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EXPERIMENTAL SYSTEM FOR THE STUDY OF CVT TRANSMISSION PARAMETERS

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ABSTRACT
This paper firstly recalls the parameters that need to be known in order to develop and apply a general methodology for the dimensioning of continuously variable V-belt transmissions.
A description of the experimental system object of this paper is then provided, which permits the testing of CVT transmissions in the most wide-ranging operating conditions, making it possible to measure numerous functional parameters simultaneously.
In particular, a detailed description of the laser technology-based device is provided, which was created to measure the local speed of the belt at the various points along the wrap arc, highlighting the extreme usefulness of such measurement.
Keywords: Transmission, Belt, CVT.

1. INTRODUCTION
Continuously variable V-belt transmissions are increasingly widely used, especially in motorcycles, due to their well known positive functional characteristics.
Nevertheless, the related dimensioning is still today carried out partially on an empirical basis, due to the lack of a complete general methodology which makes it possible to perform the dimensioning on the basis of the main characteristics of the engine and of the vehicle.
One of the reasons which make it difficult to develop a general methodology is the lack of experimental data for certain parameters necessary for dimensioning operations, in particular as regards the belt slip phases with respect to the pulleys.
The experimental system described in this paper aims to provide a useful instrument for measuring some of the above mentioned parameters.

2. OBJECTIVES
A preliminary kynematic and dynamic study on CVT transmissions has shown how their functioning, and hence their dimensioning, is connected to a very large number of parameters, which are normally not interdependent, such as for example: stiffness and preload of the helical spring of the torque driver, mass and diameter of the centrifugal masses, slope of the cams of the torque driver, geometry of the ramps of the centrifugal masses, belt-pulley slip angle, etc.
The possibility of experimentally determining some of these parameters, as illustrated below, will permit to reduce the unknowns and the dependent variables and, hence, to develop a dimensioning methodology based on the analysis of the effects caused by the variation of a small number of parameters.

3. DESCRIPTION OF THE EXPERIMENTAL SYSTEM

The experimental system examined in this paper essentially consists of a test bench for continuously variable V-belt transmissions, in which both the motor driving the driving pulley and the load driven by the driven pulley consist of electrical machines; the system is equipped with a wide range of sensors for the contemporaneous measurement of numerous quantities under various operating conditions. The electric drive system allows for an easy and flexible control through a PC, as well as for its use also in environments which are not suited for the operation of internal combustion engines.

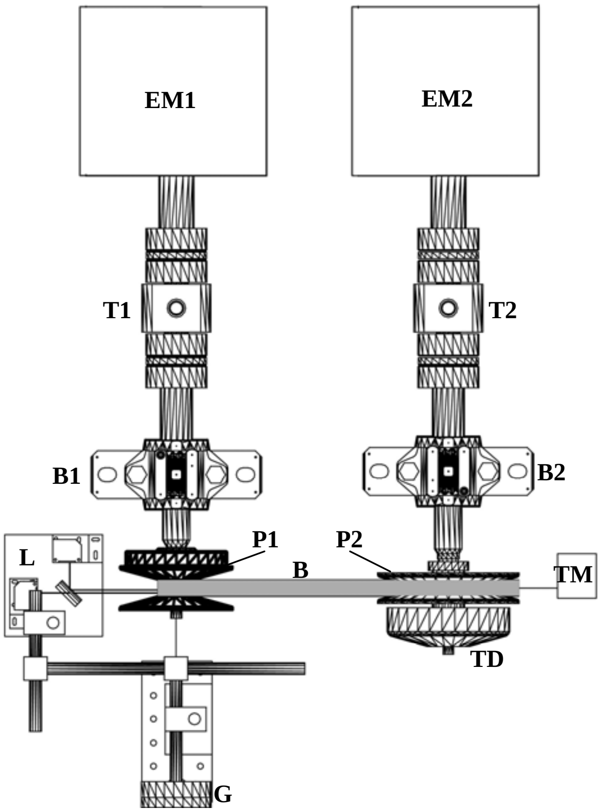

Figure 1. Overview of the experimental system.

With reference to Figure 1, the main components of the system are outlined below.

- Two electrical machines (EM1 and EM2), which simulate the thermic engine and the load respectively. In order to simulate the operating conditions of transmissions of models up to 150cc, asynchronous motors with solid shaft and forced ventilation manufactured by Siemens, model 1PH7-107-2HG00-0LJ0, were used. Their main mechanical characteristics are the following: maximum rotation speed 12000 rpms, maximum torque 50.1 Nm, maximum power 12 kW, overall performance 85.9%.
- An electronic drive system (Siemens Sinamics S120), which includes an inverter and makes it possible to control the electrical machines' speed (drive machine) and torque (driven machine) and to feed the electrical power generated by the driven machine back into the network or re-use it to power the drive machine.
- Two torquemeters (T1 and T2), positioned on the transmission input shaft and output shaft respectively. These transducers acquire torque using strain gages and contact-less energy and signal transmission; they are manufactured by HBM (model T22) and are capable of measuring torques of up to 50 Nm also at high speed (up to 12000 rpms).

- Two self-aligning ball bearings, on an adapter sleeve (B1 and B2, designation 2208 EKTN9 + H 308) supporting the shafts, complete with bearing units.
- Driving pulley (P1) and driven pulley (P2) of the CVT transmission.
- Transmission belt (B).
- CVT transmission torque driver (TD).
- Laser device (L) for measuring the local instantaneous speed of the belt, which will be examined more closely below.
- Goniometer (G) for the angular positioning of the laser device L.
- Laser telemeter (TM) for measuring the winding diameter of the belt.
- Infrared thermometer for measuring the belt temperature.
- National Instruments PCI 6251 data acquisition card (24 Channels, 16 bits, maximum sampling rate 1.25 MS/s), which, housed in a suitable PC using Labview® software, makes it possible to manage all the physical quantities measured by the system sensors at the same time.

4. MEASURED QUANTITIES

By the electronic drive system of the two electrical machines, which permits to set the input speed and the output torque, the experimental system is able to reproduce the possible operating conditions of the belt transmission.
Whatever the operating condition, the system measures the values of numerous physical quantities simultaneously:
rotation speed of the two electrical machines (and, therefore, of the driving and of the driven pulley closely connected to the latter), measured directly by the same machines;
transmission input and output torque, by means of the two torquemeters;
belt winding diameter on the pulleys (and, consequently, instant value of the transmission ratio), through the laser telemeter;
belt operating temperature, through the infrared thermometer;
belt speed along the wrap arc on the pulley, through the laser system referred to in the following paragraph.

4.1. Belt speed measurement

As already said, a laser system was created for measuring the local speed of the belt along the wrap arc on the pulleys; this speed, as is know, varies along a section of the above said wrap arc, such as to cause a variation in the belt speed between the tight side (higher speed) and the slack side (lower speed).

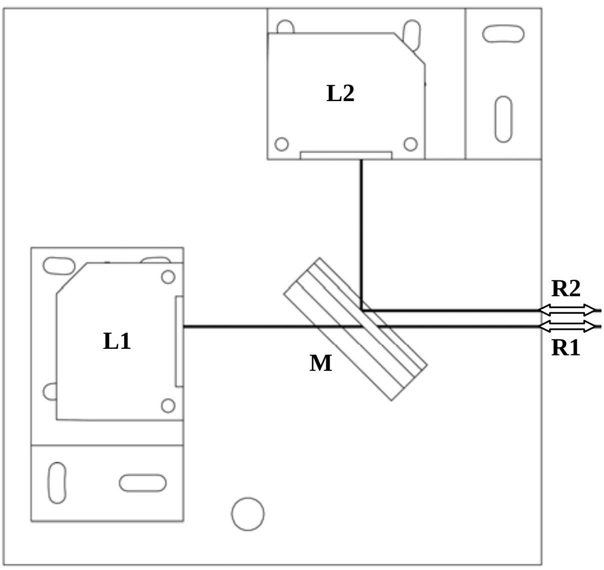

Figure 2. Laser system for measuring belt speed.

The system (Figure 2) consists of two reflective type laser emitters/receivers (L1 and L2) manufactured by Panasonic SunX (model LS-H21), including the related amplifier, as well as of a partial reflection mirror (M). The position and the direction of all the components are adjustable; by adjusting the latter, the device will project two parallel laser rays (R1 and R2).

The two laser rays are shot against the belt wound around the pulley (see Figure 3), thus generating two light spots (S1 and S2).

A refracting band (R) is created on the belt, which runs first through spot S1 and then through spot S2, generating a return beam for laser L1 and for laser L2, respectively. The electronic management of the system prevents interference phenomena from occurring between the various laser beams. Given that the entire device shown in figure 2 is mounted on an appropriate adjustable support, it is possible to repeat the measurement from any angular position along the belt's winding arc on the pulley.

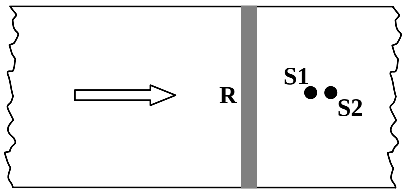

Figure 3. Belt section from which the speed is measured

Using the data acquisition software, the time interval between the two return beams generated by the passage of the refracting band is measured; consequently, the percentage variations in the belt speed along the wrap arc on the pulley are determined, the speed measured at the tight side being set at 100.

It is thus possible to determine the speed of the various belt sections based on their angular position with respect to the pulley; it is also possible to identify the slip arc corresponding to the belt section which exchanges power with the pulley.

5. CONCLUSIONS

The experimental system described in this article permits to completely monitor the main functional parameters of a continuously variable V-belt transmission, while the operating conditions of speed and torque vary.

In particular, it is possible to measure the performance of the belt local speed; such performance can be compared with other important functional parameters, such as belt tension, slip arc width and belt-pulley friction; the knowledge of such system is therefore extremely useful for the purpose of developing a general methodology for the dimensioning of CVT transmissions, for which the knowledge of said parameters is essential.

6. REFERENCES

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