complicated art. It is continuously developing under the demand for more accurate, less expensive, quieter running, lighter weight and powerful transmission. Most machine designers don't have the time to keep up with the developments of gear design. Hence, there is a great need for efficient, accurate and optimum design approach that takes into account various aspects. Many published papers were dealing with the optimum design of gears(1)–(9). However, most of these are based on ready design formulae with simple kinematical analysis. In this work, the vibration effect is considered in the optimum design of a two-stage spur gear system. A dynamic model with 12-degrees of freedom is used(10). The need of the dynamic modeling arises from the necessity to estimate accurate values of dynamic loads excited in various elements of the mechanism under design.

The optimum design includes the minimization of seven objective functions. Five of them are the dynamic factors induced in gear teeth meshing of the two stages, input, intermediate, and output shafts. The other two are the gears volume and the overall center distance.

The objective functions are controlled by eleven selected design variables. They are the number of teeth and face width (or meshing stiffness which is directly proportional to face width) of the first and third gears, the stiffness of the three transmitting shafts and the inertia of the four gear wheels.

The design criteria are treated as independent objective functions to be minimized simultaneously. The well-known Min-Max principle of optimality(1) is combined with a univariate search method. This technique is used to specify the optimal design variables necessary to determine the gear system proportions.

A comparison between the suggested optimum design and the classical one is investigated. The effect of the angle between the power transmitting directions of the two meshings is discussed and curves of optimality for this angle are drawn.

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