Enhancing Plant Capacity Through Implementation of SMED in SME – A Case Study

R. Duraisamy*[1], C. Dhanasekaran[2], P.R. Ramakrishnan[3],Pugazhenthi. R[4]

[81] Research Scholar, VISTAS, Chennai, India
[2] Professor, Department of Mechanical Engineering, VISTAS, Chennai, India
[3] Professor & Dean - School of Management & Commerce, VISTAS, Chennai, India
[4] Associate Professor, Department of Mechanical Engineering, VISTAS, Chennai, India

Abstract

To survive and grow in the stiff competitive environment, every organization needs to adapt the best manufacturing practices. As the body of knowledge(bok) expands, conventional wisdom needs to be improvised with some innovative add-Ons. "Winners don't do different things, they do things differently'-(Shiv Khera)Many manufacturing lines may need to run multiple products in the same production line by making change in setting of machinery. The time spent for changeover from product A to Product B is the CHANGEOVER TIME and eventually, this is a Non-Production Time. During this machine waiting time, organizations other resources like Men, Materials etc are all waiting. This paper shares a real case study of enhancing the plant capacity by reducing the set changeover time through application of new tools along with Single-Minute Exchange Die (SMED) method. This case study was done in a SME (Small & Medium Enterprises) of Machining Industry. Substantial improvement obtained both in terms of tangible and intangible.

Keywords: Lean Manufacturing, 7 Wastes, Over Production, Large Batch Quantities,Single-Minute Exchange of Dies (SMED), sequencing, 5S, Visual Management

1. INTRODUCTION

Wastes in manufacturing environment are classified in to 7 Categories which are called as 7 Wastes. These are Transportation, Inventory, Motion, Waiting, Over Production, Over Processing and Defect (TIMWOOD). Among the 7 wastes, "Overproduction" is a deadliest waste, since this will result in other 6 types of wastes.

Over Production is producing "additional quantities than that day's customer need". The major cause for "Overproduction" is "larger batch quantities" which is due to Longer Setup times. There is plenty of body of knowledge (bok) regarding Economic Batch Quantity (EBQ). But in Toyota's parlance, EBQ is one. If suppose, an organization could reduce the changeover time to single digit minute, or to few seconds, that is the level of flexibility, the organization can have to meet the customer's varying needs. Taking clue from pit stops, now the machine changeover times are close to Zero Minute Exchange of Dies (ZMED).

Hence this case study is regarding implementation of SMED to reduce the Set up Change over Time, to minimize the batch quantities, eliminating "Over Production Waste" and there by improving the Overall Plant capacity. The terms "changeover" and "setup" has been used interchangeably by many. Generally, setup time is the time required for preparing the necessary resources to perform a task. It also refers to the time elapsed between producing the last good part of the first lot and the first good part of the next lot.

2. LITERATURE REVIEW:

[Rosmaini Ahmad et al (2018)]demonstrated SMED with other support tools for analysis. They have done the improvement in trimming operation at a composite industry.[Marcello Bragliaet al] integrated 5-Whys Analysis along with SMED and also traced the upstream processes.[Semra Boran] presented the integration of Taguchi method and ergonomic risks of worker in performing the Setup process.[Jonathan David Morales Méndez et al] discussed the method adopted in carrying out SMED improvement in axle manufacturing.

[Rodrigo Borges Ribeiro et al] quantitatively evaluated the benefits of SMED with little investment, making greater improvements.[Dror Hermel et al] evolved accurate estimation of set up change time using minimal path approach.[J.Lozano et al] proposed a model for measuring SMED results using MTBF and MTTR. [Mehmet Cakmakci et al] stressed the importance of sustainability of improvements. They integrated MTM with SMED.[M.Kemal Karasu et al]presented fuzzy inference system (FIS) to reduce the for parameter adjustments in plastic injection molding process. This also helps in reducing dependence of set up expert.

[Biman Das et al] investigated the Lean improvement carried out in air conditioner manufacturing expander machine by use of VSM, SMED and Kaizen. They stressed the importance of top management support and training for employees for successful implementation.[Shivneri Deshmukh et al] carried out review of literatures on SMED implementation along with other tools.[Alexandre Silva et al] analyzed the set up methods and established procedures for effective implementation of setup change. They compared the methodology in two cutting lines.

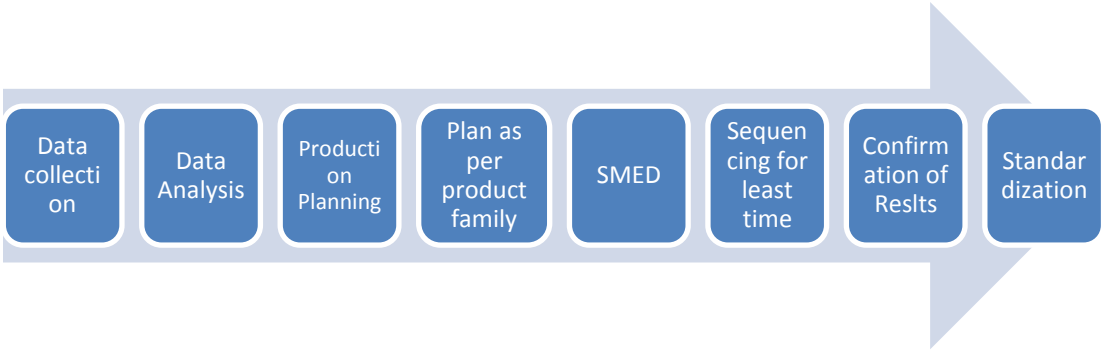
[Deepak Maurya et al] carried out the set up changeover in chassis press shop.[D.Kumaravel et al] carried out an improvement project for set up time reduction in a steering pump manufacturing industry. They have used Flow process diagrams to depict the practical observation.[Mohammed Viqar et al] implemented SMED to reduce setup time in Gear Hobbing machine.[Rushikesh Gavali et al] demonstrated a case study of Lean and SMED in forging industry

[António Carrizo Moreira et al] introduced SMED project which yielded substantial cost saving to the organization. They have shown how the internal and external setup times are staked by using Yamazumi chart.[Mohd Norzaimi bin Che Ani et al]focused implementing SMED in a CNC Machine.

3. RESEARCH GAPS

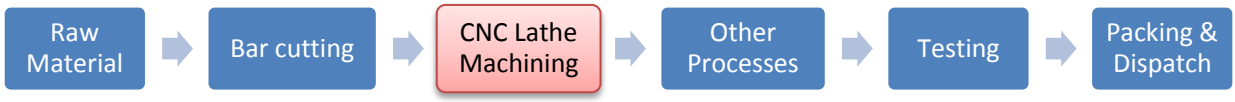
In the literatures surveyed, the conventional SMED method is used and in few cases other support tools were also used. There existing a gap in addressing the Scientific method of Production Sequencing to minimize the overall downtime due to changeover, in least time path of model changeover. This case study implementation made an effort to create a least time path.

4. METHODOLOGY ADAPTED:



5. BASELINE STUDY, DATA COLLECTION:

Manufacturing Process Flow:



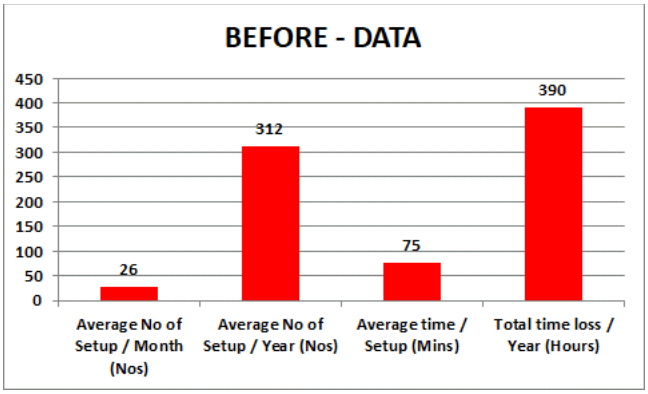
Variety of Products:

There are 2 Major shape of products produced in the plant, which are Roundand Hexagonal. There are many Varieties in each of the shapes.

For the purpose of easily and pictorially understanding the case, the below table is an illustrative example of the products like Round (R1, R2, R3, …Rn) and Hexagonal (H1, H2, H3,…..Hn)

SHAPE	SIZE 1	SIZE 2	SIZE 3	SIZE n
ROUND	R1	R2	R3	Rn
HEXAGONAL	H1	H2	H3	Hn

Data of Average number of changeovers and Total Time loss per Year



Data on changeover timing between various models.

DIAGONAL MATRIX - SETUP TIME (in Minutes) - BEFORE

PRODUCTS	R1	R2	R3	H1	H2	H3
R1	NA	45	60	80	90	90
R2		NA	50	90	70	80
R3			NA	70	80	75
H1				NA	40	50
H2					NA	45
H3						NA

6. ANALYSIS OF DATA:

After data collection, detailed analysis were done on different perspective

Total setup time for the month (C) = Number of Changes per month (A) x Time per changeover (B)

Analyzing Number of changes per month (A):

While studying the sequences of changeovers took place, it was found the on many occasions the changeover was done in a random manner, that too between across the shapes (Round – Hexgon – Round)

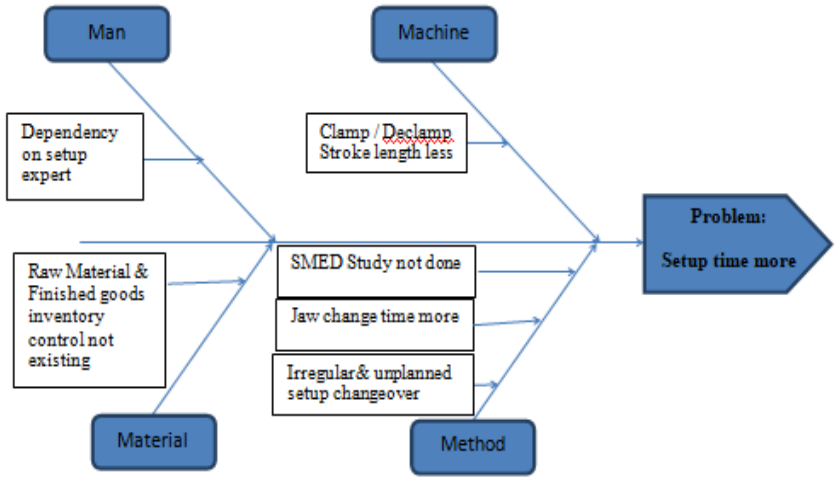
i. Setups were happening on an unplanned, random manner
   a. Shortage of raw material
   b. Dispatch urgency
   c. Customer plan change
   d. FG safety stock not maintained
ii. Necessary tools were not ready before start of changeover
iii. Only skilled setup workman was able to set. Hence setups were revolving around the availability of setup expert. Hence all the set ups were done in day shift irrespective of the completion of the planned batch quantity.

Analyzing Time per changeover (B):

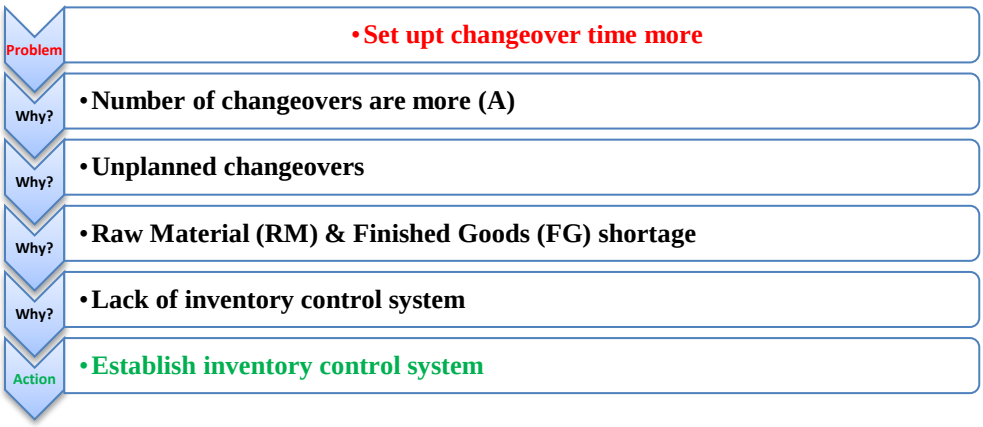
iv. Set up time more
   a. SMED improvements were never done before systematically
   b. Jaw boring was done to make Jaw alignment. Jaw boring frequency was more

With the detail gathered from analysis and observation, a Cause and Effect Diagram was constructed with "Set up time more as Effect (Problem) and Man, Machine, Material & Method as Categories of Causes.

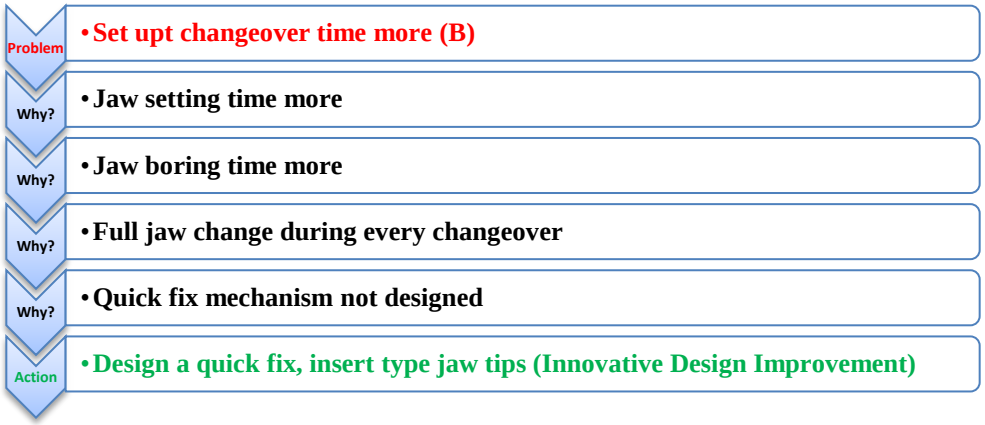
Cause & Effect Diagram (or) Fish-bone Diagram (or) Ishikawa Diagram



Why? - Why? Analysis for More Number of changeovers (A):



Why? - Why? Analysis for More time during every changeover (B):



7. SELECTION OF APROPRIATE TOOLS & TECHNIQUES (T&T):

1. Cause and Effect Diagram
2. Why-Why analysis to find the root cause
3. Scientific inventory management of Raw Material and Finished Goods
4. Systematic production planning
5. Sequencing for shorter setup times
6. SMED
7. Innovative design in Jaw inserts

8. DETAIL OF IMPROVEMENTS CARRIED OUT:

GIST:

Sl No	Causes	Solution
1	Customer was not providing firm and forecast of schedules	Customer started providing firm and tentative schedules
2	RM Supplier were not supplying on-time leading to stock out situations	Supplier has been provided with ROL & ROQ information and has been asked to maintain one PULL stock always ready with him
3	RM, FG inventories not maintained	Introduced Scientific inventory management system
4	Overall set up time more –on the machine	SMED improvement done. (Setup Trolley, Tools Pre-setter)
5	Jaw setting time more	Innovative jaw inserts design introduced
6	Random changeovers	Changeover Sequencing introduced
7	High dependency on setup expert	Set up deskilled, additional set up experts trained. Working towards machine operator doing the set up himself.

Material Related - Cause: Raw Material & Finished goods inventory control not existing

Solution:

For Finished Goods (FG):

In the beginning, few meetings were conducted with the primary client (regarding their production ordering pattern. They were explained; about the how the order change affects the production planning system. They were also requested to provide forecasting for future month. That is, the firm schedule and a tentative forecasting for the next 2 months. The client was considerate for the request and they started giving schedules one month (N) firm and 2 months (N+2) forecast.

Finished Goods were classified into Runner, Repeater & Stranger (R-R-S). Previous 6 months off take by customer and the forecast were considered for the data analysis. Different stock keeping strategies introduced to ensure 100 % On-Time Delivery (OTD) to the customer at the same time, to minimize inventory and number of changes in the production line.

For Raw Material (RM):

We had meetings with the Raw Material supplier about our issues in existing system and sought their cooperation in the proposed system. We had established, the Re-Order Level (ROL) and the Re-Order Quantity (ROQ) and thereby the replenishment system, which is a Kanban PULL system.

Supplier was told to keep one ROQ quantity of material stock readily available with them, so that they can supply immediately as soon as the Kanban PULL trigger reaches them. Initially, some teething issues were there in communication and adapting to the new practice. By close training and on field troubleshooting, the issues were overcome and smooth flow was established.

Method Related - Cause: Irregular and unplanned machine changeover

Solution:

Production planning system introduced to make the changeover in scientific way. Products were grouped in to "Product family wise" (example: Round & Hexagonal families) and the planning was primarily among the Round shapes and among Hexagonal shapes. Cris-cross set ups between Round←→Hexagons avoided as much as possible. This was possible since we established systems for RM and FG Stock controls. This reduced lot of irregular and unplanned machine changeovers. The Diagonal matrix helped to identify the short duration path for changeover.Being a small scale industry, having less number of models we didn't complicate them with mathematical model or a special software program etc. Implementing software programs in SMEs creates problems if the particular skilled person leaves the job. The owners are also not well versed with computer software applications.

DIAGONAL MATRIX - SETUP TIME (in Minutes) - AFTER

PRODUCTS	R1	R2	R3	H1	H2	H3
R1	NA	25	33	44	50	50
R2		NA	28	50	39	44
R3			NA	39	44	41
H1				NA	22	28
H2					NA	25
H3						NA
SEQUENCE						
ROUND	R1	R2	R3			
HEXAGONAL				H1	H2	H3

Method Related - Cause: SMED Study not carried out.

Solution: Carryout SMED improvement

The SMED improvement methodology has the following steps.

1. Video record (last ok piece of previous model to first ok piece of next model)

2. Activity study

3. Internal / External activity classification

4. Conversion of internal to external activity

5. Reduce both internal & external time

6. 7. Standardize the new set up process and Train Employees

SMED:

Video footage was taken in normal condition and the video elements recorded as activity and orresponding time it takes. We classified the activities as either Internal (Inside the machine) or External (Outside the machine). While looking for potential solutions, we used Eliminate, Combine, Reduce / Rearrange, Simplify (ECRS) method.

Set up Time Analysis

Sl.No	Activity Elements	Time (Secs)	I / E	NVA	Improvement action
1	Collecting Allen key and pipe	14	E	14	Set up Tool Trolley
2	Removing the old jaws	40	I		
3	Removing T nut from old jaws	30	E		
4	Air cleaning the chuck	6	I		
5	Assy of T nut in new jaw 1 - 3	72	E		
6	Assy, check run out & adjust	288	I		
7	Collecting hammer	36	E	36	Quick Change Jaws
8	Tighten the jaws	28	I		
9	Checking chuck pressure	8	E	8	
10	Clamping & check run out	22	I		
11	Taking Hand tools	52	E	52	Set up Tool Trolley
12	Index turret & remove tool	197	I		
13	Air cleaning the tool & mount	80	E		
14	Air cleaning & Mount	348	I		
15	Tool searching	36	E	36	Set up Tool Trolley
16	Fixing the tool	66	I		
17	Program checking	317	E	317	Standardize program
18	Cut piece dimension check	43	E	43	
19	1st & 2nd piece run out check	52	I	52	Jaws Redesign
20	OD turning tool rough offset	115	I	115	
21	OD turning sequence running	186	I		
22	Clean & check dimension	34	E		
23	Taking offset to 2nd & 3rd tool	175	I	175	Tool Pre-setter
24	2nd & 3rd sequence running	300	I	100	Tool Pre-setter
25	Air cleaning the component	37	E		
26	Coolant flow checking & aligning	98	I		
27	Checking the dimension	19	E		
28	Taking offset to 4th & 5th tool	245	I	245	Tool Pre-setter
29	4th & 5th sequence running	172	I		
30	Air cleaning the component	36	I		
31	Checking the dimension	32	E		
32	Searching gauge	42	E	42	Set up Tool Trolley
33	Checking the gauge	34	I	24	Tool Pre-setter
34	Recalling the 5th tool	114	I	88	Tool Pre-setter
35	Air cleaning & visual check	30	E		
36	Checking second side stock	30	I		
37	Clamping 2nd side in chuck	12	I		
38	Taking offset to 6th - 10th tool	752	I	752	Tool Pre-setter
39	Checking component run out	51	I		
40	6th - 10th running & recalling	331	I		
41	Clean and Inspect	207	I		
42	De clamp & air cleaning	7	E		
	Total Time in Secs	**4794**		**2099**	
	Total Time in Mins	**80**		**35**	

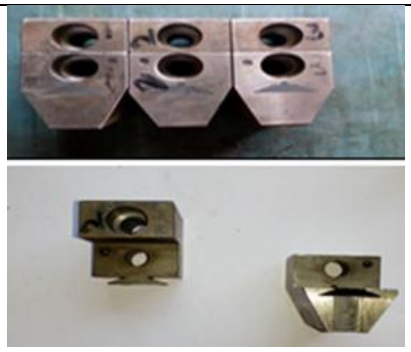
IMPROVEMENTS CARRIED OUT:

1. **Set-up box introduced**
2. **Tool Pre-setter introduced**
3. **Jaw design modified**

Setup box with measuring instruments

Tool Pre-setter

Method Related - Cause: Jaw Change Time more

BEFORE	**AFTER (innovative idea)**
	
Removing the Jaws from Chuck and replacing with different Jaws for different diameter jobs, truing, doing a skin cut of soft jaw to control run-out	Mother jaws not removed from chuck. Only newly designed Jaw Inserts needs replacement

STANDARDIZATION & TRAINING TO EMPLOYEES:

SKILL (VERSATILITY) MATRIX FOR CNC LATHE SET UP CHANGE

SL No	EMPLOYEE NAME	KNOWLEDGE OF PART DRAWING	KNOWLEDGE OF FIXTURE DRAWING & DIMENSION	HANDLING TOOLS AND TOOL PRE SETTER	CHUCK, JAW, MECHANICAL ELEMENTS SETTING	HANDLING CNC PROGRAMS, OFFSETS	FIRST-PIECE INSPECTION
1	ASHOK						
2	NANDHA						
3	SURESH						
4	ARUN						
5	VEERA						

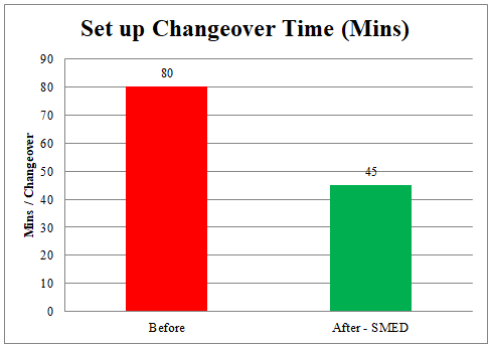
DEFINITION	 UNDER TRAINING	 KNOWS JOB, CAN WORK UNDER SUPERVISION	 KNOWS JOB, CAN WORK WITHOUT SUPERVISION	 EXPERT, CAN TEACH OTHERS

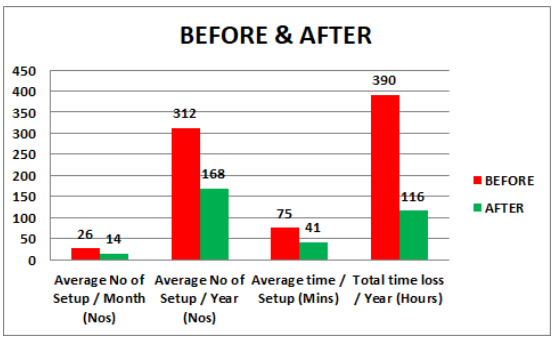
9. RESULTS

a. TANGIBLE RESULTS:

i. Reduction in setup time from 80 Mins to 45 Mins (44% Reduction) achieved in one machine on PILOT basis. As Horizontal Deployment (HD), the same improvement was extended to all the machines in the plant.

ii. This improvement has resulted in overall cost benefit of INR 2.9 Mn / Year





Capacity loss due to changeover was at 9%. After the case study the loss has come down to 3 % and hence the Plant capacity is increased by 6%

b. RESULTS – INTAGIBLE, SYSTEMIC IMPROVEMENTS:

1. Morale of Setup employee improved manifold.
2. Since, setup has been "deskilled" the dependency on the set up operator has reduced. We have trained 3 other setup experts so that the changeovers can happen in day shift as well as night shift as required by the planned production. There are ongoing efforts to train all the machine operators in setting their own machines. With this the concept of setup expert will get eliminated.
3. Standardization of the activities done through Standard Operating Procedures (SOP).

10. CONCLUSION:

Scientific approach has been brought in Set up change sequence and Production planning.

Implementation of SMED has resulted in substantial improvement in flexibility of meeting customer needs and also improved capacity utilization

SMED implementation necessitated implementation of other Practices like Visual Management, Production Planning & Control, 5S (Workplace organization etc.)

11. LIMITATIONS AND FUTURE RESEARCH:

Set up time data between various models has been captured thru Diagonal Matrix. Being a small scale industry, we used it as part of Visual Management and the production planning is done as per the least path set up time, But, higher degree of mathematical model can be developed, which can be used in Large Scale industries also. Further analysis of process time can surface new possibilities of improvement.

12. ACKNOWLEDGEMENTS:

1. We thank the primary customer and raw material suppliers of the organization to consider our requirements positively, which helped us to successfully implement inventory management system.
2. We wish to acknowledge the support from the case study company (SME) and their team and the department staffs who have cooperated to carry out these improvements
3. The authors wish to acknowledge the support from the Guides who improved the contents and style of this paper.

REFERENCES:

1. Rosmaini Ahmad & Mohd Syazwan Faiz Soberi. Changeover process improvement based on modified SMED method and other process improvement tools application: an improvement project of 5-axis CNC machine operation in advanced composite manufacturing industry, Int J Adv Manuf Technol (2018) 94:433–450 DOI 10.1007/s00170-017-0827-7
2. Marcello Braglia & Marco Frosolini & Mosè Gallo. SMED enhanced with 5-Whys Analysis to improve set-up reduction programs: the SWAN approach. Int J Adv Manuf Technol (2017) 90:1845–1855 DOI 10.1007/s00170-016-9477-4
3. Semra Boran & Caner Ekincioğlu, A novel integrated SMED approach for reducing setup time,Int J Adv Manuf Technol (2017) 92:3941–3951 DOI 10.1007/s00170-017-0424-9
4. Jonathan David Morales Méndez & Ramón Silva Rodríguez,Set-up reduction in an interconnection axle manufacturing cell using SMED, Int J Adv Manuf Technol (2016) 84:1907–1916 DOI 10.1007/s00170-015-7845-0

5. Rodrigo Borges Ribeiro, José De Souza, Alexandre Beluco, Luciano Volcanoglo Biehl, Jorge Luiz Braz Medeiros, Frederico Sporket, Elton Gimenez Rossiniand Fábio Augusto Dornelles Do Amaral,Application of the single-minute exchange of die system to the CNC sector of a shoe mold company Cogent Engineering (2019), 6: 1606376 https://doi.org/10.1080/23311916.2019.1606376
6. Dror Hermel, Oded Medina and Nir Shvalb, A note on estimating minimal changeover time, Cogent Engineering (2017), 4: 1330911 https://doi.org/10.1080/23311916.2017.1330911
7. J.Lozano, J.C.Saenz-Díez, E.Martínez, E.Jiménez, J.Blanco, Methodology to improve machine changeover performance on food industry based on SMED, Int J Adv Manuf Technol (2017) 90:3607–3618 DOI 10.1007/s00170-016-9686-x
8. Mehmet Cakmakci, Mahmut Kemal Karasu, Set-up time reduction process and integrated predetermined time system MTM-UAS: A study of application in a large size company of automobile industry,Int J Adv Manuf Technol (2007) 33: 334–344 DOI 10.1007/s00170-006-0466-x
9. M.Kemal Karasu & Latif Salum, FIS-SMED: a fuzzy inference system application for plastic injection mold changeover, Int J Adv Manuf Technol (2018) 94:545–559 DOI 10.1007/s00170-017-0799-7.
10. Pugazhenthi, R., and M. Anthony Xavior. "A characteristic study of exponential distribution technique in a flowshop using taillard benchmark problems." Pak Acad Sci 51 (2014): 187-192.
11. Pugazhenthi, R., and M. Anthony Xavior. "A heuristic to minimise the idle time of the rental/critical machine in a flowshop." International Journal of Services and Operations Management 22, no. 4 (2015): 395-412.
12. Biman Das & Uday Venkatadri & Pankajkumar Pandey, Applying lean manufacturing system to improving productivity of airconditioning coil manufacturing, Int J Adv Manuf Technol (2014) 71:307–323 DOI 10.1007/s00170-013-5407-x
13. Shivneri Deshmukh, Manish Shete, A Literature Review on Single Minute Exchange of Dies, IJSRD, Vol. 5, Issue 12, 2018 | ISSN (online): 2321-0613
14. Pugazhenthi, R., and M. Anthony Xavior. "Optimisation of permutation flow shop with multi objective criteria." international journal of applied engineering research 8, no. 15 (2013): 1807-1813.
15. Pugazhenthi, R., and M. Anthony Xavior. "Optimisation of permutation flow shop with multi objective criteria." international journal of applied engineering research 8, no. 15 (2013): 1807-1813.
16. Pugazhenthi, R., and Anthony Xavior. "A genetic algorithm applied heuristic to minimize the makespan in a flow shop." Procedia Engineering 97 (2014): 1735-1744.
17. Alexandre Silva, José C. Sá, Gilberto Santos, Francisco J.G. Silva, Luís P. Ferreira, Maria T. Pereira, A Comparison of the Application of the SMED Methodology in Two Different Cutting Lines, Article in Quality Innovation Prosperity - April 2021 DOI: 10.12776/qip.v25i1.1446
18. Pugazhenthi, R., and M. Anthony Xavior. "Minimizing Material Processing Time and Idle Time of a Critical Machine in a Flow Shop." In Advanced Materials Research, vol. 984, pp. 106-110. Trans Tech Publications Ltd, 2014.
19. Deepak Maurya, Yagnesh Yadav, Deepak Pandey Prof Rajeshwar.S.Deshmukh, Change Over Time Reduction Using SMED: An Industrial Case Study, International Journal of Scientific & Engineering Research Volume 9, Issue 3, March-2018, ISSN 2229-5518
20. D.Kumaravel, R.Sathya Bharathi, M.Kavinandini, Enhancing the production through SMED methodology, International Journal of Engineering & Technology, 7 (2.8) (2018) 382-385
21. Mohammed Viqar Nadaf Pinjar, Dr.Shivakumar S, Dr.G V Patil, Productivity Improvement through Single Minute Exchange of Die (SMED) Technique, International Journal of Scientific and Research Publications, Volume 5, Issue 7, July 2015, ISSN 2250-3153
22. Rushikesh Gavali, Shrikant Chavan, Prof.Dr.Ganesh.G.Dongre, Set-up Time Reduction of a Manufacturing Line using SMED Technique, International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 07 | July -2016, e-ISSN: 2395 -0056, p-ISSN: 2395-0072
23. António Carrizo Moreira, Gil Campos Silva Pais, Single Minute Exchange of Die. A Case Study Implementation, J. Technol. Manag. Innov. 2011, Volume 6, Issue 1

24. Mohd Norzaimi bin Che Ani, Mohd Sollahuddin Solihin Bin Shafei, The Effectiveness of the Single Minute Exchange of Die (SMED) Technique for the Productivity Improvement, Applied Mechanics and Materials Vols. 465-466 (2014) pp 1144-1148, doi: 10.4028/www.scientific.net/AMM.465-466.1144
25. Pugazhenthi, R., M. Anthony Xavior, and R. Saravanan. "A case study on effect of grouping technique in a multi-stage hybrid flow shop." International Journal of Computing Science and Mathematics 7, no. 1 (2016): 42-53.
26. Vivek, P., R. Saravanan, M. Chandrasekaran, and R. Pugazhenthi. "Minimizing idle time of critical machine in permutation flow environment with weighted scheduling." ARPN Journal of Engineering and Applied Sciences 11, no. 5 (2016): 473-3483.