Integration of production planning, scheduling and lockout/tagout activities in a manufacturing system

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Abstract: Accidents related to involuntary start-up of machines during preventive maintenance are still important and mainly caused by deficient lockout/tagout procedures. Would it be of value to integrate lockout/tagout procedures in production scheduling? In this paper, the different steps of the lockout/tagout are presented and the literature on production planning and scheduling reviewed. Lockout/tagout procedures, production planning and scheduling are treated as independent subjects. Future research should integrate lockout/tagout procedures in production planning and scheduling. Doing so, may help in planning and scheduling enough space-time to reduce incomplete lockout/tagout procedures, but needs to be demonstrated.

Keywords: Integration, production scheduling, preventive maintenance, production planning, lockout/tagout procedure

1. Introduction

According to a report published in 2008 by the Quebec occupational health and safety commission (CSST, 2008), workplace accidents involving machinery restarted involuntary or locked out improperly are still important (5225 cases in 2007). Six of these accidents caused death. Figures such as these raise the following question: Would it be beneficial to integrate a lockout procedure into operations scheduling in manufacturing?

In much of the current literature, lockout policy and production planning and scheduling, are treated as very distinct subjects. The purpose of this article is to show the importance of integrating them. A judicious compromise between their aims could lead to major improvements in company performance in terms of decreased numbers of workplace accidents and increased production capacity.

This article consists of two sections. The first provides a description of the different steps that make up the lockout procedure. The second provides an analysis of the various existing mathematical models applicable to the integration of the lockout procedure into production planning and scheduling.

2. Method

We carried out searches of the literature published in English or French during the period 2008–2014 using the following databases: Compendex, Scopus, Web of science, IEEE Explorer, and Knovel (see Table 1). We also consulted governmental

organizations such as the Robert-Sauvé occupational health and safety research institute (IRSST), the national institute of occupational safety and health (NIOSH), occupational safety and health administration (OSHA), the national institute of scientific research (INRS), the national association of securities dealers (NASD), and the CSST (*Commission de la santé et sécurité au travail*). The following keywords were used initially: integration, lockout/tagout (LOTO). The search was then refined using the following terms: integration, lockout/tagout, production scheduling, production planning, preventive maintenance. The scientific literature was thus consulted, including conference proceedings, memoirs, and reports produced in the practice of occupational health and safety. Articles of which the contents did not address the purpose of this article were excluded. By examining the bibliographies of the documents judged relevant to the study, we completed an exhaustive search of the subject area through the snowball effect.

Table 1. *Documents found and retained for consideration*

Source	Documents found	Documents retained
Compendex	10	5
Web of science	12	3
Scopus	27	5
IEEE Explorer	6	0
Knovel	144	30

3. Results

3.1 Lockout/tagout procedure

Statistics provided by the Quebec occupational health and safety commission (CSST, 2008) show the importance of integrating lockout into maintenance activities. In addition, the commission began in 2005 to implement a “zero tolerance” action plan aimed at improving the safety of industrial equipment by decreasing the risk of contact with moving parts. From 2011 to 2012, the number of machine-related accidents resulting in work stoppage dropped by 15 % (Préventica, 2014). This figure reflects the involvement of businesses in the reduction of accidents involving the moving parts of equipment. Two conditions must be met to control an equipment-related danger. The first of these is that all energy sources are disconnected from the moving parts. The second is that access to moving parts or residual energy is controlled. Under these conditions, the servicing or maintenance intervention can be carried out safely. The LOTO procedure must be obligatory for all company personnel and sub-contractors for all activities associated with maintenance, cleaning and routine operations. Safe working conditions require respect of a LOTO procedure composed of three steps. The first of these, called “separation”, consists of dissipating the energy present in the machine. Before any intervention, an analysis of risk must be carried out, which consists of determining the different sources of energy involved in the machine operation and the means of shutting them off. In some cases, it is not necessary to lock out the entire machine. Partial lockout, in which a part of the machine remains energized, may be acceptable. Precautions must be taken in this case to identify all parts that remain energized and to ensure that these do not interact with the parts under lockout (INRS, 2011). For machine shutdown, OSHA (2002) requires

that the normal procedure be followed, which consists of placing the power switch in the off position and closing all of the various valves. Bennett and Forsen (2002) have shown the importance of the second step of the LOTO procedure, the lockout per se. They describe the difference between a machine of which the power switch or other means of shutdown is in the off position and a machine of which the shutoff is blocked mechanically. When all of the locking devices have been installed on the machine, a tag must be attached to the principal cutting mechanism. This tag must indicate clearly the name of the servicer and bear the notification “DO NOT OPERATE” and must not be removed under any conditions before the servicing is completed (Keller *et al*. 2010). In the case where more than one person services a given machine, each servicer locks out the principal energy source with his own lock. This method guarantees the safety of all servicers who work on the machine (Keller *et al*. 2010). To verify disconnection from the principal energy source and suppression of residual energy in the machine, one must press the start cycle button (Scott and Segers, 2012). From this moment on, the machine is and will remain non-operational and nearby activities associated with maintenance or production will take place in safety. The third step, unlocking, restores operational status to the machine that was locked out. Once all the locking devices have been removed, the machine can be switched on again.

Numerous efforts have been undertaken to implement lockout/tagout procedures in industries. The procedure is unfortunately not always respected, often because of time constraints that it imposes on production. In addition, in some situations, such as during test phases or diagnosis of equipment breakdown, machine lockout may be impossible to implement. The energy source must generally remain connected to determine the cause of breakdown. This situation represents a hazard for servicers.

3.2 Integration of lockout into production planning and scheduling

Numerous researchers have studied the integration of preventive maintenance and production scheduling on a single machine (Cassady and Kutanoglu, 2003; Pan *et al.* 2010). Cassady and Kutanoglu have shown that this makes it possible to minimize production-related delays. These same researchers later developed a Markov-chain-based mathematical model that achieves this integration for the purpose of reducing the expected preventive maintenance and task scheduling time (Cassady and Kutanoglu *et al.,* 2005). Sortrakul *et al*. (2005) pursued the Cassady and Kutanoglu studies and resolved some of the questions raised using genetic algorithms. Shijin et al. (2013) later used branch and bound algorithm. Meanwhile, Yulan *et al*. (2009) improved the mathematical model by taking into consideration additional parameters such as maintenance costs and machine availability.

Some researchers have studied the integration of preventive maintenance and production scheduling on parallel machines (Berrichi *et al.* 2010, Benmansour *et al.* 2011, Mirabedini and Iranmanesh 2014) for the purpose of reducing makespan, while taking into account various factors associated with the maintenance problem such as cost and time.

Only a few researchers have integrated lockout control policy on a single machine (during maintenance activities) into production planning (Charlot *et al*. 2007, Lodree et al. 2009, Emami-Mehrgani *et al* 2011). These studies show that the lockout process during machine maintenance or cleaning tasks ultimately increases machine availability. However, lockout time must be monitored, since it generates greater production costs.

We have found no study of integration of lockout into a model that takes into consideration the planning of production and maintenance and also scheduling of tasks in a manufacturing setting.

3. Discussion and Conclusion

Since the introduction of the “zero tolerance” policy in Quebec in 2005, there has been a net reduction in the numbers of workplace accidents. However, it remains practically impossible to introduce lockout procedures in certain situations. This is the case most notably during certain phases of the process of determining the cause of machine breakdown.

The current literature in this subject area may be divided into two categories. The first of these is focused on the integration of production planning and lockout procedures. The second deals with problems associated with production scheduling and planning.

It would be helpful if future writings took into consideration lockout policies in planning and scheduling of both production and maintenance. The workplace accident data provided by the CSST make abundantly clear the importance of lockout policy integration. For the time being, very few researchers have studied the integration of these combined elements and it is therefore difficult to describe the beneficial impact in precise terms.

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