SETUP TIME AND COST REDUCTION IN CONDITIONS OF LOW VOLUME AND OVERCAPACITY

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Increasing diversity of products, reduced size of product lots, shortened delivery time, decreasing customer demands, production overcapacity and products and processes more and more complex require a continuous increase in the level of flexibility of production systems to cope with a global market. Continuously improve the effectiveness and efficiency of setup time for equipment is a challenge for many manufacturing companies. This paper focuses on reducing setup times and associated costs for plastic molding machine under low volume and overcapacity for equipment having impact on the level of losses and costs.

Keywords: setup time, cost reduction, SMED, overcapacity, OEE, kaizen

1. Introduction

The effectiveness and efficiency [24, pp 8] of production systems are and will be the quintessence of the success in the global market for manufacturing companies that rely on equipment [16, pp. 21-42, 17]. The strategies of production systems for continuously decreasing costs by maximizing the efficiency of equipment and production in general requires the development of policies for continuous improvement in productivity [31, pp. 49-65] and quality [15, pp. 44-50]. Building a flexible production system [23] to meet market needs [4, pp. 34-35], needs often uncertain, is a response to excessive consumption of resources in companies. Downscaling and increasing complexity of products and processes [6, 14, 41] determines a higher consumption of resources in the process. The increased consumption of resources is found mainly in the equipment activity times, in the times for direct and indirect labor, in the raw materials and consumables and in utilities level [36, pp. 52-61], which generates losses [16]. Therefore, the resource consumption must be carefully managed so as not to reach unjustified increases in costs both direct and especially indirect, which may be impossible to bear long-term by market price, having a negative impact on the flow and profit cash [7, 20]. The production systems strategy is focused on continuous improvement of productivity and quality levels for resource

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consumption (improvement of manufacturing costs) [36, pp. 69, 42] and *development of targets and politics for manufacturing cost deployment* [3, pp. 211-236, 4, pp. 4-13], in the under-capacity situation (*planned production quantity > capacity of the production system*), and especially in the overcapacity situation (*planned production quantity < capacity of the production system*), situation in which the waste of resources is higher [44].

Increasing the equipment flexibility by reducing setup time in conditions of overcapacity [5, 13, pp. 475-540], accepting small and frequent batches and continuous reduction of costs for setup operations [31, pp. 177-190] by increasing the equipment effectiveness [2] is the purpose of our work. The contribution of our research is represented by: (1) development of mathematical formulas for transforming setup and adjustments in costs; (2) directing improvement projects by the need to reduce setup costs, (3) identifying directions for setup time cost reduction and (4) practical application in a company.

Based on the purpose of our work, from the requirement formulated by the top management of an automotive company, *respectively reducing setup costs having implications along the production flow in conditions of reduced volumes and overcapacity (part of the production is performed without firm order)*, we developed our own methodology in 7 steps. The basic principles of *plan–do–check–act (PDCA)* cycle [12], the *single-minute exchange of die - SMED* method [5],the *Kaizen* technique [43] and the research steps/cycles of action research [9, 11] and of case study methodology [45] were used.

After this introductory *first part*, we continue in the *second section* with theoretical frameworks, in the *third section* with a brief presentation of the 7 steps of our methodology, in the *fourth section* we briefly present a practical example held over 21 weeks in an automotive company, and in the end there are our conclusions (*fifth section*).

2. Theoretical framework

For manufacturing and assembly industries [33, pp. 149-283] which have specific repetitive plots and possibly reduced, complex products and processes which focuses predominantly on the level of productivity and quality of equipment [13, pp. 541-616] (industries like: machinery, metal products, electrical and electronic products, automotive, precision instruments, pharmaceutical, etc.), increasing the effectiveness and efficiency of the equipment [1] [2] is the main strategic direction [36, pp. 40-51]. The development of these strategies is often reflected by tracking the *Overall Equipment Effectiveness – OEE* level rise [1, 2, 22, 40, pp. 21-45] using *Kaizen* projects [43]. OEE aims to identify the 7 *equipment losses (failure losses, setup/adjustment losses, cutting-blade losses, start-up losses, minor stoppage/idling losses, speed loss, defects and rework* *losses),* in order to continuously increase the *"availability rate",* taking into account the *"shutdown loss"* [36, pp. 40-51, 40, pp. 21-44]).

Suzuki believes that the assessment of production companies results is made using six major elements (PQCDSM): *production (with emphasis on productivity), cost, safety, quality, and morale* [40, pp. 47-49]. The six elements of evaluation of the output of manufacturing companies are common to both Shirose [36, pp. 550-556] and other authors [2], and the productivity of equipment is shown to be very important in the case of small batches. Further, at the level of productivity and quality of the equipment activities we have two major categories of losses:*"normal production losses"* (startup, shutdown and *setup*) and *"abnormal production losses"* (especially defects and abnormalities as a result of the difference between the standard set and the current situation) [40, pp. 22-23, 25, 79-80], but also *minor stops/idling* [37] growing the overcapacity.

Creating a culture based on human-machine relationships [18, 38] and a working environment [25] that continuously support the maximization of the effectiveness and efficiency of equipment [28] and flexibility, more exactly increasing OEE [22], requires involvement of all people in the company at all levels from top management to front-line employees [25], developing improvement projects to achieve the desired state of zero losses for equipment [33, 40, pp. 51-52], hence the zero losses for setup time [40, pp. 51-52] and continuously observing the environmental regulations [26]. In many companies the use of SMED method became usual [27, 32, pp. 117, 126-127, 191, 33, pp. 29-63, 35, 40, pp. 22-23]. Sekine and Arai believe that: *"zero changeover is changeover that can be completed within 3 minutes"*[33, pp. 3].

SMED technique is dedicated to reducing setup time and has been developed for over 19 years by Shingo [34, 35, pp. 2-3]. The setup time means all the time for setup, adjustment and testing (including defects and testing rework): *"the elapsed downtime between the last production piece of part "A" and first good production piece of part "B"* [30, pp. 319]. According to SMED technique [35, pp. 2-3] the setup operations can be divided in two categories: *internal setup ("that part of setup which must be done while the machine is shut down, for example, removing or attaching dies" [30, pp. 319])* and *external setup ("that part of the setup which can be done while the machine is still running, for example, preheating a "hot" tool before the actual setup begins and while the press is still producing part "A")* [30, pp. 319]). Further, if the objective of SMED technique is a setup time of *"9 minutes" ("single changeover", or changeover within a single-digits number of minutes")* [33, pp. 3], the objective of Sekine for *"kaizen for quick changeover"* [33, pp. 2-12] is a 3 minutes setup.

Conceptually addressing the *economic order quantity (EOQ)* – developed by Harris in 1913 [29], Cimorelli [8, pp. 37-47] believes that reducing the *"setup cost"* is a challenge for companies to increase the flexibility of equipment facing customer orders to help achieve the principles of *one-piece flow [32]* and *pull system [13]* in order to reduce the *lead time* [20] and hence the stock level. This need for knowledge and reducing of setup cost using the SMED technique to optimize the batch size has been described by Martin [19, pp. 351-353] and by Coimbra [10, pp. 81- 93]. Over time, based on SMED technique, different methodologies have been developed to reduce setup time by several authors such as: Hirano [13, pp. 500-532], Shirose [36, pp. 145-157], Birmingham [5], Rubrich and Watson [30, pp. 323-350], Coimbra [10, pp. 84-86] or Posteucă and Zapciu who developed 6 steps to address reducing setup costs across the flow [27].

In conclusion, even if Suzuki [40, pp. 22-23] believes that the setup time is a *normal loss*, it is needed to minimize this time by standardizing the setup activities in order to increase the performances of the control system to early detect setup variations [40, pp. 79-82] and the associated costs [21, pp. 243-263, 27, 39, 44]. In order to fully enjoy all the benefits of reducing setup time (*reducing defects, reducing delivery delays, reducing storage costs, increasing productivity, increasing customer satisfaction and increasing profitability* [35, pp. 15-17]), full attention is needed on increasing profitability, especially in the situation of overcapacity when setup costs tend to increase [44].

3. Setup time and cost reduction methodology

In order to support small (low volume) and thick batches, under the conditions of a reduced demand of customer orders (with production overcapacity), we developed the methodology in seven steps, presented below.

According to this paper purpose, the methodology has 2 main objectives:

(1) determining the optimal batch size in terms of customer need and in terms of *reducing the variable cost of the setup* (with the target to reduce setup time) and

(2) reducing the excess stock to reduce lead time and to optimally charge the equipment - *reducing the production overcapacity* (excess stock being one of the major waste generating other waste such as handling, transportation, obsolescence, physical deterioration, blocking with storage space, possible delays, waiting times search: all these hidden losses generate extra hidden costs and continuously decrease the company resources).

Step 1: *selection process/equipment and setting targets to reduce costs*

In order to identify exactly the needs to improve the setup time, selecting and documenting processes and equipment are required **(Figure 2).**

Process identification and documentation are done in order to determine equipment, human work and production resource losses. Measurements are taken to know: cycle time and correlation with takt time, number of operators, number of shifts, standard level for work in progress (WIP), type of equipment, the amount of actual production, planned production quantity, etc.

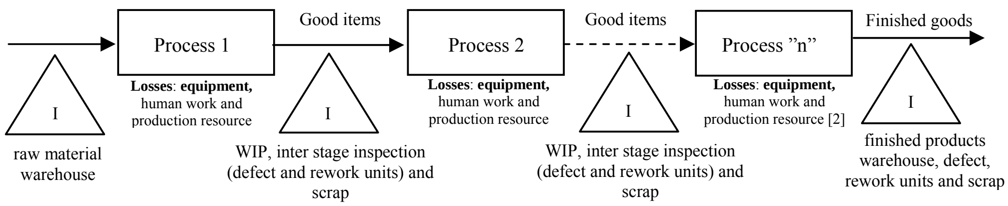

Fig. 2: Location loss of equipment/processes (for setup time in our case)

In order to determine the targets to reduce setup time we calculate:

- ✓ the *economic order quantity (EOQ)* [8, pp. 39-44]:

$$EOQ = \sqrt{\frac{2AS}{IC}} \tag{1}$$

Where: A= annual usage (units/Year); S = Setup or Order Cost; I = Inventory Carrying Cost (%/Year) ; C = Unit Cost (€/unit).

- ✓ *the current capacity of equipment* OEE [22]:

$$OEE = availability \times performance\ rate \times quality\ rate \tag{2}$$

- ✓ *the setup and adjustment time:*
  - ➢ actual time with setup and adjustment (min.):

$$SAT = NS \times STE \tag{3}$$

Where: SAT = setup and adjustment time (min.); NS = number of setups in a period; STE = the setup time of equipment (min.).

  - ➢ adjustment effects in quality (min.):

$$QA = (NDA \times DT) + (NRA \times RT) \tag{4}$$

Where: QA = adjustment effects in quality (min.); NDA = number of defects in a period caused by adjustment; DT = time spent for one defective part (min.); NRA = number of rework in a period caused by adjustment; RT = time spent for one rework part (min.)

  - ➢ total setup and adjustment time (TSA):

$$TSA = SAT + QA \tag{5}$$

- ✓ *variation related to total setup and adjustment time:*

$$VST = TSA\,1 - TSA\,0 \tag{6}$$

Where: VST = variation setup and adjustment time; TSA 1 = current TSA; TS 0 = standard TSA.

The average percentage held by the setup time from the total equipment available time or equipment loading time is often calculated.

The maintenance manager is responsible for the correct measurement, monitoring and continuous improvement of set-up and adjustment time. Data and information related to setup and adjustment are reported weekly by operators (data are collected continuously).

Since in our methodology e*ach equipment is a cost centre* (with fixed and variable costs), to determine targets for reducing the setup costs we calculate:

- ✓ setup and adjustment cost:

$$SC = TC \times TSA \tag{7}$$

Where: SC = setup and adjustment cost; TC = transformation cost; TSA = total setup and adjustment time.

- ✓ transformation cost:

$$TC = VTCR + FTCR \tag{8}$$

Where: TC = transformation cost; VTCR = variable transformation cost ratio; FTCR = fixed transformation cost ratio;

Examples of VTCR: auxiliary materials, utilities, repairs and maintenance, rent, insurance, services, travel, fees, salary costs, etc.); Example of FTCR: depreciation of equipment.

When variable resources are reallocated to other tasks, setup and adjustment cost (SC) consider only FTCR, and SC is calculated as follows:

$$SC = FTCR \times TSA \tag{9}$$

- ✓ *variation related to total setup and adjustment time and cost (VSTC):*

$$VSTC = (TSA\,1 - TSA\,0) \times (SC\,1 - SC\,0) \tag{10}$$

Where: TSA 1 = current TSA; TS 0 = standard TSA; SC 1 = current SC; SC0 = standard SC.

Then, knowing the setup time and the associated cost, the reduction targets are established to satisfy the need for flexibility/small volume and also the need to reduce the cost in conditions of overcapacity. Targets are established dynamically, based on a master plan for improving the equipment in time.

Step 2: *identify opportunities for improvement*

Through *continuous monitoring of the OEE indicator level,* the structure of the equipment losses is determined. Within the structure of equipment losses there is also the setup time (more exactly within the structure of losses on the availability of equipment). After setting the objectives and targets for reduction, in order to continuously improve the effectiveness and efficiency of setup time, the kaizen projects are planned to eliminate time waste during setup activities. Kaizen projects are carried out in *interdisciplinary teams.*

To identify opportunities to improve the setup, the *understanding of the purpose of data collecting in setup operations* is needed. Among the data needed to be collected: lead time required batch size, succession of products, setup times, number of setters, walking distance of setters and transport distances (with spaghetti diagram), necessary space, setup operations (video analysis), the current scrap and rework level, type, shape and precision of the dies, jigs and other parts used, operating principles and parameters of the equipment, etc.

At the end of this phase some preliminary opportunities for *workplace organization improvement* are identified. Consequently, 5S actions are initiated to eliminate waste such as: *eliminating unnecessary activities, eliminating unnecessary items in the setup zone, trimming work devices, activities that require a deeper study, the need to establish standard procedures, etc.* [27]. However, the team activities agenda is set in order to meet the deadline.

Step 3: *setting improvements for setup and associated costs*

To identify constraints and improvements to setup, non-value added activities and associated costs for setup operations, the detailed analysis of setup operations is made. On *video analysis* basis in which setup activities are decomposed in work sequences *(setup time diagram)* we aim to identify the opportunities for time shortening by: *eliminate, combine or rearrange, simplify and automation*. In the video analysis, in accordance with SMED methodology, we divide the setup activities in domestic activities (replacement of jigs/ tools and centring) and external activities (such as: preparation of tools, preparation of place, partial assembly work and preheating work).

Step 4: *setting standards for external and internal setup work*

The procedure continues with setting *standards for external setup time achieved through a good 5S strategy* (especially the first 2S's - seiri/sorting and seiton/setting in order. The internal setup standardization is done in order to *increase the efficiency (cost reduction) and reduce the remaining activities with internal setup*.

Step 5: *implement solutions using new standards for setup*

The new setup standard is explained to persons designated to implement the solutions set, which is to achieve consistent shortening the setup time, reduce / eliminate unnecessary adjustments, increase flexibility (acceptance of small volume batches), increase equipment loading with value added activity (making good items) and thus reduce overcapacity.

Step 6: *checking cost reductions achieved*

The results of the setup improvement project should lead to feasible cost reduction (both fixed and especially indirect variable costs, both on the cost of the equipment cost centre level to which shorting setup time is made, and especially along the flow) by simultaneously balanced performing the two objectives of our methodology. Also, we check if the improvements implemented after the setup time reduction project had a positive or negative impact on reducing the other equipment losses, such as: *failure, cutting-blade, start-up, minor stoppage, speed, defects and rework or shutdown [2]* or on labour effectiveness and waste throughout the entire production flow.

Step 7: *monitoring, horizontal expansion and greeting the team*

Monitoring improvements made on setup time and equipment adjustments are made using the OEE indicator. The improvement solutions will be expanded horizontally to other similar equipment. Usually after setup time and associated costs improvement projects, as with any other improvement project, new ideas for setup time improvement and other improvements are resulting, for which are established future implementation plans. Out of respect for people who have worked hard, at the end of the project the project team is congratulated and encouraged to continue the infinite journey on the path of improvement.

4. Example of an application

The project consisted in analysing the mold setup processes.

Information about the project:

- ✓ Project period (21 weeks), work area (manufacturing sector - EAS), production line (1), work cell **(**plastic-molding machine – **AS2**), products name (plastic vats: SA015, AA30, EA02).
- ✓ Forecast for the next 4 months: the need to increase flexibility and capacity used for AS2 (from 7.765 good pieces to 8.280 good pieces – decrease of current overcapacity).

Process current data (plastic-molding processes):

- ➢ **material flow: process 1** - raw material warehouse; **process 2 - plastic-molding (AS2); process 3** - assembling and **process 4** - finished products warehouse;
- ➢ **6 Steps for AS2: Step1:** loading sheet area; **Step 2:** preheating area; **Step 3:** heating area; **Step 4:** forming area; **Step 5:** unloading area; **Step 6:** perimeter cut area.
- ➢ additional equipment: electrical cabinet near heating area; mold support near forming area; computer near unloading area; air compressor & air tank near perimeter cut area;
- ➢ data collected for **AS2**: 1 operator; production capacity = about 32 plastic vats/hour; 15 molds change/month//shift; not defined an optimal batch; a standard setup time is not defined, the setup cost either; production scheduling is done by the logistic department, regardless of necessary setup time; the setup type is included in cycle time in 10%, regardless of the number of changes made; sometimes operators record data erroneously and incompletely;
- ➢ data and information on the evolution of OEE **(table 1):** equipment dedicated to the realization of 3 relatively similar products; Working Hours [WH] - 14.400 available max./month; the total number of parts produced [N]: 7.950 pieces; total pieces of scrap [S] (pieces): 185 pieces; standard cycle time [Sct] (sec./piece): 60 seconds per piece; real time cycle [Rct] (sec./piece): 65 sec./piece.

Initial information about costs (plastic-molding processes costs):

- ➢ the total manufacturing cost structure is: 62% - raw material; 12% administrative and sales; 26% transformation cost (budgeted expenses allocated to cost centres; including AS2 centre);
- ➢ transformation cost for **AS2** is: ***VTCR*** is 1,57 €/min.; monthly fixed transformation cost budget is 17,36 €/minute is 250.000 € per month; therefore, 250.000 €/14.400 minutes with monthly working hours ; ***FTCR*** = monthly fixed transformation cost budget/loading time =17,36 €/min./13.144 min.= 0,0013 €/min.;
- ➢ TC = VTCR + FTCR = 1,57 €/min. + 0,0013 €/min. = 1,571 €/piece/min.; (8)

Setup time and cost reduction methodology

Step 1: *selection process/equipment and setting targets to reduce costs*

Target for volume:

- ✓ Increase from 7.950 pieces/month/shift to 8.500 pieces/month/shift for the next 4 months, with maximum of total pieces of scrap [S] (pieces): 220 pieces

Target for setup time (table 2):

- ✓ setup time share: reduction from 9% to 5% from loading time (table 2);
- ✓ setup time decreased from 76 minute/setup to 20 minute/setup;
- ✓ increased number of setup per month : from 15 to about 30 setups/month/shift.
- ✓ data and information for plastic-molding processes:

Table 1

The evolution of OEE for plastic-molding processes

	Calculation of loss of effectiveness of equipment (month/shift), average for 6 months; 3 shifts; 8 hours per shift	monthly average (min.)	no. of events/ month	average time/ event min.	defects
1	**Monthly working hours** (30 days * 8 hours * 60 min.)	**14.400**			
2	**Scheduled downtime** (Σ[a…g])	**1,256**			
a	Short breaks (5-10 minutes/break)	150	30	5	0
b	Time to count the stocks	26	26	1	0
c	Time to return of poor quality materials	15	5	3	0

d	Waiting for materials	10	5	2	0
e	Lunch break (maximum 30 minutes)	900	30	30	0
f	Planned maintenance activities	5	1	5	0
g	Cleaning equipment	150	30	5	0
3	**Loading time [LT]** (1)-(2)	**13.144**			
4	Breakdown time (Σ[h…k])	280			
h	Time to failure of the tool (mold)	90	9	10	30
i	Mechanical failure	45	9	5	15
j	Electrical failure	85	10	8,5	25
k	Waiting for repairs	60	6	10	0
5	Set-up & adjustment time (Σ[l…o])	1.141	15	76	0
l	Time to change the parameters	90	15	6	0
m	Time to adjust parameters	75	15	5	0
n	**Time to change the tool (mold)**	**900**	**15**	**60**	**0**
o	Time to adjust the tool (mold)	75	15	5	0
6	Cutting tool replacement time	380	20	19	0
7	Start-up & yield	200	50	4	2
8	**Operating time [OT]** (3) - (4) - (5) - (6) - (7)	**11.143**			
9	Loss of speed [Ls] (*)	662,5			
10	Minor stops and idling [MSI] (**)	2.211,5			
11	**Net Operating Time [NOT]** (Sct * N)	**7.950**			
12	Rework time	320	80	4	
13	Total loss with scrap [TLS] (***)	185			
14	**Value-adding operating time [VAOT]** (****)	**7.765**			

(*) Ls = N * Rct-Sct = 7.950 pieces * (65 sec. – 60 sec.) = 7.950 * 5 sec. = 39.750 sec. = 662,5 min.; (**) MSI = WH - (2+4+5+6+7+9+12+13) - VAOT = 14.400 – 4.424,5 – 7.765 = 2.210,5 min.; (***) TLS = Sct * S = 60 sec./piece * 185 pieces = 11.100 sec. = 185 min.; (****) VAOT = [Sct*(N-S)] = 60 sec./piece * (7.950 pieces – 185 pieces) = 7.765 min.

OEE = Availability x Performance x Quality = OT/LT x NOT/OT x VAOT/NOT = 11.143/13.144 x 7.950/11.143 x 7.765/7.950 = 0,848 x 0,713 x 0,977 = **0,5907** or **OEE = VAOT/LT** = 7.765 / 13.144 = **0,5907** (2)

Table 2

OEE and equipment losses (current vs. target)

	OEE	Speed	Breakdown	Setup	Cutting Tool Replacement	Minor Stops/ Idling	Start -up	Defect/ Rework	Total
Current	59%	5%	2%	**9%**	3%	17%	2%	3%	**100%**
Target	63%	5%	2%	**5%**	3%	16%	2%	4%	**100%**

Obs.: OEE is the percentage of time the equipment spends creating value; the other percentage up to 100% represents losses; losses should be reduced (including those related to the changeover time) through kaizen projects in order to increase equipment capacity of creating value (to be more productive). Other downtime losses are monitored.

Transformation of set-up & adjustment losses in costs:

- ✓ SAT=NS x STE = 15 events/month x 76 min./event = 1.141 min (3)
- ✓ setup & adjustment cost = transformation cost x set-up & adjustment time = 1,571 €/min. * 1.141 min. = 1.792,5 €/ month; (7)
- ✓ 1 setup & adjustment cost = 1.792,5 €/ month /15 events = 119,5 €/ event.

Target for setup cost:

- ✓ SC = TC x set-up & adjustment time = 1,571 €/min. * (20 min. X 30 events/month) = 1,571 €/min. * 600 min. = 942,6 €/ month;
- ✓ 1 setup & adjustment target cost = 942,6 €/ month /30 events = 31,42 €/ event.

Total product cost (6,0435 €): transformation cost is 1,571 € (26%); the raw material is 3,7472 € (62%); administrative and sales is 0,7253 € (12%);

Adaptation of EOQ [8, pp. 39-44] for target volume 8.500 pieces/month/shift:

$$EOQ = \sqrt{\frac{2 \times \text{planned annual volume} \times \text{target for setup cost}}{\%\ \text{inventory carrying cost (\%/year)} \times \text{unit cost}}}$$ **= 3.988 pieces/batch** (1)

- ✓ annual volume for SA015, AA30, EA02 = 8.500 pieces/month/shift * 3 shifts * 12 month = 306.000 pieces
- ✓ target for setup cost = 31,42 €/ event (previous calculation);
- ✓ % inventory carrying cost = 20% (the average percentage calculated based on the history and forecasts)
- ✓ Unit cost = 6,0435 € / piece (previous calculation);

Interpretation: for a batch of 3.988 pieces it will be economical to make a setup

Step 2: *identify opportunities for improvement*

7 great improvement opportunities were identified (video analysis) **(table 3).**

Step 3: *setting improvements for setup and associated costs* – based on setup time diagram; investment required is 3.950 € (of which 3.450 € die preheating system).

Table 3

Improvement opportunities and solutions chosen

	setup with 76 minutes		setup with 20 minutes		
	Opportunity	Wasted time	Improvement	New time	Actions
1	disassembly/assembly mold extractors	30 sec	new mold with extractors	5 sec	external setup
2	loosening ties (left-right) mobile part	50 sec. left + 60 sec. right	Clamping system (tightening torque: 660 Nm)	10 sec. left + 10 sec. right	reducing internal setup
3	loosening ties (left-right) fix part	55 sec. left + 60 sec. right		10 sec. left + 10 sec. right	reducing internal setup
4	tightening ties (left-right) fix part	50 sec. left + 60 sec. right		10 sec. left + 10 sec. right.	reducing internal setup
5	tightening ties (left-right) mobile part	50 sec. left + 60 sec. right		10 sec. left + 10 sec. right	reducing internal setup
6	heating the mold	3.165 sec	Mold preheating system	240 sec	**external setup** (230 ° C heating mold (outside the equipment); **internal setup** (heating the mold from 200 ° C to 230 ° C on equipment for 240 sec.)
7	Introducing the mold parameters for the new model	50 sec.	Preset parameters for new mold	5 sec.	external setup
	Time to reduce 3.690 sec		New time 330		

Step 4: *setting standards for external and internal setup work:* new working procedures;

Step 5: *implement solutions using new standards for setup:* implementation plan for chosen solutions;

Step 6: *checking cost reductions achieved:* cost is reduced from 119,5 € to 31,42 €/event;

Step 7: *monitoring, horizontal expansion and greeting the team* – the improvement was strictly monitored for 90 days and was expanded to other 12 similar equipment.

5. Conclusions

After applying the methodology to reduce setup time and associated costs for plastic-molding processes the following five major tangible results were obtained: (1) increasing flexibility in accepting orders with small volumes (from 15 setup/shift/month to about 30 setup/shift/month - 1 setup for 3.988 pieces); (2) reduced setup time from 76 minutes to 20 minutes; (3) the cost of a setup was reduced from 119.5 €/event at € 31.42/event; (4) overcapacity decreased by reducing minor stops and idling by 1% following the setup time reduction [37] and (5) piece stocks were reduced by 56 pieces for each setup done, and lead time was implicitly reduced (76 min. initial setup time less obtained 20 min. setup time means a reduction of 56 min.; with a standard cycle time of 60 seconds/piece).

It is considered that the methodology presented can be used for virtually any type of setup and adjustment.

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