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RESEARCH ARTICLE

Application of Single Minute Exchange of Die Lean Method in Improving Productivity: Study of an Injection Molding Process

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ABSTRACT

This paper investigates reduction in work-in-process inventory by implementing Single-Minute Exchange of die technique and Kanban System in injection molding process of automotive parts manufacturing organization. Data was collected regarding setup time for most voluminous produced emblem, recognition of tasks involved in method of change over, finding and removing unnecessary internal activities and standardizing the modified process through Kanban implementation. Findings indicated that after SMED implementation setup-time was cut by 53% and 25 minutes per set up were saved implying saving of total 750 minutes of production time per month which is almost equivalent to improvement in 2% productivity. Daily production quantity was reduced by 25% and WIP stock of injection molding process was reduced by 50%. Demonstration of application of SMED in an automobile parts company showing real time reduction in inventory and productivity improvement was core of this paper. The results can apply to other intermediate component manufacturers to have wider beneficial implications for the entire supply chain.

Keywords: Kanban, SMED, Setup time, Lean manufacturing, Work-in-process, Daily production quantity, Productivity

INTRODUCTION

Fickle and continuous changing demand of customer has put enormous pressure to manufacturing processes enforcing organizations to be lean enough to respond to such changes. However, demand for increased variety forces machines to undergo change over frequently, that is, preparation time among two manufacture instructions has increased (Arasanipalai *et al.,* 2014). This time is considered as wasteful activity as it is not adding any value to the production process (Carrizo and Campos, 2011). One way to decrease time lost in setting of machines is to produce in mass by applying a particular operation before switching to production of another type. However, such way results in compiling of unwanted quantity causing heavy inventory.

Thus, production process faces a dilemma between producing in excess to lessen change over frequency and producing smaller batches of different variety, thus perpetuating need for recurrent change over and subsequently higher set-up times. This current study proposes application of SMED method to resolve such dilemma. The technique as a lean method has been extensively applied in different production setups to achieve reduction in set-up times by recognizing and removing appropriately wasteful tasks (Shinde *et al.,* 2014). Though reducing set-up

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time completely has been recognized as almost impossible and unnecessary but it is essential to classify supplementary tasks, which needlessly drive-up set-up time. Consequently, key factor in purpose of SMED is to categorize tasks into activities that tangibly add value to the production process and those that do not (Singh *et al.,* 2018).

An attempt has been made by this study to add to lean production literature in general and SMED in particular by examining the SMED method and its impact on improving key metrics of productivity such as set-up time, safety stock and inventory in a large-scale auto parts company involved in manufacturing of emblems for various car companies. Considering sales data of past one year, the study ensured to examine largest selling by volume emblem, which was Emblem Maruti Suzuki. Method of mapping all tasks involved in the entire production process identified that this part was produced based on push system and no process was producing parts based on customer demand. High inventory levels were found in injection molding process of this part. Thus, this part was considered suitable for implementation of SMED. Though such implementation has been comprehensively documented, however, its influence is not examined among suppliers that form the vital link in entire supply chain. With increasing encouragement from original equipment manufacturers suppliers intend to accrue benefits of lean principles to make their processes leaner that are easily responsive to changes in processes without resulting in cost pressures. This extracts its novelty from documenting the practical implementation of SMED in same endeavor.

REVIEW OF LITERATURE

Among different established lean production principles SMED has been established as massively effective in reducing wasteful non-value adding tasks, over-production by enabling production of smaller batches and yet has smaller set-up times (Tekin *et al.,* 2019). Over production refers to tendency to manufacture in excess of demand, or creating the output too early before required. This amplifies the danger of products getting obsolete or producing erroneously (Ravichandran and Kumar, 2015). Surplus inventory augment lead-time, eat useful floor-space, impede the detection of troubles, and restrains communication. Over-production is simply producing anything that does not need to be produced (Olaitan *et al.,* 2017). To mitigate the waste of over-production established primarily to off-set the variations in demand SMED provides redesigning of processes that would be responsive to such variations by producing smaller batches of different range of products (Rosa *et al.,* 2017). In the method the emphasis is on reducing the time involved in setting up machines for production by combining or removing unnecessary activities.

The first step of SMED very importantly involves classifying tasks during machine preparation into external and internal. This difference is vital in exercising SMED. Task required in production process but performed when machine is engaged in manufacturing another part is called as external to the process. This is done so as to perform two different activities involved in production of an output simultaneously, rather than sequentially. On the other hand, tasks performed on the machine when it is inoperable are called as internal (Sayem *et al.,* 2014). As the purpose is to mitigate impact of set-up times on production output by reducing them, thus vital purpose of SMED method is finding out specifically those tasks that can be carried out as external. This is critically important in reducing set-up time during transition from one process to other. Lastly, after removing external tasks and engaging the machine only on internal tasks new operation is rationalized by automation, standardization, and training (Da Silva *et al.,* 2019).

Appropriate implementation of these steps has been found to provide significant improvement in productivity among different processes of variety of industries (Rodriguez-Mendez *et al.,* 2015). Sayem *et al.* (2014) showed that practicing SMED in furniture manufacturing processes caused enhancement in productivity by 66% as its implementation reduced lead-time and inventory. Similarly, study by Bevilacqua *et al.* (2015) done in pharmaceutical packaging processes further instituted the importance of SMED method as results when compared with Bevilacqua *et al.* (2013) showed that detailed seven step application of SMED is vastly effective in reducing set-up time, enhancement in manufacturing capacity by small improvements in tasks without incurring any cost increments. Authors Garg *et al.* (2016) demonstrated similar results in a small enterprise, wherein application of SMED showed decrease in set-up times to the extent of 87%.

Furthermore, SMED has gained lot of attention when production processes in addition to intend to achieve benefits not only in lessening of set-up times or over-production but also of permanent progress (Karam *et al.,* 2018; Palanisamy and Siddiqui, 2013). This was amply illustrated (Azizi, 2015; Junior *et al.,* 2022) where in mapping method was designed to identify non-value adding tasks and then apply kaizen in collaboration with SMED to successfully advance the procedure in an assembly line. Brito *et al.* (2017) allied SMED with ergonomics to cut set-up time and advance due delivery time. These studies specify vast consequence of productivity augmentation as an imperative index of a firm's competitiveness through function of SMED.

Thus, literature clearly elucidates the significance of implementation of SMED to improve production processes. Subsequent sections provide real time application in the injection molding process of an emblem manufacturer.

METHODOLOGY

Data Collection

Data as shown in Table 1 was collected regarding customer requirement per day, daily production quantity by each process, cycle-time of process, process flow of the part, standard quantity of parts kept in bin for every process, change-over time, process wise safety stock and replenishment stock (quantity which is needed between time interval of one order and the next order).

The data clearly indicated work-in-process inventory in the process to be very high. For instance, for emblem, Maruti Suzuki 10560 units were produced after injection molding and they were kept as in process material to be asked for processing by next step of plating. Data collection involved discussion with process owners which resulted in indicating that such huge WIP is kept in stock due to elevated mold change over time and lack of capacity. This problem was rectified by applying SMED technique. In this endeavor following steps were undertaken.

Listing of Activities in Change-over and Performance Time

This step focused on collecting information about set-up tasks and time taken for each task. Times were estimated by observing change over operation five times. As discussed set-up time is time between last production of prior order and first order of next production. Thus list of activites (Table 2) involved

Table 1: Process wise data collection of part

Part name	Customer requirement/ day	Process	Daily production quantity	Cycle time (seconds)	Change Over time (Minutes)	Lot size	Safety stock
Emblem Maruti Suzuki	2640	Injection molding	3500	40	47	972	10560

Table 2: Listing of activities in change-over and performance time

Mold unloading time study		Mold loading time study	
Activity	**Time (min.)**	**Activity**	**Time (min.)**
Crane movement from fixed location to machine	3	Parameter loading from m/c/ memory	1
Collection necessary tools for mold change	3	I-bolt tighten on the mold	1
Injection unit backword	1	Mold movement from storage to machine	3
MTC pipe removal from mold	2	Mold loading and matching	3
Antirust spray application on core and cavity	1	Mold clamp	5
Lock plate fixation	1	Lock plate removal	1
I-bolt and crane fixation	2	Crane removal from mold	1
Clamp removal from core and cavity	3	MTC connection	1
Moving plate open	1	HRTC connection	2
Mold removal from machine	1	Core and cavity cleaning	2
Mold movement to its fixed location	3	Setting locking tonnage	2
		05 shot approval	4
Total	21	Total	26

mold unloading and mold loading. Times for activities in both processes were also calculated.

According to Table 2, unloading task takes 21 minutes while loading task takes 26 minutes. Total time taken for mold change-over is almost 47 minutes. All activities were performed as internal activity. Reasons for a high set-up time were observed to be lack of coordination among workers involved in the set-up, lack of fulfillment of the pre-established procedures for carrying out the setup, lack of knowledge of the procedures for carrying out the set-up and die tools in poor conditions. Thus, lot of scope was found to reduce the mold change over time.

Separation of Internal and External Activities

Observation of processes and dialogue with their owner, following activites were separated into internal and external for mold unloading and mold loading (Table 3).

Data in Table 3 shows that if some of the activites are performed externally (before the change over starts or after the change over ends) 09 minutes can be saved in mold unloading activity and 09 minutes can be saved in mold loading activity. Thus, total 18 minutes can be saved in total mold setup time only by converting feasible internal activities into external activities. Almost 38% of the change over time can be reduced or saved through this method only.

FINDINGS AND ANALYSIS

Removal or Time Reduction of Internal Activities

After formal discussions with process owners and understanding the process some of the activities were considered which can be removed or their time can be reduced. Table 3a showed such activities for mold unloading.

Table 3b showed posible improvement methods for each activity with regard to mold loading.

Reduction in Safety Stock

Above data shows that mold unloading time provides a reduction from 21 to 7.5 minutes and mold loading from 26 to 14.5 minutes in case of synchronizing and

Table 3: Separation of internal and external activities

Mold unloading time study			Mold loading time study		
Activity	**Time (min.)**	**Activity type**	**Activity**	**Time (min.)**	**Activity type**
Crane movement from fixed location to machine	3	External	Parameter loading from m/c memory	1	External
Collection of necessary tools for mold change	3	External	I-bolt tighten on the mold	1	External
Injection unit backword	1	Internal	Mold movement from storage to machine	3	External
MTC pipe removal from mold	2	Internal	Mold loading and matching	3	Internal
Antirust spray application on core and cavity	1	Internal	Mold clamp	5	Internal
Lock plate fixation	1	Internal	Lock plate removal	1	Internal
I-bolt and crane fixation	2	Internal	Crane removal from mold	1	External
Clamp removal from core and cavity	3	Internal	MTC connection	1	External
Moving plate open	1	Internal	HRTC connection	2	External
Mold removal from machine	1	Internal	Core and cavity cleaning	2	Internal
Mold movement to its fixed location	3	External	Setting locking tonnage	2	Internal
			05 shot approval	4	Internal
Total	21		Total	26	

Table 3a: Mold unloading time study

Activity	Time (min.)	Improvement method	Revised time (min.)
Crane movement from fixed location to machine	3	Convert into external	0
Collection of necessary tools for mold change	3	Convert into external	0
Injection unit backword	1	No scope	1
MTC pipe removal from mold	2	Can be done inparallel by foreman and machine operator	2
Antirust spray application on core and cavity	1		
Lock plate fixation	1		
I-bolt and crane fixation	2	Can be done inparallel by foreman and machine operator	1
Clamp removal from core and cavity	3	Can be done inparallel by foreman and machine operator	1.5
Moving plate open	1	No scope	1
Mold removal from machine	1	No scope	1
Mold movement to its fixed location	3	Convert into external	0
Total	21	Total	7.5

Table 3b: Mold loading time study

Activity	Time (min.)	Improvement method	Revised time (min.)
Parameter loading from m/c/ memory	1	Convert into external	0
I-bolt tighten on the mold	1	Convert into external	0
Mold movement from storage to machine	3	Convert into external	0
Mold loading and matching	3	No scope	3
Clamp the mold	5	Can be done inparallel by foreman and machine operator	2.5
Lock plate removal	1	No scope	1
Crane removal from mold	1	Convert into external	0
MTC connection	1	Convert into external	0
HRTC connection	2	Convert into external	0
Core and cavity cleaning	2	No scope	2
Setting locking tonnage	2	No scope	2
05 shot approval	4	No scope	4
Total	26	Total	14.5

standardizing the change over process through some improvements. Furthermore, the results showed change over time reduction to 22 minutes from 47 minutes implying a saving of 53%. Lastly, efficacy of SMED method was ascertained by comparing set-up time and safety stock before and after implemetnation of the lean method. The outcomes of the results are shown through following Table 4.

Table 4: Before-After evaluation data

Part name	Set up time (minutes)		Safety Stock (qty.)	
	Before	After	Before	After
Emblem Maruti Suzuki	47	22	10560	5280

Before – After data available in above Table 4 clearly shows that set-up time or mold change over time is reduced by more than 50%. Before SMED, implementation set-up time was 47 minutes while after SMED implementation set-up time is 22 minutes, that means almost 53% time is saved or reduced in change over activity. So safety stock is also reduced by 50%. After working on safety stock, our next target was to reduce the chances of increase in inventory / safety stock. This was done by fixing the daily production involving customer demand and by effective visualization of any abnormality in inventory levels. This was done by implementation of Kanban (Savino and Mazza, 2015).

To implement the kanban system, pre-requisite data already collected in Table 1 was utilized. Next setps were deciding number of kanban needed & implementation of kanban system.

Kanban Implementation

Identifying number of kanban for each task was critical so that regular customer supply could be maintained and optimum inventory could be kept. Number of kanban required for each process was decided by the following formula derived from production processes of Toyota Kirloskar Motor Pvt. Ltd.

$$\text{Number of Kanban} = \frac{\text{(Customer requirement per day + Safety Stock + Replenishment Stock)}}{\text{Quantity per bin}}$$

The formula is explained by illustrating number of Kanban required for Emblem Maruti Suzuki at injection molding process. Customer demand of Emblem Maruti Suzuki per day is 2640 units (Table 1). A lot of 972 units (Table 1) is produced in injection molding (M1) process as first batch after receiving raw material from store (M0) and finally finished product moves to next process of plating (M2). It was decided that a safety stock of 5280 (Table 4) molded units has to be kept so M1 has to produce these parts as well. After manufacturing 2640 + 5280 = 7920 units, the process will stop as demand is fulfilled. However, M1 has to produce 2640 units for next day. So, an order of 2640 units or 2640 Kanban are sent back to raw material section. It is important to remember that Kanban control system is a system of communication between workstations so total stock for which number of Kanban has to be generated is combination of actual products produced which goes for processing on next machine (2640 units) plus safety stock (5280 units) and signal of replenishment stock of next day's demand (2640 units) which goes to previous workstation.
Thus,

Number of Kanban for Emblem Maruti Suzuki after injection molding would be

$$\frac{\text{\{Customer requirement per day (2640) + Safety Stock (5280) + Replenishment Stock (2640)\}}}{\text{Quantity/bin (972)}}$$

= 7920 / 972

= 8.14 = aprroximated to 9

Implementation of kanban will ensure sustainability in daily production quantity and WIP stock. In case of any variation in daily production quantity or WIP stock, number of kanban cards needs to be revised because as per kanban rules, parts were moved only with kanban. Implementation of kanban showed daily production quantity reduced from 3500 to 2640.

Evaluation

Evaluation of SMED and kanban system performance was done by using lean metrics of change over time, daily production and WIP stock / safety stock. Assessment of before and after results of SMED and kanban system validated application of these lean methods. The outcomes are shown in Table 5.

Before – After data shown in Table 5 clearly illustrates that daily production quantity is reduced. Initially, before condition process was not producing the part based on daily customer demand. After implementation of SMED and kanban process has to produce only customer demand on daily basis and also, rejection or breakdowns can be managed through safety stock/WIP stock. Safety stock was also reduced after implementation of SMED. Reduction in setup time, daily production quantity and safety stock/ WIP stock leads space availability, machine availability or spare capacity generation for production of other parts.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The present research study has been conducted in large scale company of Indian automotive manufacturing organizations only, while in future, similar research can be conducted in medium and small-scale manufacturing industries in order to understand the compatibility of findings. Furthermore, this study focused on batch production system. However, future studies adopting this approach to hybrid systems would provide interesting results about applicability of SMED and kanban.

Table 5: Before - After Evaluation Data

Part name	Process	Change over time (Minutes)		Daily production (qty.)		WIP stock/safety stock (qty.)	
		Before	After	Before	After	Before	After
Emblem Maruti Suzuki	Injection molding	47	22	3500	2640	10560	5280

CONCLUSION

Based on above result it is concluded that SMED helped in achieving total discipline in mold change over process. The SMED is one of the proactive steps to gain the competitive advantage & productivity improvement. This paper presented a real industrial case study of SMED implementation at manufacturing site. Approx. 30 change overs take place on 50-ton machine per month, that means if 25 minutes are saved / set up, total 750 minutes are saved per month. 750 minutes is almost 2% of total production time available on 50-ton machine per month. Which means 2% productivity is increased through SMED implementation. Implementation of kanban ensured sustainability in daily production quantity and WIP stock. In case of any variation in daily production quantity or WIP stock, numbers of kanban cards needs to be revised because as per kanban rules parts has to be moved only with kanban. The results exemplify the advantages of implementing the proposed method that include reducing set-up time noticeably, growing machine utilization, reducing daily production quantity, increasing spare availability, and improving productivity.

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