USE OF OEE COEFFICIENT FOR IDENTIFICATION OF BOTTLENECKS FOR PRESSURE DIE CASTING PROCESSES

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Abstract

This paper discusses OEE index used for identification of critical locations in the technological processes of manufacturing casting products. Analysis involved nine stages in technological process, starting from casting through cutting to washing and drying. Then, we analysed how product quality varies at the stages of technological process in order to verify whether it depends on the presence of bottlenecks. For this purpose we used r correlation coefficient.

Keywords: OEE, die casting, bottlenecks

1. INTRODUCTION

The final product undergoes several consecutive processes used in manufacturing. Therefore, the effectiveness of the whole technological process depends on individual sub-processes. Each of them are performed by means of another machine which has specific processing capabilities. Based on the data from production process and data that result from specification of individual machines, we evaluated the effectiveness of nine stages/processes: Die Casting, Clipping, Trimming, Tambling, Drying I, Drilling, Milling, Washing, Drying II. Evaluation of the effectiveness was carried out using OEE coefficient, which helps measure the effectiveness of using machines and equipment [1, 2, 3]. OEE (Overall Equipment Effectiveness) is a key index to describe the effectiveness of the equipment installed in an enterprise. This index is used to comprehensively describe the three main areas of business activity in the enterprise: availability, effectiveness of use and quality of the products manufactured.

OEE (Overall Equipment Effectiveness) is and index that measures the effectiveness of the use of machines and devices based on a simple analysis of the time of stoppages, maintenance, failures and other factors that affect the effectiveness. **Fig. 1**. presents the main types of wastes which limit the equipment effectiveness.

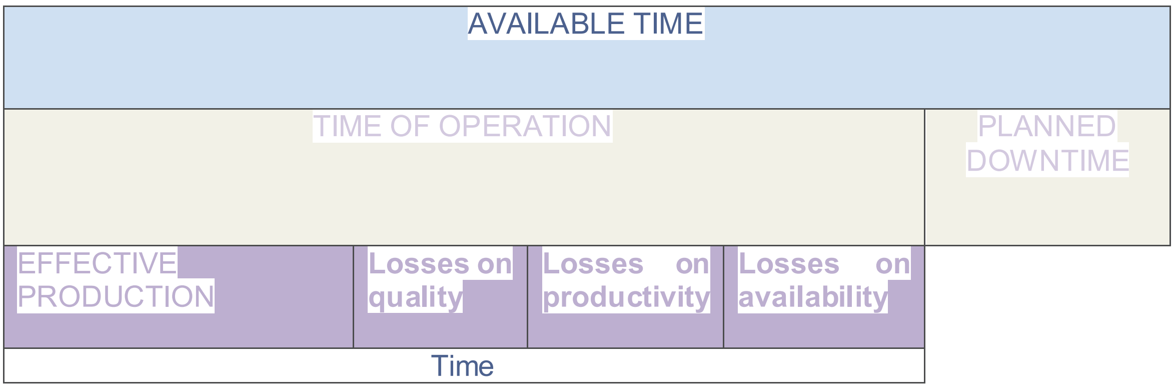

Fig. 1 Types of wastes which limit the equipment effectiveness

Source: own study based on [1÷5]

These losses are mainly related to the failures of machines and equipment. An analysis of damages and failures of machines and structures caused by material defects is possible using modern research methods, such as reported in [6, 7]. The main aim of computation of OEE is to reveal the directions of operations that improve manufacturing processes [2, 3]. The next step was to identify the stages in the technological process which do not meet the production requirements (bottlenecks). Bottlenecks are represented by a machine, function, division or resources, which, due to their manufacturing capability, exhibit high level of use [5]. Such places in specific technological lines have the lowest manufacturing capability and limit the production size that can be achieved in the whole chain of interrelated workstations [3, 4]. Bottleneck points determine production in the whole system. Elimination of critical locations is achieved through synchronization of the processes in a production department [8, 9]. Level of utilization of non-critical resources should cover the demand for critical resources, which means that an hour lost in a bottleneck point is lost for the whole system, whereas an hour saved outside this point has no actual effect [1, 8, 10]. The aim of identification of bottleneck points is to reduce costs presented in **Fig. 1** through determination of a production schedule. The production schedule that includes times of individual operations allows for meeting the assumptions of such systems as Just in Time or SMED. Just in Time system helps reduce warehouse surface area and rationally manage stocks and time. Scheduling also helps eliminate additional changeovers (SMED) and the related technological failures.

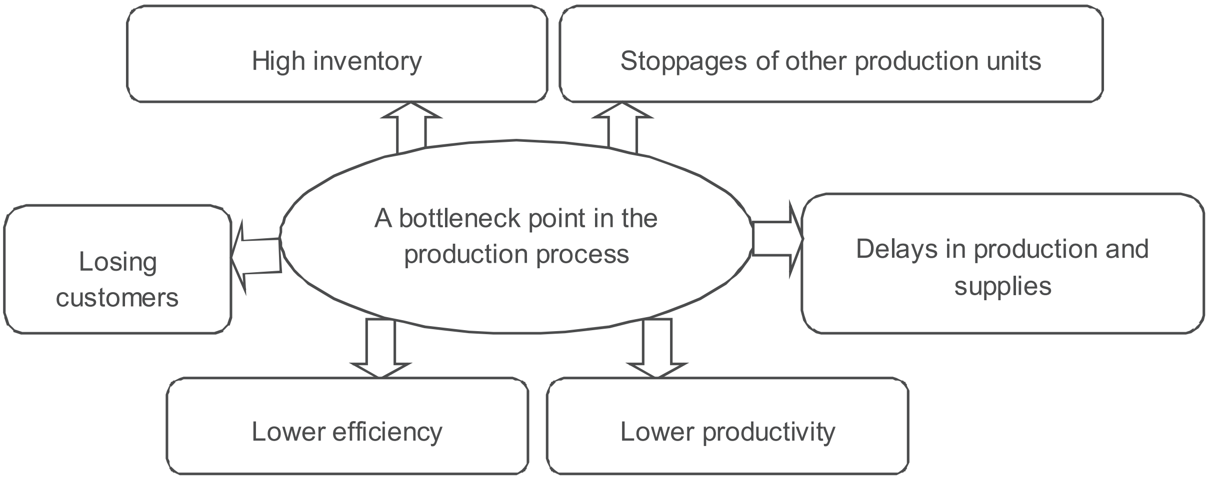

Fig. 2 Effect of bottlenecks in the production process on the components of the system

Source: own study based on [1, 8]

3. RESEARCH AND THEIR ANALYSIS

Based on the data from production process and data that result from specification of individual machines, we analysed processes involved in die casting in terms of a throughput for each of them. The aim of this analysis is to identify bottleneck points as a basis for production scheduling.

Table 1 [Analysis of die casting capacity] OEE calculation is presented to one of the process steps in which a finished product casting - casting process (1).

From the analysis of **Table 1** indicates that the device is not fully used (OEE = 64.5 %). We observe also a large level of quality (QR = 96.6 %). Percent above/below DPV for Die casting process was -3.28 %. Percent above/below for other processes taking part in the production of die-cast presented in **Table 2** (Percent above/below DPV for other processes). Graphically level DPV process for all processes is presented in **Fig. 3**.

Table 1 Analysis of die casting capacity

Operating pattern and machine data:		**Formula**	**Die Casting**
A.	Shifts/day		3
B.	Hours/shift		8
C.	Minutes/shift	=B x 60	480
D.	Planned downtime: lunch, breaks (minutes/shift) Note: If tag relief is used, enter 0		30
E.	Total planned production time/shift (minutes)	=C - D	450
F.	Total planned production time/day (minutes)	=A x E	1350
G.	Days/week		5
H.	Total planned production time/week (minutes)	=F x G	6750
Sample production run data:		**Formula**	**Die Casting**
I.	Total minutes run		6750
J.	Total breakdown time + time for minor set-ups and adjustments (minutes)		600
K.	Total number of parts made (good + bad)		48610
L.	Total good parts (first time through only- do not include parts that were re-processed or reworked)		46940
M.	Total bad parts	=K - L	1670
N.	Actual cycle time (sec/part)	=((I - J)*60) / K	7.6
Other data:		**Formula**	**Die Casting**
O.	Planned cycle time-the one used for capacity planning (seconds/part)		6.00
P.	Projected time per changeover (minutes)		240
Q.	Projected changeovers per shift		0.166
R.	Projected downtime: changeover time/shift (minutes)	=P x Q	39.8
S.	Projected downtime: (breakdown time+time for minor set-ups and adjustments)/shift (minutes)	This should agree with field J	30
T.	Total projected unplanned downtime/day (minutes)	= (R + S) x A	209.5
OEE calculation		**Formula**	**Die Casting**
U.	Equipment Availability:	=(F-T)/F	84.5%
V.	Performance Efficiency	=O / N	79.0%
W.	Quality Rate:	=L / K	96.6%
X.	OEE:	=U x V x W	64.5%
Capacity analysis		**Formula**	**Die Casting**
Y.	Planned uptime (hours/day)	= F/60	22.5
Z.	Planned uptime (days/week)	= G	5
AA.	Planned rate of production (parts/minute)	= 60/O	10.0
AB.	Theoretical production capacity per day	= Y x 60 x AA	13500
AC.	Theoretical production capacity per week	= AB x Z	67500
AD.	Weekly Demand		45000
AE.	Weekly Parts Available for Shipment	= AC x X	43524
AF.	Daily Demand (DPV)	= AD/Z	9000
AG.	Daily Parts Available for Shipment	= AB x X	8705
AH.	Percent above/below DPV	= (AG-AF)/AF	-3.28%

The second after casting process, which to a small extent disturbs the technological process is milling (DPV - 4.62 %).

Table 2 Percent above/below DPV for other processes

Kind of processes	Die Casting	Clipping	Trimming	Tambling	Drying	Drilling Ø7,3	Milling	Washing	Drying
DPV [%]	-3.28	-15.96	-11.93	-12.28	-7.8	-7.70	-4.62	-7.00	-6.70
QR [%]	96.6	91.4	97.7	99.5	100	92,1	93	99.8	100

Percent above/below DPV for bottleneck operation (Minimum value of AH) - clipping (-15.96 %). This result indicates that the clipping process does not comply with the whole process. Two more processes that do not meet the technological cycle is Tambling (DPV = 12.28 %) and Trimming (DPV = 11.93 %).

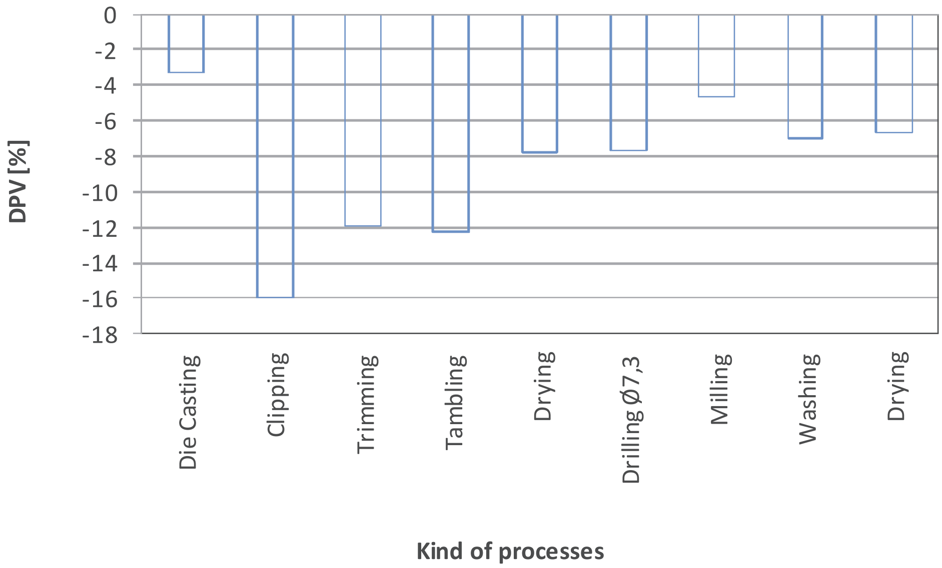

Fig. 3 Percent above/below DPV for other processes

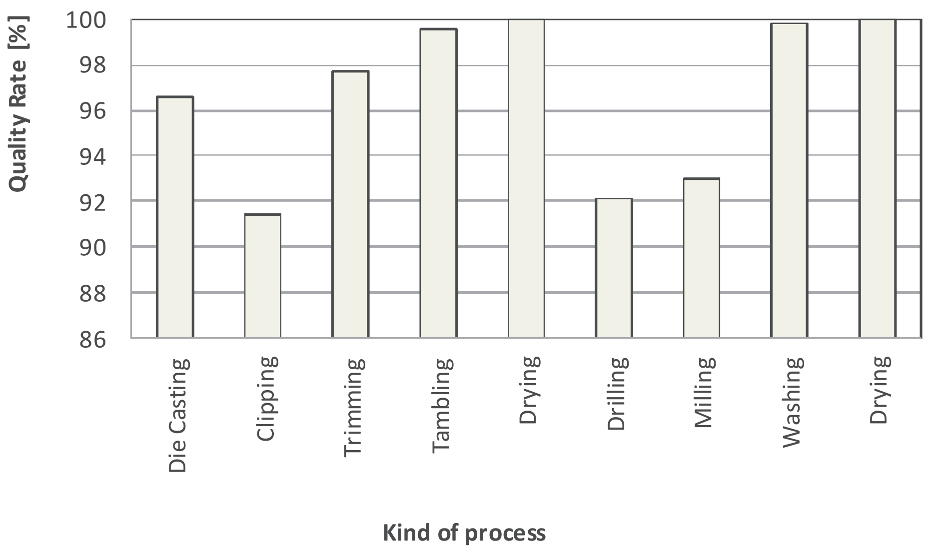

Fig. 4 The level of quality for eight other subprocesses

Then, we analysed how product quality varies at the stages of technological process in order to verify whether it depends on the presence of bottlenecks. **Fig. 4** illustrates the level of quality for eight other subprocesses. The analysis of the graph shows that the highest level of quality is at the stage of Drilling I, Drilling II and Washing. The lowest level of quality occurred in three processes: Clipping, Drilling and Milling.

Analysis of this figure reveals that the lowest quality is observed for clipping, which also represents the most substantial bottleneck. The scatter diagram helps determine whether and to which degree these values (DPV and QR) are correlated with each other (**Fig. 5**).

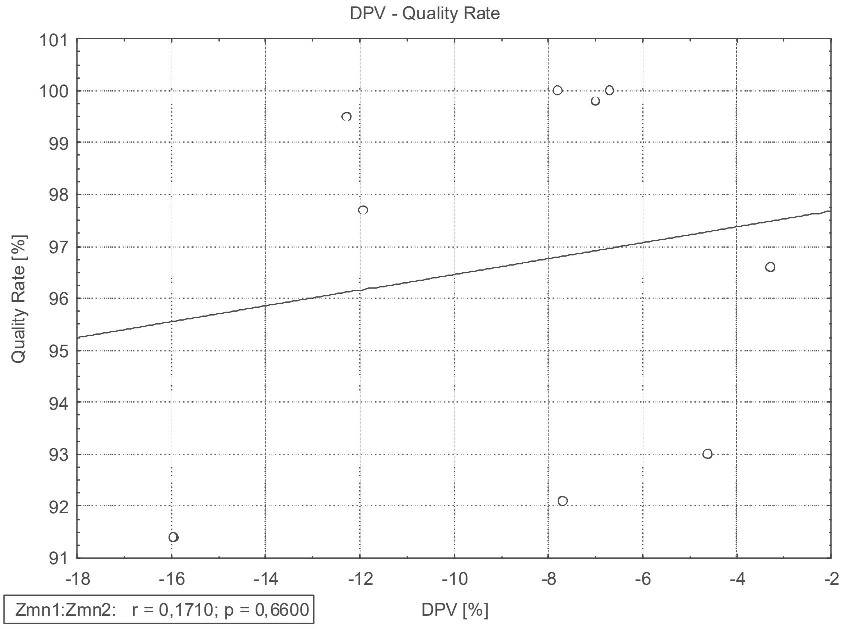

Fig. 5 Scattering diagram between Quality Rate and DPV [%]

However, analysis of other processes demonstrated that the lowest level of quality was not connected with DPV for the processes (**Fig. 5**). Coefficient of correlation [9, 10, 11, 12] *r* of 0.17 represents the lack of relationship between quality and DPV. Pressure die casting has been known to be a specific process, where internal defects are often hidden and can be revealed only at the stage of cast processing. The processes discussed (Clipping, Drilling, Milling) are highly invasive. Therefore, they reveal pores or gas bubbles, which increases the number of products that do not meet quality requirements.

3. CONCLUSION

The analysis of the above investigations shows that the process that meets the requirements to the highest degree is casting. The processes aimed at finishing of products showed worse results. A bottleneck, which is the process which limits meeting all the customer requirements is Clipping, followed by Tambling. The process of tambling can be enhanced through using additional machine of this type into the production line or replacing it into the more automated. The activities aimed at improved tambling process will undoubtedly cause moving of the bottleneck location. Analysis of the investigations presented in this study shows that quality is not correlated with the presence of bottleneck. The study found that bottleneck points determine the efficiency and productivity of a production system. In order to ensure the efficiency of a production cycle, it is insufficient to determine a single transport batch for all the phases of a process. The experiences from previous production cycles should be used to define production schedules. They should be defined based on the production flow rather than production capabilities. Stages in a production process should be considered as interrelated and interconnected components rather than individual processes. Production cycles are based on the schedules and should not be defined in advance.

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