The test bed for investigation of the machine tools' auxiliary units' energy consumption

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Abstract

Investigation of interrelationships among energy consumption of each machine tool's functional units and the other factors (control method and settings, process load etc.) is necessary for assessment of these units' submodels. These submodels can be later used for modelling of energy consumption of whole machine tool. The specifics of each machine tools' auxiliary unit impose special requirements on the measuring equipment which is used for their analysis. The fact that the measuring device should allow analysis of a wide range of the machine tools' auxiliary units has to be reflected in design of this measuring device. The result of this effort is creation of the measuring device which is described in this paper.

Keywords: machine tool, auxiliary unit, power, energy, measurement

1. Introduction

The measurement of energy consumption of the machine tools is an important part of all energy saving strategies. This is the reason why the measurements let us know how the machine tool consume energy and which components need to be improved [1].

Nowadays, it exists many ways to be more energy efficient. One of them is modelling of energy consumption which provides us better plan production process. Another one is energy consumption tuning of the machine tools' components, especially of the machine tools auxiliary units, which can greatly involve in the consumption of whole machine tool [2]. This approach is very efficient tool how to reduce energy consumption especially if it is deployed in design stage of the machine tool. The design of all machine tools should ideally reflect future purpose of use. The energy models of the machine tool's components can help us in selection decisions during development process of the machine tool. They also can help us to predict energy consumption of the machine tool in use.

For understanding of all energy flow in each components thorough analysis of them is necessary. Energy consumption of some component is determined by its own functionality and also by control from the machine tool's control system. This is the reason why the identification of interdependencies of power demand and process parameters requires measurement of various non electric values which affect the energy consumption. For comprehension of functionality of sophisticated auxiliary units, it is also needed to ensure an independency on machine tool's control system. The best way how to respect this need is to test these auxiliary units separately but very often the separate auxiliary units are not available or it is not possible detach them from the machine tools for testing. The special test device was developed for these cases and will be described in the following sections of this paper.

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2. Test bed description

As it was already mentioned in the previous text, for some specific tests we needed to ensure the independency of auxiliary units on the machine tool control system and measure a large number of signals. The presented measuring apparatus was originally established as a temporary facility. However when it was used for measuring of cutting fluid pump's characteristics, the potential for using in the other fields of the machine tools' energy flows identification was discovered. Thus, the used measuring equipment was rebuilt into its present form. During this modifications we have proceeded from the experience in building of multichannel measuring device [4].

2.1 Conception of the measurement

The measurement concept will be explained using the example of the original measurement which started the formation of the described measuring device. In our research we are interested in the evaluation of the cutting fluid pumps power consumption by models [3]. The aim of the performed measurement was to check the pump's characteristics listed in the catalogue of the pump's producer. The characteristics values listed in the catalogue are usually established for pure water as a working fluid. In the application of cutting fluid pumping in the machine tools the sorts of fluid based on mixture of water and other additives are often used. Thus, our goal was to compare the catalogue values with the real measured values. We have not any similar type of these auxiliary units available, thus we must test this unit as a part of the machine tool's assembly. This test was performed on the pump used for manual flushing of chips installed on the lathe SP 430 fa K-MAS in RCMT laboratories. The basic idea of the coolant pump measurement arrangement performed on this machine tool is shown in Fig. 1.

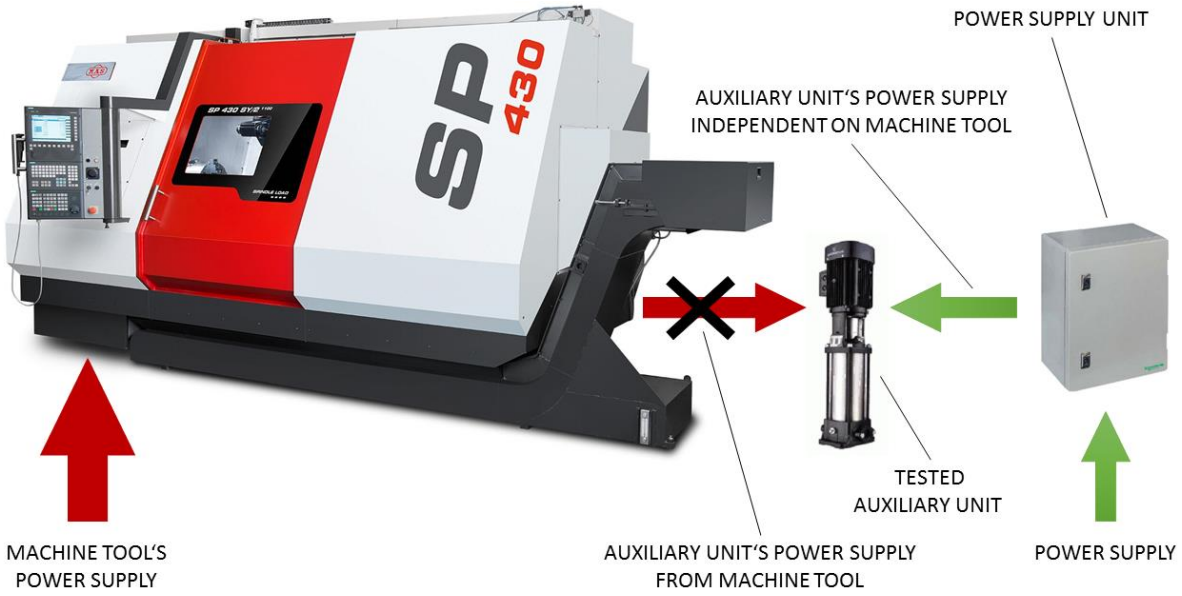

Fig. 1. *Conception of the measurement*

We had to create our own power supply unit to obtain the ability to measure power consumption and also safely control operation of the pump without influence of the machine tool's control system. Further, the replacement of the machine tool's fluid circuit by the testing circuit was necessary. This testing circuit allows us to change the pump load and to quantify it by measuring of pressure of the cutting fluid together with the measuring of supply of electric energy and flow of the fluid. It should be said that in some special cases the arrangement of the measurement using machine tool's fluid circuit helps us simulate real process load of the unit. This statement does not apply when we focus on the measurement of the pumps' characteristics.

2.2 Composition of the measurement equipment

The apparatus consists of three major parts. The first one is *the test circuit / equipment*. Generally it is a device for changing operating conditions and for measuring their parameters. In the case of pump's characteristics measurement, the test circuit is composed of the gate valve for changing of the pump load, flowmeter and pressure gauge whose provide information about measured values in the form of an electrical analog signals. In Fig. 2 is shown the test fluid circuit additionally mounted into the machine.

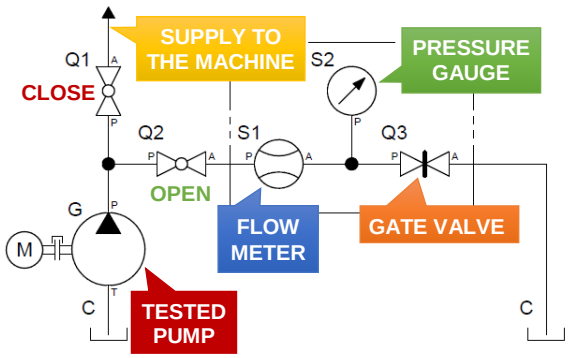

Fig. 2. *Diagram of the test circuit*

The second one is *the measuring device* as a datalogger of measured analog signals and power consumption. For the measuring of power consumption the power analyzer is used and for measuring of analog signals the programmable logical controller with additional analogue input modules is used.

The third one is *the power supply unit* (see Fig. 3) which provides power supply of electricity from distribution network to the measured auxiliary unit. It also allows safe operation control and contains the electric current and voltage probe for measuring of the energy consumption. The auxiliary units are very often composed by electromotors, so the main part of the power supply unit is the motor circuit breaker, which protects the motor from destruction.

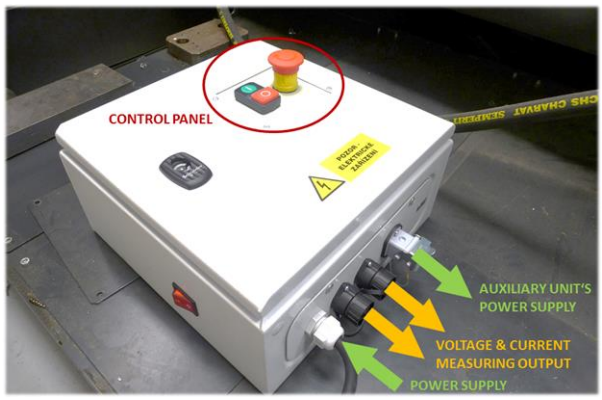

Fig. 3. *Power supply unit*

The measurement device and power supply unit are applicable for a wide range of tests of various auxiliary units. The arrangement of measurement for general use in the analysis of various auxiliary unit is shown in Fig. 4. It should be pointed that the machine's border varies according to substitution of the machine tool's operational behaviour by simulated process load as it was already noted in the text above.

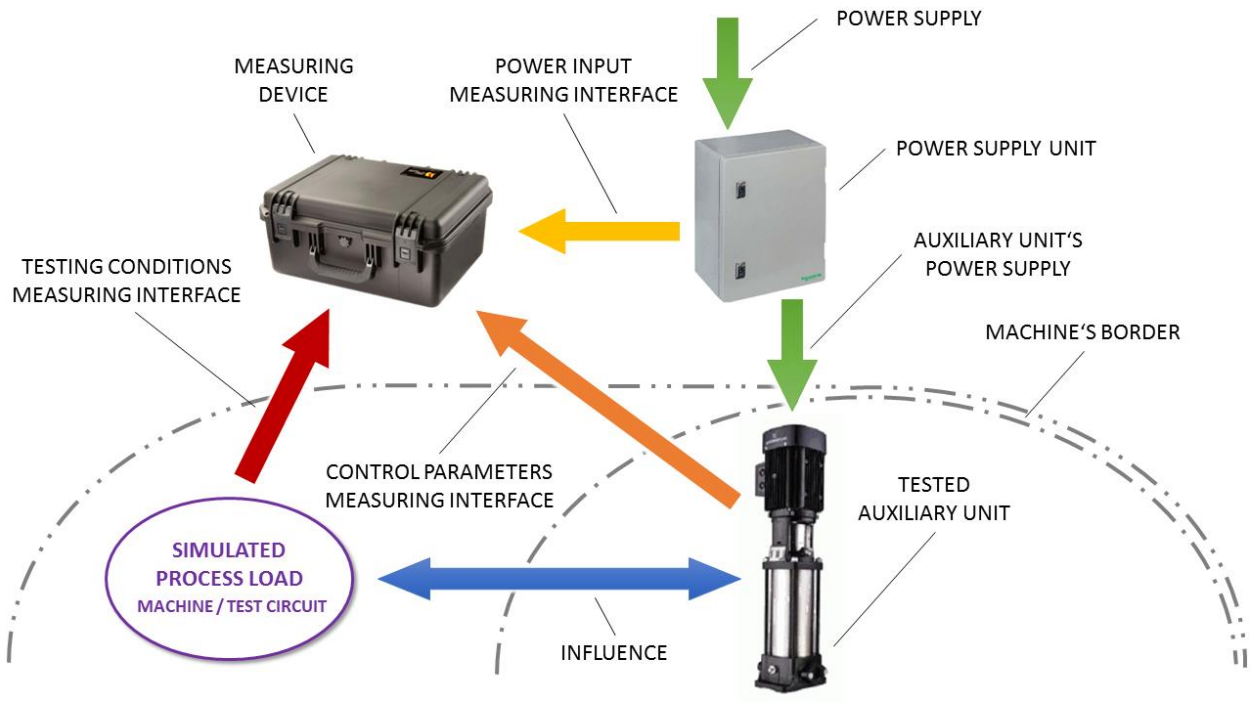

Fig. 4. *Arrangement of the measurement*

2.3 Example of the performed measurement

The measurement was performed on low pressure cutting fluid pump on the lathe SP 430 as it was mentioned above. The measurement carried out so that the gate valve in testing fluid circuit was gradually closed in 8 steps from the fully open to the fully close state. In each step after stabilization of flow, the measured values of flow, pressure, and power input have been read. After closing of the valve, its reopening, also in 8 steps, followed. The measured values were recorded. The entire measurement was repeated three times to exclude statistical measurement error.

The measured values of flow, pressure and power input were subsequently evaluated in MATLAB. The resulting characteristics of pump and their comparison with catalogue values are shown in Fig. 5.

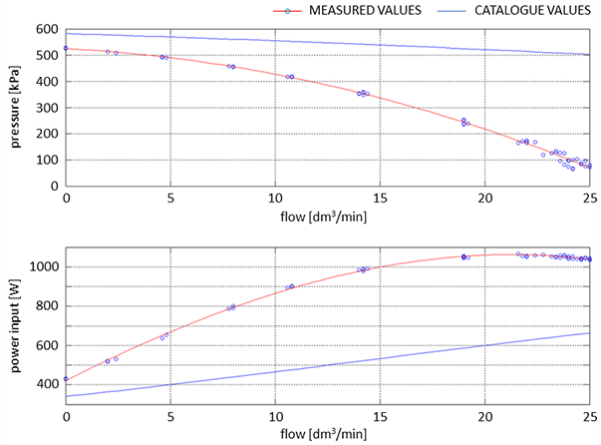

Fig. 5. *Comparison of the catalogue and the measured characteristics of the pump*

The performed test of pump demonstrates the need to verify auxiliary units' power consumption models to achieve their greater accuracy. Although the composition of cutting fluid is close to pure water, the difference between the catalogue and real measured values is significant. It must be said that the condition of the cutting fluids during use of the machine tools change especially due to water evaporation and also due to release of small impurities into the liquid.

2.4 Measuring equipment properties

The measuring device has been installed into a durable case which provides portability and resistance to damage during its transportation and electrical coverage. The power supply unit is installed in a small metal cabinet. Both of these devices are made as appliances with protection class I defined by IEC 61140.

The main properties of power supply unit and measuring device are listed in Tab 1 and Tab. 2.

Tab. 1. *Properties of power supply unit*

instrument power supply voltage	3 x 400 V_{AC}
instrument coverage	IP 4x D
rated operational current	1.1 A (6.0 A)
nominal output power	0.75 kW (4.0 kW)

NOTE: The rated operational current and the nominal output power in brackets are the theoretical values which can be achieved after changing of motor circuit breaker.

Tab. 2. *Properties of measuring device*

instrument power supply voltage	82 ÷ 264 V_{AC} 125 ÷ 370 V_{DC}
instrument coverage	IP 4x D
instrument communication	ETHERNET
number of power measuring point	1
voltage input measuring range	6 ÷ 375 $V_{AC\ (phase - neutral)}$ 8 ÷ 660 $V_{AC\ (phase - phase)}$
voltage input measuring uncertainty	± 0.05 % of value ± 0.02 % of range
type of current input	X / 100 mA
current input measuring range	0.001 ÷ 0.39 A_{AC}
current input measuring uncertainty	± 0.05 % of value ± 0.02 % of range
active & reactive power measuring uncertainty	± 1.0 % of value ± 0.01 % of range
number of digital inputs	6
type of digital inputs	24 V_{DC}
number of analog inputs	15 + 3
type of analog inputs	0 ÷ 10 V 0 ÷ 20 mA / 4 ÷ 20 mA Pt 100 / Pt 1000 / Ni 1000
analog inputs measuring uncertainty	± 0.3 % of range (voltage inputs) ± 0.4 % of range (current inputs) ± 0.5 % of range (passive RTD inputs)

3. Summary

In this paper the measuring system useful for the machine tools' auxiliary units' energy identification together with an example of use for verification of cutting fluid pumps characteristics was presented. The measurement of power consumption and the other functional parameters provides an opportunity to better understand energy flows in the tools.

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