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Set Up Change Time Optimization Using Single Minute Exchange of Die (SMED) Methodology

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Abstract
Earlier, the set-up time was considered as a part of productive hours and there was lack of awareness and motivation amongst operators to reduce set-up time. The knowledge of single minute exchange of die (SMED) was limited to a small group of individuals. Lack of investment in mechanisms to aid set-up time reductions and preventive errors restricted the use SMED. At present set-up time optimization is done mainly using work study and by the use of SMED methodology. The SMED technique performs equipment setup and changeover operation in less than 10 minutes. SMED improves setup process and provide setup time reduction up to 90% with moderate investments. The three main steps of SMED system namely- separating internal and external setup, converting internal setup to external setup, and streamlining all aspects of the setup operation is discussed in detail. The various types of setting process errors observed during the study are also analyzed to eliminate the potential for further mistakes. Imparting knowledge and training on these methodologies helps to focus on reducing the amount of productive time that is lost when a machine is being set. This paper presents case study of an Automobile company for the sequential application of the SMED methodology. The implementation has enabled reduction in setup time through company's internal resources reorganization without the need for significant additional investment.

Key Words
Single minute exchange of die, Lean Manufacturing, Changeover, Internal setup, External setup

I. Introduction

Most of the machines and machine lines in manufacturing plants are shared resources. Quick change-over is essential for a shop to process numerous jobs in small batches [1]. Reducing the downtime due to set-up results in additional available production time thereby reducing production cost.

II. Set Up Time

The setup time is defined as the time interval between the completion of the current job and the beginning of the next job [2]. Setup involves all activities of preparing a machine or workstation to perform the next operation, and may depend on the type of job, the type of machine or both [3]. Setup time is one of the vital parameters used in any manufacturing industry and is a form of necessary input to every machine or workstation [4]. The time between producing the last product of a series and producing the first product of a new series that meets all quality requirements has always been considered as waste or as *added cost* due to decreasing sizes of series orders [5, 6].

The equation for calculating the time required for manufacturing a series of parts and the assembly of components is [7]:

$$t = t_s + m \cdot t_1 \qquad (1)$$

Where, t = time required for manufacturing parts and assembling components [Nh/series]

t_s = machine setup time or assembly workplace setup time [Nh/series]

m = number of units within a series [pieces/series]

t_1 =manufacturing/assembly time per unit [Nh/piece].

The setup operation can be divided into two parts: Internal setup and external setup. Internal setup is the operation that can be done only when the machine is shut down (attaching or removing the dies). External setup is the setup operation that can be done when the machine is still running. The changeover contains the following periods or stages:

1) Setup and
2) Run-up or start-up [8].

There are two ways to reduce the total downtime due to set-ups: reduce the set-up frequency or reduce the time that is needed to perform the set-up. Reducing the set-up frequency is less preferable compared to reducing the set-up time. Setup reduction benefits are shorter lead times, higher productivity, increased capacity, greater flexibility and fewer defects [9].

III. Single Minute Exchange of Die (SMED)

The phrase *single minute* does not mean all changeovers and startups take only one minute, but that they should take less than 10 minutes (in other words, *single-digit minute*) [10]. SMED is one of the main lean production methods for reducing set-up time in a manufacturing process [11]. This method differentiates set-up activities that need to be performed during the downtime (internal activities) and activities that can be executed while the machine is still running (external activities) [9]. It provides a rapid and efficient way of converting a manufacturing process from running the current product to running the next product [12]. Rapid changeover is a fundamental technique for attaining just-in-time (JIT) production and for addressing the issues of flexibility and responsiveness, and is a substantial part of the lean philosophy. For this scope, Shingo [13] introduced his methodology called Single Minute Exchange of Dies (SMED). It can be defined as a set of structured techniques that make it possible to provide a setup time reduction (up to 90%) with moderate investments [14]. SMED is the key to manufacturing flexibility. However utility of SMED is not limited to manufacturing [15].

The focus of SMED is to reduce from hours to minutes, the time required to move from producing one product to another. An appropriate target for a SMED implementation is to reduce the setup time by 75%, [16]. SMED is a world renowned methodology with proven record of helping organizations delivering outstanding business results and improvement in customer satisfaction levels [17]. Another highly significant contribution of SMED is the emphasize on active employee involvements in both problem solving and decision making which has shown in outstanding

setup time reduction cases[18]. Some of the major setback of the SMED techniques is the sustainability issue due to lack focus and commitment by management in the long run. Other disadvantage is low focus on hardware part redesigning, not so clearly described through available SMED techniques [19].
SMED improvement should pass through four conceptual stages:
A) Ensure that external setup actions are performed while the machine is still running, B) separate external and internal setup actions, ensure that the parts all function and implement efficient ways of transporting the die and other parts, C) convert internal setup actions to external and D) Improve all setup actions [20].

1. Implementation of SMED

The following eight techniques should be considered in implementing SMED [21].

1. Separate internal from external setup operations
2. Convert internal to external setup
3. Standardize function, not shape
4. Use functional clamps or eliminate fasteners altogether
5. Use intermediate jigs
6. Adopt parallel operations (see image below)
7. Eliminate adjustments
8. Mechanization

Thus SMED is an important lean tool to reduce waste and improve flexibility in manufacturing processes allowing lot size reduction and manufacturing flow improvements. SMED reduces the non-productive time by streamlining and standardizing the operations for exchange tools, using simple techniques and easy applications. Streamlining all aspects of the setup operation is needed to shorten the setup times. Implementing parallel operations, using functional clamps, eliminating adjustment and mechanization techniques are used to further setup time reduction.

Table 1 summarizes the typical seven prominent waste in lean context .

Table 1: The seven waste in Lean context [22]

S.No	Waste	Description
1	Overproduction	Producing items earlier or in greater quantities than needed by the customer. Generates other wastes, such as overstaffing, storage, and transportation costs because of excess inventory. Inventory can be physical inventory or a queue of information.
2	Waiting	Workers merely serving as watch persons for an automated machine, or having to stand around waiting for the next processing step, tool, supply, part, etc., or just plain having no work because of no stock, lot processing delays, equipment downtime, and capacity bottlenecks.
3	Transportation	Moving work in progress (WIP) from place to place in a process, even if it is only a short distance. Or having to move materials, parts, or finished goods into or out of storage or between processes.
4	Over processing	Taking unneeded steps to process the parts. Inefficiently processing due to poor tool and product design, causing unnecessary motion and producing defects. Waste is when providing higher quality products than is necessary.
5	Excess Inventory	Excess raw material, WIP, or finished goods causing longer lead times, obsolescence, damaged goods, transportation and storage costs, and delay. Also, extra inventory such as production imbalances, late deliveries from suppliers, defects, equipment downtime, and long setup times.
6	Unnecessary Motion	Any motion performed by employees during the course of their work other than adding value to the part.
7	Defects	Production of defective parts or correction. Repairing of rework, scrap, replacement production, and inspection means wasteful handling, time, and effort.

Fig.1: Shows a general changeover process and the total elapsed time that is measured from the ramp down period of current product to the time the new product is fully ramped up [23]. Figure 2 shows the Shingo's conceptual stages and SMED techniques.

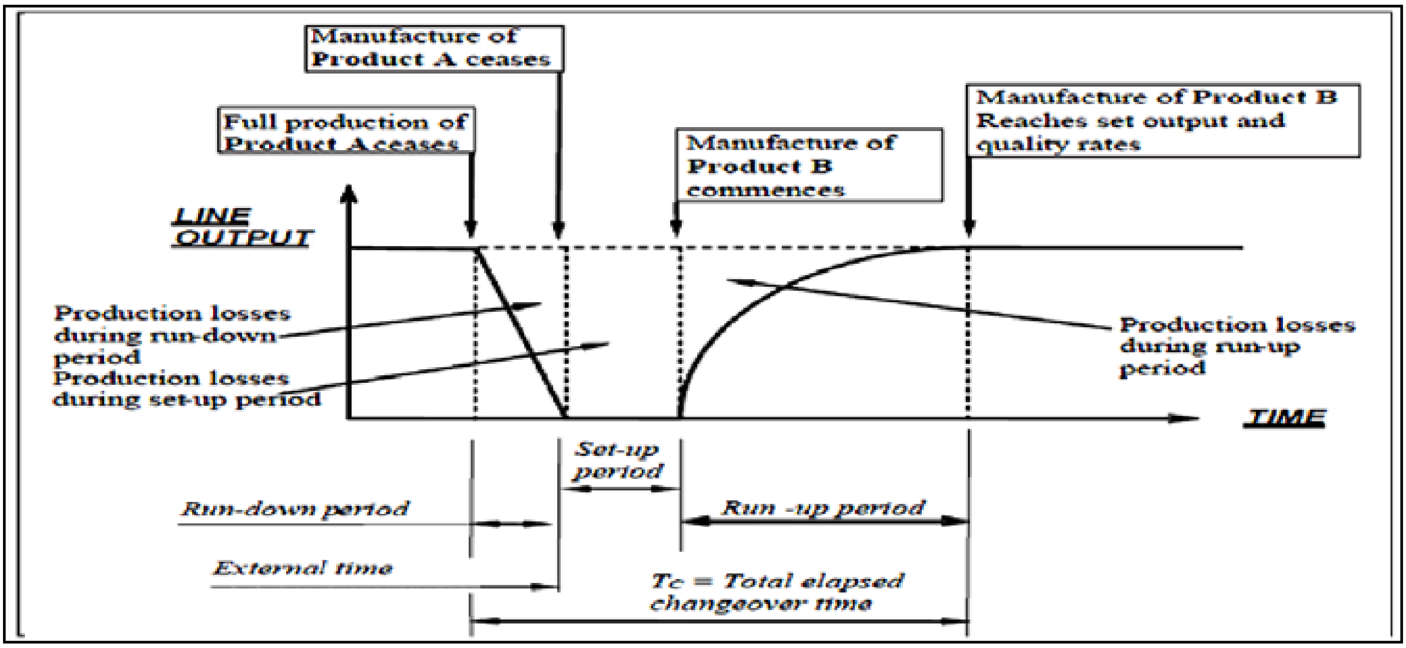

Fig. 1: General changeover process [23]

IV. Methodology

In the present work, experiments were carried out to reduce the setup time and tool change time in an automobile industry. The applicability of the proposed SMED approach was tested for shaping machines The observations were undertaken using manual means employing a standardized recording and analysis sheet. The first step involves separating internal and external set up activities. A check list was prepared as shown in Table 2, which leads to saving of 30-35 minutes. Based on table, numerous other activities are eliminated, which are contributing to longer set-up times. The errors observed during the study like errors due to absentmindedness/ unintentional, errors due to a lack of concentration/lethargy, errors due to unsuitable instructions or work standards, errors due to equipment malfunctioning, errors arising from operators misjudging a situation were analyzed.

The management and control of materials is also critical to set-up reduction. Problems like improper housekeeping, unorganized inventory storage, inefficient or misplaced tools, transportation of equipment, improper storage space, etc were observed. Table 2 shows the worksheet analysis showing the original and improved machine setup time.

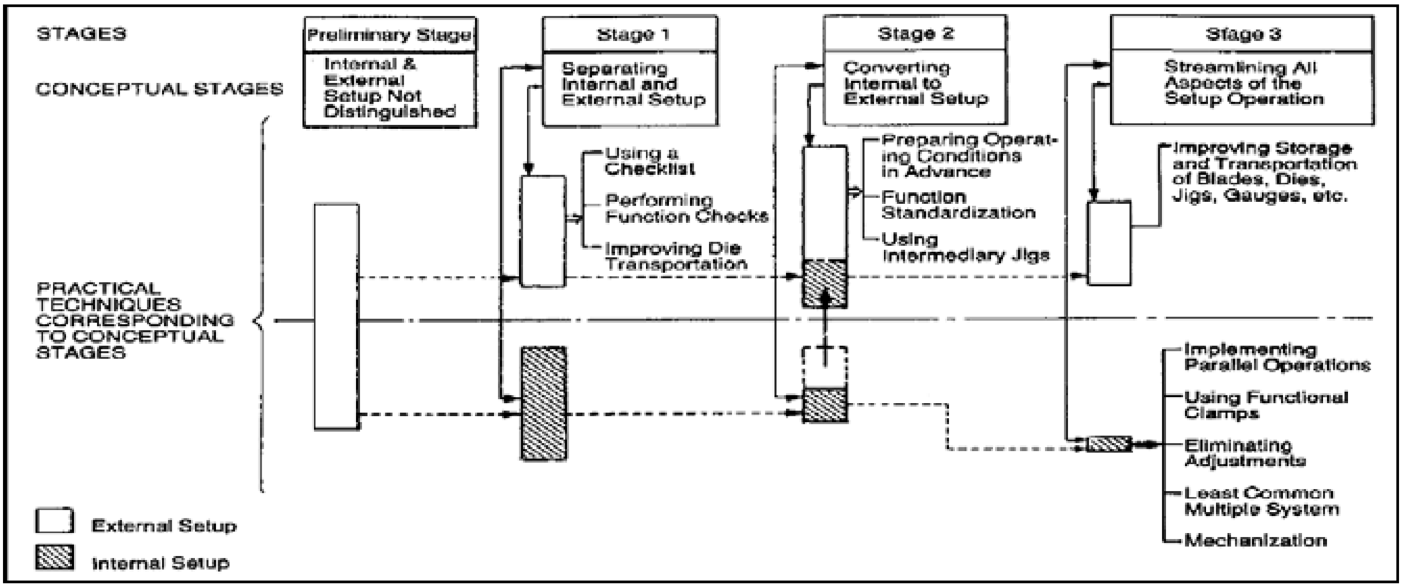

Fig. 2: The Shingo's conceptual stages and SMED techniques [14]

Table 2: Worksheet analysis showing the original and improved setup time of Machine BA 4156; Lorenz gear for the part no 2 01 3 150, Fixture: RE 332

S.No	Activities	Time (Sec) 21Dec 2009	Time (Sec) 03Jan 2010	Time (Sec) 17 Jan 2010	Activity Internal / External	Modification	Remarks	Time After 21 Mar 2010	Time After 28 Mar 2010	Time After 11Apr 2010
1	To prepare trolley for setup	120	120	120	External			0	0	0
2	Take an Allan key	10	10	10	Internal			02	02	02
3	Rotate the fixture	30	30	30	Internal		Repeated activity	20	20	18
4	Remove the tie rod	25	20	22	Internal	SP1825 screw driver, Hexagon Wrench & automatic spanner		05	05	05
5	Remove the burrs with the help of Allan key	65	60	70	Internal	By compressed Air (Air run)	Repeated activity	05	05	06
6	Remove the fixtures bolts	40	35	38	Internal	SP1825 screw driver, Hexagon Wrench & automatic Spanner		15	15	17
7	Remove the previous fixture	200	206	209	Internal	SP1825 screw driver, Hexagon Wrench & automatic Spanner		45	47	47
8	Remove the burrs from fixture	35	30	28	Internal	By compressed Air (Air run)		05	07	07
9	Remove the insert rod of fixture	20	25	30	Internal	SP1825 screw driver, Hexagon Wrench & automatic Spanner		10	10	13
10	Clean the hole or remove the burrs from base plate	68	50	56	Internal	By compressed Air (Air run)		10	12	09
11	Take new fixture	10	10	10	External			05	05	05
12	Rotate the base plate	20	20	20	Internal			15	16	15
13	Clean the new fixture by compressed air	20	20	20	External	By compressed Air (Air run)		00	00	00
14	Clean the base plate	40	40	40	Internal	By compressed Air (Air run)		10	11	12
15	Take dial indicator with magnetic stand	0	10	10	External		Repeated activity	10	10	08
16	Fix & adjust the collector	65	60	58	Internal	By compressed Air (Air run)		30	32	29
17	Fix the new fixture	85	75	74	Internal	By compressed Air (Air run)		60	62	61
18	Fix the bolts of fixture	278	240	253	Internal	By compressed Air (Air run)		30	32	33

19	Rotate, tight & adjust the fixture	120	100	110	Internal	By compressed Air (Air run)		30	29	27
20	Fix the stand of dial indicator	10	10	10	Internal			12	10	11
21	Check the run-out of tie rod	100	100	100	Internal		Repeated activity	50	49	48
22	Rotate, tighten & adjust the fixtures bolts w.r.to run out	245	240	243	Internal	By compressed Air (Air run)		20	22	23
23	Remove the dial indicator	20	20	20	Internal			10	10	09
24	Fix the bottom bolts of fixture	20	25	27	Internal	SP1825 screw driver, Hexagon Wrench & automatic Spanner		10	10	12
25	Fix and adjust the height of tie rod	800	940	955	Internal	Design the fixed/ dedicated tie rod	Very Critical Activity	40	43	44
26	Fix the job & fix the cap	45	50	50	Internal			25	24	25
27	Set the M/c parameter	150	100	120	Internal		External activity	00	00	00
	Total time (sec)	2651	2636	2743				474	478	486
	Total time (Min)	45	44	46				7.9	7.96	8.1

As shown at the bottom of Table 2, the set up time was reduced to single minute. A further consideration with respect to set-up is the potential for error in the setting process. Hence, it is imperative to focus on reducing the amount of productive time and to eliminate errors.

V. Conclusions

In the present study, SMED methodology is applied to prepare an optimal standard procedure for changeover operations on defined machine. Ergonomics and safety issues were also taken into consideration during setup and simple but crucial changes were suggested. Further studies in the facility may include 5S and Kaizen for internal setup. It can be seen that SMED (in other words *Quick Changeover*) is still a suitable method not only for manufacturing improvement but also for equipment/ die design development.

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