

Pulley Optimization for Improved Steering Pump Airborne Noise Performance

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05/17/2011Christian Fernholz, Ronald Perri, David Watts, David Willmer and Jeff Williams
Ford Motor Company

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ABSTRACT

This paper discusses the optimization of an automotive hydraulic steering pump pulley design for improved in-vehicle pump NVH performance. Levels of steering pump whine noise heard inside a vehicle were deemed objectionable. Vehicle and component transfer path analyses indicated that the dominant noise path for the whine noise was airborne in nature. Subsequent experimental modal analysis indicated that the steering pump pulley was a major contributor to the amount of radiated noise produced by the pump/pulley system. CAE analysis was used to further analyze the dynamic behavior of the pulley and develop an optimized design with decreased noise radiation efficiency. The results predicted with the CAE analysis were verified in-vehicle, resulting in a vehicle with acceptable steering pump whine noise performance.

INTRODUCTION

Automotive hydraulic steering pump noise is typically categorized either as steering pump “moan” or steering pump “whine” [1]. In the case of the former, the noise transfer paths tend to be either structure borne or fluid borne in nature. Conversely, steering pump whine noise, which is typically higher in frequency than moan noise, usually has a strong airborne noise path component [2].

For the present study, unacceptable levels of hydraulic steering system noise were observed in a particular vehicle. Conventional approaches involving improved hose tuning, steering pump metering notch changes and isolation were used to reduce much of the frequency content of this noise. However, these efforts proved to be insufficient to address steering pump whine noise heard at a particular engine speed. Applying standard experimental transfer path and modal

analysis methods, the authors were able to identify the steering pump pulley as the principal contributor to steering whine noise heard in the vehicle.

The present work discusses the efforts employed by the authors to first identify the influence of the pulley on the NVH performance of the pump, and then the optimization approach used to improve the noise performance of the steering pump and pulley system.

PROBLEM DESCRIPTION

VEHICLE MEASUREMENTS

Subjectively, the steering pump noise heard inside the vehicle and deemed objectionable was identified as steering pump “whine” noise. As shown in [Figure 1](#), high levels of steering pump 22nd and 33rd orders were audible in the vehicle. Furthermore, both of these orders exhibited peak levels at the same frequency of approximately 800 Hz, a strong indication of the presence of a resonance in the system.

NOISE TRANSFER PATH MEASUREMENTS

Following the analysis techniques outlined in [3], a reciprocal noise transfer path method was applied to quantify the airborne noise path in the vehicle. Steering pump sound power was measured on a test bench following SAE procedure J2747 [4] and converted to volume velocity. The predicted interior noise level due to airborne noise sources was computed as

$$P_{pred} = \left[\frac{P}{Q} \right] Q_p$$

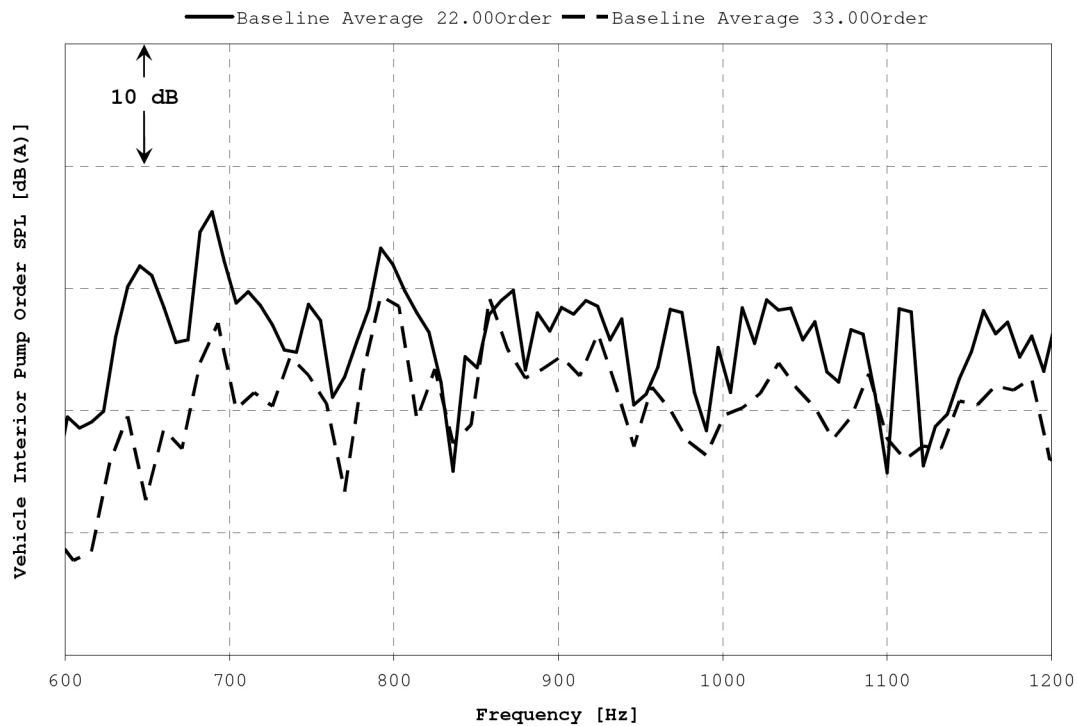


Figure 1. Vehicle interior SPL versus frequency for the steering pump 22nd and 33rd orders.

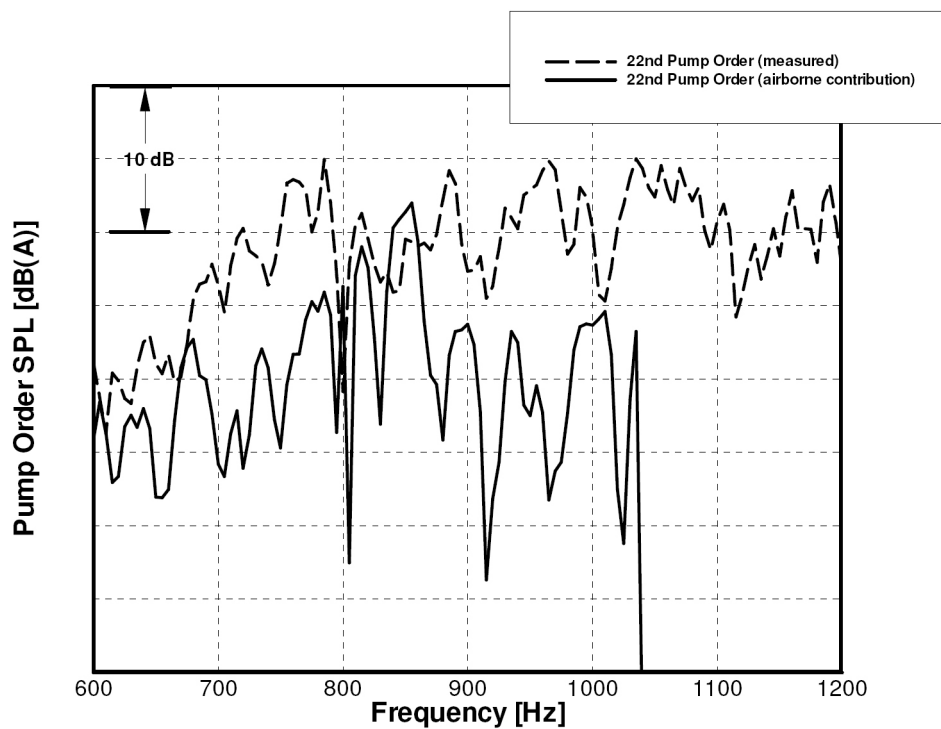


Figure 2. Airborne noise contribution analysis for steering pump 22nd order. The airborne noise path dominates vehicle interior noise over a range of frequencies from about 800 to 860 Hz.

$$\frac{P}{Q}$$

where $\frac{P}{Q}$ represented the airborne noise transfer path for the vehicle from the driver's ear to the steering pump and Q_p was the volume velocity of the pump, as measured on a test bench. The interior sound pressure levels computed in this manner were compared with actual interior noise measurements made in the vehicle during normal operation.

The results of the airborne noise path contribution analysis for the steering pump 22nd and 33rd orders are shown in [Figure 2](#) and [Figure 3](#) respectively. In both cases, these results clearly indicate that interior noise in the range from approximately 800 to 850 Hz is dominated by the airborne noise path in the vehicle. In the case of the 22nd order ([Figure 2](#)), the experimental transfer path model actually over-predicts vehicle interior noise at approximately 850 Hz. The operating data used for this analysis was taken from

component-level measurements of steering pump sound power. That is, only the airborne component of the noise generated by the pump/pulley system alone was considered, not the structure or fluid borne components. This operating data is shown in [Figure 4](#). As shown in [Figure 4](#), when considering the airborne noise radiated by the pump/pulley system, it was noted that the steering pump 22nd through 55th orders all show peak levels at a frequency of approximately 840 Hz. This data, combined with the contribution analysis data, indicated that the resonance noted in the vehicle data ([Figure 1](#)) was not present in the vehicle path, but in the pump/pulley system.

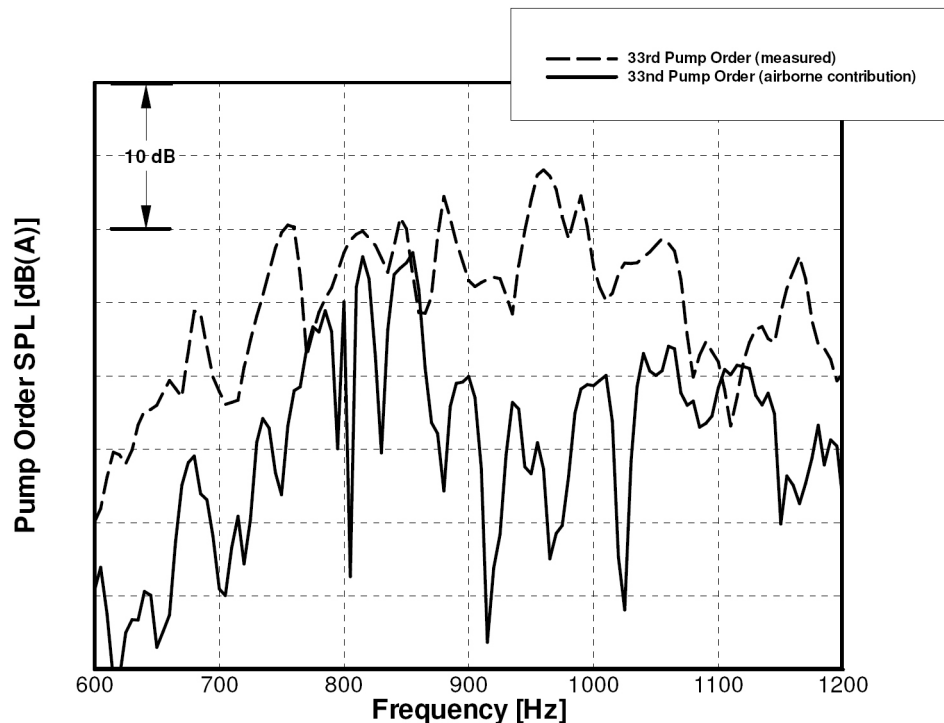


Figure 3. Airborne noise contribution analysis for steering pump 33rd order. The airborne noise path dominates vehicle interior noise over a range of frequencies from about 760 to 860 Hz.