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Energy Demand of Compressor Machines Used in Foundry Plants

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Abstract

The paper investigates the issues relating to energy consumption in the compressed air installations in foundry plants. Basing on the general characteristics of modern compressors, the major factor and conditions are identified that affect the energy consumption by compressor machines in installations with equalising tanks. Selected aspects are addressed on the basis of measurement data of a screw compressor available in the laboratory of the Faculty of Foundry Engineering AGH-UST.

Keywords: Automation of foundry plants, Energy demand by machines and installations, Compressors in foundry plants

1. Introduction

Air compression installation is of particular importance in foundry plants because of production and process requirements. It is a consequence of the complexity of structures incorporating the receivers of compressed air. Pneumatic drives play a major role in numerous process machines and in transport facilities. For example, in a majority of moulding machines, the pre-compaction process is effected with the use of compressed air (pneumatic moulding machines, air flow moulding machines, impact moulding machines) [1,2,3,4]. The specificity of pneumatic machines and irregular cycles of manufacturing processes in foundry plants give rise to uneven demand both in the short- and long-term [1,2]. That gives rise to increased operational costs, which are largely associated with the design and efficiency of compressor machines. Every effort is made, therefore, to modernise the air production and compression systems. In the range of grid pressures, widely used piston (reciprocating) compressors are being replaced by rotary compressors: screw- or vane- compressors [2,5]. On account of the complexity of the system installation the replacement procedures must be closely observed. That is why the selection of the compressor model should be based on the prognosticated compressed air demand and variability of this demand over time. Typical solutions involve the application of a single, powerful compressor, which may not prove cost-effective. The alternative solution involves the use of two (or more) less powerful compressors, interacting with an equalising tank [5,6]. In this option one compressors acts as essential equipment while the other is started only when the demand for compressed air is maximal. Alongside the actual operating parameters, the selection of the compressor machines should be based on the following criteria: quality, maintenance costs, seller's company experience, availability of spare parts and consumables [5,6]. Of particular importance is the energy demand. Compressed air is a quite expensive source [7], the energy costs accounting for 70-80% of total costs involved in maintenance of compressor machines [6,7]. Unit energy consumption by a compressor machine is the function of several factors, such as: efficiency, control systems, operating modes. The graph in Fig. 1 is based on the manufacturers' data [6], revealing the trend lines expressing the ratio of the driving motors to the compressor's efficiency in relation to its dimensions. Real costs of compressing a unit volume of air can be higher than those indicated in Fig. 1 (particularly in foundry plants equipped with old reciprocating (piston) compressors).

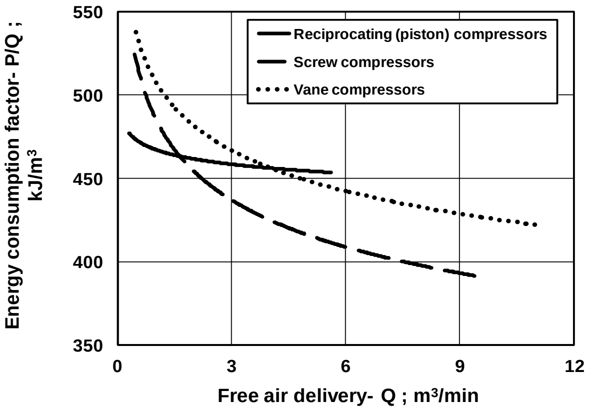

Fig. 1. Driving motor power to efficiency ratio for various types of compressor machines and related to the compressor's dimensions (nominal pressure 1 MPa)

Modern compressors receive a great deal of favourable comments from foundry engineers [5]. They are regarded as reliable and effective machines as long as the proper maintenance is provided. Of particular importance is proper servicing, in accordance with the manufacturer's recommendations [5,6]. Nowadays screw compressors are quite widely used.

2. Energy consumption measurements in laboratory conditions

Experiments were run to test the compressed air installation comprising a new-generation screw compressor, an equalising tank, a receiving unit (a moulding machine FKT 54) and the system of pipes forming a network.

Measurements were taken with a power quality analyser KEW 6310, manufactured by Kyoritsu company, Japan, enabling the recording of power parameters in single- or three-phase systems and in 2, 3,4- cable installations [8]. Additionally, a prototype recorder of instantaneous voltage and currents was employed [9,10]. A detailed description of these devices and their technical specification are presented elsewhere [11,12,13]. Pressure measurements were taken with the unit comprising a Honeywell pressure transducer, the power-supply system and a microprocessor recorder of fast-changing parameters.

The experiments were performed to monitor the variations in the power consumption by the compressor while the equalising tank was filled with compressed air. Power uptake measurement data (selected results) are shown in Fig. 2. The critical value where the power consumption by a compressor is nearly constant is the pressure level below 0.3 MPa. A significantly increased power consumption is registered at pressure levels in excess of this value. The results summarised in Fig. 2 show the importance of controlling the working pressure in the installation. Unnecessary increase of this value always gives rise to enhanced energy uptake [15].

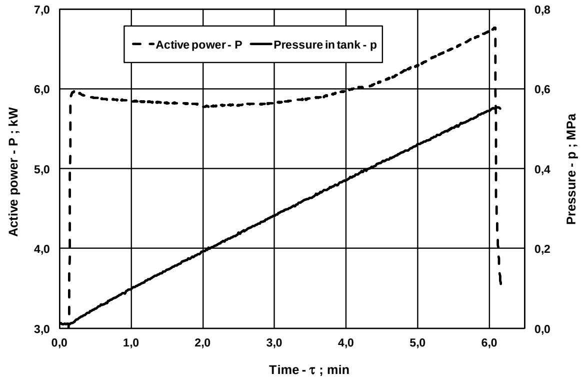

Fig. 2. Active power P and pressure p in the equalising tank being filled, in the function of time

The active power uptake by the compressor in the function of time is shown in Fig. 3, measured under the conditions of relatively stabilised compressed air delivery. The air from the tank flows out to the atmosphere via a nozzle with a constant diameter. The instants when the compressor is switched on and off are controlled by the threshold pressure values programmable in the control system.

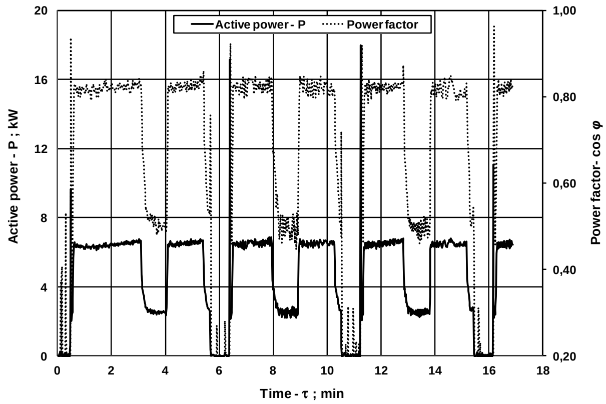

Fig. 3. Time run of the active power P and the power factor cosφ during the operation of the compressor-equalising tank system for stabilised conditions of compressed air delivery- outflow to the atmosphere through a nozzle with a constant diameter

The selection of the idle run or the drive's off mode is invoked by the implemented control algorithm. Programming of the compressor's status and operating modes has a major influence on energy consumption in the air compression system [5,6,14]. Even though the air is not compressed during the idle run, the power consumption is considerable. Its value is still lower than the nominal power rating. The data summarised in Fig. 3 reveal a number of undesirable phenomena due to compressor-power mains interactions, such as step changes of power uptake during the start- up (associated with the surge voltages generated when the drives switch from the idle run to the loading condition) or diversity of power factor values during the idle run and under load. Fig. 4 gives the time history of the power uptake (the power increase peaks associated with the compressor's being switched on are omitted) and the plot of pressure in the equaliser tank under the conditions of stabilised air outflow. A relatively 'regular" pattern of pressure is revealed, characteristic of on-off regulation systems. The outflow of air to the atmosphere takes place in the supercritical range, with the relatively low deviations of pressure in an equaliser tank. The air flows out through a small nozzle with a constant diameter, of the order of several millimetres. The data compiled in Fig. 4 well illustrate the effects of leaks in the compressed air installation on the increased power consumption by the system. According to most experts, these leaks in the systems give rise to increased costs of air compression [5,6,7].

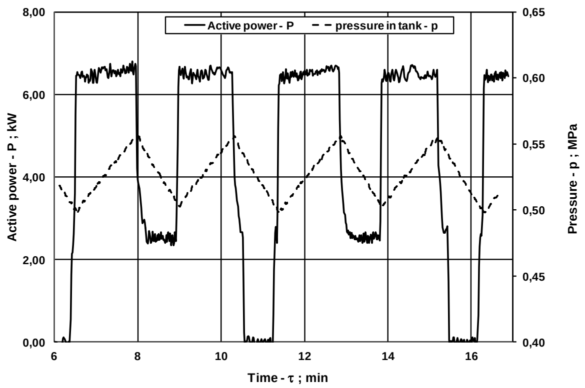

Fig. 4. Active power P and pressure p in the pressure tank in the function of time (under the relatively stabilised condition of air delivery- air outflow to the atmosphere through a nozzle with a constant diameter)

Results shown in Fig. 5 represent the conditions in the compressor-pressure tank system during the air delivery to an operative jolt and squeeze moulding machine FKT-54. The plot captures 15 duty cycles of moulding (including air uptake operations during the jolting, squeezing and mould separation from pattern plate) and reveals a less regular pressure pattern (compared to Fig 4), due to the occurrence of wave phenomena attributable to the action of valves controlling the particular phases of the moulding machine operation.

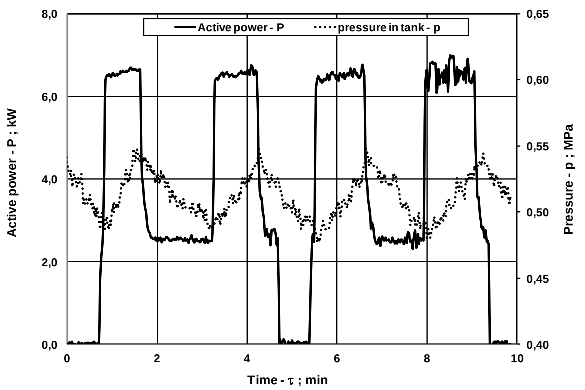

Fig. 5. Active power P and pressure p in the equalising tank during the air delivery in the operation of the moulding machine FKT-54

One has to bear in mind that the plot in Fig. 5 captures the process of compressed air delivery by a single moulding machine. Manufacturing processes typically use two moulding machines (to make a lower and upper half of the mould) and the air delivery process becomes more irregular due to unsynchronised operation of machines [2,15].

The demand for compressed air in a foundry plant usually varies throughout the manufacturing cycle. In such systems the energy consumption factor can be improved by using compressors with variable rotational speed [5,6]. In terms of the current stage of expertise, these solutions are most widespread. Currently used controllers, equipped with touch screens and with internal memory), allow for generating plots representing the compressed air demand, compressor loading (for example current load variations). Widely employed are supervisory systems to control the compressor operation. The supervisory controller restricts the idle run, thus improving the efficiency of air compression. In this solution the system of compressors works under one, relatively low pressure level, which brings direct energy savings [5,6].

3. Summing-up

Test results clearly indicate how to properly operate and maintain compressor machines, which parameters affect the energy consumption and when the amounts of compressed air and pressure in the system should vary. Currently, the available compressors are characterized by high technical level, especially in the terms of control systems. Advanced regulation and control systems have the interactive capability. The communication with the user can be effected via the Ethernet interface (communication modules based on Profibus DP, Modbus, Profinet, Devicenet systems) [6]. Besides, manufacturers offer servicing platforms, incorporating data transmission, visualisation and monitoring of air compression processes. These novel solutions, however, cannot substitute the users' supervision of the entire compressed air installation (particularly in terms of leaks in the installation) or their setting the relevant values of the working pressure in machines and installations. It is required that the compressed air demand should be determined at the stage of design and re-design of the foundry plant, and the machines in the compressed installations should be selected accordingly.

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