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NOISE CAUSED BY POWER ASSISTED BRAKE: CHARACTERISTICS AND CONTROL

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ABSTRACT
In order to measure levels and characteristics of the noise caused by power assisted-brake it had carried out an experimental device allowing the measurement of the mechanic variables of the actuation (stroke and force) hydraulic circuit (pressure) and noise levels. It will show the dependencies between hydraulic pressure gradients and sound levels as well as with the actuation velocity. Likewise it will show the noise levels diminution caused by different silencers placed at the air intake. The more important conclusions are the following: a) the maximum noise levels happen simultaneously to the maximum pressure gradients. b) maximum noise levels are lineal dependent with the actuation speed, and c) spectral power is dominant around 6 kHz.

1 - INTRODUCTION
The power assisted-brake is an element of the brake system whose purpose is to provide a help force to own to the driver himself. Such force is obtained because of the pressure difference existing between the two chambers that constitute the body of the power-assisted brake. In summarized form, the process is as follows. When the engine starts the air of the front chamber is extracted through an exhaust valve. The forces due to the pressure difference, together with the elastic forces of the springs, end being balanced. In this equilibrium, the front chamber and the rear chamber are at pressures of 0.1 and 0.2 bar, respectively. They are isolated each other. Also, the rear chamber remains isolated of the outside. During these balanced movements, the power-assisted brake has acquired all their position tolerances remaining ready to be activated. In these conditions-when the pedal for the brake is pressed- force on the input rod is applied, opening a way between the rear chamber and the outside. The entry of the outside air in the rear chamber provides a force that it is proportional to the difference of pressures as well as to the diameter of the power-assisted brake. If during this phase the input force is constantly maintained (that is to say- advance of the input rod is stopped) the rear chamber and the outside is again isolated. It remains then a small vacuum into the rear chamber maintaining the equilibrium of the forces. The point of saturation of the power-assisted-brake is produced when the rear chamber is found at atmospheric pressure. In this moment, an increase in the output force requires the same increase that of the input force. When the pedal of the brake is released, the process is repeated again. The efficiency curve of a power-assisted brake represents the output force in function of the input force. At the zone of interest, this relationship is a straight line whose slope is approximately three.
The air passing through small sections originates turbulence that is the cause of the noise produced by the actuation of the power-assisted brake. The objective of the present work has been to implement both an experimental device and appropriate software that permit us to measure and to analyze levels and characteristic of the emitted noise, its dependence with the physical variables and the efficiency of different silencers.

2 - EXPERIMENTAL DEVICE
The figure 1 shows the experimental device and the data processing. When the vacuum is doing a force operates on the pedal of the brake. A sensor gets the path of the pedal and other sensor gets the

hydraulic pressure in the circuit. Both signals, properly amplified, are recorded in a digital oscilloscope. Simultaneously, a microphone measures the acoustics signal that is passed to the analyzer. The three signals (noise, stroke and pressure) are analyzed thereinafter with MatLab®. The microphone was placed in the direction of the maximum acoustic emission at 30 cm of the air input to the power-assisted brake. The spectral power of the acoustics signal was analyzed in 1/3 octave bands from 80 Hz to 16 kHz with averaged linear each 62.5 ms.

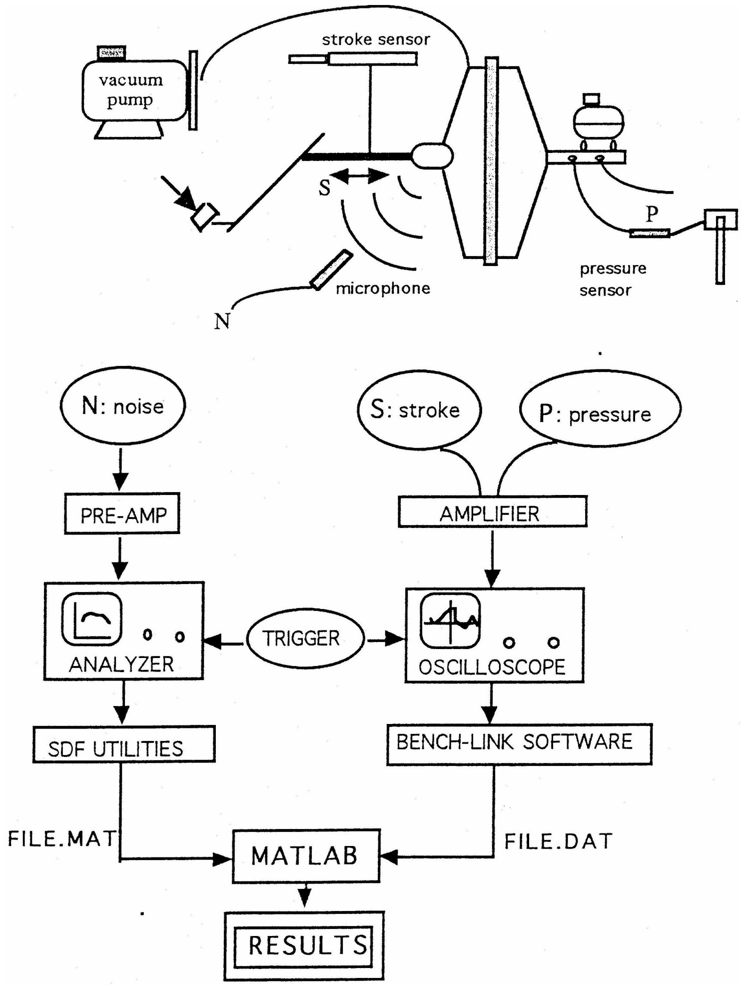

Figure 1: Experimental set-up and data processing system.

3 - RESULTS

3.1 - Histogram of the variables

Figure 2 shows the results obtained in a typical actuation for the stroke, pressure and sound level variables. The graph shows clearly the process; while the pedal is moving forward the hydraulic pressure increases and the power assisted-brake emits noise; this action follows while admission of the air remains. When the maximum path is reached, the pressure is stabilized and the noise ceases. The process is similar during the backward movement of the pedal. The last of the three peaks of the signal of the noise corresponds to the mechanical noise of the catch. Its spectral analysis is very different of the rest and was eliminated for the subsequent analysis. The most noticeable result is that the maximum noise levels are produced when both the maximum stroke and pressure gradients are given, that is to say, at the maximum actuation speed. During such time (tenths of second) supersonic speeds are reached into the valve body, due to the reduced step section and the high pressure gradients. In such instants are generated strong turbulence that originates noise.

3.2 - Noise – speed correlation

For all types of power assisted-brakes tested the maximum sound levels grow linearity with the speed, at least until speeds of 100 mm/s. Over that speed, the noise keeps in practically constant. All the regression

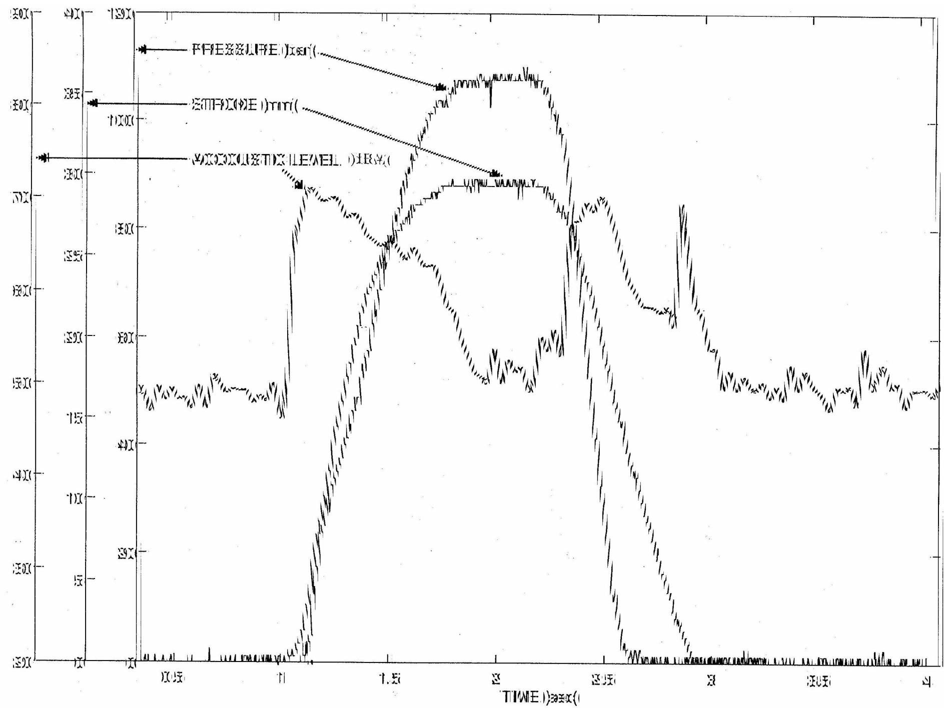

Figure 2: Histograms for the stroke, pressure and sound level variables.

lines are very similar. For the five types of power assisted-brakes tested, correlation coefficients had been practically identical (R=0.96). The figure 3 shows this dependence. In all cases, the maximum noise level for each actuation corresponded to the section on the way up (see figure 2). For each type of power assisted-brake 70 actuations were carried out uniformly distributed on the speed variable.

3.3 - Spectral analysis

The spectral analysis shows a strong dependence between noise and actuation speed. When the speed of actuation increases the band of the maximum emission increases. In general, the noise emitted is at high frequencies, always above 2 kHz. Figure 4 shows the average of the records obtained for low speeds (20-30 mm/s) and for the different five power assisted-brakes. The selected traces are the corresponding to the time of maximum sound emission.

4 - CONCLUSIONS

1. The implemented experimental device permits both the measure and the analysis of the influential variables on noise produced by the actuation of power assisted-brakes.
2. The maximum noise levels emitted in the braking are produced simultaneously to the maximum gradients of pressure.
3. There is a linear dependence between the maximum noise levels and the actuation speed.
4. The acoustics emission is predominantly in the range from 4 to 10 kHz.

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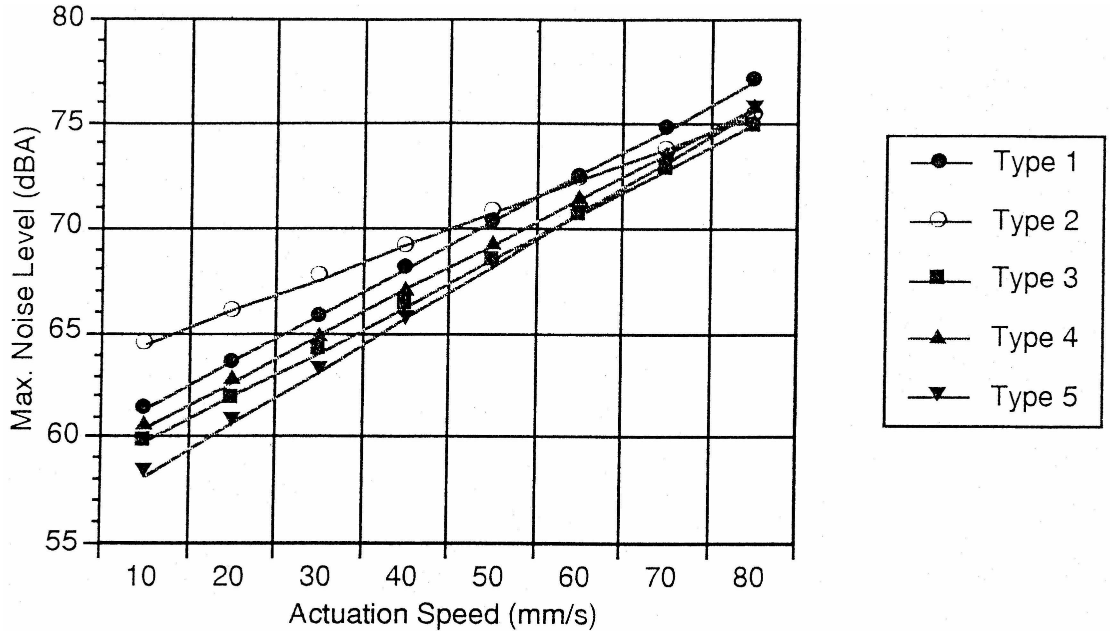

Figure 3: Maximum noise levels versus depending on actuation speed.

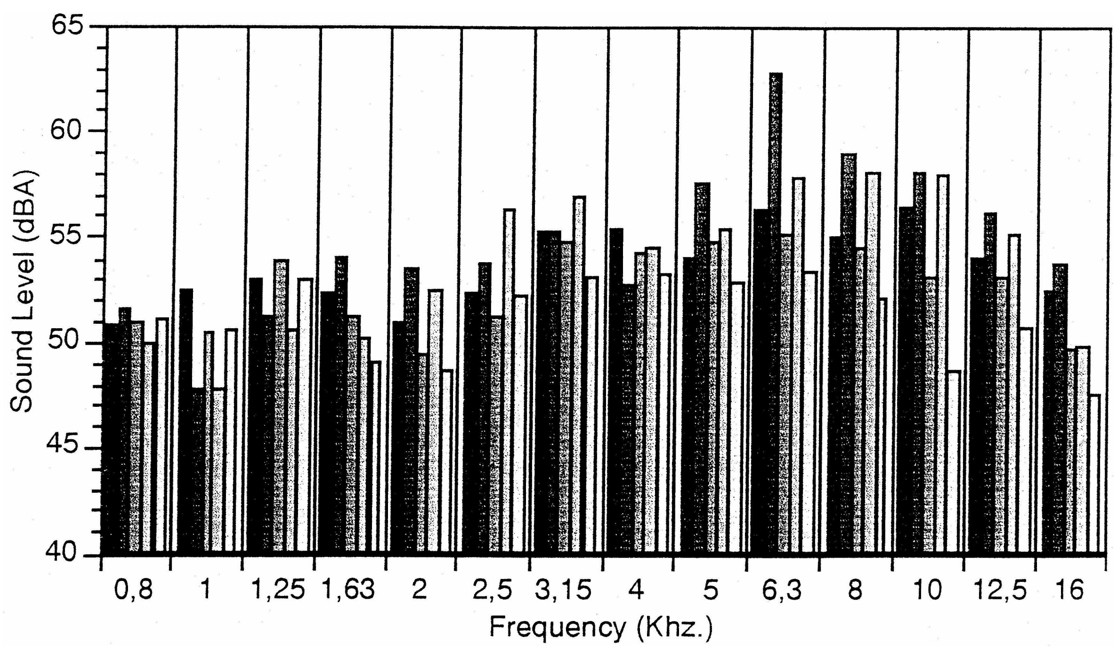

Figure 4: Spectral power for the five types (see figure 3) at low speeds.