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A STUDY OF THE NOISE REDUCTION POTENTIAL OF MILLING CUTTERS EMPLOYING NON-UNIFORM INSERT PITCH

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INTRODUCTION

This paper details the results of tests undertaken to evaluate the noise reduction potential of multi-insert milling cutters with non-uniform pitch. Noise measurements were carried out on a high volume transfer line when machining the engine mounting face of a production automobile transmission case. See Figure 1.

BACKGROUND

The use of lightweight components in the transportation industry has necessitated the milling of thin walled aluminum castings on high volume, multi-station transfer machines. In the particular case of aluminum transmission housings, the combination of high cutting speeds, thin walls and bell-like geometry can result in excessive noise generation during the machining process. Sound levels as high as 118 dBA at a distance of 3m have been measured on actual production machines. The majority of this noise, by far, is radiated by the workpiece under the influence of the forced excitation imparted by the engagement of the milling cutter inserts.

It is theoretically possible to reduce this noise generation by applying, for example, during the machining cycle, damping pads at appropriate positions on the workpiece. However, the cost of extra equipment, space limitations and possible workpiece deflections due to pad pressure make this solution unattractive. Similiar objections can be raised to other peripheral methods. The most attractive procedure, in every respect, is to reduce the workpiece vibration at its source. This can be best achieved by modifying the milling cutter in such a manner as to minimize the vibration response, and hence noise, of the workpiece under the action of the forces generated by cutter insert engagements.

Studies by various researchers (1)-(5) have indicated that non-uniform spacing of events in a multi-event cycle has the potential to reduce the resultant vibration and noise by redistributing the concentrated energy over a wider bandwidth. When this principle is applied to milling cutters the result is an irregular cutting insert pitch, the actual values of which are a function of the specific generating principle employed.

MEASUREMENTS

A total of five different milling cutters, all with 18 cutting inserts, were employed in the study. One was an evenly spaced control, two were variations of the "white noise" type, and the last two employed 5 randomly placed modified inserts. (In the one cutter the 5 inserts were ground back 1.5mm, in the other the 5 inserts were ground with an Inscribed Circle of 1.5mm smaller diameter). All noise measurements, which were A-weighted, were made at the same position along an unobstructed line of sight to the workpiece. Samples of both the background and idle (spindle rotating but not cutting) noise levels were recorded for use in "correcting" the cutting noise levels. Measurements were made for each milling cutter at eight depths of cut, from 2.1mm to 3.8mm The process cutting time was 9.4 seconds.

RESULTS

Based on the Leq values determined during each cutting noise cycle it was found that the four milling cutters employing non-uniform insert spacing generated noise levels similiar to, or higher than those of the equally spaced control. For all five cutter designs the noise level increased with the depth of cut.

Frequency spectra of each cutter design indicate that the non-uniform insert pitch caused redistribution of the sound energy over a wider bandwidth when compared with the equally spaced cutter. This is illustrated in Figure 2. Test #24 and Test #25 produced the same Leq value, yet the redistribution of energy due to the non-uniform pitch employed in Test #24 is readily apparent.

Further study of Figure 2 shows that although no change in overall Leq value was achieved, Test #24 indicates a reduction in "noisiness" relative to Test #25 due to the significant decrease of sound energy concentrated at discrete, harmonically related components (6). This result was not restricted to particular test groupings but was found to be generally applicable.

Review of the sound level vs. time readings which were generated during the cutting cycle of each test milling tool indicates that, although unique, they do exhibit remarkable similarities. It is apparent from all the traces that various common regimes of noise generation (characterized by changes in overall sound level and the predominant spectral components) are excited as the cutter moves across the part. It would seem that the changing geometry of the part (and its associated properties such as stiffness, etc.) and the changing geometry of the cut itself (entrance angle, exit angle, width of cut, etc.) are the dominant factors in producing these regimes. Figure 3 shows how the regimes are defined by the changes in geometry encountered by the cutter as it moves over the part profile. Such phenomena play a very important part in determining the overall noise generation during the milling process, yet they are not adequately accounted for in the existing procedures employed to determine insert geometry for quiet cutters.

CONCLUSIONS

Milling cutters of non-uniform insert pitch, designed using presently available techniques for "quiet" cutters, failed to provide a noise reduction relative to a standard cutter utilizing equally spaced inserts. Equally, it is clear that this method of reducing workpiece vibration and noise is the only viable solution for practical applications. Consequently further work must be undertaken to better understand cutter-workpiece interaction and hence provide a means of predicting cutter geometries likely to produce minimum noise generation.

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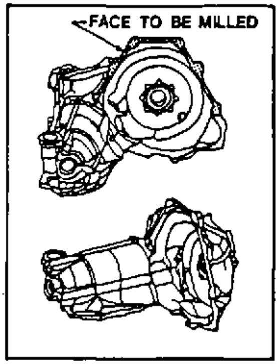

Fig. 1. Two views of the transmission case.

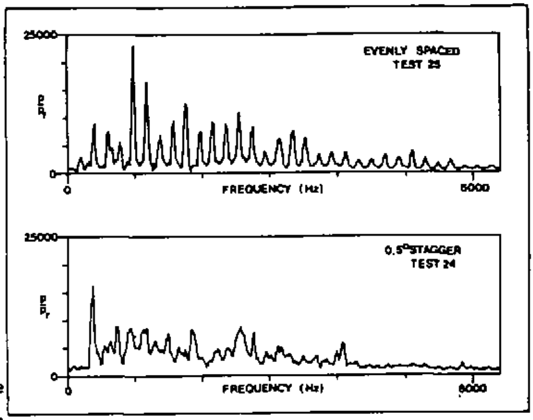

Fig. 2. Comparison of spectra from two tests.

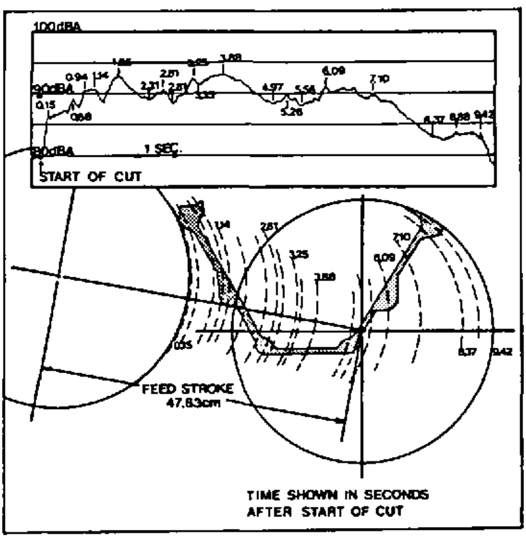

Fig. 3. Typical sound level vs. time history.