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Dynamic modeling of compressors illustrated by an oil-flooded twin helical screw compressor

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ABSTRACT

Compressed air is a basic energy source in several industrial areas. The energy of pressurized air is used during manufacturing processes, commonly as driving force for actuating pneumatic cylinders and in power tools such as pneumatic screwdrivers. The widespread use of this energy source justifies efforts to reduce losses within the compressed air infrastructure. One of the main energy consumers in the network is the production of compressed air. Thus, one problem area is generation with compressors of different kinds and sizes. Another problem affects the transmission through piping networks with non-negligible leakage effects adding to energy losses within the pneumatic infrastructure. This paper focuses on the process of compressing air and describes a dynamic simulation model of an oil-flooded screw compressor. A single compressor block, part of an overall compressor station, is split into four subsystems which are presented as mathematical models. Simulation results are compared to physical measurements and studied with respect to energy losses. The presented model is detailed enough to account for dynamic effects in real machines. But it is also abstract enough to be integrated in further simulations with more components. Future work will be done on optimizing compressor station design with respect to the reduction of energy losses.

1. Introduction

Published European studies [1] state that the electrical energy used to produce compressed air is up to a considerable percentage of the overall European electrical energy consumption. There are about 300,000 compressors with a range of capacity between 10 kW and 300 kW. Over the years, the pneumatic energy sector is slowly but steadily growing. Energy in compressed air is used in various industrial applications: highly-automated production lines, pneumatic cylinders, valves and swivel-drives, industrial paint applications, pneumatic screwdrivers and even as cooling air [2,3]. Pneumatic energy is used due to its environmentally-friendly impact and simple manageability. Thus, it represents an essential component of current manufacturing processes. The widespread use of this energy source justifies efforts to reduce losses within its infrastructure. Previous works show which part of the infrastructure offers best practical energy-saving potential: it is estimated to be 16% in generation, 18% in distribution and 2% in usage [4]. The high number in transport losses results from leakage losses in outworn pipe systems and pressure losses due to wrong dimensioning of network components. Currently, there are no standardized models and approaches for the energy-efficient optimization of pneumatic systems. This paper deals with the beginning of the pneumatic drive chain: the process of generating compressed air. A detailed compressor model that accounts not only for static effects, but also for dynamic ones is developed. There are two fundamental principles for compressors: dynamic compressors which accelerate the air, and displacement compressors such as well-known piston or twin screw compressors. Reciprocating ones, also known as piston compressors, are mostly applied for portable systems on construction sites, smaller production lines which do not require constant runtime or lines with demands of high pressure levels [5,6]. For highly-automated processes with pressure levels up to 20 bar, compressors with two rotating positive displacement helical screws are state-of-the-art. The intermeshed helical screws are housed within a specially shaped chamber and produce a series of volume-reducing cavities for compressing intake air (see Fig. 1). There are dry-running/oil-free compressors (which introduce less oil in the compressed air and thus better air quality) and lubricant-injected/oil-flooded ones being discussed in this paper. The latter require much lower acquisition costs. Previous research has been done on optimizing the shape of the screws and the housing to enhance their effectiveness [7,8]. The sequential compression of air in each cavity has been studied and modeled in detail by [9]. General mathematical descriptions of

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