

Noise Reduction in a Plastic and Powder Metal Gear Set Through Control of “Mean Involute Slope”

by: Robert E. Smith, R.E. Smith & Co., Inc.
Irving Laskin, Consultant

American Gear Manufacturers Association



TECHNICAL PAPER

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Robert E. Smith, R.E. Smith & Co., Inc. Rochester, NY
Irving Laskin, Consultant, Sharon, MA

[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:

Mis-matched involute profiles are recognized as a cause of tooth meshing noise. This paper traces a noise reduction process applied to a consumer product with a noisy gear set consisting of a powder metal (P/M) pinion driving a molded plastic gear.

The process started with identifying the objectionable noise frequency components and tracing them to this gear set as a source. Measurements of profiles on both gears showed a mismatch of pressure angles, which could be related to "mean involute slopes." When the mismatch was reduced by corrective grinding of test sample pinions, these noise components dropped to acceptable levels.

Experimental study of the plastic gear shrinkage during molding led to a mold cavity design to achieve the desired pressure angle. This was accompanied by the introduction of a simple, practical means for molding process control so that the molded gear "mean involute slope" could be continually matched to that of the P/M pinion. With this in place, the noise reduction could be maintained, permitting the manufacture and sale of the product.

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Robert E. Smith, Consultant
R.E. Smith & Co., Inc., Rochester, NY 14616

Irving Laskin, Consultant
Sharon, MA 02067

1.0. INTRODUCTION.

1.1. **Product Under Test.** The data discussed in this paper was taken on an upright vacuum cleaner. This was a prototype cleaner that was self propelled through the use of a geared transmission. It was the first time that the manufacturer had used a geared transmission in their cleaner, so it was their first exposure to the use of gears.

The transmission, shown in Figure 1, is driven by a timing belt takeoff from the fan motor shaft. It contains a 12 tooth powder metal (P/M) pinion driving a pair of 48 tooth plastic gears. Because of the molding and sintering processes, these gears had been specified as AGMA Q6 quality. Through a clutching arrangement, one or the other of the plastic gears is driving the machine in the forward or reverse direction. Pushing or pulling on the upright handle actuates a rocker arm that engages the appropriate clutch. Another timing belt drive connects the 48 tooth gears to a final set of bevel gears. The large bevel gear is on the final drive axle.

1.2. **Noise Characteristics.** When operating the vacuum cleaner in the self propelled mode, a nearly pure tone whine was heard while the machine was moving in each direction. It was of a fairly high pitch and was objectionable when compared to previous non-self propelled machines. The vacuum fan and beater bar also make considerable noise and are responsible for most of the overall dBA sound pressure level. However, because of the "whine" characteristic of the gear noise, it was objectionable even though it was lower than the overall sound level.

2.0. IDENTIFICATION OF NOISE SOURCES.

2.1. **Spectral Analysis.** Due to the complexity of the drive, timing belts, pulleys, gears, etc., it was necessary to use spectral analysis [1] of the noise in order to identify the offending components. This was done by a FFT Real Time Analyzer. This takes a complex sound waveform and breaks it down into it's various spectral frequencies.

2.2. **Relationship to Transmission Error.** Moving elements in a complex train, such as this, cause airborne noise as well as force variations that are applied to the structure. Often, the structure will act as a mechanical amplifier of the noise at frequencies that coincide with it's resonant frequencies. The gears and other elements act as exciters. The excitation from the gears and timing pulleys comes from what is known as "Transmission Error" [2],[3]. Transmission error is a non-uniform motion that is the result of errors in geometry of the gear or pulley teeth, as well as runout.

2.3. **Comparison of Noise Frequencies.** Gears will generate noise excitation at their mesh frequency as well as multiples of mesh frequency. They can also generate noise as a result of runout. This usually shows up at once per revolution frequency, or at once per revolution sidebands of mesh frequency. In order to identify the offending source, one must know the operating speed of the machine as well as the discrete frequencies of noise. In this case, the speed varies with load and was different for each test. Therefore, it was easier to create a table of "rotational orders" that could be used for any operating speed. Such a table is shown in Table 1.