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Setup Time Reduction with SMED in a Corrugated Box Plant

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Abstract

The Single-Minute Exchange of Dies (SMED) methodology proved to be an effective approach for reducing setup times on a bottleneck 66” Koppers rotary die-cutter machine center in a corrugated box plant. Root cause analysis techniques, such as a check sheet and control charts, aided the analysis. The supervisor and work crew, consisting of both the operator and setup person, played an integral role in reducing setup times by consenting to being videotaped during a typical setup and then breaking down the video to distinguish internal versus external steps. By converting many internal steps to external steps, average setup times were reduced from 55 minutes to 32 minutes, a 42% improvement.

Keywords: SMED, Setup time reduction, Corrugated box plant, Lean, Check sheet, Control charts.

1 | Introduction

The success of the lean paradigm is well-published from industrial applications and from many other economic sectors. A significant element of Lean focuses on setup time reduction which, when achieved, offers a multitude of benefits to an organization, such as increased production capacity, shorter lead times, and relief to bottleneck operations without the necessity of investing in additional machinery or people.

The Single-Minute Exchange of Dies (SMED) methodology was developed by Shigeo Shingo, a consultant to Toyota [31]. Its objective is to reduce setup times to less than ten minutes, principally, by converting as many internal tasks to external tasks as possible. Alternative setup time reduction methods include employing a Fast Initial Link Setup (FILS) methodology to reduce intial link setup times for communications between mobile devices in passing vehicles [16], eliminating setup time outliers and performing simulations to compare the effect on reducing the mean or variability [33], and combining the SMED methodology with Presetting systems to improve system productivity, overall equipment effectiveness, and reduce lot sizes [28]. A conventional SMED approach, combined with Multiple Criteria Decision-Making (MCDM) techniques were used by Almomani et

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al. [3] to reduce setup times, improve machine utilization, and increase the production and flexibility of a facility.

This paper focuses on pilot research of a setup time reduction study on a bottleneck 66" Koppers rotary die-cutter machine center in a corrugated box plant. This machine center needed relief and the SMED methodology, coupled with Five Whys and control charts, was employed as the alleviating mechanism.

2 | Literature Review

The literature reveals successful setup time reduction in a variety of industries using the SMED methodology coupled with continuous improvement and root cause analysis techniques. Modified applications of SMED include combining the Five Whys technique to identify all possible root causes and their possible interations of setup losses to reduce setup times on a screen-printing machine [7] and a 5-axis CNC machine [2]. Rosa et al. [29] used Value Stream Mapping to identify areas of waste and simulation software to calculate simulated completions times and lead times in a steel-wire-rope manufacturing process, resulting in a 58.3% reduction in weekly setup times. Lora-Soto et al. [22] used SMED, Kaizen, 5S, and Value Stream Mapping to reduce setup times to impact machine layout and productivity in a copper transformation company.

Cakmakci and Karasu [10] integrated Methods-Time Measurement (MTM) with SMED, whereby MTM analysis was used to standardize internal setup activities and SMED was used to standardize and document logical setup procedures. In another study, Cakmakci [9] applied a Cpk index to actual data from dies of an air hole boring machine as a measure of equipment efficiency in conjunction with SMED to reduce setup times in an automotive rim manufacturing process.

Modern information technology can be used with SMED in complex situations, such as printed circuit board assembly processes to reduce setup times by 85% with savings of $1.7 million per year [32] and in flat glass processing with savings up to 30% annually of the time spent on setups [15]. Lozano et al. [23] suggest using mean time between failure and mean time to repair for a more in-depth analysis of internal setup steps once internal and external steps have been identified.

Filho and Uzsoy [13] constructed a systems dynamic model combined with the Factory Physics perspective on a single-stage system producing a single product to demonstrate cumulative improvement gains in both machine setup time and repair time. King [20] suggests dramatic breakthroughs can be gained by involving knowledgeable people in brainstorming sessions during the SMED process.

SMED can be used to reduce the time per setup and to decrease the number of setups [27] and [4] and to reduce other time wasted activities in a metal stamping plant [5]. SMED was applied at two bottleneck operations to study the cost saving effect after reducing the setup times on an automotive battery assembly line [12]. Setup time reduction techniques have also been used to reduce inventory [24], inventory holding costs [21], total costs [30], and lead time [11] in the supply chain.

3 | Methodology

The first step in this pilot study was to form a project team and then establish a setup time reduction goal. The project team consisted of both the operator and setup person (the Koppers crew), along with their supervisor, a maintenance technician, and the general foreman. The initial meeting took place in the breakroom. The discussion focused on reducing setup times on this bottleneck machine in order to increase production capacity and relieve stress on the Koppers crew. The Koppers die-cutter average setup time of 55.24 minutes during the last 25 setups before this meeting, as shown in *Fig. 1* using X-Individuals and Moving Range control charts, was discussed as a baseline metric, not as a means to point blame. An agreed upon setup time reduction goal was reached – a minimum 25% reduction of the current average setup time.

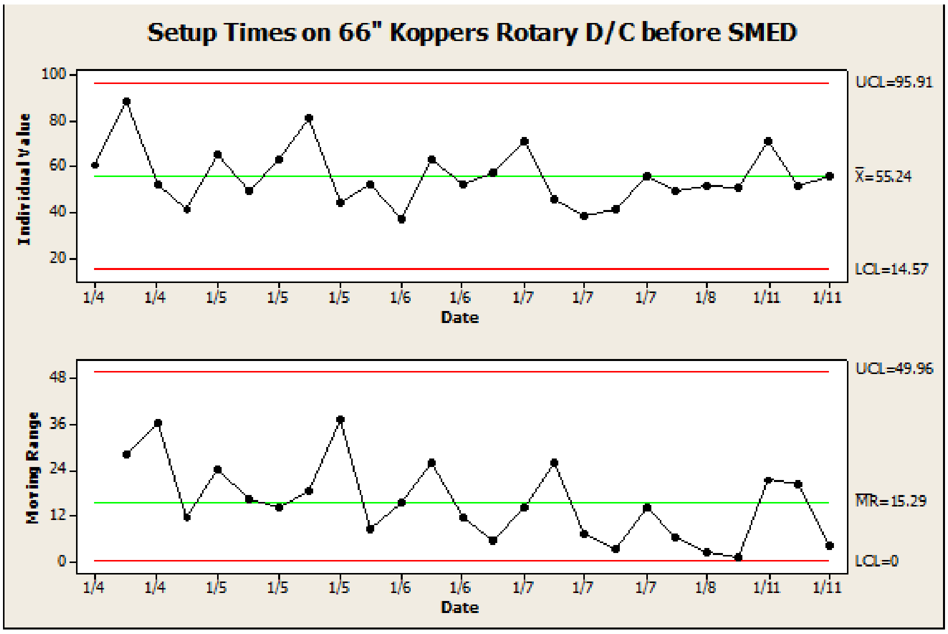

Fig. 1. Setup times during the last 25 setups before SMED.

The second step was to have the work crew define the setup tasks for each person, which encompassed all activities that occur from the last good box (or die-cut) from the previous run to the first good box (or die-cut) for the new run. Setup activities included breaking down the previous setup, setting up the new job, inspecting knock-off samples to match customer requirements on the work order with the sample, and getting the new job to run with all proper adjustments set.

The third step was to discuss the difference between internal tasks (setup tasks that must be performed while the machine is stopped) and external tasks (setup tasks that can be performed while the machine is running).

The fourth step was, with the Koppers crew's consent, to video record an average setup process with a handheld camcorder. The operator and setup person were recorded in separate videos by the supervisor and maintenance technician, respectively, while performing their setup tasks simultaneously. The recording began at the time the last box from the previous order was produced and continued until the first box on the next order was ready to run. It was important to video record an average setup as it is currently being performed in order to create a valid baseline by which to compare setup times after implementing SMED.

The fifth step was to return to the breakroom and have the project team create a list of all tasks involved in the setup process. The objective was to have the Koppers crew identify and then categorize all tasks as either internal or external. Check sheets were used to itemize tasks, note their respective times, and then label each task as either internal or external. The Koppers crew understood that there may be opportunities to convert some internal tasks to external tasks to aid in reducing overall setup times. As anticipated, some internal tasks were, indeed, converted to external tasks as indicated on the check sheets.

The sixth step was to apply the revised internal and external tasks to future setups. Setup times were recorded for the first 25 consecutive setups after SMED implementation on X-Individuals and Moving Range control charts.

The seventh step consisted of reconvening in the breakroom and having the project team evaluate the control charts together. A discussion of (1) what was learned and (2) the benefits of setup time reduction ensued.

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4 | Analysis

Following the video recording of the setup process on the Koppers die-cutter, the setup team met in the breakroom to break down the videos of both the operator and setup person on the same job. As the work crew reviewed the videos, the setup team created a list of tasks involved in the setup for both the operator (*Table 1*) and setup person (*Table 2*), with times required per task noted, and all tasks were identified as either internal tasks or external tasks. Some internal tasks were converted to external tasks, as indicated on the check sheets.

Table 1. Check sheet for identifying setup tasks by operator.

Task No.	Description	Task Time (in min)	Internal or External
1	Set up feeder section	1	Internal
2	Check misc. items (caliper, etc.)	4	Internal => External
3	Open machine and double lock-out	2	Internal
4	Replace printing dies	6	Internal
5	Mount pull straps	2	Internal
6	Check alignment of slots, pull rolls	1	Internal
7	Remove lock-outs and close machine	2	Internal
8	Run samples and make adjustments	4	Internal
9	Set belts on beater section and layboy	2	Internal
10	Final adjustments	2	Internal => External
	Total	26	

Table 2. Check sheet for identifying setup tasks by setup person.

Task No.	Description	Task Time (in min)	Internal or External
1	Mark final load tag from previous order	2	Internal
2	Get die-board for next order	1	Internal => External
3	Open machine and double lock-out	1	Internal
4	Remove old die-board on machine	3	Internal
5	Mount new die-board	5	Internal
6	Measure die-board for score placement	1	Internal
7	Set scores	3	Internal
8	Set stacker up	5	Internal
9	Get load tags ready	2	Internal => External
10	Get dunnage	5	Internal => External
11	Remove lock-outs and close machine	1	Internal
12	Clean printing dies from previous order	2	Internal => External
13	Get ink for order	5	Internal => External
14	Check ink viscosity	2	Internal => External
15	Get print card to check print	1	Internal
16	Put more blanks in hopper	1	Internal
17	Check print on boxes	1	Internal
18	Adjust stacker	1	Internal
19	Prepare shrink-wrap machine	13	Internal => External
	Total	55	

The modifications to setup tasks were applied to the first 25 jobs on the Koppers die-cutter post-SMED implementation. Individual setup times, along with moving range values, were plotted on an X-Individuals and Moving Range control chart in *Fig. 2*.

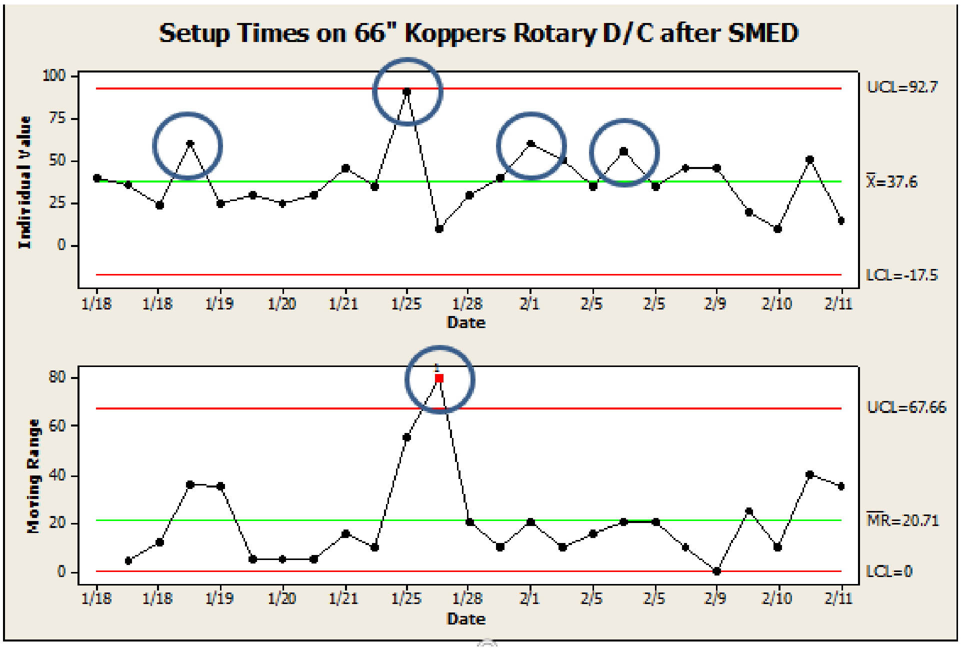

Fig. 2. Setup times during the last 25 setups after SMED.

Although the mean setup time had been reduced to 37.6 minutes for these 25 setups, the average moving range increased from 15.29 minutes before SMED to 20.71 minutes after SMED. Upon closer inspection and discussion, this was attributed to four unusually high data points on the X-Individuals chart. Specifically, the setup times for data points 4, 11, 15, and 18 were 60, 90, 60, and 55 minutes, respectively. Recalling from memory and production sheet comments, the Koppers crew discussed reasons for why these unusually high setup times occurred.

For data point #4, an ink spill on the floor occurred during the setup process. The extra cleanup time extended this setup time. For data point #11, a dimensional mismatch between the work order and the customer print card resulted in extra time involving the supervisor and customer service to resolve this issue. For data point #15, the sheet size of sme of the raw material sheet stock was out-of-spec. sheet length variation from the corrugator led to the entire lot being manually sorted before running the order. For data point #18, extra time was required to get the two-color print (blue and red) within the narrow customer spec tolerance on the color swatches. This involved a trial-and-error approach of adding water and/or ammonia to the ink kits, cycling through the ink system, and inspecting knock-off samples until the desired shade of both ink colors were achieved.

Satisfied with justifying these anomalies and with corrective actions taken, these data points were removed from the post-SMED analysis and a revised control chart with 21 data points was evaluated, as shown in *Fig. 3*.

With 21 representative setup times after SMED, we observe that both the X-Individuals and Moving Range control charts are in-control. The average setup time is 32.14 minutes, and the average moving range is 12.85 minutes. Results before SMED versus after SMED are shown in *Table 3*.

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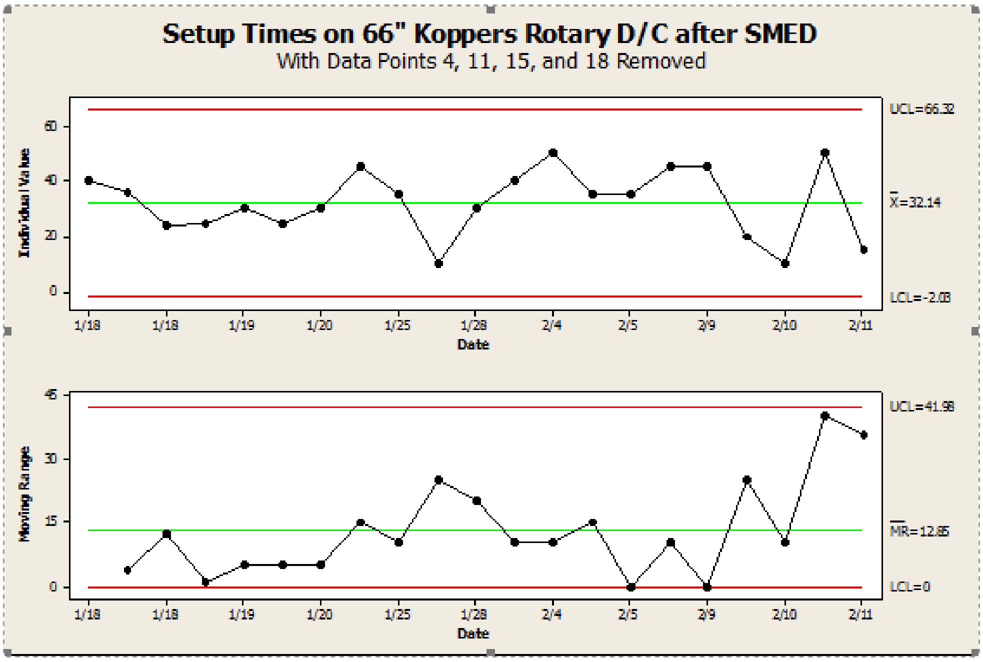

Fig. 3. Setup times during the first 25 setups after SMED with data points 4, 11, 15, and 18 removed.

Table 3. Results before and after SMED.

	X-Ind (in min)	MR (in min)
Before SMED	55.24	15.29
After SMED	32.14	12.85
Net change	⬇ 23.1	⬇ 2.44
Improvement	42%	16%

5 | Conclusions

The objective of this pilot study, to reduce average setup time on the 66” Koppers rotary die-cutter by at least 25%, was achieved after implementing the SMED methodology. After four unusually high setup times were justifiably removed, the average setup time for the remaining 21 jobs after SMED was reduced by 42% versus the baseline average setup time. Further, the moving range chart showed a 16% reduction in average setup-to-setup times.

The contrast in results before and after SMED came as quite a surprise to the project team, particularly, the operator and setup person. A team discussion of what was learned led to creating a list of benefits associated with reduced setup times. The project team realized that by changing the way the Koppers crew performed their setup tasks, converting as many internal tasks to external tasks as possible, they could dramatically reduce their average setup times. In turn, this increases the machine center’s production capacity. By running more orders through on each shift, it will relieve the stress associated with feeling like one has to work harder because the Koppers machine always appeared to be behind schedule. In addition, if similar results were achieved across all machine centers on all three shifts, then the production capacity of the box plant would increase substantially without adding any additional resources or expense, such as new machines, new hires, working overtime, working extra shifts (or days), etc.

The Koppers crew also suggested that longer setup times before SMED were not the result of machine neglect. Upon reflection, they stated that the maintenance department scheduled monthly PMs for all machines in the CMMS database. No issues were cited with the maintenance department during this study.

The operator and setup person were especially pleased with their involvement on this pilot study and were quick to buy-in to the SMED process for the next round of setup time reduction efforts on this machine center.

5.1| Areas for Future Study

Future research could include a follow-up study of this particular machine center to try to further reduce setup times from an average of 32 minutes towards the SMED objective of less than ten minutes. Additionally, the SMED methodology could be applied to other machine centers in other departments at this facility to achieve similar results. Application of the SMED methodology used in this case study could also be applied in other industries to expand on the success of this setup time reduction approach.

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Conflicts of Interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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