Available online at www.sciencedirect.com

ScienceDirect

IFAC-PapersOnLine 49-29 (2016) 042–047

Efficiencies through the Automatic Control of Age-Profiled Manufacturing Machines: A Case Study of Cost-Saving in an Irish Production Facility

Mary Doyle Kent*, Helen Curtis, Raymond Darcy***, Dr Larry Stapleton****, Stephen Norton*****.**

**Dept of Engineering Technology, Waterford Institute of Technology, Waterford, X91 KOEK, Ireland. (Tel +353 51 302058 Email MDKENT@WIT.IE)*
***Dept of Engineering Technology, WIT, Waterford, X91 KOEK, Ireland. (Email rayhelen18@gmail.com)*
****Dept of Engineering Technology, WIT, Waterford, X91 KOEK, Ireland. (Email rayhelen18@gmail.com)*
*****Dept of Computing and Mathematics, WIT, Waterford, X91 KOEK, Ireland. (Email LSTAPLETON@WIT.IE)*
******Dept of Engineering Technology,* WIT, *Waterford, X91 KOEK, Ireland. (Email SNORTON@WIT.IE)*

Abstract: This paper asked if an effective energy measurement and monitoring system could be designed which was capable of controlling production machines to reduce operational costs. The solution had to be itself a low cost which could also be relatively easily deployed in developing regions. Developing regions are typically characterized by production facilities with outmoded equipment, but often have one or two more advanced machines available. This study identified a solution which evaluated energy consumption of machines at rest and oil consumption. It found that these two variables, when profiled against machine age, could be controlled in such a way as to significantly reduce production costs. Tests showed that, in addition to these variables, surge featured as an important variable which needed to be added to the control model. The solution itself could be deployed with very low cost. The experiment was carried out on CNC machines in a manufacturing site in Ireland.

Keywords: Energy Efficiency, Low Cost Automation; CNC Machines; Cost Effective Operation.

1. INTRODUCTION

The control and automation of energy systems has long been a subject of interest for instability research. Recent IFAC conferences have paid particular attention to energy issues coming at the change of waste control and energy consumption management from a variety of perspectives. These include renewable energy sources for power plants (Stoyanov & Vachkov (2015)), passive heating in construction engineering in developing regions (Dugolli (2015)) and digital synchronization techniques for phase control in electrical systems (Yakimov (2015)).

Advanced solutions for the control of energy efficiency and use have also received attention in IFAC. Fuzzy cognitive maps have been used to model the total energy behaviour of commercial buildings (Mpelogianni, P. Marnetta & P. Groumpos (2015)). Control systems which improve energy efficiencies and waste management have also attracted the attention of control applications utilising wireless robotics with a wide range of application domains (Shakev et. al. (2015), Kazala et. al. (2015)).

The manufacturing sector is one of the major contributors to high energy consumption on an international scale. Studies of automatic control of production equipment in developing regions have characterized the equipment profile of these facilities as older machines which are in the process of being replaced (e.g. Hajrizi, Shala and Stapleton (2015)). Consequently, it is reasonable to speculate that these facilities typically feature either a series of older, higher-energy consuming machines, or a combination of new energy equipment and older machines which may be slowly being replaced. In these cases there are significant opportunities for industrial facilities to reduce or prevent pollution and waste through the application of proven technologies in the manufacturing area, which offer finical savings as well as helping to protect the environment. Energy consumption for industrial machines has also been rising greatly particularly within the past ten years). Solutions which can control energy usage across the age range of machines may prove to deliver important efficiencies at a relatively low cost.

Energy management systems aid the continuous improvement of the energy performance in industry, these systems can be quite costly and smaller firms may not commit to this expensive nor may it be financially feasible to implement such a system as the payback over time may be significantly large and therefore management do not consider the idea. Despite this, it is still extremely important for any manufacturing company to be aware of their energy usage and this can be achieved through alternative methods of measuring and monitoring equipment and machines. Self-installed or utility meters can be read daily or weekly to ensure the collection of data is frequent; these meters are within a price range for small manufacturing firms, as little or no upfront capital investment is needed when implementing the measuring and monitoring system with an exception of the meters. The outcome can be greatly beneficial in the identification of energy wastage of equipment and machines and may result in immediate savings. (Worrell, 2010) The measuring and monitoring of the machines within a facility will help a company to identify key areas of concern, see the energy performance of certain machines and help the energy managers to interpret energy efficiency trends over time. (Selko, 2012) These benefits would not be possible without

2405-8963 © 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.
Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.11.071

data, as it is not possible to manage what is not measured. (Worrell, 2010)

Adaptable and efficient methods for controlling machines can be determined from the energy consumption data; Financial savings can be made if an idle machine is shut down or turned down if feasible and this can also increase the life of the equipment or machine and reduce required maintenance.

The areas to consider in the measuring and monitoring process were power consumption and oil usage. Power consumption is best measured and monitored with the use of power meters. Power should be measured during all parts of the process to grasp a finer interpretation of when energy consumption is at its highest and therefore areas where improvement is needed can be identified. With the data obtained, the energy cost of a machine at rest can be determined and reduced if found to be unreasonable. If possible it is recommended that high-power consumption machines run at off-peak hours when electricity rates are generally lower. The key for the oil use is increasing the effectiveness of existing lubrication systems and attempting to reduce the usage of such oils. (Sarhan, 2012) Therefore this oil is wasted during rest times and no value is being added and electricity is consumed to pump and heat the oil.

In summary, the following research question was posed:

RQ: Can an effective energy measuring and monitoring system be designed which can control production machines so as to reduce operational costs?

On the basis of this question a secondary question was formulated:

RQ1.1 Can energy efficiencies be profiled on the basis of the relative rest-periods of machines?

RQ1.2 Can energy efficiencies be profiled on the basis of the relative oil-consumption of machines?

This paper sets out the findings of a case study. In order to test the idea, an Irish manufacturing firm was selected and agreed to participate in a study. The facility used a range of computer numerical control (CNC) milling and turning machines which varied significantly in size, power, capability, age as well as the production processes and cycle times of machining. The company had no means of knowing the energy used and potentially wasted during the machine rest times and it is these rest times that this paper will focus on. This approach came about through the lean six sigma methodologies and tools which the project followed in order to maintain the high quality of standard procedures that the company currently represent and expect. This paper will outline the approach taken to collect the necessary data from the CNC milling and turning machines required to derive the calculations and methods needed to determine a result to make a decision whether it would be feasible to shut down a machine while it is at rest or do the start costs overcome these savings if shut down. The results are be based on the machines within the company and many other factors such as rest hours and temperature contribute to these results which need to be taken into consideration when applying the calculation, and results should not be assumed to be similar on other machines under other circumstances.

2. METHODOLOGY

Two areas of concern were identified and evaluated to achieved the possible overall energy savings for each machine within the manufacturing facility; the major contributor was assumed to be the electricity expense of a machine at rest was and the second factor was said to be the slide-way oil consumption of a machine at rest.

2.1. Oil Consumption and Cost

A solution to quantify the amount and cost of oil consumption used by a machine at rest could be achieved by measuring and recording the amount of oil taken to refill the oil tank of each machine. This was done on a daily basis as it was an existing protocol carried out by the company to refill the oil tanks daily. With the further protocol to measure and record this daily action the data obtained allowed for the calculations of total oil consumed and cost for each machine and therefore the cost of oil consumed while a machine was at rest could be calculated once data was obtained about the duration of time a machine is at rest. In order to achieve a realistic, true figure of oil consumption the monitoring was carried out over a four week period and the average per hour was considered in the calculation.

Oil cost at rest per hour, O_{cr}: can be expressed as the following equation:

$$O_{cr} = \left(\frac{O_{con} \times H_r}{168}\right) O_c \qquad (1)$$

Where O_{con} is oil consumed by the machine, H_r are the hours that the machine is at rest over a period of a week and O_c is the cost of oil type used by the machine. In this case it was required to determine the cost per hour of oil usage and therefore O_{con} is the average oil consumption per hour obtained from the monitoring of a machine. H_r was only available over a week period and therefore $O_{con} \times H_r$ is divided by the number of hours in a week, 168, to obtain oil consumed per hour during rest time. This value is then multiplied by the cost of oil type used by the machine, O_c

2.2. Rest Power and Inrush Data Monitoring

To calculate the cost of running each of the machines while at rest, a current value for each of the concerned machines needed to be measured.. Power can then be calculated from the known power formula = (I x V x PF x 1.732)/1000. However, such a method would not be recommended as there would only be one instant reading and this may not result in accurate or true values. The main reasoning for the disapproval of this method is that in the case for measuring the cost of current during start up (inrush current) as this type of multimeter would not be able to capture the instantaneous inrush of current as it occurred so rapidly.

More advanced continuous measuring, high accuracy analogue power measuring solutions were prohibitively expensive and undermined the cost savings goal of the analysis.

The meter used recorded energy data automatically and continuously with 3 sensor clamps attached to the three phases of a machine and this data was sent a transmitter