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An Experimental Test Stand to Measure Loaded Transmission Error in Fine-Pitch Plastic Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

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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

This paper describes a developed experimental test stand to measure transmission error in fine-pitch gears. The paper introduces the importance of transmission error in office equipment that have uniform motion requirements. Transmission error is computed by measuring the phase difference between the driver shaft and the driven shaft using optical encoders. The test stand has a variable operating center distance and can apply shaft alignment errors in both parallel and skew directions. Results from the test stand show the effect of gear elemental errors, transmitted load, and shaft misalignment on transmission error in fine-pitch plastic gears.

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1 INTRODUCTION

The need for a photographic-quality image from a color printer or a color copier demands the movement of the media be uniform and precise. Any variation in the uniform motion of a drive can cause scan lines on an image to be closer together at a slower transport speed, and farther apart at a faster transport speed. Often, these variations are periodic in nature and result in periodic bands of varying density on an image. Entities like gear mesh frequency and shaft frequency are directly related to the distance between the bands on an image. However, the relationship between the amount of density variation in an image and the amount of non-uniform motion in a drive train is not known. This presents a need to measure the non-uniform motion of a gear drive.

Additionally, stringent low-acoustic noise requirements in work areas have resulted in a need to study the noise and vibration characteristics of power transmissions in office equipment. In the past few years, researchers have linked gear mesh induced noise and vibration to the static transmission error in a gear mesh. Welbourn (1977) defined static transmission error as the "the difference between the actual position of the output gear and the position it would occupy if the gear drive is perfect." This definition of static transmission error provides a direct measure of non-uniform motion in a gear drive.

Commercially available systems that measure transmission error did not meet our need to

measure transmission error in fine-pitch gears under changes in center distance, at low values of torque, and for small variations in shaft alignment. This paper describes a test stand designed to address this need.

The rest of this paper is organized as follows: Section 2 describes the mechanical drive system layout of the test stand. Section 3 presents the transmission error measuring system. Section 4 discusses sample measurement results on fine-pitch plastic gears. Section 5 concludes this paper with our directions for future work.

2 MECHANICAL DRIVE SYSTEM LAYOUT

Our objective was to design a test stand that would meet the following requirements:

1. Measure transmission error for gear meshes that have non-unity gear ratios
2. Measure transmission error for gear meshes at various values of center distance
3. Measure transmission error for gear meshes at various low values of torque
4. Measure transmission error under variations in parallel and skew alignment
5. Measure non-uniform motion in other drive components, such as timing belt pulleys and couplings

The test stand was designed to meet all of these requirements. The test stand can apply mesh torque between 5 and 90 oz-inches at angular speeds between 5 and 100 rpm. The transmission

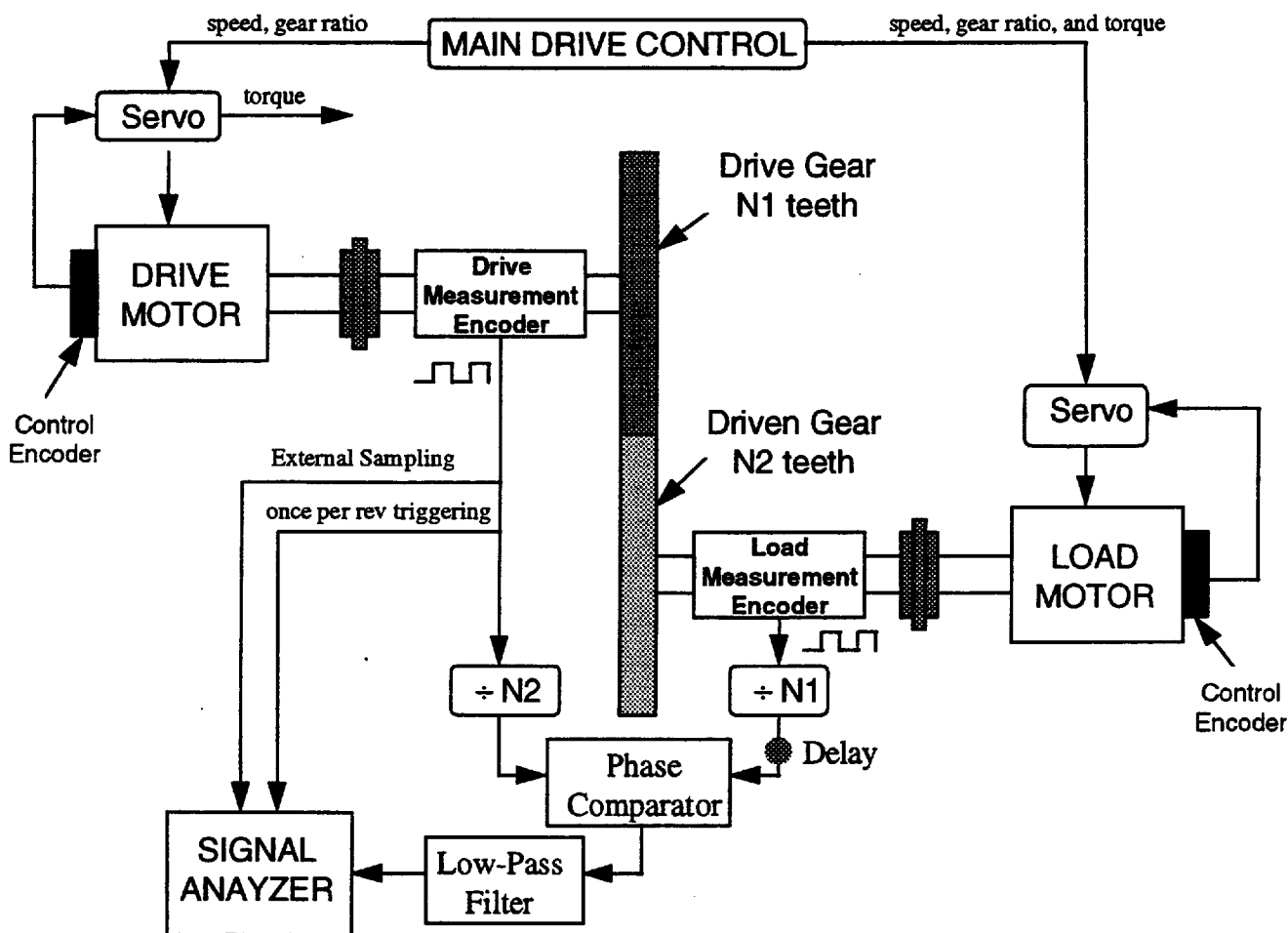


Fig. 1 Schematic sketch of the test stand

error measuring system can measure transmission error when the angular velocity of the gears is less than 100 rpm. The mounting center distance can be varied from 0 to 4.5 inches. The test stand can apply errors in parallel alignment and skew alignment up to 5 degrees. The drive control can accommodate the change in direction of rotation of the output drive member when timing belt pulleys or couplings are used instead of gears. This section gives a detailed description of the mechanical layout of the test stand.

The test stand consists of the following two mechanical assemblies: Drive Side Assembly (DSA) and Load Side Assembly (LSA). Figure 1 shows the schematic sketch of the test stand. The two assemblies are mounted on a pneumatic table. The load side assembly is rigidly mounted on the table and the drive side assembly can be moved on the table to achieve the required meshing center distance. A precisely ground, rigid steel plate is mounted in front of the table to provide a reference/datum plane for the test stand. The load

side assembly and drive side assembly are aligned using the reference plane.

The drive side assembly consists of a servo-controlled DC motor, three optical encoders, and a driver shaft with a 0.400 inch bore. The DC motor is servo-controlled for constant velocity using a 5000-line optical encoder that is mounted on the motor shaft. An 18000-line optical encoder (drive measurement encoder) provides the angular position of the driver shaft for transmission error computation. The test gears are mounted on arbors that are inserted into the 0.400 inch bore on the driver shaft and clamped using split-hub clamps. The mounting frame that holds the DC motor, encoders, and driver shaft can be moved in Y direction a maximum of 0.025 inches (X-Y plane represents the plane of the air table) by deflecting thin steel plates that act as flexures. This provides a method to change center distance by small amounts when gears are mounted on shafts. The mounting frame can also be rotated about the Z-axis (in the plane of the table) to achieve parallel alignment