Energy Efficiency In Continuous Galvanizing Lines

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Abstract – This paper aims at analyzing the process and system parameters in galvanizing lines using a decision support system. Real time galvanizing line data from the facilities of the participating companies were collected and entered into the decision support system called Galvanizing Energy Profiler and Decision Support System (GEPDSS) [1]. The major process and system parameters which are of interest to the galvanizing industry were varied in the decision support model for insight into sensitivity of these parameters with respect to energy efficiency. The results and trends of the variables are analyzed with a particular focus on energy consumption during both production hours and downtime to better understand the productivity of production lines. A detailed analysis is undertaken to study potential energy and cost savings achievable if new pot hardware of increased life were adopted, downtime was decreased or other energy efficiency measures were implemented on a line. Finally a comparison between the amount of energy consumption by the participating lines reported by the decision support system and the actual energy bills of those lines was done to verify the effectiveness and accuracy of GEPDSS.

Keywords: Energy Analysis, Continuous Galvanizing, Energy Consumption, Campaign Period, Pot Hardware.

I. INTRODUCTION

The steel industry accounts for 2-3 % of total US energy consumption [2]. The process of applying a coating of zinc to steel, called “galvanizing”, is becoming significant in the modern era. Between 1992 and 2002, the use of galvanized steel increased by an average annual growth rate of 6.6%. Over the same period, the percentage of steel being galvanized has increased from 12.9% to 17.6%, at an average annual growth rate of 3.6% [3]. Studies reveal that more than 13,500 MMBtu of energy is wasted annually when a single galvanizing line is down for hardware replacement for duration of a few hours every 2 weeks. This energy, if utilized for production, will yield about 13,000 tons of galvanized sheet steel annually from a single galvanizing line. Thus for the 57 hot dip galvanizing lines in US this figure results in a production loss of 741,000 tons/year [4]. Therefore a detailed analysis of the amount of electricity and natural gas wastage during downtime is absolutely necessary.

The process of continuous galvanizing is an energy intensive process in the steel industry. However, not much is known about the amount of energy per ton of galvanized steel (MMBtu/ton) that is wasted during downtime for a galvanizing line. Through this research we intend to find the energy expended by each line to produce one ton of steel and by doing so we can benchmark the MMBtu/ton of one line with respect to the others. This would consequently help plant managers on decisions to implement energy efficiency measures for lines with high MMBtu/ton value. It is presently unknown how much electrical energy and natural gas are actually consumed by a galvanizing line during the campaign period and its downtime hours. Through this research, an effort is made to find the impact of pot hardware life and downtime hours on MMBtu/ton of steel produced. Presently, it is known that natural gas consumption by a line is more than electricity consumption. However, it is still unknown how much more the natural gas cost for a generic galvanizing line is over the electricity cost. Also, plant managers do not clearly comprehend the economic justification of implementing new pot hardware. Although the initial cost of using pot hardware is higher, the increased campaign period and reduced number of downtime hours per year will result in energy cost savings. The major objectives are to study the process and system parameters of a galvanizing line and determine their sensitivity to energy consumption and cost, to quantify the electricity and natural gas usage of eight lines during off-production hours and the cost incurred due to energy wastage during those times, and to study the energy profile of the eight
II. LITERATURE REVIEW

A. Improvement of Galvanizing Lines

According to a recent manufacturing energy consumption survey, in 1994 the US steel industry consumed 2 quads (quadrillion Btu or 1015 Btu) of energy. This study includes the losses incurred during the distribution, generation, and transmission of electricity [5]. To cope with the increasing demand, continuous hot dip galvanizing methods have been adopted, developed and automated. Subsequently, substantial studies were conducted relating to continuous galvanizing processes to increase the performance of the line. Takanori Adachi and Yasuo Tomura have investigated the techniques of automation in a continuous galvanizing line. Their investigation includes the techniques of automation at the entry section, zinc coating weight control and galvannealing control in a line [3]. N-Y. Tang developed new technologies for continuous galvanizing bath management. The research includes fundamental studies of the Zn-Fe-Al ternary system. The revised Zn-Fe-Al phase diagram has been applied to continuous galvanizing production for determining effective aluminum in zinc through the development of a computer program entitled DEAL™ and MAP™ [6]. A research team from West Virginia University, Oak Ridge national Laboratory (ORNL) and an the International Lead Zinc and Research Organization (ILZRO) focused on improving the life of pot hardware and reduction in nucleation and deposition of inter metallic particles (dross) on pot hardware, especially on roll surfaces [4]. Through this project decision support software called Galvanizing Energy Profiler Decision Support System (GEPDSS) was developed that could energy profile to a maximum of three galvanizing lines. The software is capable of finding the overall electrical energy and natural gas consumption by a continuous galvanizing line [7]. The flow of the molten metal and its behavior during functioning of a line was also modeled [8]. Sensors were developed that are capable of providing accurate bath composition and temperature [9]. The technology deployment software tools developed by US Department of Energy (DOE) are intended to help all energy intensive industries such as steel galvanizing industry. These tools are generic for all industry and benefit facilities by helping in the energy efficiency analysis and constructing what-if scenarios of implementation of energy efficiency measures. The tools do not specifically focus on galvanizing or any other industry. Some previous studies done in the area of energy consumption associated with the galvanizing industry include research done by S. G. Blakey and S. B. M. Beck [4]. They developed a dimensionless equation-demonstrating method for improving furnace efficiency. In their analysis they showed that the current method of burner turndown to reduce energy consumption worsens the thermal efficiency.

B. GEPDSS: Galvanizing Line Process Model

The galvanizing process can be continuous or a hot dip process. The major steps in hot dip galvanizing process are inspection prior to galvanizing, caustic cleaning, acid cleaning (pickling), fluxing, hot dip galvanizing, and quenching. Similarly, the steps in continuous galvanizing lines can be outlined. The details about these steps can be found in reference [1].

The GEPDSS software was developed by Industrial Assessment Center at WVU. It is application software which can analyze the effect of improved pot hardware and improved process equipment in continuous galvanizing lines. It does the analysis from an energy perspective and can provide information about the amount of energy saved due to increase in pot hardware or any other process and system parameters. It can also perform an economic analysis on energy efficiency measures resulting from improved pot hardware or any other process related equipment in a continuous galvanizing line.

III. PARAMETERS ANALYSIS

The data that were obtained from the existing galvanizing lines were entered into GEPDSS and the output was analyzed. Prior to the analysis, a detailed discussion was conducted with the plant engineers, researchers and industry personnel. This research only focused on the parameters that were cited as important to the industry personnel. The companies that participated in the project were Nucor steel, Wheeling Nissin, California Steel and GalvTech. The process and system data were collected from the existing lines in the facilities of the participating companies. The parameters of special interest to the different stake holders are as follows:

a. Energy required to produce one ton of galvanized steel, (MMBtu/ton).
b. Energy consumed per ton of galvanized steel during production hours and downtime.
c. Potential Energy savings and dollar savings by implementing energy efficiency measures on electrical and natural gas equipment.

d. Energy consumption Benchmark during production and downtime and comparison with other lines.

e. Electricity and natural gas consumption for the production of one ton of galvanized steel and which utility is more significant.

f. How much energy can be saved if the life of pot hardware is improved and the campaign period is increased?

g. Cost savings for galvanizing lines in the United States, if new pot hardware is adopted

h. Economic viability of adopting new pot hardware

A utility analysis of electricity ($/MMBtu), demand cost ($/kW) and natural gas cost ($/MMBtu) was performed (Table 1).

A. Total energy Consumption per ton for all lines

Total energy consumption including natural gas and electricity was calculated using GEPDSS and shown in Fig. 1. The campaign period used was 2.67 weeks and a total downtime of 12 hours. Fig.1 shows L6 is the most efficient line consuming 0.94395 MMBtu/ton. This is because L6 had 38 burners at the preheat section with a capacity of 1.43 MMBtu/hr, which were on low fire 20% of the time as compared to L7 which had 36 burners at the preheat section with a capacity of 1.6 MMBtu/hr. Most of the motors on L6 were partially loaded during downtime. The compressor capacity used for L6 was 70 hp and L7 was 140 hp.

B. Energy Efficiency Measures

Energy efficiency measures (EEM) are those measures which result in energy savings, if they are implemented on energy consuming equipment. Usually there is 2% to 10% reduction in energy consumption by implementing EEMs. The examples of energy efficiency measures for natural gas equipment include adjustment of air-fuel ratios, preheating charge, combustion air, insulation, oxy-fuel burners, closing gaps and openings on furnaces. For the electrical equipment different projects such as variable frequency drives, properly sized motors, sequenced compressors, using vortex nozzles where appropriate, etc. can be undertaken.

![Figure 1: Energy consumption per ton of galvanized steel produced by each line](image)

The energy savings are subjective and depend on operating parameters at a given facility. Fig. 2 and Fig. 3 show the decrease in energy consumption per ton after implementation of EEMs on NG and electrical equipment respectively. It is can be seen from figures that the EEMs implemented on the NG equipment will impact the energy consumption per ton of steel greater than the electrical equipment. The gradient or downward slope electricity is 0.0026 whereas for natural gas the slope is 0.021. In other words the facility should prioritize their NG EEMs and then tackle the electrical equipment.

Fig. 4 and Fig. 5 show that an annual saving, as high as $35,775 is feasible by saving 6% energy. It is to be noted that this analysis was done for a particular galvanizing line which has a campaign period of 2.67 weeks and a total downtime of 12 hours. Similar kinds of analyses can be done for all other lines and graphs can be generated for them as well. Of note, natural gas savings is 2.5 times higher than electricity savings for line one (L1).

C. Campaign and Downtime

It was observed that line one (L1) had a campaign period of 2.67 weeks after which the line was shut down. One of the main reasons for downtime is the change or repairs of the pot hardware.
Also the downtime was for 12 hours on average. However, during the downtime all or some of the equipment was running at full or partial load. More importantly, the zinc was maintained in a molten state during the downtime. These factors generally contribute to a lot of energy wastage during downtime. It is evident from the Fig. 6 that there is a non-linear decrease in the MMBtu/ton when there is a decrease in downtime hours and increase in campaign period.

The best scenario is the highest periods of campaign with the least amount of downtime. However the most likely hours of downtime would vary between 8 to 12 hours. The total annual energy usage (MMBtu/yr) varies for all the lines when campaign period and hours of downtime are kept constant. The data for the graph in the Fig. 7 has been generated by keeping the campaign period and hours of downtime fixed at 2 weeks and 10 hours respectively for all the lines. However the other parameters such as the line equipment, utility rates etc. were line-specific. The total annual energy consumption and annual energy consumption during production hours are shown with respect to the primary axes on the left side x-axis, whereas the annual energy consumption during downtime is shown with respect to the secondary axes on the right side x-axis in Fig.7. The analysis reveals the fact that nearly 1.0% to 1.4% of the overall energy is used during downtime for the specified campaign period and the total downtime. Also the amount of energy consumption for line one (L1) during downtime is more with respect to other lines.

Fig.8 shows how the energy consumption varied with different campaign periods and different hours of downtime separately, for all lines. The annual energy consumption during production hours for eight galvanizing lines when the
campaign period and hours of downtime are changed to various levels are also shown.

![Figure 7: Total annual energy consumption for different lines for 10 hours downtime](image)

**D. Hourly Energy Consumption During Production**

Fig. 9 shows the energy consumption for each line during its hours of production. The campaign period here is 2.67 weeks with a downtime of 12 hours between campaigns. Line ten (L10) consumes lower NG because it has no burners in its preheat section whereas line one (L1) consumes more natural gas since it has 36 preheat burners of 2.4 MMBtu/hr capacity. Line ten (L10) consumes more electricity because the melting pot has six melting grids of total 4MW capacity. The melting pot of line one (L1) consumes lower electricity because it’s three melting grids are rated 360 kW total. The annual production of line ten (L10) is considerably higher than line 1 (L1) (Table 1). The energy cost comparison between lines becomes more meaningful when they are compared with the ratio of total energy cost to the total production volume of galvanized steel ($/ton).

**E. Hourly Energy Consumption during Downtime**

Fig. 10 shows the amount of hourly energy, MMBtu/hr, which was used up for running the line during downtime. There are two series, one showing the amount of electric and the other showing the amount of NG used up in MMBtu/hr.

![Figure 8: Annual energy consumption by lines at various campaign period and downtime](image)

![Figure 9: Hourly energy consumption for each line during production](image)

**F. Potential for Energy Savings in the United States**

The funding agency for the project was interested in knowing how much energy could be saved by all the galvanizing lines in United States if production hours were increased by reducing downtime. Fig. 11 shows achievable savings through 56 galvanizing lines, when downtime is reduced by any given measure. Presently, it was considered that the lines operate at 2.67 weeks per campaign with 12 hours of downtime and that the production rate is 60 tons/hour. In the Fig.11, 2 x 10 means 2 wk campaign time and 10 hours downtime between campaigns. It should be noted that all the lines in this analysis are considered similar with the same rating for electric and natural gas consuming.
equipment. This analysis was done with the one line which had the most similarity with the other lines.

Figure 11: Energy savings for 56 lines

IV MODEL VALIDATION

The production and downtime energy costs were summed from GEPDSS and compared with the utility bills obtained from participating facilities for total costs. The comparison shows that costs obtained from GEPDSS and total utility bills were nearly equal. The marginally higher values in the utility bills can be attributed to lighting, HVAC energy systems that are not considered by GEPDSS.

V CONCLUSION

The useful life of pot hardware is significant for energy savings. The downtime between campaigns has significant effect on energy consumption and savings. The utility analysis revealed that natural gas cost is more sensitive to the specific energy consumption ($/ton) than electricity cost. The energy efficiency measures on natural gas equipment should be given higher priority and result in significant savings in studied facilities. Different lines have varying characteristics during production and downtime in terms of energy consumption, and hardware cost and profit per ton play a role in economic feasibility of pot hardware adoption [10].

As a part of future work the decision support model can be enhanced to incorporate different types of heat treatment cycles for galvanized steel. The changes in load on electric grid as new zinc is added can be considered to make the model more accurate.

REFERENCES


| Table 2: Operating Characteristics and Energy and Cost Savings Possible with Increased Campaign Time and Decreased Downtime |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Lines | L1  | L4  | L5  | L6  | L7  | L8  | L10 | L11 |
| Wk/Campaign | 2.67 | 0.89 | 0.89 | 0.89 | 0.9  | 0.9  | 0.67 | 0.67 |
| Downtime (hrs) | 12  | 8   | 8.25 | 10  | 8   | 8.25 | 4   | 4   |

4 weeks per campaign with 12 hours of downtime

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4 weeks per campaign with 8 hours of downtime

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