Abstract

Machine maintenance plays an important role in creating a sustainable production line. An effective machine maintenance schedule can reduce waste by reducing the machine failures and the time spent on failures. A proper maintenance schedule can also decrease the amount of wasted parts by decreasing the number of lost products, hence increasing productivity and sustainability. In this study, discrete event simulation software, Arena by Rockwell Automation, is used to model and simulate a fully automated production line. This study will review how to decide on a maintenance schedule technique by implementing a multi criteria decision-making (MCDM) model.

The methodology examined in this study provides an overview of selecting a scheduling technique for production lines to improve sustainability and productivity of the lines. The used methodology can be applied to any production line.

Introduction

A circuit breaker assembly line with eight stations/machines is used as a model for this experiment. The purpose was to decide on a Preventive Maintenance (PM) schedule for a fully automated assembly line using discrete event simulation software, and implementing a multi criteria decision-making process. Enforcing a proper maintenance schedule can also decrease the amount of wasted parts by decreasing the number of lost products, hence increasing productivity and sustainability. The preventative maintenance techniques tested are:

- **Global-based Maintenance (GBM):** Requires halting production so all machines can be maintained at the same time. There are two ways to apply this technique. The first is to stop the machines every 55 minutes for 10 minutes, given there are multiple maintenance personnel. The second is to stop the machines every 150 minutes for 10 minutes, given there is only one maintenance personnel.

- **Reliability-based Maintenance (RBM):** Machine is stopped every 60 minutes for 5 minutes, and implementing a multi criteria decision-making process. Enforcing a proper maintenance schedule can also decrease the amount of wasted parts by decreasing the number of lost products, hence increasing productivity and sustainability. The preventative maintenance techniques tested are:

- **Value-based Maintenance (VBM):** favors the machines toward the end of the production line, so they undergo maintenance first. The first method is called the equal weights method. We have 5 criterion, so each maintenance schedule with the highest utility is favored.

- **Methodology cont.**

Von Neumann & Morgenstern's Utility Theory

The next step to applying the MCDM method is applying Von Neumann & Morgenstern's Utility Theory because as seen previously deciding on a maintenance schedule based on a weighed grade is not conclusive. The utility theory uses the equation $U_i = (w_i \times u_i)$, where $U_i$ is the utility, $w_i$ is weight value assigned to each criteria, and $u_i$ average value. The maintenance schedule with the highest utility is favored. We first assign a weight to each criteria. There are 5 methods of assigning weight, but the sum of the weights must be one. The first method is called the equal weights method. We have 5 criterion, so each criteria is .2. The remaining 4 methods require ranking the criteria in order of most important to least. Ranking order can vary due to professionals opinion, so 2 rank orders we created. Rank A: Utilization> Cost of good product> Total Time Blocked (TTB)> Total time Starved (TTS)> Cost of Lost Product (CLP). The second method is called Rank Order Sum Method. It uses the equation $w_i = \frac{n!}{(n-r)!} \frac{1}{n}$, where $n$ = total number of criteria (n=5), $r$ = ranking of each criteria under consideration. The order of the weight values will be $U_1 > U_2 > U_3 > U_4 > U_5$. The third method is Rank Order Reciprocal uses the equation $w_i = \frac{1}{\sum_{j=1}^{n} u_j}$, and the corresponding weight values will be $0.44, 0.27, 0.15, 0.11, 0.09$. The fourth method is Rank Order Centroid Method uses the equation $w_i = \frac{1}{n} \sum_{k=1}^{n} \frac{1}{u_k}$, and the corresponding weight values are $0.46, 0.26, 0.16, 0.09, 0.04$. The fifth method allows the experimenter to decide how to contribute weight to each criteria. The corresponding weight values are $0.41, 0.26, 0.16, 0.09$. We then compare each criteria at the same reliability level for each PM technique. We take the average grade of each PM technique and apply it to Von Neumann and Morgenstern's Utility theory ($u$), as shown to the left.

Results and Conclusion

Once the Utility theory is applied there are 36 results to compare. For instance at 70% reliability Global maintenance order with one maintenance person was favored 6 out of 9 times. At 80% reliability, rank order A favored Value based maintenance with one maintenance personnel, and rank B favored Global based maintenance with one maintenance person. At 90% reliability, Reliability-based maintenance was favored 6 out of 9 times. The difference was Rank A favored Value-based maintenance the remaining 3 times. At 95% reliability, Value-based maintenance was favored 6 out of 9 times, with Rank B favoring Reliability-based maintenance. We can conclude that at the higher reliability levels, Value-based and Reliability-based maintenance are favored, and at lower reliability level Global-based maintenance is preferred for the circuit breaker assembly line. The order of how the criterion ranked could affect the utility outcomes. The method used above could be applied to any production line.