A DATA PROCESSING METHOD FOR NOISE MEASUREMENTS OF SNOWMOBILES AND THEIR SUB-SYSTEMS ON TEST BENCH

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1 Introduction

Snowmobile sound emission is qualified using standards SAE J1161 and J192. They set the noise level limit during Pass-by test, test depending on environmental conditions [1]. As the objective is to compare two models of CVT driving pulleys (responsible of noise) and to avoid this dependency, use of a test bench is a solution. Maximum engine speed has to be reached and maintained on test bench to reproduce Pass-by condition. But speed and load controls can be hard to achieve and comparison of pulleys (using time averaging of the recorded signal) led to results different from Pass-by comparison (time averaging is applied on the signal for maximum engine speed on test bench). This is because engine speed can vary up to 20% even with wide open throttle. Engine speed has to be accounted when using a test bench to predict noise level reduction in Pass-by test between two snowmobile CVT, as noise depends on it [2, 3]. Test bench measurements also need a processing method, this one taking into account engine speed. Including statistical indicators improves the analysis [4]. This paper describes and discusses a data processing method based on bench tests measurement, allowing reliable noise comparison between two different models of a snowmobile CVT, and predictions on Pass-by noise reduction.

2 Method

2.1 Measurement

The test bench used is a functional snowmobile, fixed to a plate using the two front skis. The track is not driven. A water-brake torque load is attached to the driven pulley, attempting to reproduce normal use torque. All noise sources but the CVT driving pulley are isolated. An antenna of four microphones faces the CVT within 2.2 meters (8 times the minimal considered wave length, i.e. 1200 Hz). Time signals of the microphones and the engine speed are recorded. One measurement lasts 8 seconds, during which wide open throttle acceleration is maintained. Because of speed variations and to make statistical indicators more robust, a minimal number of 10 measurements are made. Two models of CVT are compared : model 'A' (noisy) and model 'B' (silent).

2.2 Calculation

Data processing algorithm

To take noise level dependency to engine speed into account, data will be processed and ranked in relation to the engine speed. The data is processed as following :

• Step 1 - For each pulley model :

First, for each of the 10 measurements, the algorithm slices the signals into FFT blocks with overlap. Then, it computes, for each block, the frequency spectrum of every microphone and the mean rpm of the block. As the speed range was cut into steps, the mean rpm will match a rpm step. So for each rpm step increment, it averages the microphones' frequency spectra. If, for the duration of the measurement, several time intervals match the same rpm step, it finally averages those spectra.

Secondly, for each rpm step, the algorithm averages the frequency spectra of every measurement (having a spectrum matching the rpm step). This provides the mean spectrum of the model and the number of contributing measurements for each rpm step. Thanks to this, variance is finally computed.

• Step 2 - Comparison between two models :

To compare two models, the algorithm computes the statistical indicators for each rpm step and each frequency band.

Statistical indicators

Confidence intervals : This indicator depends on the standard deviation, calculated as the square root of the unbiased variance estimator. To compare the results of two CVT models, we look at the overlap of their confidence intervals (CI) for the 'A' and 'B' models as in (1) :

$$\bar{x}_A > \bar{x}_B \rightarrow \begin{cases} CI_A & = \bar{x}_A - t^{n_A-1}_{1-\alpha/2} \times (\sigma_A/\sqrt{n_A}) \\ CI_B & = \bar{x}_B + t^{n_B-1}_{1-\alpha/2} \times (\sigma_B/\sqrt{n_B}) \end{cases} \quad (1)$$

where $t^{n-1}_{1-\alpha/2}$ is the quantile from the t-distribution table depending on the degrees of freedom $n-1$ and the confidence level α (Student's law), and $\bar{x}_A$ and $\bar{x}_B$ are the models' mean values. The computation starts with a large α (small interval entails small confidence). If the two intervals do not overlap, the value of α is decreased and the previous test is repeated, and so on until the intervals overlap. The last value of α for which there is no overlap is kept, giving the confidence $P(\%) = 100(1-\alpha)$. This indicator can not be used to state on the reality of the difference, as the true means may be very close to each other.

Significance of differences coefficient : The significance of the differences coefficient (SDC thereafter) is introduced in this study to answer the need to better understand and determine the noise differences between two models. This coefficient is based on the mean difference between the models 'A' and 'B'. First, the difference between unbiased variances

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is calculated as $\Delta_\sigma = |\Delta_m| - k \times (\sigma_A + \sigma_B)$, where σ_A and σ_B are the standard deviation respectively of model A and model B, $\Delta_m = \bar{x}_A - \bar{x}_B$, and k which is a factor representing the number of standard deviations for the normal distribution which is a characteristic of the population proportion taken into consideration. Hence, the SDC is introduced as the relation between Δ_σ and Δ_m, i.e. $SDC_k = \Delta_\sigma / \Delta_m$.

The SDC is non-dimensional and can also easily be computed as a percentage of the mean difference as in (2) :

$$SDC_{k,\%} = 100 \left(1 - k \times \frac{\sigma_A + \sigma_B}{|\Delta_m|}\right) \quad (2)$$

The SDC enlightens about the toughness of the results, particularly when the samples include few measures (for instance because of highly variable engine speed). It can be used to state on the probability to obtain a minimum difference or that a mean difference is accurate (not a measurement error).

3 Results

3.1 Comparison with Pass-by noise measurement and simple time averaging

On the figure 1 below, results from the data processing method are compared with Pass-by measurement and time averaging method ones, for two different test bench measurement sessions (first with middling torque and speed control, second with improved control). Noise level difference is between CVT 'A' and 'B'. Numbers of measurements are equivalent for both sessions.

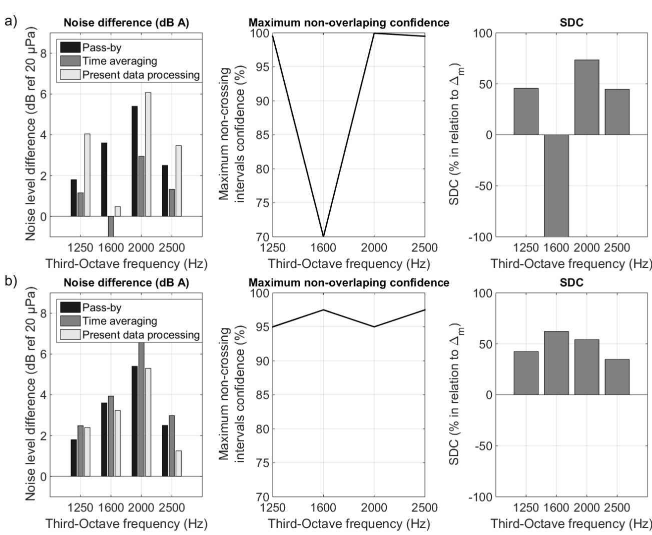

Figure 1: Comparison of noise level differences and performance of the method : a) with middling torque and speed control, b) with improved control.

3.2 Tests results analysis

Time averaging always returns relatively different results from Pass-by ones. The data processing method yields closer results to those from Pass-by, so long as the conditions on the test bench remain well controlled. Moreover, indicators facilitates the judgement on the quality of the measurements and help make predictions : in the case of the middling control, SDC values show that results are unreliable, unlike for the second case.

4 Discussion

During some of the tests, comparison of the 2 pulleys using time averaging on test bench returned completely false results compared with Pass-by comparison, as engine speed can vary a lot. Even if the proposed method takes more time to process data, gains are potentially large, thanks to statistical indicators improving the reliability of the results and predictions. Test conditions are also really important on the test bench so as to obtain comparable results with those from Pass-by. Moreover, this method provides results for an extended large range of speed.

5 Conclusions

A new data processing method for noise measurements on test bench has been described and used to compare noise levels between two snowmobile CVT. This method is a relatively simple algorithm associating noise level to the engine speed. Included statistical indicators make easier comparison and prediction, as long as test conditions on the bench are well controlled (reproduce real use conditions), and number of measures is large enough. Test bench measurement saves time and does not depend on environmental conditions compared with Pass-by measurement. The comparison fairly matches with Pass-by results and predictions seem to be made with reliability.

Acknowledgments

The authors wants to acknowledge the work of Walid Belgacem in the design of the test bench. This study was conducted as part of a project financially supported by NSERC and BRP.

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