Productivity improvement: Implementation and analysis of clustering technique in manufacturing of timing gearbox cover

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C H R O N I C L E	A B S T R A C T
	Productivity is an indicator of efficiency with which resources, both human and material, are transformed into useful services and goods. The vital purpose of the prevailing work was to analyze the factors involved in the improvement of productivity in all its types such as material, capital, labor, machine and total productivity at the plant. This was obtained by decreasing the manufacturing cost per component by reducing its cycle time and increasing the monthly production rate. The experimentation revealed that using proposed processes and improved tooling, monthly production rate has increased by 16.2% due to reduced cycle time, the number of defected components i.e. rejection rate has reduced up to 2%. A reduction of 6.78% in manufacturing cost per component was recorded. Tooling cost has reduced by more than 12%. Saving up to 50% in inspection cost has been recorded due to close dimensional tolerances and high surface finish achieved on components. An increase of 4.84% was recorded in total productivity.

1. Introduction

'Productivity' has become a versatile word as by and large everyone talks about it. The meaning of "productivity" is different for different people. Consequently, it varies from efficiency to effectiveness. Productivity is a measure of the efficiency with which a company or an enterprise converts its available resources (inputs) into finished goods or services i.e. required outputs. Measurement of productivity commonly supposed to be a ratio of outputs produced to resources consumed (Card, 2006). The ratio of output quantity index to the input quantity index is the measuring tool for productivity change (Balk, 2005) thus a total productivity measure reflects combined impact of all the inputs in producing the output. To measure productivity for multiproduct firms (Berndt & Fuss, 1989), productivity can be enhanced by producing more output with the same input or by producing the same output with fewer inputs. Productivity can be defined as human efforts to produce more and more with less and less

inputs of resources as a result of which the production benefits are distributed among maximum number of people.

Fig. 1(a).Timing gear box cover- outer side

Productivity can be increased by reducing the cycle time and controlling the process statistically (Sheth & Sisodia, 2002; Sharma et al., 2012). Different productivity improvement strategies have been implemented in SMEs (Gunasekaran & Cecille, 1998). Reduction in waste and subsequently reduced cycle time leads to the productivity improvement (Amir Hanin, 2007). Automation in process proved to be more productive, hence yielding the productivity values (Bryson et al., 2005) Productivity is constant adaptation of social and economic life to changing conditions. It is the continual effort to apply new techniques and methods. The means of productivity is balance between the entire factors of production that will give maximum output with the smallest effort. The ratio of output to one class of input is partial productivity. For example, labor productivity which is ratio of output to labor input is a partial productivity measure.

As a policy perspective, it is typical to understand which factors underlie the difference in productivity across firms and which are associated with higher productivity (Fernandez, 2008; Singh and Singhal, 2015). The ratio of net output to the sum of associated labor and capital (factor) inputs is total factor productivity. The effect of import liberalization on productivity growth in Indian industries in 1990s has been studied and concluded that trade liberalization did have a positive effect on industrial productivity (Goldar & Kumari, 2002; Goldar, 2004). Net output means total output minus intermediate goods and services purchased. The ratio of total output to the sum of all input factors is total productivity. The impact of the economic liberalization on manufacturing productivity in the industrial sector has been analyzed (Das, 2003). It has been found that in-process inventory reduction stimulated gain in productivity (Lieberman & Demeester, 2002). Greater productivity means accomplishing more science with less cost and effort (Faulk et al., 2004). More accountability is required from the employee by providing more responsibility to them by the employer, consequently increasing the productivity and retention of hourly employees (Bond & Galinsky, 2006). Technical innovation viz. information resources, technology acquisition, technological cooperation, patents, governmental support, influence productivity improvement (Doo & Sohn, 2008). A more sustainable and high productivity production system can be developed to determine the productivity level of the industry. If the fixed costs are considered, the profit of the average farm is negative (Mohaddes & Mazhari, 2008). Partial productivity and total factor productivity for total manufacturing sector decelerate during the post reform period (Kaur & Kiran, 2008). It is concluded that changing ownership by converting large number of firms to stock-holding companies positively contribute to growth in aggregate productivity (Motohashi & Yuan, 2009). Average productivity of India's manufacturing firms has been increased by unilateral reduction in final goods tariffs (Nataraj, 2009). The results indicate that the TFP growth of Indian industry primarily for the formal sector has positively affected by SBR (Kathuria et al., 2010). Most of the papers have stressed that aggregate TFP in a country can be reduced by misallocation of inputs across

the firms. Resource reallocation can increase aggregate total factor productivity (Hsieh & Klenow, 2007). The combination of unavailability of credit and high inflation aggravated distortion and further lowered the productivity growth (Gupta, 2010). Measurement of output is not a depending factor significantly for TFPG estimates (Dash et al., 2010). Focusing attention on manufacturing productivity or the overall production efficiency as the key indicator of competitive ability and strength, overall performance could be improved (Sohail, 2006).

2. Problem formulation

Problem formulation describes a brief background of the automobile parts manufacturing company and importance of achieving / maintaining high quality production. Further it relates to our specific study and leads to our problem definition**.** As to start defining a problem; first part of the research is to conduct a pre study in order to understand the manufacturing process in a better way and to find possible aspects affecting the productivity performance of industry or company. The various operations on different machines using conventional techniques require/ consume more time, space, labor cost, material handling cost, shipping cost and hence total production cost is combination of all of the above mentioned factors and productivity is a dependent term on different aspects. Requirement of the modern manufacturing is to achieve high productivity and consequently to reduce unit production cost. This necessitates some improved manufacturing methods or techniques to be devised for manufacturing the required parts or components. Resources need to be utilized effectively and work holding devices to be efficient ensuring quick loading / unloading to speed up manufacturing operation.

The present work was carried out in a tractor parts manufacturing company near Ambala City of Haryana (India), where the management of the company desired that with the existing resources; productivity be increased by reducing the lead time of complex shaped components, increase the production of such vital component i.e. Timing Gear Box Cover and also monthly rejection rate be reduced by clustering different operations and performing maximum clustered operations on a single CNC machine comprising the required facilities.

Fig. 1(b). Timing gear box cover- inner side

3. The proposed study

For Existing Manufacturing Process, various components manufactured by the company and the machinery/equipment installed at the company were studied. Main component among the automobile parts manufactured by the company i.e. Timing Gearbox Cover has been shown in Fig. 1(a) and Fig. 1 (b), respectively. Operation time chart for vital component Timing Gearbox cover is shown in Table 1. Table 1 shows existing operations with their sequence, different machines needed, machine hour rate, time elapsed on each of the machines to perform the required operation, machining cost per component, helper cost and in-plant material handling cost in manufacturing the so-called vital component Timing Gearbox Cover.

Table1

Operation time chart for timing gearbox cover using the existing process

Op. No.	Description of Operation	Machine Tool	M/c Hour Rate (Rs)	Time Elapsed on Machine(Minutes)	Machining Cost per Component (Rs)	Helper cost (Rs)	In Plant Material Handling/Shipping Cost (Rs)
1	Rough Facing of Joint Face	C- Lathe	80/-	18.5	24.66	NIL	1.00
2	Rough Milling Top Face	V-Milling	100/-	4.6	7.66	NIL	1.00
3	Rough and Finish Mill Joint Face, drilling 14 holes Ø 10.5	VMC – 800	350/-	10.2	59.5	2.57	1.00
4	Finish Mill Top Face, Rough & Finish bore Ø 82.55 H8, Ø 72 H8 and Ø 20 H11	VMC – 550	400/-	12.4	82.66	3.1	1.00
5	Rough Milling Sump Face	H-MILL	100/-	3.6	6.00	0.875	0.50
6	Finish Milling Sump Face	H-MILL	100/-	2.7	4.5	0.675	1.00
7	Milling and Boring of Breather of bore Ø 45 H8	VMC-840	325/-	6.0	32.5	1.45	NIL
8	Drilling, C'bore and Tap 3 holes M 10	R-Drilling	100/-	4.7	7.83	1.17	0.50
8a	Opening of drill 14 Holes Ø 10.5	R-Drilling	100/-	4.4	7.33	NIL	1.00
9	Tap 5 Holes M8, Spot Face 11 Holes Ø28	R-Drilling	100/-	3.7	6.16	0.95	0.50
10	C' Boring of 3 Holes Ø 18.0 (bolt holes)	R-Drilling	100/-	2.5	4.16	NIL	1.00
11	Mill Boss for Clearance of Water Pump Mounting	H-Milling	100/-	1.8	2.0	0.45	0.50
12	Turning of Ø 84 Holes	C-Lathe	80/-	3.6	4.8	NIL	1.00
13	D'Buring& Cleaning, Check Leakage, & Dimensions 28	Manual	NIL	2.0	3.0	2.5	1.00
14	Final Inspection	Manual	NIL	2.0	NIL	1.5	1.00

Following necessary assumptions have been considered in preparing the operation time chart mentioned in said Table.

- Machine hour rate for different machines shown in Table includes purchasing cost of machine, interest, wages incurred, power consumed, and cost of tooling, depreciation and miscellaneous expenditures/overheads.
- Cost of machining was calculated by multiplying machine hour rate with time elapsed on each of machines for performing different operations required to manufacture the said component.
- The manufacturing cost for the component comprising of machining cost, helper cost and in-plant material handling/shipping cost.
- In plant material handling cost has been taken asRs1/-for movement of comparatively longer distance and Rs 0.50 for smaller distance movement between various machines.
- Helper rate was considered as Rs15 per hour.

4. Data-Collection

Data pertaining to production with corresponding rejections for the main component i.e. Timing Gearbox Cover was collected on monthly production basis for the last more than 1 year with existing and improved process to study and analyze the defects produced and is shown in Tables 2 and Table3, respectively. The existing production/ rejection trend for 9 months i.e. from Apr, 2013 to Dec, 2013 has been shown in the Table 2.

Table 2

Monthly Production / rejection trend for Existing Process.

Month	Timing Gearbox Cover	
	Production	Rejection
April, 2013	2400	108
May, 2013	2500	109
June, 2013	2200	80
July,2013	2300	104
Aug, 2013	2500	112
Sep, 2013	2400	106
Oct, 2013	2500	117
Nov, 2013	2400	105
Dec, 2013	2350	98

Subsequently Table3 shows production/ rejection trend for another 9 months i.e. from March, 2014 to Nov, 2014 using the improved process.

Table 3
Monthly Production / rejection trend for Improved Process

Month	Timing Gearbox Cover	
	Production	Rejection
March, 2014	2750	55
April,2014	2875	58
May, 2014	2500	52
June, 2014	2700	55
July, 2014	2900	60
Aug, 2014	2700	56
Sep, 2014	2850	57
Oct, 2014	2725	56
Nov, 2014	2600	53

The existing material productivity, labor- capital- machine productivity and total productivity has been calculated on the monthly production basis for main component viz. Timing Gearbox Cover and is shown in Table4 which is based on the following information given by the accounts department of company;

Selling Price per component (Rs)   : 975=00
Material Cost per component (Rs)   : 625=00
Manufacturing Cost per component (Rs)   : 280=00

Table 4
Existing material, labor-capital-machine and total productivity

Month	Revenue from Production (Rs) [a]	Material Cost (Rs) [b]	Labor, Capital & Machining Cost (Rs) [c]	Material Productivity [a/b]	Labor, Capital and Machine Productivity [a/c]	Total Productivity [a/ b +c]
April, 2013	2234700	1500000	672000	1.4898	3.3254	1.0288
May, 2013	2340000	1562500	700000	1.4976	3.3428	1.0342
June, 2013	2067000	1375000	616000	1.5032	3.3555	1.0381
July, 2013	2141100	1437500	644000	1.4894	3.3246	1.0286
Aug, 2013	2328300	1562500	700000	1.4901	3.3261	1.0290
Sep, 2013	2236650	1500000	672000	1.4911	3.3283	1.0297
Oct, 2013	2327325	1562500	700000	1.4894	3.3247	1.0286
Nov, 2013	2237625	1500000	672000	1.4917	3.3297	1.0302
Dec,2013	2195700	1468750	658000	1.4949	3.3369	1.0324

5. Methods to Reduce Rejection Rate

➢ Rejection rate has been reduced on monthly basis by clustering some of the operations required to manufacture the component and performing all the clustered operations in a single set up on CNC machine equipped with all the intended facilities.
➢ Due to reduced number of set-ups probability of error got reduced.
➢ CNC machine proved to be more rigid then the conventional machines, hence close dimensional tolerances are attained on the components, consequently rejection rate is reduced.
➢ An extendable universal fixture has-been developed to ensure quick and easy supporting, firm holding and rigid clamping of the so called semi-finished component during its manufacturing.

Operation time chart for the said component timing gearbox cover using improved process has been shown in Table 5.

Table 5
Operation time chart for improved process

Op. No	Description	Machine Tool	M/c Hour Rate (Rs)	Ave. Cycle Time (Minutes)	Cost Per Compo-nent(Rs)	Help-er cost (Rs)	In Plant Material Handling Cost (Rs)
1	Rough Facing/ machining of Joint Face	C- Lathe	80/-	18.5	24.66	NIL	1.00
2	Rough Milling Top Face	V-Milling	100/-	4.6	7.66	NIL	1.00
3	Rough & Finish Mill Joint Face, drill 14 holes Ø 10.5	VMC – 800	350/-	10.2	59.5	2.57	1.00
4	Finish Mill Top Face, Rough & Finish bore Ø 82.55 H8, Ø 72 H8 and Ø 20 H11	VMC – 550	400/-	12.4	82.66	3.1	1.00
5	Rough Mill Sump Face, Finish Mill Sump Face, Milling and Boring of Breather, Ø 45 H8, Drill, C'bore and Tap 3 holes M 10, Mill Boss for Clearance of Water Pump Mounting	HMC-440	450/-	5.4	40.50	0.95	NIL
6	Opening of drill 14 Holes Ø 10.5	R-Drilling	100/-	4.4	7.33	NIL	1.00
7	Tap 5 Holes M8, Spot Face 11 Holes Ø28	R-Drilling	100/-	3.7	6.16	0.95	0.50
8	C' Boring of 3 Holes Ø 18.0 (bolt holes)	R-Drilling	100/-	2.5	4.16	NIL	0.50
9	Turning of Ø 84 Holes	C-Lathe	80/-	3.6	4.8	NIL	1.00
10	D'Buring, Cleaning, Check Leakage, & Dimension 28	Manual	NIL	2.0	3.0	2.5	1.00
11	Final Inspection	Manual	NIL	2.0	NIL	1.5	1.00

6. Improvement of Productivity Using Developed Fixture

Use of the developed universal fixture for manufacturing the above mentioned component Timing Gearbox Cover has reduced number of machines from eight to six because of clustering. Despite of using higher hourly rate machine, the manufacturing cost per component has reduced due to less machining and helper cost on account of reduced cycle time, as compared with earlier manufacturing cost per component. Operation number 5,6,7,8 and 11shown in Table I are clustered and performed in a single set up on HMC, and are shown by a single operation 5 in Table5). Cycle time of manufacturing the main component has reduced tremendously causing proportionate increase in monthly production and consequently in monthly productivity. Monthly Material, Labor- Capital- Machine and Total Productivity using improved process has been calculated on the basis of following reduced elements of cost and is shown in Table 6. Manufacturing cost per component has reduced considerably due to the reduction in cycle time.

Selling Price per component (Rs)   : 975=00
Material Cost per component (Rs)   : 625=00
Manufacturing Cost per component (Rs)   : 261=00

Table6
Improved Material, Labor- Capital- Machine and Total Productivity

Month	Revenue from Production (Rs) [a]	Material Cost (Rs) [b]	Labor, Capital & Machining Cost (Rs) [c]	Material Productivity [a/b]	Labor, Capital and Machine Productivity [a/c]	Total Productivity [a/ b +c]
March, 2014	2627625	1718750	717750	1.5288	3.6609	1.0784
April,2014	2746575	1796875	750375	1.5285	3.6602	1.0782
May, 2014	2386800	1562500	652500	1.5275	3.6579	1.0775
June, 2014	2578875	1687500	704700	1.5282	3.6595	1.0780
July, 2014	2769000	1812500	756900	1.5277	3.6583	1.0776
Aug, 2014	2577900	1687500	704700	1.5276	3.6581	1.0776
Sep, 2014	2723175	1781250	743850	1.5288	3.6609	1.0784
Oct, 2014	2602275	1703125	711225	1.5279	3.6588	1.0778
Nov, 2014	2483325	1625000	678600	1.5282	3.6594	1.0780

7. Analysis of Productivity

The data used in this study for calculating various aspects of productivity was taken from monthly production basis of the company. Using the improved process the company inspects every 10th component instead of every 5th component, due to high accuracy and surface finish achieved on HMC,

thereby reducing the inspection cost considerably. HMC takes 5.40 minutes including the air cut time in performing the clustered operations. Cycle time of required component viz. Timing Gearbox Cover is coming as 69.3 minutes using improved process and is shown in Table5, which earlier was 82.7 minutes with the existing process as shown in the Table 1.

8. Effect of improved tooling

Using combination tooling on HMC, an accurate surface with close dimensional tolerances is easily achievable. Tolerances up to the limit ±0.02 mm which is closer than the existing tolerance limit of ±0.05 mm is easily obtainable on the components resulting in low rejection rate. Use of carbide tools on CNC machine instead of using HSS tools on conventional machines has resulted in more than 12 % reduction in tooling cost. The said carbide tools withstand higher temperature and retain their cutting edges for comparatively longer time due to excellent property of red hardness and toughness, consequently resulting in longer tool life. Feed rate and rotational speed have also increased tremendously for performing the same operation.

9. Statistical comparison of existing process and improved process using control chart for fraction defectives

The chart used for fraction defective with variable subgroup size is P-Chart. The straight line with ordinate value 0.044 is the centre line, CL of the chart shown in the Fig 2. It is inferred that triangular point for 3rd and 7th sample is comparatively more distant from the centerline, which means the quality of the product is not up to the required level rendering higher fraction defectives and increasing rejection rate. The centerline, CL has ordinate value as 0.0199and is shown in Fig. 3pertaining to improved process. On interpretation of the graphs for existing and improved process it is apparent that the square points in figure 3 are falling at closer distance to the centerline, CL in improved process. Hence is in better statistical control. Comparison of existing and improved chart has analyzed that monthly fraction defectives variation has reduced for improved process.

Fig. 2. Control chart for existing process

Fig. 3. Control chart for improved process
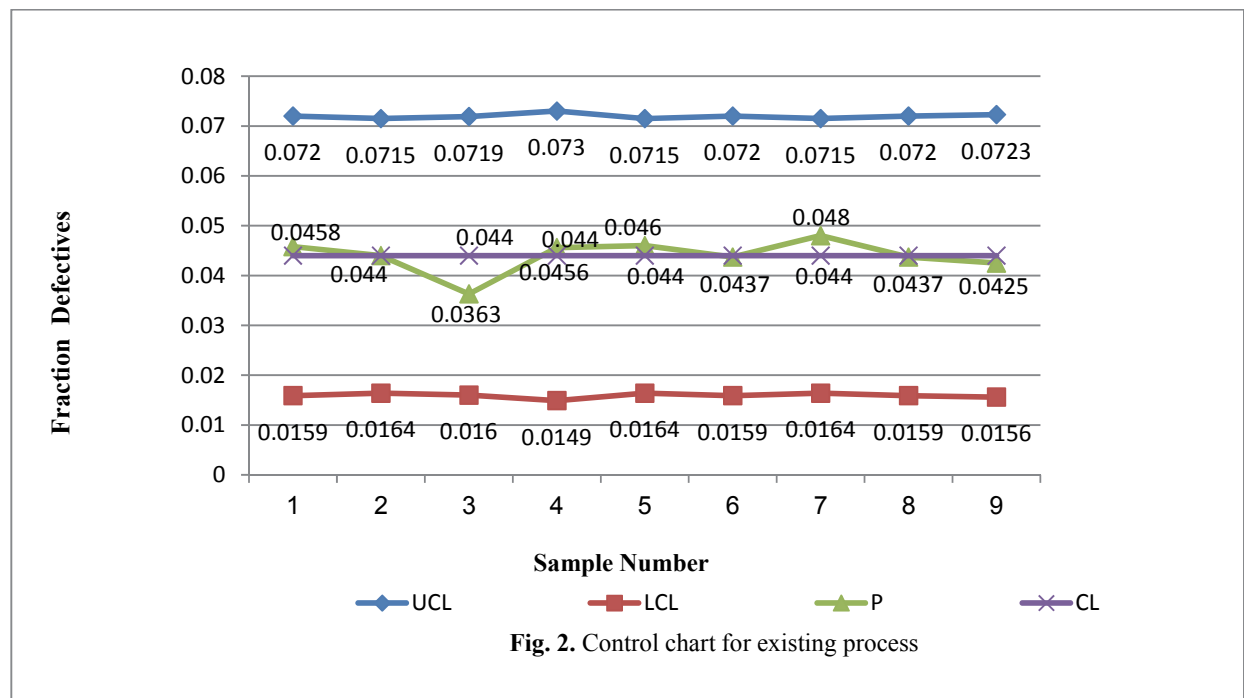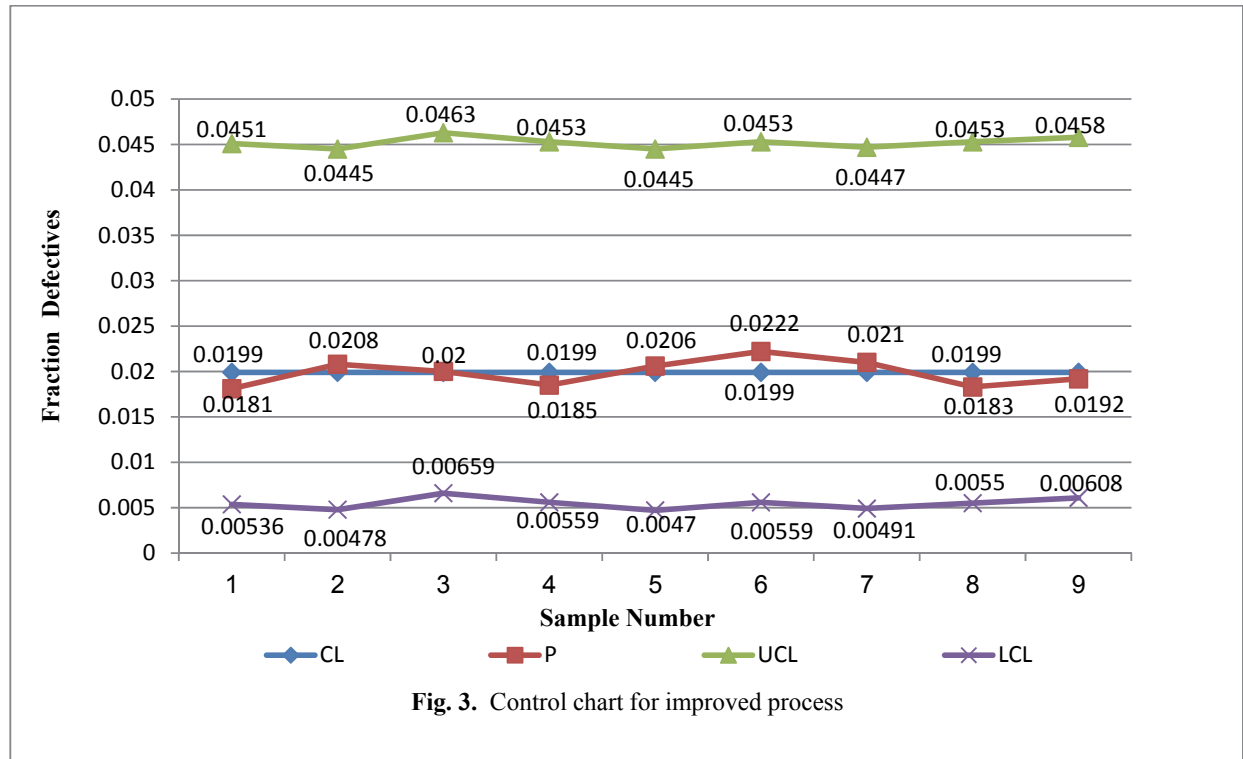
10. Conclusion

Less variation of the curve has been depicted from the interpretation of controlled charts so it is inferred that the process is better statistically controlled. As the number of machines performing the required operations has been reduced from eight to six, chances of error has got reduced due to higher rigidity of the machine. A reduction of 6.78% in manufacturing cost per component was obtained on account of reduction in cycle time despite of using machines with higher hourly rate of the machines. Tooling cost was reduced by more than 12% due to increased tool life of carbide tools used on CNC machine. Close dimensional tolerance has also been possible after clustering viz ± 0.02mm, instead of earlier ±0.05 mm due to reduction in set-ups. Due to reduced cycle time monthly production rate has increased by 16.2%, and rejection rate was lowered by more than 2% as a result of performing different operations accurately. A total saving of more than 13 minutes in cycle time was observed due to clustering. Consequently material productivity has increased by 2.51%, while capital, labor and machine productivity has increased by 10.01%.Resultantly total productivity has increased by 4.84%.

Acknowledgement

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