Implementation of SMED techniques to improve machine capacity and work posture analysis using OWAS: A case study in steel company

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Abstract. The increasing number of high buildings resulted in rising demand for building materials, especially wire mesh. The research was conducted at a steel company to increase production capacity by reducing setup time on drawing machine and improving work posture on the welding machine. Setup time decreased 5.86 minutes and effective capacity increased 21% as a result of setup process re-arrangement using Single Minutes Exchange of Die (SMED) technique and Maynard Operation Sequence Technique (MOST) is used to determine process time. Work posture analysis using Ovako Working Posture Analysis System (OWAS) in the welding machine and development wire mesh’s table decrease number of operating procedures from 7 activities to 6 activities and change working postures from bad work posture to good work posture.

Keywords: Single Minutes Exchange of Die (SMED), Maynard Operation Sequence Technique (MOST), Ovako Working Posture Analysis System (OWAS), Setup, work posture

1. Introduction
The development of multistorey buildings in Indonesia is very rapid, especially in urban areas. DKI Jakarta as the capital of Indonesia has 800 multistorey buildings inspected by the Construction Safety Committee[1]. The 800-storey building consists of 168 lower-middle-class apartment buildings, 408 office buildings, and 224 shopping centres. Based on this data, the number of multistorey buildings in Jakarta can still increase due to buildings that are not inspected by the committee and multistorey buildings that are still under construction.

The rapid construction of multistorey buildings must be accompanied by the availability of raw materials to build high rise buildings[2]. One of the materials needed, namely wire mesh. In multistorey buildings, wire mesh is used in the repetition of concrete plates, so that the resulting road/floor is strong and able to withstand heavy loads.

PT X is one of the manufacturers of building materials in Indonesia with its flagship product, namely wire mesh. The increase in multistorey buildings and the amount of market competition, allowing PT X to get new clients led to increased demand. The low ability of the machine to operate, especially in drawing machines can affect the production capacity of wire mesh in PT X, where the
cause of the decrease in availability value of each machine can be caused by the unplanned stops in the form of machine breakdown and planned stops in the form of setup and adjustment[3].

The availability of the drawing machine was lower due to the setup time in the form of spooler turnover on the drawing machine, whereas the drawing machine breakdown was rare. Decreased availability of the drawing machine due to setup time causes the machine not to work optimally during the working time of 8 hours so the capacity of the production machine will also decrease. Research to reduce the large setup time on drawing machines is carried out so that production capacity can increase in anticipation of growing demand. The Single-Minute Exchange of Dies (SMED) method is used to reduce the long setup time on the drawing machine to shorter. The application of SMED to drastically reduce setup time has been proven by Shigeo Shingo as the creator of SMED, namely by reducing the setup time at Toyota Motor Company which originally took 4 hours to 90 minutes [4]. Work Measurement is used to describe effective working procedures. Capacity Measurement is calculated to know the production capacity that can be achieved with the new setup time[5].

In addition to capacity problems in drawing machines, there are also musculoskeletal disorders problems at PT X. Iron and steel companies are considered to have many dangerous jobs, in the form of physical hazards. Physical harm in the form of musculoskeletal disorders can occur with repeated activities, large workloads, and poor posture [6]. Musculoskeletal disorders are injuries or disorders that can decrease function in the human muscle system. PT X as one of the iron and steel companies in Indonesia is not separated from physical hazards, let alone material handling with wire mesh load produced by 51.40 kg/sheet. PT X has implemented tools to perform material handling in the form of hoist cranes but still found material handling done manually with poor posture in welding work stations. Poor work posture due to manual handling can result in work limitations, loss of working time, increased wage compensation and medical expenses and reduced productivity [7]. This research also will improve poor work posture due to manual handling so that the hazards faced by workers can be reduced. The use of the OWAS method will be performed with ErgoFellow 3.0 software for OWAS analysis and Jack 8.0 software to visualize recommended work postures.

2. Research Methodology
At the preliminary stage, a field survey was conducted at the factory site of PT X to find the topic of the problem. The survey process is conducted with interviews with Maintenance Supervisors and Production Supervisors as well as observation of the production floor directly. Preliminary studies are conducted to enrich insights about the research and get an idea of the flow of research activities to be conducted. Literature studies are also conducted by studying textbooks, articles, paper, and case studies that cover topics on Changeover, Work Measurement, Capacity Measurement, and Ergonomics.

Data collection is done either by interviews, measurements or by requesting historical data. The data obtained at the beginning of the research activities is the downtime data of each production machine, factory layout, demand data, and production data of drawing machines from September 2018-February 2019 and manual handling observation data on welding machines. From the downtime data, each production machine will be selected as one of the machines with the lowest availability caused by a long setup time. The selected machine will be analyzed using work measurement and SMED technique to reduce long setup times. With the new setup time, the new capacity will be calculated that leads to an increase in production output that can be achieved by reducing the setup time[8].

In ergonomics analysis, manual handling activities on welding machines will be analyzed using the Ovako Working Posture Analysis System method to find out how dangerous the activity is and will be reduced or eliminated with the design of new equipment and working procedures[9]. With the design of the equipment and the new working procedures, the dangerous level of the activity will be recalculated and compared to the previous activities.

3. Result and Analysis
It is known that the machining process is up to 1 spooler roll which is 16-17 minutes. There are also cranes used to transport or move spoolers from vertical spooler units to storage areas and vice versa.
The type of crane used is overhead single girder hoist crane + 2 hooks. This crane hoist is controlled using a remote and the horizontally measured travel or displacement speed is 0.5 m/s. The overhead capacity of single girders is known to be able to retain up to 10 tons. The weight of one empty spooler is 1 ton, while one full spooler contains a wire twist of 1.7 tons.

Low availability on the machine can create a difference between effective capacity and design capacity[10]. The term effective capacity is the capacity expected or estimated by companies with existing operating limitations. Meaning that the design capacity cannot be achieved because each machine cannot operate continuously without a stop, but rather there are several activities such as repairs, setup, and adjustments that reduce the availability time of the machine to operate. It was found that the drawing machine has the lowest average availability (in percent) for 6 months among 4 other machines. This will certainly make the effective capacity of the drawing machine have the lowest production output compared to the effective capacity of other machines.

The cause of the low availability was due to the downtime of setup activities or known as changeover and adjustment. These three types of downtime losses will reduce the availability of machine time to operate and in this case, the lowest availability of uptime occurs on the drawing machine. Data on all three types of downtime losses were collected and processed to see the largest downtime contributors that reduce the availability of drawing machines.

![Figure 1. Drawing machine downtime losses for 6 months](image1)

Figure 1 is the result of processing the data of the downtime losses drawing machine for 6 months. This data was collected from the maintenance division from September 2018 to February 2019. Based on the data, setup activities have accounted for 75.1% of drawing machine downtime over the past 6 months. As for adjustment time of 21% and 4% remaining for repair time. This indicates that the drawing machine seldom suffered failure or breakdown, but in its use, it often undergoes a time-consuming setup. The above analysis is reconfirmed through the drawing machine's time-by-shift time availability diagram shown in Figure 2.

![Figure 2. Availability of drawing machine per Shift](image2)
Figure 2 above shows the remaining availability of drawing machine uptime in one shift after reduced downtime losses in the form of setup. Two other types of downtime losses are not involved. This is done based on the analysis of the previous chart which explained that setup activities are the biggest contributors to downtime losses compared to the other two types of downtime losses. The average setup time per shift after being calculated based on data from September 2018 to February 2019 is 1.56 hours so the drawing machine only has the availability of uptime in one shift which is 6.44 hours. It appears that the current setup activities are very time-consuming in one shift, whereas setup activities identify as waste. Looking at this, the time of the current setup activity needs to be evaluated for later improvements.

Figure 3 below shows the loss of drawing machine capacity in each period during the six months caused by the length of the current setup activity. The calculation of design capacity and effective capacity every period can be seen in Appendix VII. Seen in Figure 3 above with an example in January 2019, the drawing machine is only capable of producing 1,355.8 kg. The amount produced is quite far from the capacity to be produced which is 2,013.9 kg. If the percentage change, the drawing machine is only able to produce 67% of design capacity. This explains the effect of setting up activities for the company in terms of production capacity. It has been explained earlier on the background that wire mesh demand from year to year is increasing so the company should target increased production capacity.

Figure 3. The decrease in Drawing Machine capacity

Using the SMED technique, the results of alteration or conversion of setup activities will be streamlined focusing on streamlining internal activities. This stage also involves improvements in the form of adding or modifying existing equipment to make activities faster.

The proposed improvement in the form of the addition of a tool cart was able to decrease the time of cutting activity and concerned the wire to the spooler. Operator 1 will move the tool cart first to the vertical spooler unit location. This tool cart carries tools including a plier placed at the top of the tool cart. That way when you want to cut and concern the wire, the range takes the plier not far. The location of the plier is in place so the operator does not have to search and spend a lot of time. A noticeable decrease occurred from 19.44 seconds to now only 10.8 seconds.
The second improvement is the removal of an empty spooler to near the vertical spooler to shorten the transfer distance later when an empty spooler is needed. So the removal of this empty spooler is first done when the vertical drawing unit is still operating or on so that this Gantt is categorized as external. The result is that the time decrease occurred from 219.6 seconds to now to 147.6 seconds.

The next improvement is the activity of opening the vertical spooler unit door to external. This can be done because when the vertical spooler unit is turned off the turn of the machine cannot stop directly, there is a slowdown first until the machine stops. It is known that before repair, the door will be opened by the operator when the machine stops. The fact is that there are about 15 seconds before the machine stops, the door can already be opened. After a discussion with the supervisor on-site, open the door in 15 seconds before the machine completely stops does not violate safety and safety procedures. This external door opening activity saves 7.92 seconds.

The last improvement is that the crane hoist must be prepared first by positioning up the vertical spooler unit when the machine has not stopped. It has previously been explained that one of the reasons for the length of time of the transfer of full wire spoolers is because of the unprepared hoist crane at the transport site. In addition to the unprepared hoist crane, a considerable distance of displacement will also take time. Looking at the problem, adding trolley material as a place to put temporary spoolers will save time. The estimated transfer time of the full wire spooler after these two changes were 72 seconds which was originally 208.8 seconds.

Table 1. Estimated setup time using MOST - Suggestion 1

| Symbol | Setup Activities                                      | I/E | Time (Seconds) |
|--------|-------------------------------------------------------|-----|----------------|
| A      | OP-1 Moving tool cart                                 | E   | 10,8           |
| B      | OP-2 Moves an empty spooler to near the vertical spooler | E   | 151,2          |
| C      | OP-1 Opens vertical spooler unit door                  | E   | 7,92           |
| D      | OP-2 Moving hoist crane up vertical spooler unit       | E   | 68,4           |
| E      | OP-1 Cuts and concerns wire to the spooler             | I   | 10,8           |
| F      | OP-2 Moving full wire spooler to trolley material      | I   | 72             |
| G      | OP-2 Move an empty spooler to a vertical spooler unit | I   | 147,6          |
| H      | OP-1 Bends and concerns wire to the spooler            | I   | 11,16          |
| I      | OP-2 Closes vertical spooler unit door                 | I   | 15,12          |

Table 1 above is the result of the estimated setup time using MOST – Suggestion 1. The total setup time will be calculated not by summing all activities, but simply internal activities resulting in the time of one spooler turnover cycle. Furthermore, the sequence of activities, as well as the total time completed in the spooler change after Suggestion 1 improvement, is clearly illustrated through the Gantt chart in figure 4.
Figure 4. Gantt chart for setup activity - Suggestion 1

Figure 5 shows an overview of the working station condition of the drawing machine after Suggestion 1 is carried out. Overall, by comparing the total setup time before the improvement, this Suggestion 1 was able to lower the time from the original 8.04 minutes to now to only 4.1 minutes. A drop of up to 3.94 minutes makes the spooler time change process short enough for the drawing machine to operate again.

Other possible solutionsto reduce setup time is given in Suggestion 2. In this Suggestion 2 improvement, there are several improvements to the same internal activities as the previous Suggestion 1, such as moving the tool cart and opening the door. The improvement that distinguishes Suggestion 2 from Suggestion 1 is the activity of moving an empty spooler to a position near the vertical spooler unit. In Suggestion 2, the second hoist is used, while in Suggestion 1 this activity still uses one hoist crane. By using two hoists, the spooler transported or moved to a location near the vertical spooler does not need to be lowered to the floor for the purpose when it is needed, the removal of the empty spooler to the vertical spooler unit is ready with a fairly close distance and there is no need for the hook installation process again. As can be seen in table 2, with this activity changing the time of moving an empty spooler to a vertical spooler unit (symbol G) can be lowered to 93.6 seconds.

The next improvement is the use of hoist 1 which will be used to move the full wire spooler. Before the full wire spooler transfer process, hoist 1 will be positioned first onto the vertical spooler unit while the machine is still on (see Figure 6– symbol C). Thus, the process of moving the full wire spooler becomes shorter because the hoist position and 2 hooks are ready to be paired when the machine has stopped. In addition to the hoist 1 transfers first, the full wire spooler transfer will also
not be transported until the storage area, but instead only moved a few meters to the side and the spooler does not need to be lowered first. Judging by table 2 for symbol F activities, this move takes only 68.4 seconds. When operator 1 controls hoist 1 to move the full wire spooler, in parallel operator 2 will also control hoist 2 to move the empty spooler already attached to the previous hook. This can be seen through the Gantt chart in figure 6 for activities with symbols F and G. The use of hoist does not need to wait for each other's queues to use it, full wire spoolers, and empty spoolers can be moved simultaneously.

Figure 6. Gantt chart for setup activity - Suggestion 2

Table 2 below is the result of converting some internal activities into external inSuggestion 2.

| Symbol | Setup Activities | 1 / E | Time (Seconds) |
|--------|------------------|-------|----------------|
| A      | OP-2 Moving tool cart | E     | 10,8           |
| B      | OP-1 Move an empty spooler to near a vertical spooler unit with hoist 2 | E     | 82,8           |
| C      | OP-2 Move hoist 1 up vertical spooler unit | E     | 14,4           |
| D      | OP-1 Opening the vertical spooler unit door | E     | 7,92           |
| E      | OP-2 Cut and attach the wire to the spooler | I     | 10,8           |
| F      | OP-1 Move the full wire spooler to the side of the machine with hoist 1 | I     | 68,4           |
| G      | OP-2 Move an empty spooler to a vertical spooler unit with hoist 2 | I     | 93,6           |
| H      | OP-2 Bending and attaching the wire to the spooler | I     | 11,16          |
| I      | OP-1 Closing the vertical spooler unit door | I     | 15,12          |

Figure 7 above shows an overview of the working station condition of the drawing machine after an alternative repair 2 is carried out. The decrease in total spooler turnover time after using the Suggestion 2 scenario is quite significant from the original 8.04 minutes to now only to 130.7 seconds or equal to 2.18 minutes.
The setup time that has been successfully lowered after the repair using the SMED technique will certainly increase the availability of this drawing machine. This availability will then have an impact on the effective capacity building of the machine[11]. Figure 8 shows the effective capacity of the drawing machine after improvement are made using Suggestion 2. When compared to before the improvement, improvements using Suggestion 2 can increase effective capacity from 67% to 88%. This capacity increase is quite significant, by only fixing problems in setup activities, the effective capacity of the machine can increase by up to 21%.

**Figure 7. Overview of Drawing Machine workstation – Suggestion 2**

**Figure 8. Comparison of Design Capacity and Effective Capacity After Improvement**

Work post analysis is conducted to determine the dangerous level of posture at work, especially in the material handling process. Ovako Working Posture Analysis System (OWAS) is used to analyze body part postures in general that are suitable for material handling, especially with large object sizes. OWAS is perfect for detailed posture analysis such as elbow angles, wrist angles and others[12]. Figure 9 shows OWAS analysis using Ergofellowsoftware and found that 7 activities are categorized as dangerous posture while working.
In this recommendation to improve good posture, there is an additional part of a roller on the base of the table to facilitate the transfer of wire mesh. In the application, the roller can be used manually and automatically. Manually, the object to be moved is given because of the pull or thrust force that triggers the roller to spin and push the object[13]. In contrast to the way the manual works, the manual roller rotates due to the absence of a braking motor that moves the roller at a certain speed. The resulting work posture will also differ between manual and automatic rollers[14]. On manual rollers, the posture works when moving the wire mesh to the slanted side of the table, while the working posture with the roller is automatic when moving the wire mesh to the slanted side of the table can be seen in figure 10.

![Figure 9. Analysis of OWAS Posture Activity Recommendations](image-url)
4. Conclusion
The application of the SMED technique on spooler changes at drawing machine work stations was successfully carried out where alternative repair solutions have been formulated. This repair solution has been able to lower the setup time quite large. The total setup time after the repair is 2.18 minutes from the beginning before the repair which is 8.04 minutes. This setup time of 2.18 minutes is recommended for the company to increase the capacity of drawing machines. By using the recommended setup time after the repair, the effective capacity on the drawing machine increases. Before the repair, the effective capacity drawing machine was only able to produce 67% of the planned capacity. After repair, the effective capacity of the machine can reach up to 88% of the design capacity. Good working posture can be realized by the development of wire mesh tables given slanted sides and automatic rollers to help move wire mesh to pallets so that the working procedure consists of 6 activities and postures that originally had a high level of hazardous to be safe.

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