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An Experimental Investigation of Energy Saving in Air Compressors

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According to the literatures, compressed-air systems account for about 10 % of total industrial-energy use for few countries. Compressed air is typically one of the most expensive utilities in an industrial facility. These compressors are ordinarily driven by constant-speed electrical motors supporting varying load conditions; i.e., substantial energy is lost since the loading conditions mismatch the designed optimal energy consumption needs of the desired purpose.
In this paper, the electric energy consumption of one-cylinder reciprocating air compressors has been experimentally investigated, once by the use of variable speed drive (VSD) and then by the use of mechanical speed drive.
Based on the experiment, the reduction of energy consumption in various compressors' discharge pressures falls between 43.6 % and 60.5 %.
The results indicate that the use of a variable speed drive reduces electrical energy consumption and thus reduces greenhouse gas emissions due to the reduction of fossil fuel consumption.

1. Introduction

Due to the constraints of fossil fuels and the environmental problems caused by the combustion of them, the necessity of energy management and enhancing the energy efficiency has been more evident than ever, especially in countries where producing electrical energy is dependent on these fuels. Energy dissipation of devices leads to climate change and eventually global warming which is the major problem for earth and its lovers (Jayamaha, 2006).
Electrical energy consumption in Iran has increased approximately from 2,220 GWh to 100,000 GWh, through the years 1976 to 2000. In Iran, about 50 percent of total energy is used to drive industrial motors (Massarrat, 2004).
Optimal energy use is fulfilled when less energy is consumed to deliver a service or, when more services are delivered by the same amount of energy (Järvinen, 2013).
Industrial units will consume more energy than other units (Abdelaziz et al., 2011). Air compressors are one of the most high-cost utilities among the industrial units and take about 10 % of the industry's total energy. Compressed air manufacturers in the US account for ten percent of the total electricity used in all industries (Senniappan, 2004). At least one type of compressor is used in 70 % of America's manufacturing industries (Xenergy Inc., 2013). In Europe (Saidur et al, 2011) and Africa (Marais, 2009), respectively, 10 and 9 % of industrial electricity consumption is devoted to air compressors. In Malaysia, 10 % of industrial electricity consumption is devoted to air compressors (Saidur et al, 2011). Therefore, any effective action towards improving the energy efficiency of the compressors is highly attended by researchers, policy makers and manufacturers.
Several measures towards reducing compressors energy consumption, such as application of high-performance engines, application of VSD, prevention of leakage, reducing pressure drop, and application of efficient nozzles in compressors system have been reported (Abdelaziz et al., 2011).
Data auditing was employed to estimate the energy use of the boiler fan motors. VSD was also used to estimate energy savings by modulating fan speed. It was found that 139,412 MWh, 268,866 MWh,

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159,328 MWh, and 99,580 MWh electrical energy could be saved up to 40 %, 60 %, 80 % and 100 % of the motor loadings, respectively with 60 % reduction in speed (Saidur, 2003). Two energy saving strategies, using high efficient motors and VSD, were adopted to reduce the energy consumption of motors while, reducing the emissions released into the atmosphere. It was reported that the use of VSDs and energy-saving motors would lead to substantial energy savings and an enormous reduction in emissions (Saidur, 2010). An experimental study was performed on energy saving in centrifugal pumps using a VSD (Dizadji et al., 2012a). The registered energy savings were recorded within the range of 15-40 % margin in this study. Also, by the replacement of the mechanical pulley and the belt drive with an electrical VSD in fans, reduction of energy loss up to 38.5 % was reported for the different flow rates (Dizadji et al., 2012b).

A VSD is an electronic power converter that generates a multi-phase, variable frequency output that can be used to drive a standard AC induction motor, and to modulate and control the motor's speed, torque and mechanical power output. Utilization of VSD's in industrial applications results in considerable energy saving (Mecrow et al., 2008).

Due to the importance of this issue, the aim of this study was to investigate the effect of applying VSD in single-cylinder piston reciprocating compressors instead of mechanical belt- pulley drive, on the amount of energy consumption.

In order to this, the amount of energy consumed by the compressor for producing compressed air at different pressures were compared in two cases: first, by the application of VSD and second, by the application of mechanical drive.

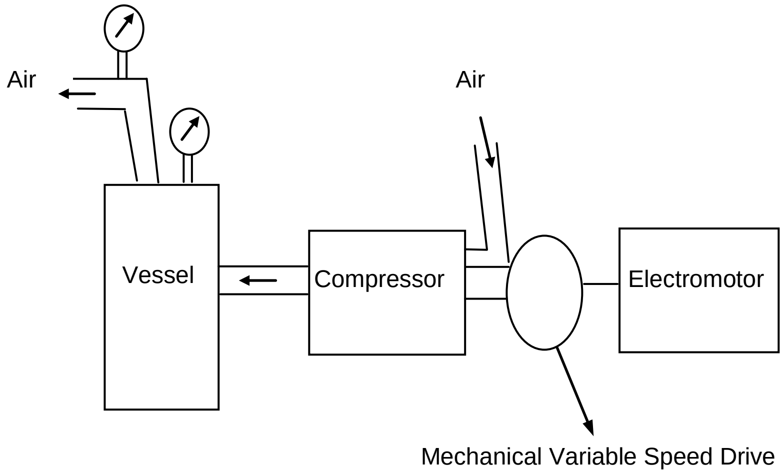
2. Materials and Methods

A single-cylinder piston reciprocating compressor is used in this experiment, and a HITACHI D106010 three-phase electric motor is used for running it.

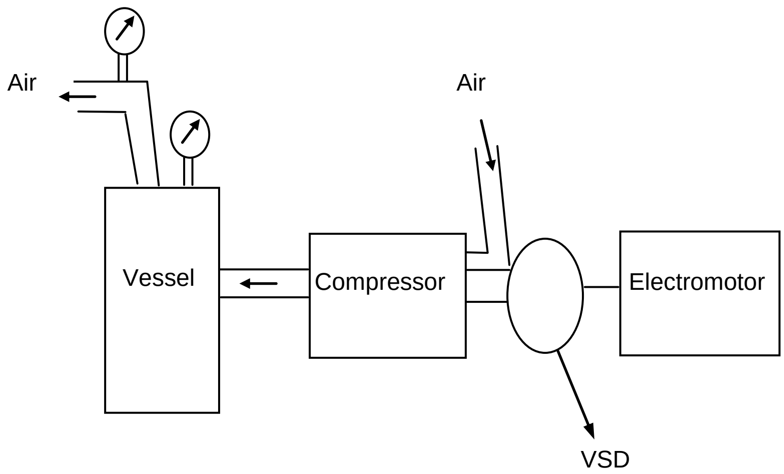
Figure 1 shows the system used in this research. Regarding the fact that the revolutions per minute (rpm) of the three-phase electric motors used in this experiment are 1,420 to 1,460 and the reciprocating motion of the compressor's piston in the aforesaid model is equal to 1,030 rpm, a mechanical belt- pulley drive is required. The existence of a mechanical drive with two pulleys and belt shifters leads to energy dissipation. Thus an electrical inverter was applied in order to prevent dissipation, so that changing the electrical power provides the required power for the movement of piston.

Figure 1: Setup used in this research

A simplified schematic of the compressor apparatus used in this series of experiments is shown in figure 2 (A and B).
The experiments were done at the vessel pressures of 0 to 883 kPa and in different mass flow rates of 0.0044, 0.0043, 0.0040, 0.0038, 0.0037, and 0.0036 kg/s, once by applying mechanical drives and once by applying VSD.
All the experiments were done at temperature of 20±1 °C and operation temperature of 40±2 °C and relative humidity of 55 %.



A



B

Figure 2: Compressor system A) with mechanical drive B) with electrical inverter

A resistance thermometer was used to measure the temperature and an optical tachometer and stroboscope was used for measuring the rotation speed of the shaft. The compressor was connected to a pressure vessel so that its pressure could be read in each step by using a digital manometer. A sharp-edged orifice was also used to measure the mass rate of air and the power consumption in electrical and mechanical drives was recorded for each pressure and mass flow rate.
Flow rate measurements were conducted on the basis of JIS B8320 - Japanese Industrial Standard which is entitled Testing Methods for Compressors and refers to for testing axial, centrifugal, and reciprocating machines with air (Van Laningham).

3. Results

With reference to the methodology and the experimental set up described above, the following experimental results were derived.
The results show significant reduction in power consumption of single-cylinder piston reciprocating air compressors, if the mechanical belt- pulley drive is replaced by the electrical one.
Based on the results obtained in this study, as the pressure is increased to about 500 kPa the energy consumption reduction is increased.
Figures 3 and 4 represent the amount of reduction in power consumption and the percent of compressors' energy consumption at different pressures of the vessel, in case an electrical inverter is used instead of the mechanical one.

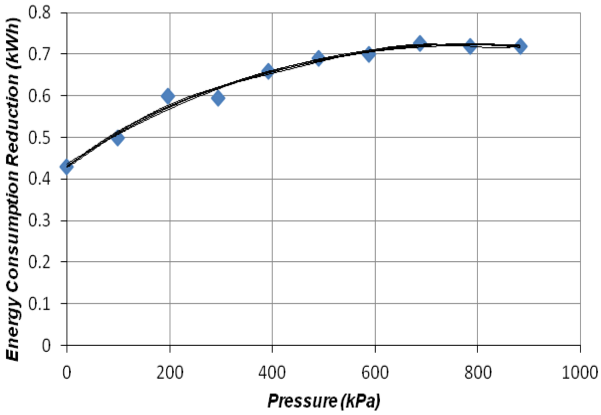


Figure 3: The amount of energy consumption reduction versus pressure

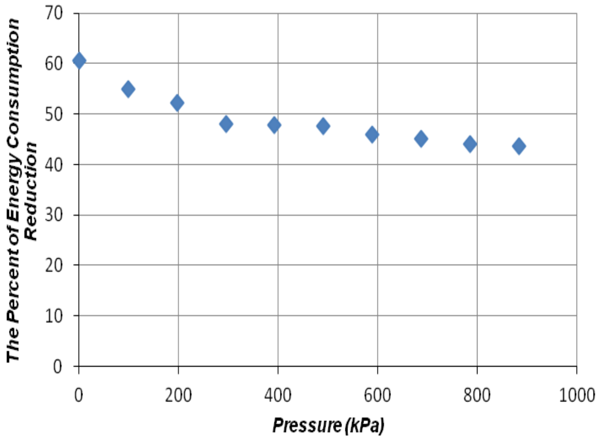


Figure 4: The percent of energy consumption reduction versus pressure

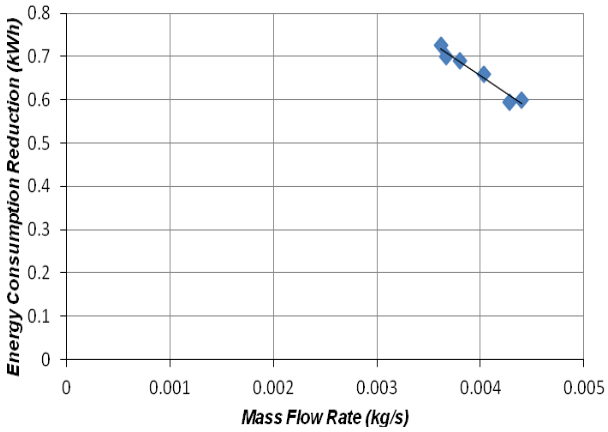


Figure 5: The amount of energy consumption reduction versus mass flow rate

Figure 5 represents the electrical energy consumed by the compressor at different mass flow rates of the vessel, if an electrical inverter is applied instead of the mechanical one.

The consumed energy is reduced by a minimum of 43.6 and a maximum of 60.5 %, at the studied pressures.

Annual financial saving can be calculated based on energy consumption reduction and the unit price of energy.

The calculations used for achieving the monetary value of energy savings show that the cost savings of only one compressor with eight thousand hours of performance per year and industrial electricity price of 0.5 $/kWh, would be equal to at least $ 1,744 and at most $ 2,420.

4. Conclusions

Energy saving in single-cylinder piston reciprocating compressors widely used in industrial applications was studied in this research.

The study suggests that applying electrical inverters instead of mechanical drives causes an efficient reduction in power consumption which eventually leads to a significant electrical cost reduction of 43.6 to 60.5 %.

It also, with reducing the use of fossil fuels, declines the greenhouse effect and pleases the environment lovers.

Using electrical inverters is a potential method for reducing these sorts of emissions and is strongly recommended.

References

Abdelaziz E.A., Saidur R., Mekhilef S., 2011, A Review on Energy Saving Strategies in Industrial Sector, Renewable and Sustainable Energy Reviews, 15, 150–168.

Dizadji N., Entezar P., Shabani A., 2012a, Energy Savings in Pumps, World Academy of Science, Engineering and Technology, 61, 1056–1059.

Dizadji N., Mahmoudkhani A.M., Nouri N., 2012b, Theoretical and Experimental Aspects of Saving Energy in Fans, Renewable and Sustainable Energy Reviews, 9, 729–736.

Jayamaha L., 2006, Energy-Efficient Building Systems. McGraw Hill, New York, USa.

Järvinen T.E.K., Holmberg H., Ahtila P., 2013, Theoretical Potential to Convert Excess Heat into Mechanical Work in the Finnish Industry, Chemical Engineering Transactions, 35, 253-258.

Mecrow, B.C., Jack, A.G., 2008, Efficiency Trends in Electric Machines and Drives, Energy Policy, 36, 4336–434.

Marais J., Kleingeld M., Pelzer R., 2013, Increased Energy Savings Through a Compressed Air Leakage Documentation System, <timetable.cput.ac.za/_other_web_files/_cue/ICUE/2009/PDF/Paper-Marais JH.pdf> accessed 20.01.2013.

Massarrat M., 2004, Iran's Energy Policy: Current Dilemmas and Perspective for a Sustainable Energy Policy, International journal of Environmental Science and Technology, 3, 233–245.

Senniappan AP., 2004, Baselining a Compressed Air System an Expert Systems Approach, MS Disertation, Morgantown, West Virginia University, USA.

Saidur R., 2003. Energy Savings and Emission Reductions in Industrial Boilers, Department of Mechanical Engineering, University of Malaya, Kuala Lumpur, Malaysia.

Saidur R., Hasanuzzaman M., Rahim N.A., 2010, Energy Consumption, Energy Savings and Emission Analysis for Industrial Motors, In Proceedings of the 2010 International Conference on Industrial Engineering and Operations Management, <www.iieom.org/paper/Final Paper for PDF/224 R. Saidur.pdf> accessed 20.01.2013.

Saidur R., Hasanuzzaman M., Rahim N.A., 2011,Energy and Environmental Analysis for Compressed air System ASME, In Malaysia, Washington, 1-9.

Van Laningham F.L., 2013, Guidelines for Performance Testing Centrifugal Compressor, <turbolab.tamu.edu/proc/turboproc/T10/T10169-171.pdf> accessed 20.12.2013.

Xenergy, Inc., Assessment of the Market for Compressed Air Efficiency Services, Burlington, MAS. <www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/newmarket5.pdf> accessed 20.01.2013.