SETUP TIME REDUCTION OF MACHINE USING SMED TECHNIQUE AND LEAN MANUFACTURING

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Abstract— Growth of an industry and its productivity ultimately depends on its ability to systematically and continuously respond to the market changes for enhancing the product value. Value addition process is necessary to achieve this perfection; hence implementing a lean manufacturing system and its tools is becoming a core competency. Since setup time is a major cause for production downtime, minimum setup time is always desirable. Single Minute Exchange of Dies (SMED) as proposed by Shingo is a tool which aims to reduce excessive setup time, but not effective when used alone. SMED can be effectively implemented with the help of additional tools like ECRS (Eliminate, Combine, Reduce and Simplify). This paper presents a procedure for organizing and implementing SMED along with other useful tools. It is based on teamwork which allows a gradual reduction of machine setup time to less than 10 minutes accompanied by continuous improvement system. This paper also presents the case study of bearing manufacturing industry suggesting improvements that will significantly reduce machine setup time by 30%-35%. The methodology explained is this paper is applicable to most of the batch manufacturing industries.

INDEX TERM- GRINDING MACHINE, PARETO, SETUP TIME, SMED

I. INTRODUCTION

"One of the most noteworthy accomplishments in keeping the price of products low is the gradual shortening of the production cycle. The longer an article is in the process of manufacture and the more it is moved about, the greater is its ultimate cost."- Henry Ford 1926. In an industry, time is money. The product cycle time directly reflects in cost. Due to flexibility in market demand and competitiveness, many manufacturers are opting to reduce machine setup time and down time. Machine setup is to be changed according to customer requirements. Set up time is the time passed between the completion of the last product of the old batch and the completion of the first good product of the new batch. There is always a need to change set up of equipment, unfortunately with the production loss accompanied with it. In the past two decades, setup time reduction and quality improvement programs have become prevalent in manufacturing industry. These programs had contributed towards higher efficiency and agility needed by manufacturers. At present manufacturers must be able to manufacture a wide variety of high quality products in a cost-effective manner with reduced inventories and respond quickly to changes in the product volumes in order to sustain in the market. [1], [2]

One of the significant losses is equipment setup or a tooling changeover. The principles pioneered by Shigeo Shingo, known as SMED or Single Minute Exchange of Dies, can be used to dramatically reduce this time. Also known as "quick changeover," or "rapid changeover", this method can be applied any time equipment is "changed" from one physical state to another. This may include tool changes, material changes, or changing to a different product or configuration. [3]

Fig. 1 shows the relations between setup time and costs with three strategies. It can be seen that a reduction of setup time using the SMED method is cheaper, but reduction in time achieved is not significant. Replacing an existing machine is most effective strategy, unfortunately cost associated with it is higher and generally industries are reluctant for such a change. So optimum solution is to use SMED along with other tools and some improvements in the existing design of machine. [4]

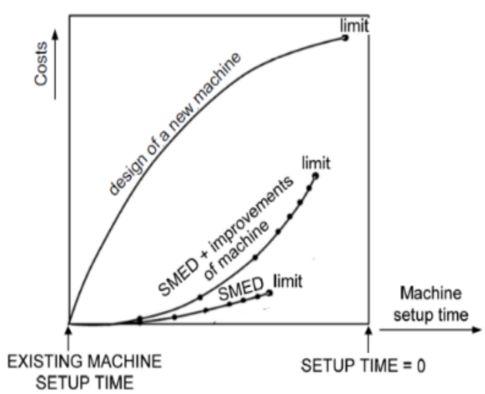

Fig-1.Dependency between machine set up time and cost(4).

II. LITERATUE REVIEW

SMED is one of the most effective method in lean manufacturing to reduce waste. [5] The father of scientific management, Winslow Taylor from United States, were studying methods for reduction of changeover techniques. He analysed setup process, but did not specify a structured approach. In 1915 Henry Ford described the various setup reduction techniques, but were not satisfactory. Then finally the concept was put forth by Shigeo Shingo in 1950 while consulting variety of companies including Toyota and was contemplating their inability to eliminate bottlenecks at car body-moulding presses. Ohno at Toyota further developed SMED in 1950 so as to reduce the time for exchange of dies, from a day to three minutes. Hence the main principle, to reduce setup time to single digit minute, was achieved. [6]

III. ORGNIZATION AND EXECUTION OF SMED TECHNIQUE

First step in execution of SMED is formation of SMED team. It should include all personnel involved in the process, from operators to managers. To start with a workshop, the process is to be understood thoroughly from operators and supervisors. This helps in identifying and categorising the activities according to their priorities.

STEP I: PRIORITIZE MACHINES

The selection of machine is done by consideration of factors such as setup time, frequency of setup, bottleneck machines, efficiency loss, and complexity of operation and on the basis of ABC analysis. In materials management, the ABC analysis (or Selective Inventory Control) is an inventory categorization technique. ABC analysis divides an inventory into three categories- "A items" with very tight control and accurate records, "B items" with less tightly controlled and good records, and "C items" with the simplest controls possible and minimal records. [4]

STEP II: DOCUMENTATION OF MACHINE TOOLS AND PROCESSES

SMED team must have thorough knowledge of machine and process. The current process data and working methodology is collected from machines' operators, line supervisors and managers. Plenty of tools and components have to be replaced during machine setup which is a complex activity in batch manufacturing. So as to simplify the analytical data, check sheets are designed according to specification of product. It will help in finding the tools and parts in short time and hence ultimately reducing the overall setup time.

STEP III: TIME AND MOTION STUDY

Time and motion study is a work measurement and business efficiency technique for recording the times of performing a certain specific job or its elements carried out under specified conditions. For analyzing the data so as to obtain the time necessary for an operator to carry it out at a defined rate of performance. [7]

Purpose of time and motion study:

1. To eliminate unnecessary motions
2. Identify the best sequence for maximum efficiency
3. Standardization of work

STEP IV: DESCRIBE STEPS IN DETAIL WITH TIME FOR EACH

From Time and Motion Study all processes are to be divided in sub processes, with the time required for the same. It will provide a base for initial prioritizing of activities which will ultimately decide the workflow.

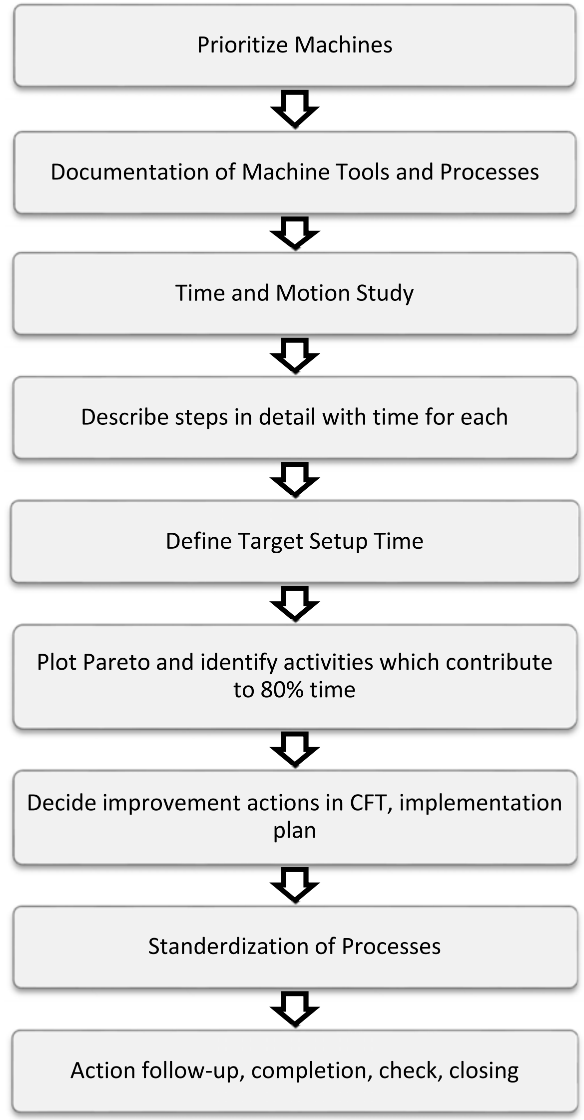

Fig. 2. Steps in organization and execution of SMED workshop

STEP V: DEFINE TARGET SETUP TIME

The motivation of team members gets influenced by the definition of target setup time. It should be optimum and practical to achieve, otherwise it will demotivate the team members. It is generally taken as 20% to 30% less than the current setup time. [3]

STEP VI: PLOT PARETO AND IDENTIFY ACTIVITIES WHICH CONTRIBUTE TO 80% TIME

Pareto analysis is a formal technique useful where many possible courses of action are competing for attention. In essence, the problem-solver estimates the benefit delivered by each action, then selects a number of the most effective actions that deliver a total benefit reasonably close to the maximal possible one. Basically it helps in prioritising the activities. [6]

STEP VII: DECIDE IMPROVEMENT ACTIONS IN CFT, IMPLEMENTATION PLAN

Cross Functional Team (CFT): A cross-functional team is a small group of individuals that cross formal departmental boundaries and levels of hierarchy. The group is committed to a common purpose or goal of improvement; it acts and works as a unit-communicating frequently, cooperating and providing mutual support, coordinating activities, drawing upon and exploiting the skills and capabilities of the team while considering the needs of individual members.

CFT will decide the plan for improvement on the basis of prioritization of activities which is done by considering factors such as complexity and frequency of operation.

STEP VIII: STANDARDIZATION

Developing standardized work is the first step in waste elimination. The analytical process will reveal waste that should be eliminated for developing the standardized work. Operators should be encouraged to suggest changes that will improve the process and be reflected in revisions to the standardized work. [3]

STEP IX: ACTION FOLLOW-UP, COMPLETION, CHECK, CLOSING

When standard work is developed and with skilled manpower, regular audits are needed to check on whether the standards are being followed, and if not, why. But this is continuous and time consuming process as regular assessment is necessary. [3]

IV. CASE STUDY

Case study is carried out on bore grinding machine at bearing manufacturing industry. This Machine is used for bore grinding of inner ring (IR) of taper roller bearing (TRB). Frequency of setup is high because of batch production. SMED technique and ECRS principle are used to reduce machine setup time.

I. Prioritize Machines

Main criteria for machine selection is frequency of setup. Also bottleneck and average setup changeover time obtained from previous data is considered. Hence 1st bottleneck machine i.e. IR bore grinding machine is selected.

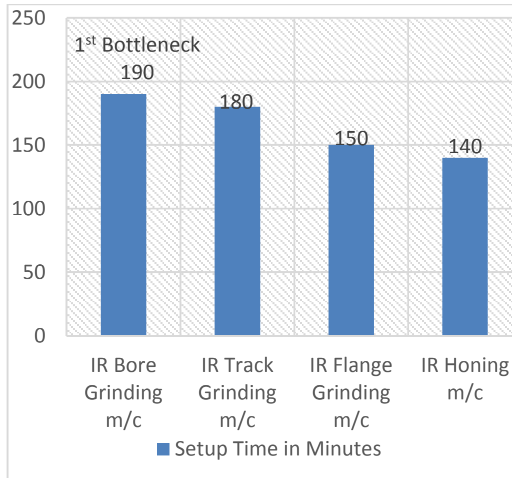

Fig. 3. Average Setup Time for Machines

Table I. Check Sheet Format

BEARING TYPE	COLUMN 1651721	SUPPORT FOR CROSS BAR 1651724	SIDE CYL FLANGE 1651725	MANDREL FOR ROLLER 1651741	BAR 1651742	GIRDER BEAM 1651743	TOP FLANGE 1651744	MEDIUM FLANGE 1651745
QTY	2	1	2	1	2	2	1	1
30207	10	15	11	15	15	15	1	1
30208	14	16	15	16	15	16	1	1
30209	8	9	9	9	9	9	1	1
30306	2	17	2	17	17	17	1	1
02872/02320	8	21	9	22	22	21	1	1
344/332	7	29	8	32	30	29	1	1
LM 603049	12	13	13	13	13	13	1	1
25577/25523	13	18	14	18	18	18	1	1
25590	13	18	14	20	20	18	1	1
32911	29	43	32	49	44	44	1	1
M 88048/Q	12	47	13	54	48	49	1	1
BT1-0381	26	38	28	42	39	38	1	1
32207	7	8	8	8	8	8	1	1
33110	17	40	18	46	41	41	1	1
2789/2729	7	30	8	33	31	30	1	1
25877	13	14	14	14	14	14	1	1
25572	13	18	14	35	18	18	1	1
4181Q	9	10	10	10	10	10	1	1
33010	1663521-13	51	1663525-5	1663541-14	1663541-14	53	1663544	1663545
31594	1663521-2	23	1663525-5	1663541-2	1663541-2	23	1663544	1663545

II. Documentation of Machine Tools and Processes:

Data collection is done with the help of operators, supervisors and managers. It includes listing down all components which are to be replaced and required tooling. Each process is to be defined separately and divided in small sub processes if possible. This will help in implementing ECRS principle and prioritizing activities at later stage. To reduce the complexity in analysis, special types of check sheets are formed which is shown in table I.

III. Video Shooting of Setup Changeover Activities:

Video shooting and analysis is one of the effective methods of Time and Motion study. With very little knowledge also one can understand the procedure of changeover which is essential.

IV. Describe Steps in detail with time for each:

Video Analysis involves reviewing recorded setup process and simultaneously defining each sub process. These activities are classified into internal (done when machine is offline) and external (performed as the machine is running) activities [8]. Critical and lengthy activities are further subdivided into simpler ones. Then the time required for each process is mentioned as shown in table II. (a), (b) and table III.

V. Define Target Setup Time:

After getting an idea about the current procedure and total time required for individual activity, the target setup time is defined. It should be optimum i.e. not too low and not too high. Very low setup time makes team members feel that it is impossible to achieve. On the other hand, very lesser reduction in setup time will not improve the productivity substantially.

There is no standard procedure to define the target setup time. It will be variable depending upon activities and their complexity. After brainstorming session between all the team members, 30%-35% reduction in current setup time is targeted.

VI. Plot Pareto and Identify activities which contributes to 80% time:

The basic principle of Pareto analysis is 80% activities consumes 20% time and 20% activities consumes 80% time. The Pareto chart for internal and external activities is shown in fig. 4 and fig. 5 respectively.

VII. Decide improvement actions in CFT, implementation plan:

Cross Functional Team (CFT) will form action plan for setup time reduction. For internal as well as external activities ECRS (Eliminate, Combine, Rearrange & simplify) principle is applied. Refer remarks in table II. (a) and II. (b).

VIII. Standardization:

Standardization is mostly applicable to external activities e.g. Shoe Setting, Ring Chucking which consumes more time than internal activities. It also includes defining standardization of procedures (SOP) for driving plate rework, shoe setting. SOP made the rework process simpler from supplier point of view which ensures specifications as per the requirement.

Table II. (a). Internal Activity Analysis

Machine : Bore Grinding Machine				
#	Step	Time in secs	Cum time	Remark
1	Take m/c in man mode, Stop wheel and open covers			
2	Remove clamping unit	86	01:26	One quick release connector difficult to open
3	Remove two inlet chute sensors	49	02:15	
4	Remove connections for shoe coolant, ring loader pneumatic pipe & sensors, main coolant pipe, megar	105	04:00	One quick release connector of ring loading cylinder diffcult to open, main coolant pipe slightly difficult to open, sometimes during resetting it founds broken
5	Attach overhead chuck lifter	20	04:20	
6	Remove 3 bolts of chuck	73	05:33	
7	Remove chuck from machine (keep it hang)	11	05:44	
8	Remove grinding wheel from machine	253	09:57	Nut runner used, searched for nut runner and socket near machine for 25 secs, few bolts not getting removed by nut runner, used pipe and allen key and wheel locking arrangement
9	Put old type wheel in rack, bring next type wheel	33	10:30	Video was paused, time is more than 240 secs, for searching and identifying wheel
10	Remove dresser rotation sensor	15	10:45	
11	Remove dresser spindle locking and top cover & dresser by loosening all dresser clamping screws	327	16:12	Dresser spindle locking nut removed by screw driver and mallet, activity until keeping dresser and screws in box
12	Mount next type diamond dresser, top cover and clamping screw	750	28:42	Taking diam. Roll from trolley which was at SFP, applying oil to spindle and diamond roll bore, matching screw hole takes time, also sometimes it is found that screw is missing or it is o/s or u/s in length, sometimes dresser spindle comes out of pulley and downtime increases
13	Remove old type chuck from chuck lifter, remove shoe colant pipe & put on table	170	31:32	Searchin of hydraulic lift takes time, generally it is away, also hyd lift pumping time
14	Taking chuck on chuck table, replacing with new one and bring new chuck on machine	65	32:37	Shooting paused during replacement of chuck on chuck buffer table
15	Remove old type driving plate, put new type driving plate	180	35:37	For this shooting, the driving plate is same for both types, so not replaced
	Lap driving plate it till r/o >1 micron			
16	Mount next type chuck on machine	245	39:42	Chucl lifter hook attaching problem, in between shooting paused
17	Attach ring loader sensor and pneumatic connections, megar connection and shoe coolant pipe and conn.	240	43:42	Chances of reverse connection of ring loader sensor, main coolant pipe difficult to attach
18	Attach inlet chute connection and trial for ring stuck	70	44:52	
19	Inlet chute sensors fitting & trial	60	45:52	
20	Chuck adjustment for shoe and ring shifting	110	47:42	Shoe disturbed and set again manually
21	New type wheel mounting & tightening	410	54:32	Finding suitable length allen head bolt from trolley or searching, bolt tightened and again removed as length was more
22	Tight dresser screws and adjust dresser for centering with spacer, taking backing off for dresser	440	61:52	Adjusting centering with lock nut, non standard arrangement for lock nut tightening, maual checking of spacer face match with dresser face
23	Attaching dresser rotation sensor	50	62:42	
24	Dressing wheel	-		Video shooting paused during dressing, dressing time less as old wheel with same form used
25	Setting wheel on ring with centering	280	67:22	Loosening slide and adjusting centering is difficult & back side, operator needs to frequently come front & go back for repeated adjustments

Table II. (b). Internal Activity Analysis

26	Mounting clamping unit and checking for ring shifting & clamping	140	69:42	Ready clampin unit giving activity started newly to avoid clamping plate removal and tightening time
27	Taking backing off for ring	70	70:52	
28	Making small adjustment for slide & parameter entry as per setup chart	110	72:42	Gnerally operator enters data as per his judgement
29	Closing machine guards and 1st ring grinding, inspecting first ring with appratus master ring setting	200	76:02	
30	Adjstment for anagle and centering	75	77:17	Only angle adjustment done once, sometimes backing off needs to be done again
31	Grinding 2nd ring and inspecting on apparatus	41	77:58	
32	Inspection of ring in quality room			Video paused during this step
33	Minor adjustment for centering and angle			Video shooting stopped
34	Grinding 3rd ring and inspection on apparatus			
35	Inspection of ring in quality room			

Table III. External Activity Analysis

Sr. No.	Activity	Setup Time Before implementation of SMED (min)	Setup Time After implementation of SMED (min)
1	Ring checking (Shoe Setting) i. DK Chucking ii. Track Chucking	28	19
2	Driving plate lapping	10	5
3	Dresser spindle adjustment	37	23
4	Driving plate face matching	15	10
5	Tool Search	10	3
6	Idle Time	5	2
	Total Time	105	62

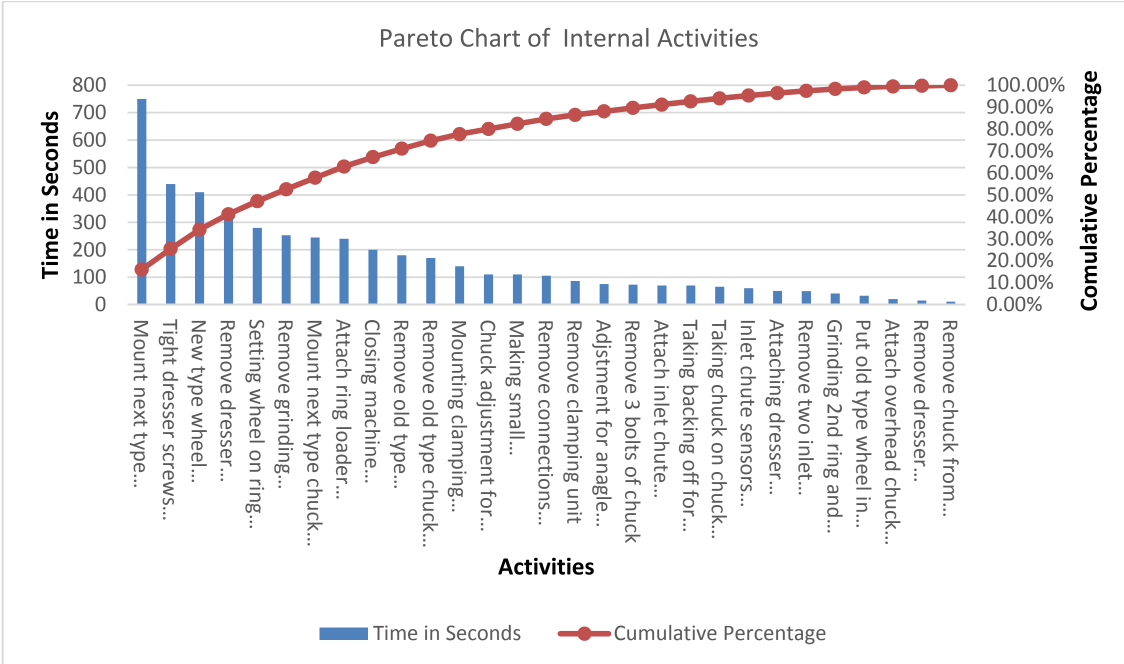

Fig. 4. Pareto chart of internal activities of bore grinding machine

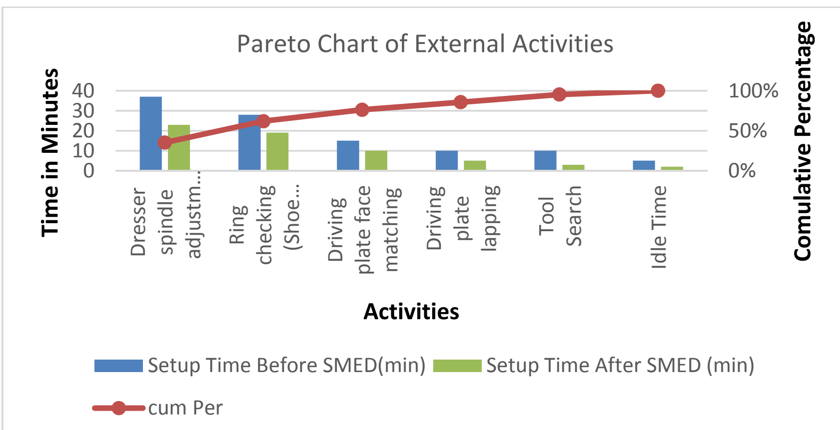

Fig. 5. Pareto chart of External activities of bore grinding machine

IX. Action Follow-Up, Completion, Check, Closing:

Whether the action plan is executed or not is to be verified by taking feedback from operators and changeover department.

The time for internal activities is reduced from 78 minutes to 60 minutes. For external activities, time is reduced from 105 minutes to 62 minutes. Therefore total time is reduced from 183 minutes to 122 minutes i.e. about 33% reduction in previous setup time as shown in fig. 6.

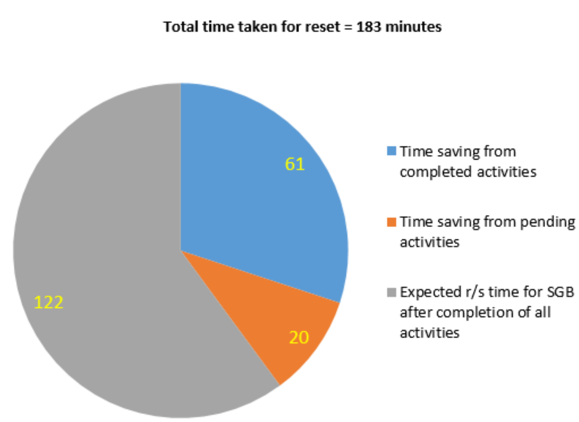

Fig. 6. Result of SMED execution

V. Conclusion

New approach for setup time reduction is proposed for effective utilization of SMED by combining it with tools of lean manufacturing like ECRS. The results illustrate that 33% setup changeover time reduction can be achieved with above methodology

VI. References

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