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Changeover Time Reduction and Productivity Improvement by Integrating Conventional SMED Method with Implementation of MES for Better Production Planning and Control

S. Palanisamy[1*], Salman Siddiqui[2]

[1]Asst. Prof., Department of Automobile Engineering, SRM University,Chennai-603203,Tamil Nadu, India
[2]UG Scholar, Department of Automobile Engineering, SRM University,Chennai-603203,Tamil Nadu, India

Corresponding Author - *

Abstract: This paper addresses a setup time reduction through SMED with an integration of MES (planning system interface). Reduction of changeover time has always been critical in most of the manufacturing industries. Most of the changeover or setup time reduction are governed or associated with Shingo's Single Minute Exchange of Die(SMED) method that suggest the conversion of internal setup operations to external operations. SMED has been initiated by most of the companies but failed to implement it. The basic reason behind this is the strict application of SMED method which does not follow the systematic approach to implement this conversion and also it is not the best method to reduce the setup time in all the circumstances and situations. In this paper SMED integration with MES (which deals with Planning System Interface) is presented that has been developed specifically for an automotive supplier. The validation of the proposed method was done through implementation on manufacturing company which manufactures radiator, compressor and HVAC. The methodology used is SMED method with MES which deals with strategic definition and preparatory activities. It also includes communication which should be two ways so as the MES can keep the planning system properly informed about activities such as labour data, inventory changes, work order progress, project targets and timescale definition, selection of the appropriate team and coordinator, allocation of specific roles and responsibilities to each team member, training of team and shop floor staff on the new methodology and changeover standards. By implementing the SMED with MES improvement programme, the company achieved much reduction on changeover time which led to the increase in high productivity.

Keywords: Single Minute Exchange of Dies, Manufacturing Execution System, Planning System Interface, Heating Ventilating Air-Conditioner.

I. INTRODUCTION

The need for shorter changeover times has been increased from the last decade across all over industries. Now days, market demands have shifted towards more product variants in parallel to customization and this evolution is not limited to certain types of industry; rather it is a general phenomenon. Customers require short delivery times and a high delivery reliability. The best way to overcome this problem is to produce small lot size in most economic and efficient way. It can be easily shown that there is a direct relationship between lot sizes and setup times. The shorter the changeover time, the smaller the lot size; therefore, it can be produced in an efficient way.

A fundamental method to reduce set-up times, the SMED method, was proposed by Shingo (1985). In SMED method, all activities of setup operations can be divided into two categories: internal activities which are performed while the machine is Offline and therefore must be minimized because they decelerate the production, and external activities that are performed while the machine is running (Shingo, 1989). For many years, modifying the conventional SMED has received an extensive attention, and there are always arguments about the expected improvement obtained by improving activities within each implementation stage in order to focus the efforts to the implementation phase that produces the maximum improvement (Alves & Tenera, 2009; Kumaresan & Saman, 2011; Melton, 2005). Design modifications and proper scheduling of change over method are the most efficient way to reduce Setup time or change over time. Thus, in order to aid the process in implementing SMED, a new approach is proposed. The proposed approach is integration of SMED with MES based on Planning System Interface. To illustrate the implementation of our proposed perception (integrated SMED/MES) approach a detailed example at Radiator, HVAC, Hoses industry is presented, and then the powerfulness of the proposed approach is assessed by the percentage of reduction in setup time upon using the approach.

The principal contributions in this paper are as follows. First, a quantitative approach based on Planning System Interface (MES) that solves the problem of scheduling set-up activities on multiple Machines. MES also helps in balancing of workload amongst the available workers; concentrating any waiting time (or slack) for a worker as much as possible toward the end of the set-up process, and minimizing the movement of the workers across machines while they are performing the scheduled setup tasks and Second, in addition to minimizing the overall downtime of the multi-machine line, we also develop design modification of die and fixtures models for optimizing various secondary objectives in a multiple-objective pre-emptive fashion. This sequential optimization scheme is prompted by normal practical considerations in the present context. Finally methodology was implemented in AC Hoses manufacturing company.

II. LITERATURE REVIEW

Abraham and kailash Motwani (2012) indicated that a setup time reduction in the bottleneck BMS machine can be accomplished by applying SMED to stamping production line. Setup time of bottleneck machine was reduced by 75%, leading to a great improvement in the productivity. Kumar and Abuthakeer (2012) reduced the setup time in an automobile industry and demonstrated that the productivity can be enhancement by SMED implementation. The SMED method can be implemented in most of the industries, but it has been applied to manufacturing process, administration services, and assembly operations. McIntosh, Owen, Culley, and Mileham (2007) have proposed that the potential improvements in the changeover time can be done either by changing the sequence of activities without any variation in the way of performing tasks or by altering the existing activities to complete the task more rapidly. Most of the authors and researchers conveyed the benefits and saving by eliminating or reducing wastefulness and non added value tasks and activities using SMED method (Kumaresan & Saman, 2011). The expected impact of implementing lean tools including SMED on cost-time profile (CTP) and cost-time investment (CTI) have been discussed by Rivera and Chen (2007). Moreira and Pais (2010) experimented and found that implementation of SMED can save about 2% of the company's sales volume (360,000 €). Ulutas (2011) proposed that the safety of workers can be enhanced by applying SMED. Kušar, Berlec, Zˇefran, and Starbek (2010) reduced setup time to less than 10 minutes in a jet machine by applying SMED method. Deros et al. (2011) also implemented SMED method in an automotive battery assembly line and achieved reduction in setup time by 35%. Abraham, Ganapathi, and Kailash Motwani (2012) suggested that conventional SMED method can bring about a great reduction in setup time of the bottleneck machine to the stamping production line. The conventional SMED approach is suitable in systems that consist of only one machine and one person. Since most industrial systems have more than one machine with a team of operators, the effectiveness of the conventional SMED approach in its simple form is not enough. Thus, a modified approach known as Multi Machine Setup Reduction (MMSUR) has been developed to deal with these situations by Goubergen (2008). Deros et al. (2011) achieved more than 35% of the setup time reduction in an automotive battery assembly line by implementing the conventional SMED. It is implemented through four different phases (Shingo, 1985): The MES system bridges the gap between the plannng system and the controlling system using online information to manage the current application of manufacturing resources: people, equipment and inventory. It is the hub that collects and provides information and direction within the production activities. Pablo Guzman and Konstantinos Salonitis (2013) proposed that if focus is only on methodology, results can be poor and the same time by combining design modifications and methodology improvements, the outcomes can be acceptable.

III. PROPOSED METHODOLOGY

From the preceding section some research gaps are found to be objective of this work. For the improvement process, project should be cleft into four phases: critical, preliminary, application and regulation. Thus the four phases can be used to separate activities and allot the people to tasks, forcing the breakthrough to occur in an optimal sequence. SMED with MES methodology is under the implementation phase. The four stages model is inspired by McIntosh et al[3] overall methodology for changeover improvements.

A. *Critical Phase*

This phase is mainly governed by MES. For a changeover improvement project to be successful, a number of aspects have to be considered in advance for defining the appropriate strategy. To start with, the senior management rational for proposing a changeover improvement initiative in a specific area should be clear, as well as the level of improvement required (target) and the timescale [3]. Secondly, there is a need of project management to achieve the targets or goals defined. Thorough planning is needed explaining how the different activities are going to be organized, and setting deadlines for each task and these planning and tasks are done by MES based on Planning System Interface. The planning should also include how the progress is going to be monitored and controlled [11]. At this phase alternative options are also considered as whether they would be better than improvement initiatives for reducing changeover times, for instance to purchase new equipment[5]. Finally, for the optimum implementation of MES, reviews of literatures are undertaken for adopting best practices. MES is the two way communication system between the shop floor and production team. It gives the real time production data and enables the good communication among the shop floor and production team.

B. Preliminary Phase

Krajewski et al [11] mentioned the need of a project manager with the appropriate skills for driving the project during the timeline defined. Every project manager should play three roles in any project: facilitator, communicator and decision maker [11]. The selection of project team has to be made carefully. Team working is especially significant in such a project because a variety of people have to be involved [5]. Krajewski et al [11] suggest forming the team with people from different department across the organization. In a changeover process, the team should add people from the shop floor, maintenance, logistics, production engineering department and management. From the shop floor, the labours want to be choose carefully for the changeover process. Krajewski et al [11] Mentioned that technical knowledge with dedication to the work as the most important characteristics that every team members should poses. Belbin Roles [10] theory can be used as a benchmark to assemble the team and allocate roles and responsibilities to each member. By doing so, each member will independent and concentrated of their own work in order to finish the given task. Belbin proposes training the team and support the shop floor workers are the key factors to entire teamwork success. Goubergen et al. [1] proposes before directly practice the changeover activity all workers should undergo training. Team members, as well as shop floor staff should get training on the overall methodology for changeover improvement before any workshop session.

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C. Application Phase

Within the application phase, training sessions should be scheduled for implementing the SMED with MES methodology. These sessions should follow the five stages route and presented in fig 2[Pablo Guzman et al 2013].

D. Regulation phase

During this phase, the senior managers and the team leader need to be focused on factors affecting the changeover performance.

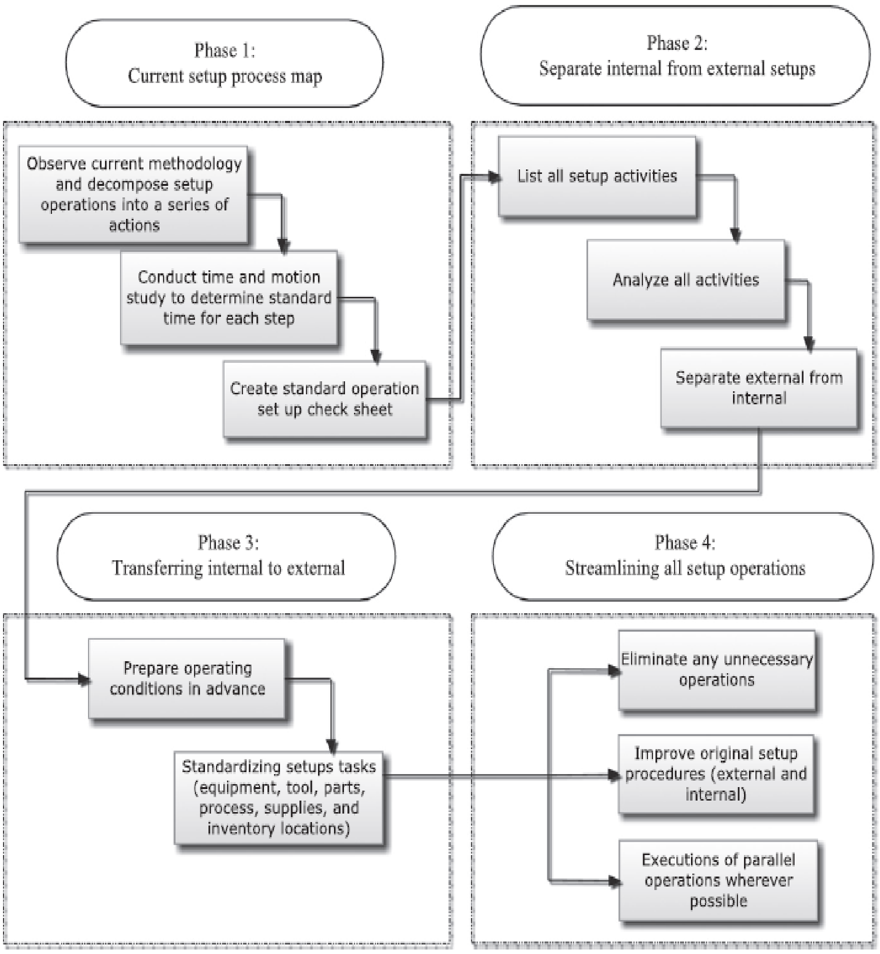

Fig. 1. Conventional SMED approach framework.
Courtesy - (Mohammed Ali Almomani et al, 2013)

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IV. CASE STUDY: DIE EXCHANGE IN CRIMPING OPERATION

The proposed SMED methodology is based on McIntosh et al [3]. It consists of five stages.

A. Stage 1: Planning Strategy

The MES should be directly coupled to the planning system to accept work orders and all other input and to provide upload information as necessary. The communications should be two ways so that the MES can keep the planning system properly informed about plant activities such as labour data, inventory changes, and work order progress. Other methods of data entry and reporting can easily be accommodated and in some cases, such as more continuous process, production orders may not be used at all.

1) Work Station: This part of the system is responsible for implementing the direction of the Work Order plan and the logical configuration of the Work Stations. The planning, scheduling, and loading of each operational Work Station is done here, providing the current and total shop load by operation using routing data and time standards. Based on this plan, the system will request and manage delivery of inventory, tooling, and data in response to the Bill of Material requirements and will issue and execute commands to move the required items to the planned WorkStation. The MES can and should include the direct control interface and connection with each WorkStation.

2) Material Movement: Another major area of MES system contribution is the movement of inventory or information to the needed location on the plant floor. This portion of the system controls material movement in the plant, in manual or automatic systems, by issuing requests for a manual move or issuing commands to material handling system control PLCs, conveyor systems, robots, etc. The commands can be as simple as “move this item from this location to that location.”

3) Data Collection: This part of the MES system is the eyes and ears for management and gathers information so the system can remain current. Through various kinds of sensing devices and control interfaces, data from the floor operations can be collected, collated, and dispersed on whatever basis is desired. This is the primary method for all personnel to communicate with the MES, either through information input/output by system operators or recognition of events electronically. Direct connections with PLCs to download and/or collect information are also part of this function area.

B. Stage 2: Recognize External and Internal process steps

Shingo [6] suggests that brain storming among the shop floor workers will give improvement ideas. During this stage, all activities have to be analysed based on whether they can be accomplished while the machine is running or not. These activities can be categorized using video recordings and routing diagrams.

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C. Stage 3: Separate External work and Internal Work

The main step after recognizing external and internal activities is to move the external work either at the beginning or the end of the changeover. This can be achieved by two ways. The external activities can be distributed among operators involved in changeover process by organization or this can be done by assigning all external activities to one specific worker. The major advantage is that it minimizes waste and transportations. The next task mainly concentrates on standardizing internal activities to distribute the task uniformly among the operators involved. The activities which have no value or importance can be directly eliminated. Proper training of workers play an important role in changeover process which results in good amount of changeover time reduction and also these workers should get the training of new methodology. One of the technique for guaranteeing that the each task has properly performed is to set checklist which checks each task performed either before changeover or after changeover.

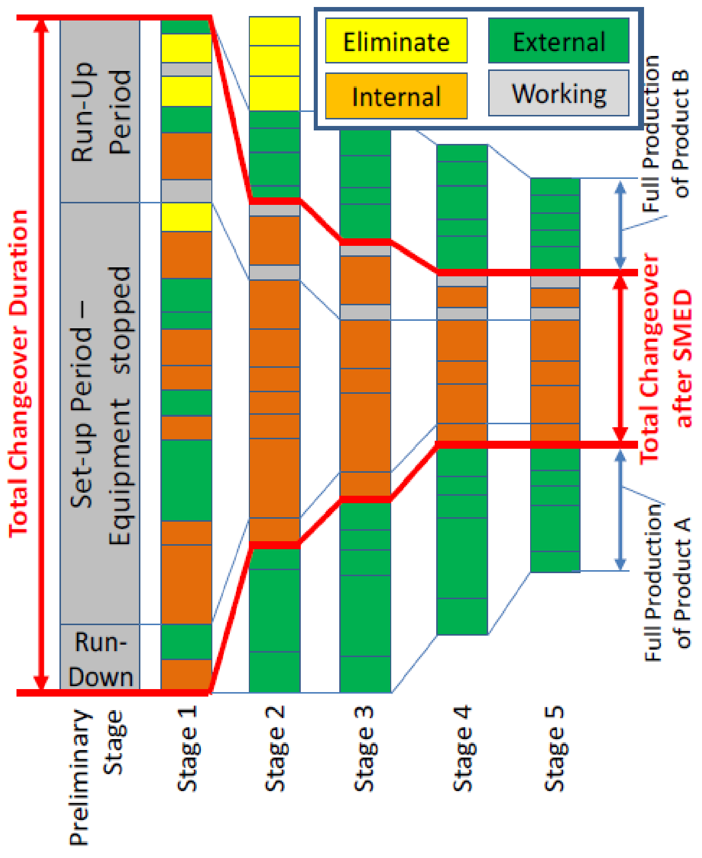

Fig 2 SMED method – Courtesy (Pablo Guzman Ferradas et al, 2013)

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D. Stage 4: Shift Internal Work to External Work.

This stage mainly deals with the improvement in the classification of activities i.e. Maximum works are converted into external work by research of all activities and design modifications which involves tool modification, tool standardization, magnetic fixtures, clamps, butterfly nuts etc. These are few techniques that reduce setup time to some extent.

E. Stage 5: Streamline all other activities

At this stage, both external and internal activities are optimized. Internal tasks are mainly optimized by technical efforts and solutions. Some of the ways to optimize the internal tasks given by Shingo are implementing parallel operations, use of magnetic clamps, increasing efficiency and accessibility of different machine components, modification of machine and tools to help on internal tasks. As these techniques are much time consuming and require high capital support hence each ideas has to be properly evaluated on the basis of reduction in changeover time and eliminate the ideas which are not effective. Reduction of internal time is more preferred than the external time because the reduction in external time does not affect the total changeover time reduction whereas the optimization of internal time brings about the total setup time reduction.

V. IMPLEMENTATION

The proposed SMED methodology was implemented in a Tier 1 Automotive supplier of AC Hose (Pipes). The method was implemented in the crimping machine and the study of changeover of each machine was done. Then the machine which had maximum changeover was chosen. This machine had the changeovers from 150 to 180 per month in average which led to the reduction of utilization of machine. Minimization in utilization of machine reduced the total efficiency of the machine. The time taken to changeover process before the application of proposed methodology was about 20 minutes with two workers which include one operator and one team leader or supervisor. Initially, engineers for improvement department proposed new solutions and ideas but this approach was proved to be partially successful. Then the MES proved to be very effective by providing real time production data which helped to schedule different types of AC hose models according to the current demand. As a result the number of changeover was effectively reduced. Now, once the proper scheduling is done then design modification of machine as well as of tool is done by the improvement engineers. The external and internal activities were recognized and separated. The whole task was divided among the operators by "Belbin Roles" Theory [10]. Proper training to each operator was given of new methodology and tools were organized near the machine. Material movement, waste management and different motions were properly controlled by routing diagram and planning system interface. A number of additional brainstorming sessions were decided for introducing design based modifications, streamlining and reducing the internal work and finally reducing the external work. The implementation of SMED method with MES was rather successful. Since a number of initiatives were implemented gradually, the changeover time at the end of the project was reduced.

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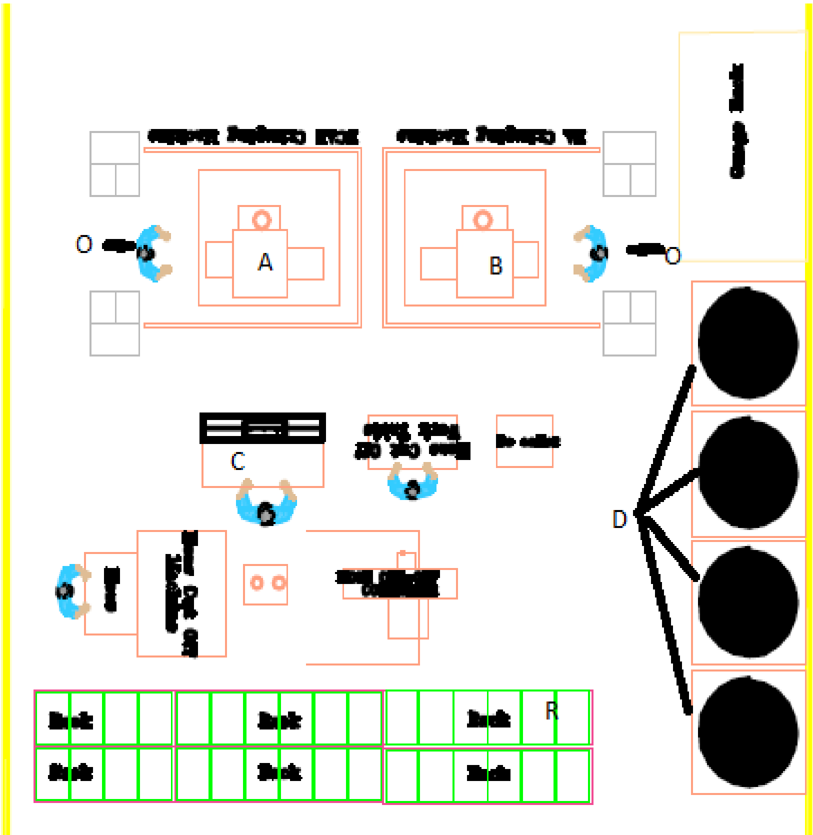

A & B – Crimping Machine   C- AC Hoses Assembly   D- Brazing Process

R- Racks for storing tools, dies, fixtures etc.

Fig 3. AC Hoses Layout

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Table I
Crimping tool setting details before implementing SMED method with MES

S. No.	Shift	Activity	Time Taken	Change over Description	Task Type
1	1	Alenkey	38 Sec	Alenkey brought from another Machine	Internal
2	1	Fixture	25 Sec	Left Side Fixture Removed	Internal
3	1	Ram	06 Sec	Ram Down	Internal
4	1	Bolt	85 Sec	Four Bolts Loosened	Internal
5	1	Ram	06 Sec	Machine Ram Up	Internal
6	1	Screw	12 Sec	Tool Bottom Screw Loosened	Internal
7	1	Tool	210 Sec	Old Tool to New Tool Replaced	Internal
8	1	Ram Slot	25 Sec	Tool Alignment for Ram Slot	Internal
9	1	Ram	08 Sec	Ram Down	Internal
10	1	Bolts	150 Sec	Four Bolts are Tightened	Internal
11	1	Screw	15 Sec	Tool bottom Screw Tightened	Internal
12	1	Ram	04 Sec	Ram Up	Internal
13	1	Fixture	36 Sec	New Fixtures taken from Location	Internal
14	1	Alenkey	25 Sec	Alenkey Searching	Internal
15	1	Fixture	08 Sec	Left Side Fixture Tightened	Internal
16	1	Fixture	54 Sec	Right Side old Fixture removed from new Tool	Internal
17	1	Fixture	80 Sec	Right Side New Fixture fixed in Tool	Internal
18	1	Fixture	35 Sec	Old Left and Right side Fixture placed in location	Internal
19	1	Hoses	46 Sec	Old Hoses replaced by New Hoses	Internal
20	1	Ferrule	25 Sec	Old Ferrule put in location and new ferrule brought	Internal
21	1	Suction Pipe A	67 Sec	Pipe A taken from Brazing Team	Internal
22	1	Suction Pipe B	98 Sec	Pipe B taken from Brazing Team	Internal
23	1	Crimp	115 Sec	Pipe crimped and Gauge checked	Internal
Total Time taken for tool Changing = 20.01 Min					

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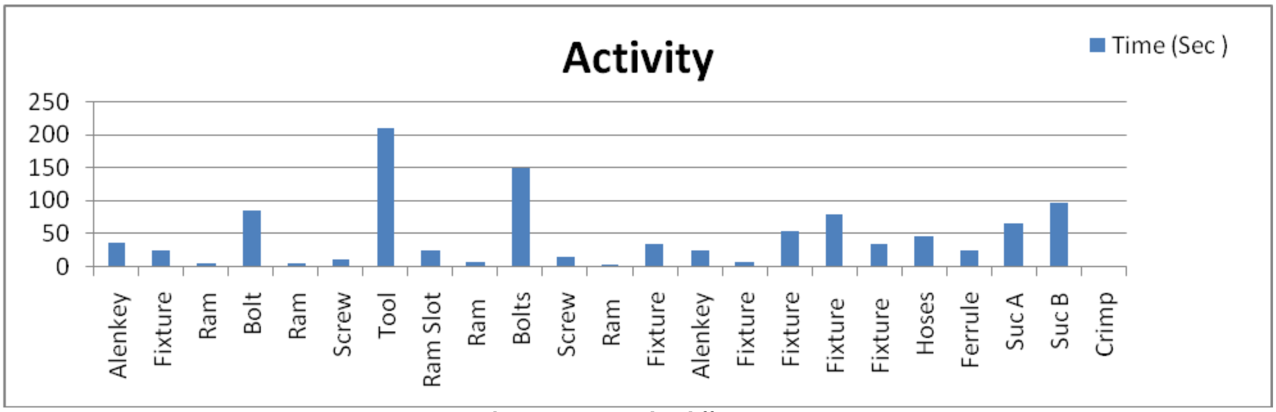

Fig 4 Showing time spend in different activities.

Table II

Crimping tool setting details after implementing SMED method

S. No.	Shift	Activity	Time Taken	Change over Description	Task Type
1	1	Alenkey	04 Sec	Alenkey taken from Shadow Board	Internal
2	1	Fixture	15 Sec	Left Side Fixture Removed	Internal
3	1	Ram	06 Sec	Ram Down	Internal
4	1	Bolt	55 Sec	Four Bolts Loosened	Internal
5	1	Ram	06 Sec	Machine Ram Up	Internal
6	1	Screw	08 Sec	Tool Bottom Screw Loosened	Internal
7	1	Tool	120 Sec	Old Tool to New Tool Replaced	Internal
8	1	Ram Slot	15 Sec	Tool Alignment for Ram Slot	Internal
9	1	Ram	08 Sec	Ram Down	Internal
10	1	Bolts	80 Sec	Four Bolts are Tightened	Internal
11	1	Screw	15 Sec	Tool bottom Screw Tightened	Internal
12	1	Ram	04 Sec	Ram Up	Internal
13	1	Fixture	30 Sec	New Fixtures taken from Location	**External**
14	1	Fixture	08 Sec	Left Side Fixture Tightened	Internal
15	1	Fixture	40 Sec	Right Side old Fixture removed from new Tool	**External**
16	1	Fixture	25 Sec	Right Side New Fixture fixed in Tool	**Internal**

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17	1	Fixture	32 Sec	Old Left and Right side Fixture placed in location	**External**
18	1	Hoses	35 Sec	Old Hoses replaced by New Hoses	**External**
19	1	Ferrule	25 Sec	Old Ferrule put in location and new ferrule brought	**External**
20	1	Suction Pipe A	54 Sec	Pipe A taken from Brazing Team	**External**
21	1	Suction Pipe B	71 Sec	Pipe B taken from Brazing Team	External
22	1	Crimp	90 Sec	Pipe crimped and Gauge checked	External
Total Internal Time taken for tool Changing = 06.15 Min					
Total External Time taken for tool Changing = 05.78 Min					

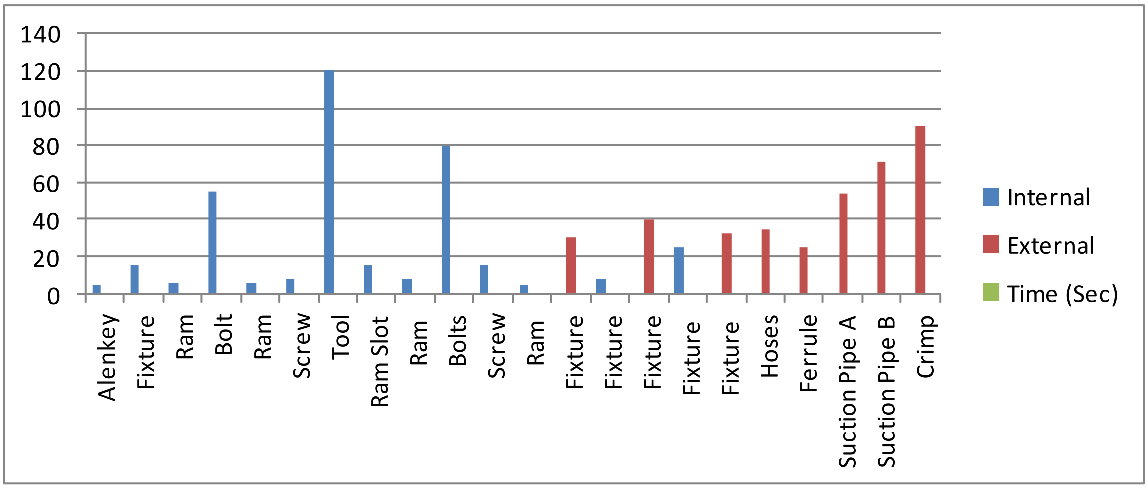

Fig V Showing reduction in change over time

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Table III

Representing productivity

Part Number	PartDescription	Total Productivity(Without implementation)	Total Productivity(With implementation)
28294-636	HOSE FLEXIBLE-PL(SUC)	178	220
28295-624	PIPE ASY RR COOLER-A	30	45
28295-628	PIPE-PIPE PL B(RR UNIT)	40	62
28295-629	PIPE-PIPE PL C(RR UNIT)	52	71
9244-01661R	LIQUID HOSE ASSY	255	290
9244-04579R	LIQUID PIPE ASSY	30	42
9248-03753R	SUCTION PIPE ASSY	260	300
9249-00643R	DISC HOSE ASSY	250	279
9249-03406R	DISC HOSE ASSY	128	148
F372-QQVDA-03	VISUAL	120	143
F374-QQ7AA-02	VISUAL	230	272
F374-QQABA-02	DIS HOSE ASSY K1.2	60	83
F374-QQDBA-01-03	HOSE DIS K1.2 GSL	350	389
F374-QQDCA-02-03	HOSE DIS U2 1.1 DSL	210	243
F375-QQ7AA-03	EPSILON SUC 1.1	80	108
F375-QQVMA-02	EMXI SUC RHD	20	32
F4A9-CBXAA-07-01	LCI - DISCHARGE ASSY EXPORT	71	89
F777-QQVMA-01	VISUAL	125	152
F839-MD9AA-03	INLET PIPE-COND	300	349

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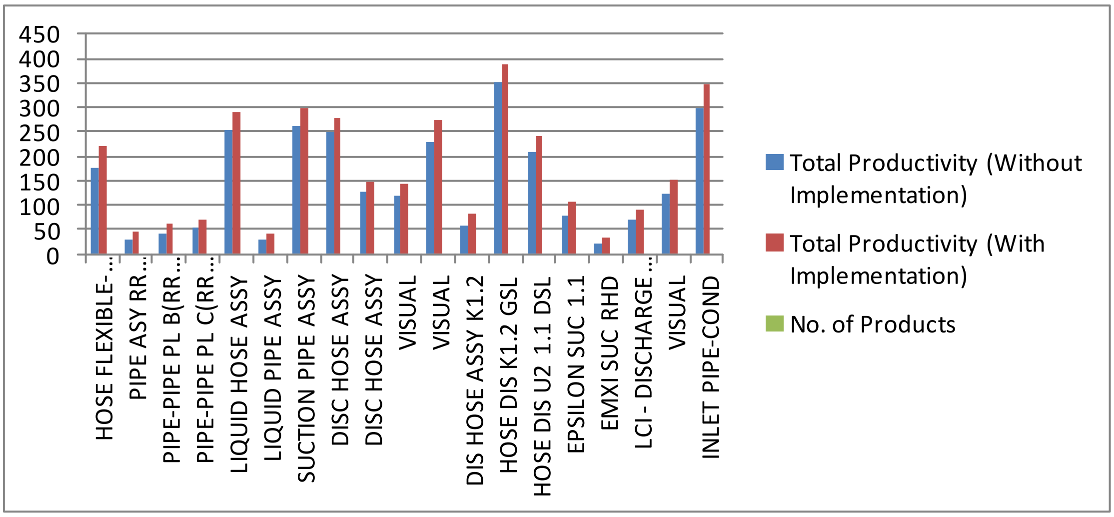

Fig 6 Showing increase in productivity

VI. CONCLUSION

In this paper, new approach for setup time reduction with MES is proposed to overcome the drawbacks of the conventional SMED and to increase its efficiency. MES techniques are effective methodologies in selecting the best setup technology among the available alternatives as well as it takes into consideration other factors including: design modification, planning, data collection, material movement and maintenance. The proposed approach provides a systematic procedure for selecting the best setup technique among the available alternatives. Integrated SMED/MES approach represents a useful modification to the Shingo' approach with systematic procedure for selecting the best setup planning and technology. The results illustrate the benefits of implementing the proposed approach that include reducing setup time considerably, increasing machine utilization, and improving productivity. After implementing the methodology the changeover time of crimping process was reduced by 69% which resulted in increase of production by 18.86%. Belbin Roles allocation proved to be very significant. It facilitated the involvement of people from different departments across the organization.

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BIOGRAPHY

The co-author, S.Palanisamy is currently working as Assistant Professor in the Department of Automobile Engineering at SRM University, Chennai since 2011. He received his B.Tech degree in Automobile Engineering from Anna University Trichy, his ME degree in Production Engineering from Thiagarajar College of Engineering, Madurai. He has published several papers in International conferences and seminars. He is a member of ISCA and POMS. His area of research includes Production planning and control, Supply chain management.

Salman Siddiqui, the author is currently an Under Graduate student pursuing his engineering in Automobile branch from SRM University. He is involved in research and industrial consultancy project. He has attended several national and international conferences and seminars. He is persistent person good at analytical and problem solving skills who keep himself up to date with new developments and regulations. . His area of interest is Production Planning and Control and Supply Chain Management.