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ADJUSTING OF A TEST BENCH OF INTERIOR HONING MACHINING PROCESSES

I. Buj Corral, J. Vivancos Calvet
Technical University of Catalonia (UPC). Departament of Mechanical Engineering.
School of Industrial Engineering of Barcelona (ETSEIB), Avda. Diagonal 647, 08028-Barcelona, Spain

ABSTRACT
In this paper a test bench of interior honing processes was studied, analyzed and adjusted in order to improve its performance. The system consists of a horizontal honing test machine where tubes are placed in a rotating device and a honing head, provided with three abrasive stones, that has alternative linear movement. The abrasive stones hone the interior surface of the tubes. The system has six sensors: for linear speed of the tool, for tangential speed of the part, for pressure of the abrasive stones on the surface of the part, for wear on the surface of the part, for wear on the surface of the abrasive stone and for the temperature of the part. The sensors were tested and their gain was modified from the software if necessary. For indirect sensors, it was explained how to obtain the final parameter from the signal of the sensor. In addition, when a disagreement was found between the selected values of some parameters of the test bench and the values recorded by the software during the process, the internal parameters of the software were also modified.
Keywords: honing, test bench, sensor

1. INTRODUCTION
Interior honing processes consist of machining cylinder surfaces with means of a honing head equipped with abrasive stones, with simultaneous rotational and linear movement in order to scrape material. Honing generates a crosshatched pattern on the workpiece surface, which is used as a network of channels for the oil flow on the cylinder surface [1]. Honing allows obtaining pre-determined dimensional and shape tolerances, as well as low surface roughness. It is usually employed after conventional machining processes such as drilling or boring [2,3]. For a given type of abrasive stone, different parameters of the honing machine influence the surface roughness of the part, such as the expansion pressure of the honing head, the tangential speed of the honing head, the linear speed of the honing head, the type of oil employed and the working temperature [4]. In order to study the behaviour of honing processes with different conditions, a test bench is used. It consists of a horizontal honing test machine where cylinders are placed in a rotating device and a honing head provided with three abrasive stones, that has an alternative linear movement. In order to quantify the possible differences between the consigned values of the parameters and the values recorded by the software of the test bench during the process, some tests were conducted. In addition, the performance of the sensors was also tested.

2. PARAMETERS AND SENSORS
The parameters detected by the sensors of the test bench are the following: 1. linear speed of the tool, 2. tangential speed of the part, 3. expansion pressure of the honing stones, 4. wear on the surface of the part, 5. wear on the surface of the abrasive stone and 6. temperature of the part. The sensors of both linear and tangential speed consist of an encoder. The expansion pressure of the honing stones takes the signal of the bleeder valve of the plunger that drives the relative displacement of the honing head for the expansion of the honing stones (Figure 3).

The sensor of workpiece wear uses a metallic stylus that contacts the interior surface of the cylinder during the honing process. The sensor of wear of the honing stones consists of a capacitive transducer for detecting the displacement between the plunger and the honing stone. The temperature is measured by means of an infrared sensor.

3. TESTING AND MODIFICATIONS OF THE SOFTWARE OF THE TEST MACHINE

In the test bench there are two types of parameters:

- Parameters which need to be selected prior to the machining operations: *linear speed, tangential speed and pressure.*
- Parameters which are obtained as a result of the honing process: *workpiece wear, tool wear and temperature.*

For a given parameter, three reference values can be used:

a. *Consigned value* (only for parameters which need to be selected). This is the value that is introduced to the software and that is expected during the process.
b. *Recorded value.* This is the value saved by the software according to the information received from the sensors during the process.
c. *Real value*. This is the value of a parameter that is actually obtained at the test bench, measured by means of a calibrated measurement instrument.

The methodology used for testing the *parameters which need to be selected* consisted of two steps:

1. Comparison between the real values and the consigned values. If the relative error between both values was > 5 %, the software was modified.
2. Comparison between the recorded values and the consigned values. If the relative error between both values was > 5 %, the software was modified.

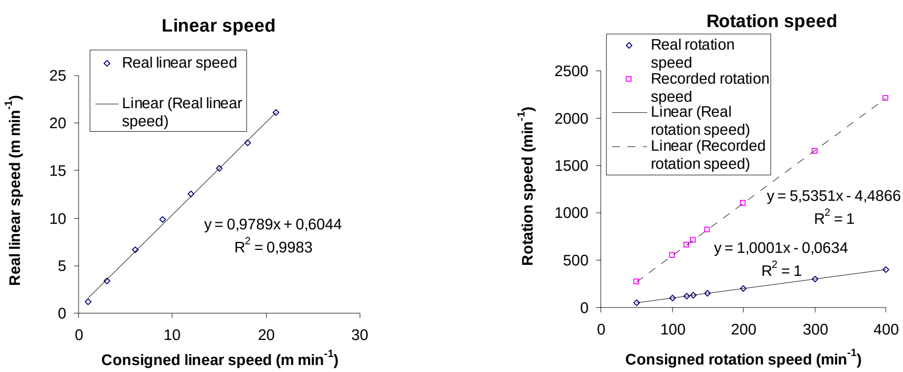
The methodology used for testing the *parameters which are obtained as a result of the honing process* consists of only one step:

1. Comparison between the recorded values and the real values. If the relative error between both values was > 5 %, the software was modified.

Note: The software of the honing test bench allows the modification of the gain of the sensors.

3.1. Sensor for linear speed of the tool

In this case, the software does not record the linear speed of the tool during the process. Therefore, only the comparison between the real values and the consigned values of the linear speed of the honing head was performed (step 1). A tachometer was employed with a special rubber wheel which is used for measuring the linear speed of the honing head. A first test was performed employing the usual run of the honing head (92 mm), but the tachometer could not stabilize the linear speed measure. In a second test, the run was increased up to 185 mm and the tachometer had more time to stabilize its measure and the real linear speed values were similar to the consigned linear speed values (Figure 1a).



(a) (b)

Figure 1. (a) Real linear speed vs. consigned linear speed, (b) Real rotation speed and recorded rotation speed vs. consigned rotation speed.

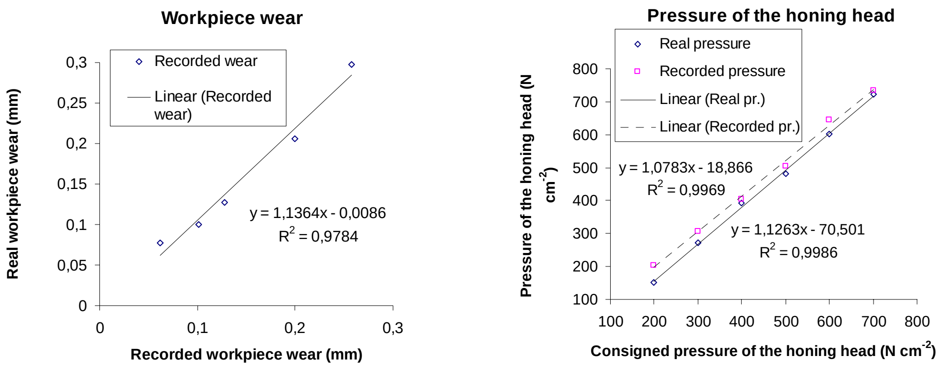
In the usual range of linear speed (above 14 m min^{-1}) the maximum relative error is 1.7 % for a consigned linear speed of 15 m min^{-1}. Thus, it was considered that in the working range the measured linear speed corresponds to the consigned linear speed.

3.2. Sensor for tangential speed of the tool

In the first step, the rotation speed of the part was measured with a tachometer. It was concluded that the maximum relative error between the consigned value and the real value was 0.2 % for a rotation speed of 200 min^{-1}. In the second step, it was found that the recorded rotation speed was 5.5 times greater than the consigned rotation speed (Figure 1b). The reason was that a speed reducer had been installed at the test bench while the software had not been modified. In order to solve the disagreement, a multiplying factor of 1/5.5 was introduced in the software between the signal obtained by the encoder and the signal that was shown at the screen. As a result, the maximum relative error between measured and consigned speed was 0.68 % for a rotation speed of 400 min^{-1}.

3.3. Sensor for wear on the surface of the part

In this case, there is no consigned value for the wear of the part. The recorded values were compared with the measured values (Figure 2a). The wear of 5 different tubes was measured using a caliper (three diameters were measured separated 120 º to each other and the mean value was taken).



(a) (b)

Figure 2. (a) Real workpiece wear vs. recorded workpiece wear, (b) Real and recorded pressure vs. consigned pressure.

The maximum relative error was 11.88 % for a real wear of 0.077 mm. Thus, the software was modified according to the linear fit so to reduce the relative error between the recorded value of the workpiece wear and the real value of the workpiece wear below 5 %.

3.4. Sensor for tool wear

In this case, there is no consigned value for the tool wear. The tool wear was measured by means of an external caliper. In the test bench, the tool wear is indirectly obtained from a sensor that measures the relative displacement of the plunger that drives the expansion of the abrasive stones. The software calculates the tool wear from expansion of the honing stones and includes the effect of the workpiece wear. Further studies are necessary so that the recorded results correspond to the real results.

3.5. Sensor for pressure of the honing head

The first step consisted of checking if the pressure given by the bleeder valve was correct. A manometer was placed in the tube that connects the bleeder valve with the plunger of the honing head in order to measure the real pressure of the honing head wedge. The real pressure at the honing stones is related to the real pressure at the plunger (Figure 3) according to equation 1.

$$P_{stones} = \frac{P_{plunger} \cdot S_{plunger}}{tg(\alpha) \cdot S_{stones}} \quad (1)$$

Where $P_{plunger}$ is the pressure of the plunger (N cm^{-2}),
$S_{plunger}$ is the cross section of the plunger = 7.257 cm^2,
S_{stones} is the surface of the honing stones = 1.8 cm^2
α is the angle of the honing head wedge = 15º

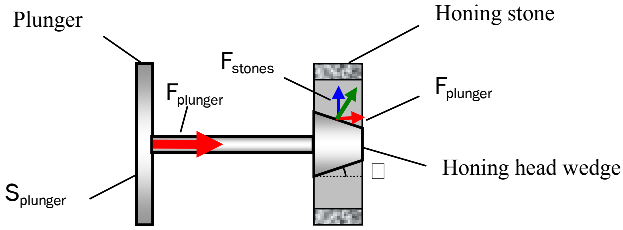


Figure 3. Schematic drawing of the plunger and of the honing head of the test bench

After the real pressure at the honing stones was calculated, it was observed that for pressure values of 400 N cm^{-2} and higher (which are usually employed at the test bench), the relative error between the real pressure of the honing stones and the consigned pressure remained below 5 % (Figure 2b). Thus, in the working range the measured pressure corresponds to the consigned pressure.
The second test consisted of comparing the recorded pressure values with the consigned pressure values. It was observed that the recorded pressure values were higher than the consigned pressure values (Figure 2b), with a maximum relative error of 7.4 % for a pressure of 600 Ncm^{-2}. The software was then modified and the relative errors became < 5 %.

3.6. Sensor for temperature

In this case, there is no consigned temperature. The temperature on the surface of the machined parts was measured by means of a K type thermocouple in order to compare the results with the results of the infrared sensor of the machine. The measured temperature was similar to the temperature given by the software (relative error < 5 %).

4. CONCLUSIONS

The six sensors of a test bench for honing processes were tested. The sensors for linear speed and temperature worked properly. The software was modified so to reduce relative errors of the recorded values of tangential speed and pressure. In addition, the gain of the sensor for workpiece wear was modified. Further studies are necessary so to improve the performance of the sensor for tool wear.

5. ACKNOWLEDGMENTS

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