2012 International Congress on Informatics, Environment, Energy and Applications-IEEA 2012
IPCSIT vol.38 (2012) © (2012) IACSIT Press, Singapore

Effective Energy Management Through Energy Monitoring: Case Study Of Sheet Metal Part Manufacturing

Chee Wai Patrick Shi[a], Hui Xian Tan[b], Tobias Bestari Tjandra[b], Ruisheng Ng[b], Fatida Rugrungruang[b], Yeo Zhiquan[b] and Bin Song[b]

[a,b]Singapore Institute of Manufacturing Technology, 71 Nanyang Drive, Singapore 638075

[a]cwshi@SIMTech.a-star.edu.sg

Abstract. A lack of energy management often leads to inefficient use of energy and improper allocation of energy resource. To overcome such issues, it is proposed to conduct energy monitoring as a first step towards energy management. Monitoring the energy consumption of a machine creates an understanding of energy usage pattern and may reveal underlying issues that are often neglected by users. A case study of sheet metal part manufacturing reveals inefficient energy consumption from machine that idled 89% during the studied period, as a result of improper scheduling of work order. The study also shows that low power factor of 0.5 may lead to early failure of motor. Results from the examined case signify the importance of energy monitoring in energy management and help to identify opportunities for improving energy efficiency and reducing energy costs.

Keywords: Energy Management; Energy Monitoring , Metal stamping

1. Introduction

Energy management is an imperative part of the process to reduce energy consumption and improve energy efficiency in manufacturing operations. Traditionally, electricity costs in manufacturing was considered as an overhead cost and manufacturing firms often do not have complex energy monitoring systems to monitor machines' energy consumption [1, 2]. The reason for this is that the main objective of manufacturing firm is to produce high quality products for their customers in the most cost effective way [2]. Energy management is often neglected in a plant's production objectives. However, in recent years, such perspective has changed. With increasing energy prices, tough competition in the marketplace and dramatic climate changes experienced worldwide, manufacturing firms are starting to value energy as an important resource to be handled strategically.

In this paper, a discussion on energy management and barriers to energy efficiency are first presented. Then an overview on energy monitoring as part of energy management is given. Finally, a case study is conducted to illustrate energy consumption of a sheet metal manufacturing company and the possible solutions to improve the consumption behaviours.

2. Energy Management

Energy management may be described as an approach to regulate energy needs, in accordance to the location, and time of demand. It can be achieved by adjusting and optimising energy consumption using systems and procedures to reduce energy requirement per unit of output, while maintaining or reducing the total cost to produce the output of these systems [3]. The objectives of energy management are to minimise energy costs and environmental impacts without affecting quality and production [4].

2.1. Energy monitoring as part of energy management

The first step in executing an effective energy management system is to understand where the energy is being consumed in the manufacturing plant. After having a thorough understanding of a company's energy profile, an analysis of its working process and its energy allocation, energy management can then be conducted. Thus, monitoring of energy usage is part of energy management and should be carried out whenever possible. Unlike energy audit which only produces a 'picture' of past energy consumption, energy monitoring is done continuously to keep control of present consumption [5].

However, many companies do not have the proper means and tools to do energy monitoring. This is especially the case for more 'traditional', small to medium sized enterprises. Due to the lack of sense of urgency, and budget constraint, enterprises usually rely on a single energy meter to observe their monthly electricity consumption. This leads to improper allocation of energy costs and distorts decision-making process in the area of energy management. Looking from a wider perspective, there is a potential for energy savings and process improvement if companies take note of their energy consumption. The majority of Singapore's energy source for electricity generation comes from natural gas, followed by petroleum, and burning of waste materials [6]. Thus, a reduction of electricity consumption in the industry will bring positive economic and environmental impacts.

2.2. Barriers to energy efficiency

As pointed out in [7], industries commonly do not readily adopt, or implement energy managing strategies. Some of the difficulties holding them back includes the misunderstanding of its business value, lack of awareness among staff and management, outdated accounting techniques, complacency with the present system, and high risk of return on investment of adopting energy efficiency technology. These difficulties show that most problems come from the human factor, i.e. the *perception* of energy usage. Most companies take the current energy resources for granted without considering the effect to the environment by the amount of energy consumed. These problems may be corrected by providing proper training and information to all staff. One more effective way to improve energy efficiency will be the deployment of energy monitoring devices to every functioning machinery and equipment within the manufacturing plant.

3. Energy Monitoring

Kara et al [1] proposed a broad division of energy monitoring in industrial applications. This division is based on the level of application and is divided into three levels namely, factory, department and unit process level. Energy consumed within these three levels can be divided into direct and indirect energy [8]. Direct energy refers to the actual energy required for manufacturing the product. Indirect energy on the other hand refers to energy consumed by activities that are not directly involved in manufacturing of the product. These are normally energy drawn by lightings, cooling/heating and ventilation systems. The energy monitoring presented in this paper focuses on direct energy at the unit process level.

At a unit process level the monitoring is done by attaching a meter to a machine or its components (i.e. compressors, motors) to obtain a detailed result of energy consumption. The unit process monitoring result is very beneficial in determining the optimisation of production planning for an energy-intensive process, and also to understand the energy signature of a specific machine during operation.

4. Case Study: Deploying a Monitoring Strategy for a Sheet Metal Company

The objectives of these analyses are to understand how the stamping machine consumes energy and identify hot spots for reducing energy wastage. The study conducted maps out the energy signature of a progressive stamping machine by deploying energy monitoring devices at the process unit level. Figure 1 clearly shows the energy signature of the machine during stamping of a sheet metal part.

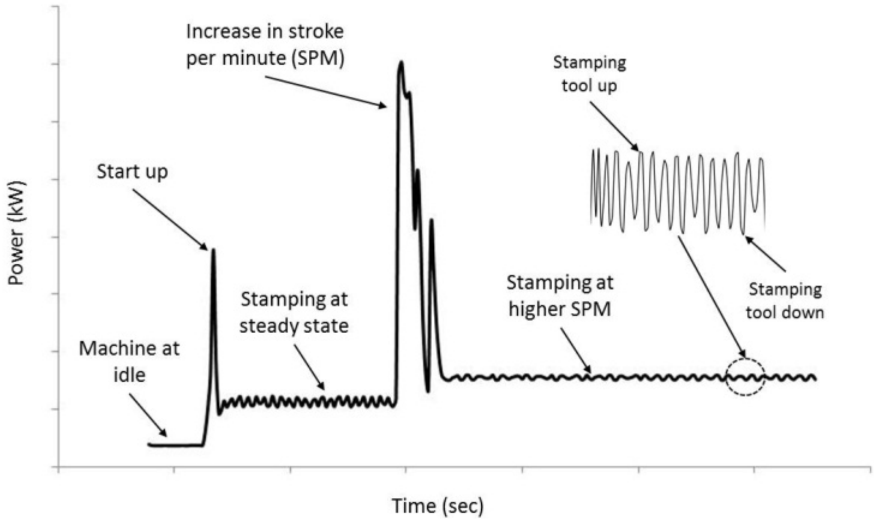

Figure 1: Energy signature of progressive stamping machine

When the stamping machine is switched on and is not producing any sheet metal parts, the machine is said to be on idle state. When the machine is at this state, the power (kW) drawn is mainly consumed by the auxiliary equipment within the stamping machine. The auxiliary equipment includes the machine electronic display panel, sheet metal waste management system of the machine, spinning of flywheel and also the machine lightings for the operators. It is observed that during the start of the actual stamping, there is a sudden spike in power consumption before going into steady state. This phenomenon also occurs when there is an increase in the stamping speed or strokes per minute (SPM), that is the frequency of up and down movement of the stamping tool. The idling power consumption is lower as compared to operating power. The power signature differs from the other machines studies conducted by Kodonowy [9] and J. Akbari et al [10]. The enlarged portion of the power signature, from Figure 1, shows the power consumption of the up and down movement of the stamping tool during the progressive stamping process. For the progressive machine monitored, it is observed that the power consumption increases with the SPM. This is reflected in Figure 2.

The power signature for the two stamped metal parts used for the case studies are presented in Figure 3. The power consumption is monitored for a period of 24 hours. From Figure 3, the power signature of the metal part 2 shows long periods where the machine is idling. Upon computation, it found that the idling time is 89% during the 24-hour period. This idling is due to the metal part queuing for quality check before continuing production. Machine idling leads to inefficiency and in turn increases the energy consumption per part. For metal part 2, idling results in energy consumption of 11.91 Wh that is much higher compared to metal part 1 with 2.23 Wh/part. To improve energy efficiency (Wh/part), it is recommended to reduce idling time or increase the active time. Figure 4 shows that if the idling time for metal part 2 is reduced to 50% (or active time is increased to 50%), it will take approximately 5.86 Wh to produce one part. From this exercise, the sheet metal company can better understand the machine status and set appropriate scheduling to reduce idling time in future production.

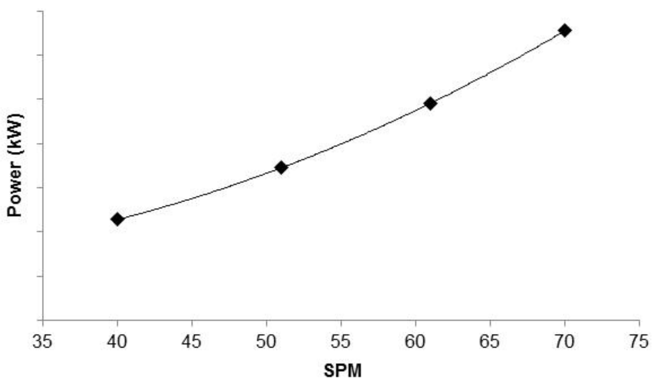

Figure 2: Increase in power consumption with the increase in stroke per minute (SPM)

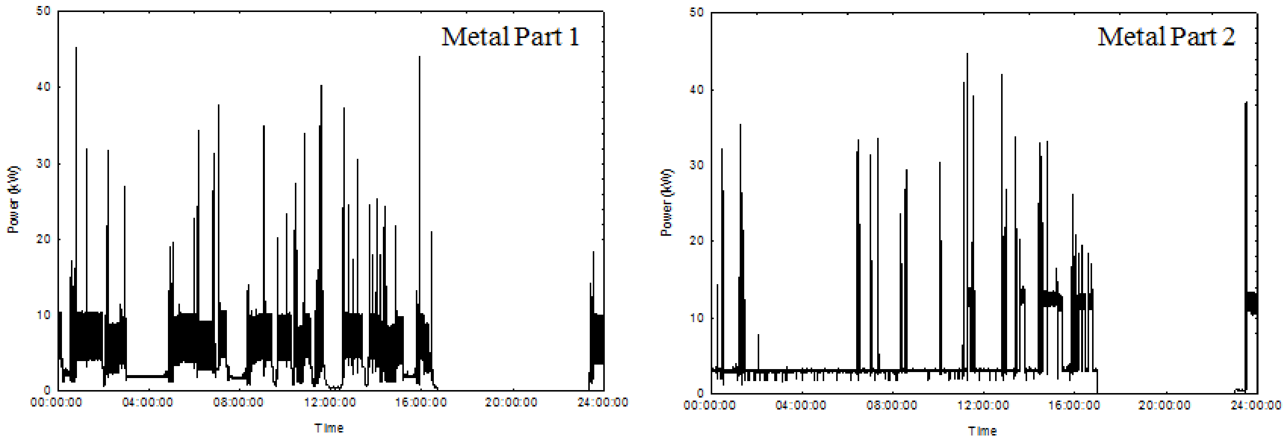

Figure 3: The power signature of the progressive stamping machine for metal part 1 and part 2

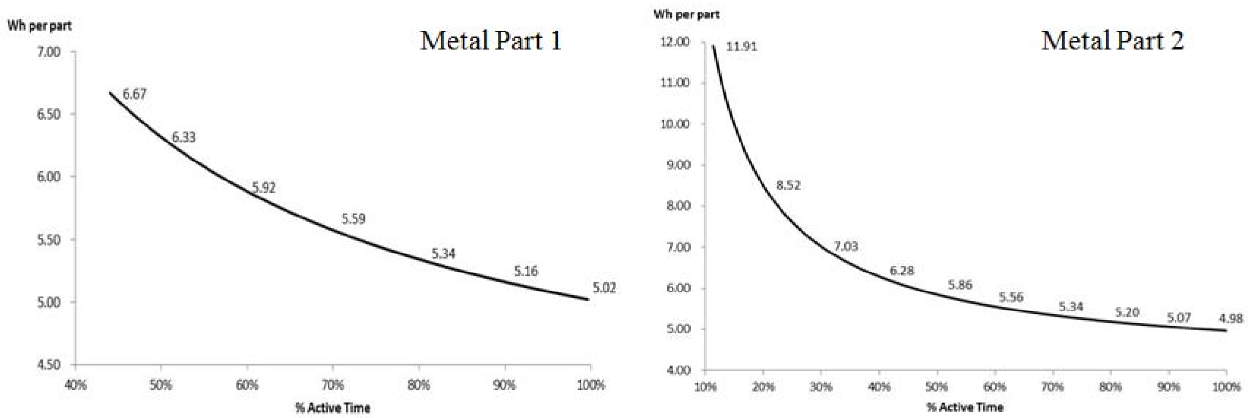

Figure 4: Reducing of machine idling time (or increasing % active time) for metal part 1 and part 2 will increase the energy efficiency

A low power factor is observed during the energy monitoring of the stamping machine. This signifies that greater amount of current is drawn by the motors of the stamping machine, therefore leading to an increase in energy consumption. The power factor noted in this study is at 0.5 and this might lead to higher motor temperature, causing early motor failure. Steps can be taken to increase this power factor by adding additional capacitance to compensate for the inductance of induction motors. From Figure 3, spikes are observed during the study. These spikes occur because high starting power is required to overcome the initial torque when stamping starts. One recommendation is to install electrical soft starters to reduce or to eliminate the high power consumption.

5. Conclusion

To ensure effective energy management, proper energy monitoring devices should be deployed to monitor the energy consumption. The unit process level energy monitoring is conducted and presented in this paper. The results presented from the study help the company to identify possible areas for improvement. Through monitoring, the company identified that there is a substantial amount of time the stamping machine is idling and not producing any metal parts. Therefore, increasing active time would reduce the Wh per metal part. The power factor of the machine is also low and spikes are observed each time the machine starts up or increases in speed. Understanding the energy signature for the stamping machine could help the company better plan for its production so that energy is consumed efficiently.

6. Acknowledgement

The authors would like to thank the team members from the Manufacturing Execution and Control (MEC) of SIMTech for helping out in the energy monitoring of the stamping machines.

7. References

[1] S. Kara, G. Bogdanski and W. Li, "Electricity Metering and Monitoring in Manufacturing Systems," in 18th CIRP International Conference on Life Cycle Engineering, 2011.

[2] J. Arinez and S. Biller, "Integration Requirements for Manufacturing-Based Energy Management Systems," in IEEE PES Conference on Innovative Smart Grid Technologies, 2010.

[3] E. Abdelaziz, R. Saidur and S. Mekhilef, "A Review on Energy Saving Strategies in Industrial Sector," Renewable and Sustainable Energy Reviews, vol. 15, pp. 150-168, 2011.

[4] "Energy Management and Audit," 2010. [Online]. Available: http://www.em-ea.org/Guide%20Books/Book-1/1.3%20Energy%20management%20&%20Audit.pdf. [Accessed 17 January 2012].

[5] C. Beggs, "Energy Monitoring, Targeting and Waste Avoidance," in Energy: Management, Supply and Conservation, Oxford, Butterworth Heinemann, 2002, pp. 103-116.

[6] "Singapore Energy Statistic 2011," Energy Market Authority, Singapore, 2011.

[7] "Efficiency and Innovation in U.S. Manufacturing Energy Use," National Association of Manufacturers, Washington DC, 2005.

[8] Y. Seow and S. Rahimifard , "A framework for modelling energy consumption within manufacturing systems," CIRP Journal of Manufacturing Science and Technology, vol. 4, pp. 258-264, 2011.

[9] D. Kordonowy, "A power assessment of machining tools, Bachelor of Science Thesis in Mechanical Engineering," Massachusetts Institute of Technology, Cambridgem Massachusetts , 2002.

[10] J. Akabari, K. Oyamada and Y. Saito, "LCA of machine tools with regard to their secondary effects on quality of machined parts," in Proceedings of 2nd International Symposium on Environmentally Conscious Design and Inverse Manufacturing (EcoDesign '01), 2001.