

The Rationalization of Automatic Units for HPDC Technology

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Received 01-02-2012; accepted in revised form 31-05-2012

Abstract

The paper deals with problem of optimal used automatic workplace for HPDC technology - mainly from aspects of operations sequence, efficiency of work cycle and planning of using and servicing of HPDC casting machine. Presented are possible ways to analyse automatic units for HPDC.

The experimental part was focused on the rationalization of the current work cycle time for die casting of aluminium alloy. The working place was described in detail in the project. The measurements were carried out in detail with the help of charts and graphs mapped cycle of casting workplace. Other parameters and settings have been identified.

The proposals for improvements were made after the first measurements and these improvements were subsequently verified. The main actions were mainly software modifications of casting center. It is for the reason that today's sophisticated workplaces have the option of a relatively wide range of modifications without any physical harm to machines themselves. It is possible to change settings or unlock some unsatisfactory parameters.

Keywords: Automation and Robotics in Foundry, Quality Management, High Pressure Die Casting (HPDC), Work Cycle, Rationalization of Automatic Unit

1. Introduction

This article deals with HPDC workplace optimisation and its first results.

Characteristics of pressure castings

High productivity is mainly based on casting technology and cast material. Productivity ranges from 15 to 1000 operations per hour. For aluminium alloys cast in cold chamber machines with the number of operations ranging from 15 to 250 per hour, but for example, with zinc alloys cast in hot chamber machines can be achieved up to 1000 cycles per hour. These variances depend on cost and weight of a casting, number of castings located on the die, machine size and workplace facilities, etc.

Utilization of molten metal is determined by the ratio of weight of metal molten into the casting chamber to the gross weight of the casting. The higher the utilization, the lower the share of the cost of melt processing is. It depends on the correct determination of the gating system, optimal utilization of the clamping force and effective ventilation system, including overflow. For die casting, the use range is 40 - 85%.

Moulding method of castings allows cast of most holes of the parts with a minimum waste during machining. It is possible to use the close dimensional tolerances to achieve the minimum number of operations during mechanical processing.

The surface quality of casting is at a level that the cast no longer needs further modifications (except after hardening and after finishing).

Possibility of casting thin-wall castings, unlike most conventional casting technologies enables the cast wall thickness from 0.8 to 4

mm. In this way pressure castings can compete with pressed parts, especially today in rapidly growing automobile industry where new technologies and production possibilities are apply.

Possibility of embedding parts made from other metals. There are many products where this option is used. The only negative side is the destruction, both scrap and finished products. Properties of alloys prepared by casting under pressure – with this technology can be achieved more favourable strength values than using the gravity sand casting.

2. Production cycle of die casting technology

This work is focused on high-pressure aluminium die casting machines with the horizontal cold pressure chamber, so we are going to deal with this technology only.

Die casting cycle consists of several phases, which are directly connected to each other, or running simultaneously. Due to changes in parameters during different parts of the process the overall quality of the casting, die casting moulds and piston wear, material consumption, total cycle time, etc. can be changed.

Stage of the die casting cycle

Metal dosage

This action takes place in a closed die, where previously determined quantity of molten metal is poured into the hole in the chamber through dispensing equipment (ladles, dosing furnaces, etc.). Metal weight must comply with the weight of casting (including gating system and pressers)

Pressing

This process is one of the most important, since there are various parameters that then determine the final quality of the casting moulds wear, cycle speed, or wear of the whole machine. Pressing is divided into several stages in terms of runway, pressure, but also the piston speed.

A) First phase – pre-filling:

This phase begins immediately after dispensing the metal into the chamber. Casting piston starts to move forward at low speed to conceal dosing hole and metal doesn't splash out of the chamber. Then the piston goes the same speed until the metal gets up into the gate. This movement is known as pre-filling phase or as the first phase of filling. Low piston speed is important, because the metal does not make a whirl and does not absorb air from the chamber. If so, it would increase the porosity in castings.

B) Second phase - filling:

Continuous follow-up of the phases is ensured through the machine control system, where the switching point is either mechanical or electronic (eg. cam, or digital code). The second phase is characterized by the fact that the piston has large acceleration to achieve high filling speed in the shortest possible time. The piston continues with given speed and pressing metal into the cavity through the gates until the cavity is completely full. After the die is filled the piston sharply brakes. Speed drops to zero, and the second phase ends.

C) Third phase – total squeeze:

Casting piston has no speed at the moment, but the force on it is still developed. Hence the pressure is made in the cavity of the die to ensure compaction of the casting, reduction of porosity, etc. These phenomena can be reached only if there is enough amount of liquid metal between the chamber and the die cavity. If the metal "freezes" inside the system, the hydraulic pressure is not transmitted and compaction of the casting cannot be done.

Cooling and solidification in the die

Cooling of the metal in the die is needed after pressing. Cooling should be fast enough to reduce casting machine cost, but not too fast, however, to avoid a hazardous freeze of a thin layer at the surface of the die. This then creates undesirable crust on the casting. High cooling rate also increases heat stress of the die, thereby causing its greater wear. Die is also at this stage, exposed to stress from squeeze and contraction from the casting. To avoid too much stress on the die and underpin its good cooling the holes are drilled inside for cooling and tempering medium. For cooling water is typically used and for tempering oil is generally used. The task of cooling medium is heat dissipation from the die, what will accelerate the setting time. Tempering medium is then used in some dies to avoid thermal shock when the die is cold and casting machine is hot or during breaks, downtime, etc., when the casting machine is in operation. Opening of the die follows immediately after the casting is solidified enough to avoid damage during extraction. On the other hand, when the time of solidification is too long, risk of die damage may occur due to shrinkage of the casting, and this longer cycle time is wasteful. From this it is obvious that parameters of temperature cooling and solidification time should be optimally chosen.

Casting removal

Removal is done by hand, or robot manipulator according to the degree of automation of the workplace. Trimming, machining, further finishing operations, palletizing and shipping follows. No part of the casting may remain in the die to avoid die damage or other unexpected event that could lead to shutdown of the machine.

Die and casting plunger treatment

The die and casting plunger should be cleaned and prepared for the next cycle after the casting removal. The die and the plunger are coated with separation device which can be either in a liquid form as aqueous solution (has cooling function) or as a powder. Specific choice of device depends on the size of a casting, its complexity, temperature and condition of the dies. Blowing with air stream follows immediately after application of the separation lubricant and this leads to disposing the excessive lubricant and creating of a film with the desired properties. Main task of the film is to simplify the removal of the casting and to prevent sticking of metal to die during solidification. Next task is to reduce influence of thermal shock. The compact layer prevents direct contact of the melt and surface of the die, and thus reduces the temperature at its surface. Spraying is carried out according to the degree of automation of the workplace, either manually or using manipulator. After die treatment, the plunger returns to its starting position where is lubricated before delivering of the metal. This will ensure less wear on both the chamber and the casting piston. Lubricant is in the liquid or granules form.

3. Design algorithm and rationalization of the die casting centre

During the design and rationalization of the aluminium die casting workplace can be generally expressed by the algorithm with use of the following flowchart.

Input Database

As the first part of the algorithm is given a database containing documents, data, plans, etc., which are used in the procedure in the algorithm. This summary of documents is created as an example of major parts, which can be extended with other materials needed for the project.

The main skeleton of the algorithm

The main skeleton of the algorithm is gradually described in this part, for example the basic process in the design and rationalization of the die casting workplace.

The basic impulse for the workplace designing is the demand. Demand is presenting request for manufacturing new products for which capacity, material and other conditions requiring investments, production engineering, cooperation of other companies or suppliers or which goes beyond the company. A lot of input parameters that affect how and whether the workplace will be designed should be considered. The most important are parameters of the actual demand. General assessment of options follows. If the contract seems onerous, does not fit into the production program, the company does not like technology, the workplace project is stopped.

If the input parameters for the acceptance of demand met, the decision goes the way the project take place. Designing workplaces for streamlining the way usually treated, if the volume of future orders smaller production capacities are sufficient, it allows the existing technological equipment of the enterprise, etc. Otherwise, proceed with ordering the workplace so-called "peace" of the demand. Both of these solutions require the correct choice of the die casting machines and other peripherals on the basis of calculations, parameters, properties, etc.

When designing the die casting workplace using rationalization way is necessary to choose adequate casting machines and peripherals. If peripherals are insufficient, e.g. due to a low degree of automation, it is necessary to adjust the equipment or buy new and supplement existing workplace. Therefore we can assume that the workplaces delivered according to requirements are better and are better adaptable peripherals. This brings us to the preliminary design of the die casting workplace.

The next step is preparation of a tender to be sent to the customer. If the customer decides to confirm the tender, it begins with the realization of the contract, whose first step is to purchase equipment needed for the realization itself. The chosen arrangement of machines, tools and equipment in space will follow. Deployment of machines in the production itself is very important especially from a logistics standpoint. Flows of material, products, process fluids, etc. are large within and around workplace, so the distribution of work in this regard should be optimal. It is necessary to ensure safety and danger areas and

separate them from its surroundings: define the runway where the material and operators move, etc.

Time sequence planning of operations and setting of all the calculated and observed parameters for peripheral devices for pressure casting machines follows after deployment of machines. The first test series production may follow.

If the test series correspond to the required quality, serial production may start (quality in this case is meant to meet a wide range of criteria such as dimensional compliance with drawings or documentation that casts have defined composition and porosity, etc.). In the opposite case change of parameters, geometry, form, and next test series follows till castings have adequate quality.

The serial production is then applied new improvement within the new department in order to minimize time consumption, production costs, etc.

Rationalization of timing

After the serial production of castings started is usually treated to the greatest possible efficiency in the manufacturing workplace. One of the first practices is to introduce time-saving in each process.

The current state of timing is mapped in detail first. In this setting, the working conditions are collected, time reserve of operations, time reserve between operations and the possibility of using production times overlapping of individual operations.

Several solutions are suggested and then the most appropriate is applied and verified. If it turns out that the key process times and overall times are not shorter, it approaches to further changes in timing, changes in parameters of casting, etc., and the cycle repeats. Otherwise, there is a targeted time-saving. If this saving is not sufficient, the procedure is the same as in the previous step. If the saving is sufficient, it is necessary to ascertain the stability of castings quality because when the quality suffered the measures for reducing cycle time has lost its meaning.

Once it is found that the quality is satisfactory, this is the only real time saving and cost savings can be expected.

This is verified in the subsequent economic calculation. When the cost of production in terms of time savings are reduced so that the company is satisfied with the results, the rationalization process is terminated.

More ways of rationalization

For maximum efficiency of production, other rationalization actions are used, such as improved spatial layout, work organization, work processes, work products, etc. This is based mostly on proposals or objections workers, preliminary economic calculations, etc.

Generally these actions begin with most detailed findings of the current situation. The obtained values are subsequently processed using appropriate methodologies and procedures. This will lead to a possible solution of the problem, than the best is applied. We verify that these solutions and the results are satisfactory, and according to it proceed further. If the results aren't satisfactory, changes of the corresponding variables and parameters follow, and the cycle repeats. Otherwise, it finds the status of all other important variables influencing the process, outputs, etc. If these are satisfactory, it will evaluate the benefits of previous actions. The process of planning and rationalization of work for the contract is than usually closed.

Table 1.

Prepared table for analysis

Technological operation	Cycle describe:						
No. Cycle	1	2	3	4	...	n	
Start cycle	x_1	x_2	x_3	x_4	...	x_n	[min:s]
End cycle	y_1	y_2	y_3	y_4	...	y_n	[min:s]
Cycle time	$y_1 - x_1$	$y_2 - x_2$	$y_3 - x_3$	$y_4 - x_4$...	$y_n - x_n$	[min:s]
arithmetic average	$\bar{z} = \frac{1}{n} \sum_{i=1}^n (y_i - x_i)$						[min:s]

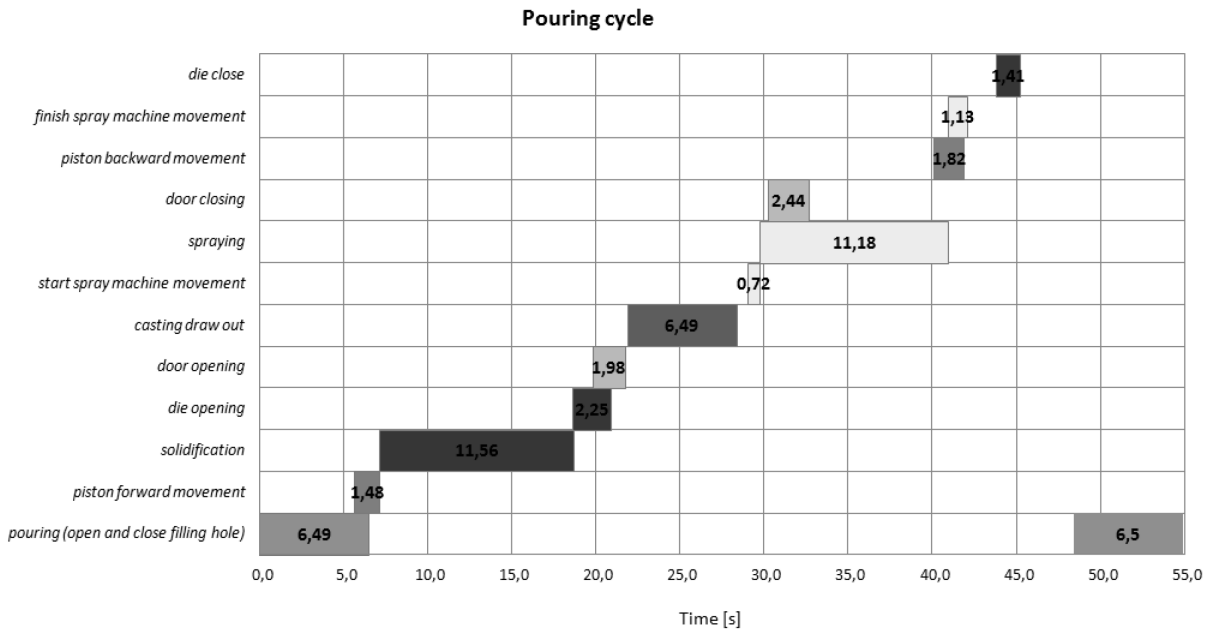


Fig. 1. Cycle with time phases elementary operation

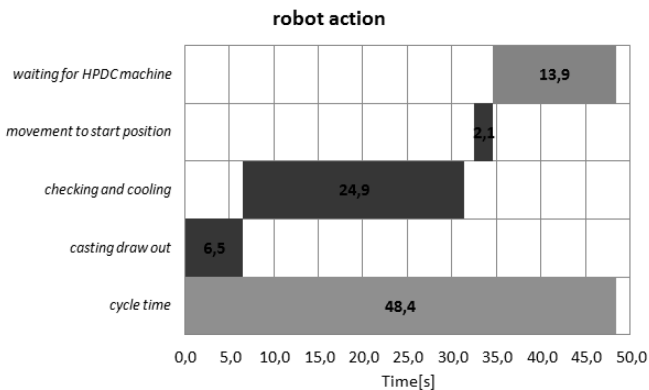


Fig. 2. The robot action during cycle

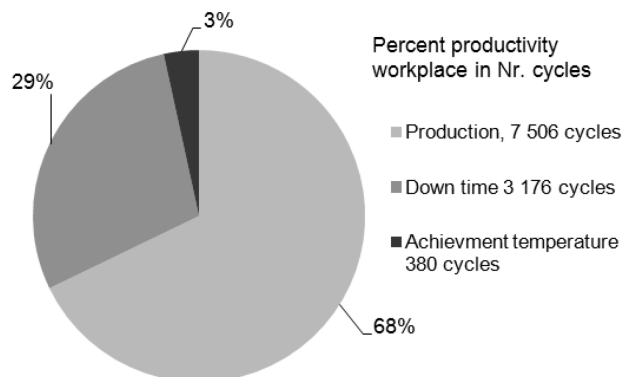


Fig. 3. Percent productivity before optimization

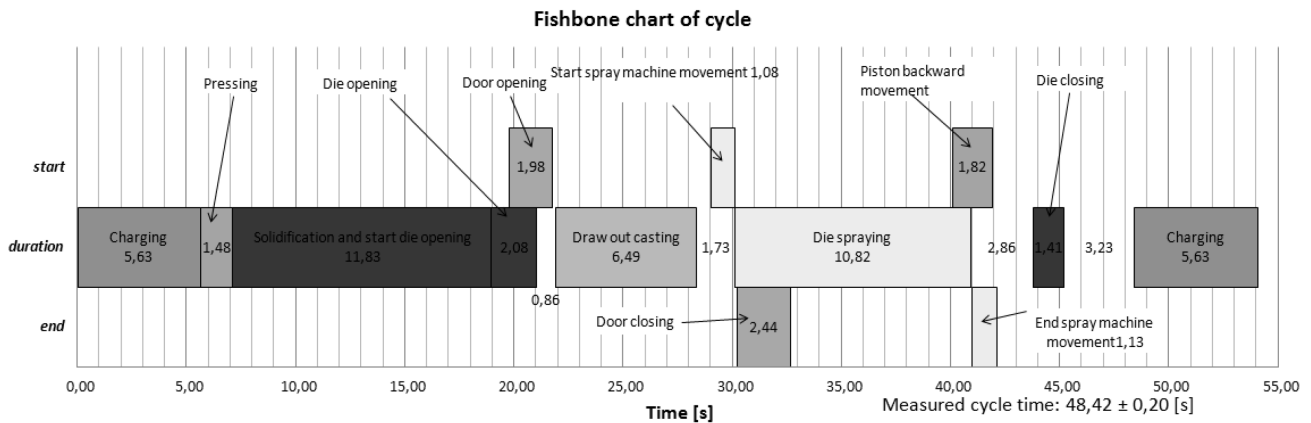


Fig. 4. Cycle in fish bone chart

4. Experiment

The aim is to rationalize the timing - to achieve increasing productivity of the workplace. This means to try to modify the individual parts of already proposed process to make them as economical for the company with preservation of product quality.

Rationalization of timing

This part will contain the results and subsequent outcomes from performed time measurements. Measurements are made using hand-held video camera and stop-watch. For each part of the process, which is mapped, is made about 100 measurements, and selected group most frequent values subsequently entered into the table (see example Table 1) to the nearest one-tenth of a second. Values are then averaged by arithmetic average. Another task was to record other important values characterizing or affecting the die casting process and is monitored them in each measurement. The measured time was compared with time record from press machine.

Measured value was analysed in two types of diagram:

- Diagram with elementary operations (Fig. 1).
- Fishbone chart diagram (Fig. 4).

There was analysed elementary operation (e.g. the works of robot – Fig. 2) and total productivity time (mainly time fund use machines – Fig. 3).

There was made optimisation with main goals:

- Reducing cycle time.
- Significant improvement time fund use machines.

All cycle repair was made on possibilities of press machine – by two machine was bought new automation with better possibilities of control and there was bought charge furnace (without ladle – significant shorter time).

The main mistakes in the cycle:

- Bad cooperation robot (the machine wait for robot – complete checking, casting cooling and broken off or cutting of gating system).
- The machine wait for spraying machine.
- The machine wait for liquid metal.
- Bad opening and closing door of machine.
- Using spraying machine with large spraying head – shorter time for spraying phase.

The production analysis was made during several months – on started was average time fund use machines 65-70%, after optimisation and creation of methodology of evaluation this parameters is productivity average around 80%. Our aim is obtain average productivity 85 – 90% - for full automatic units.

Proposals for rationalization arrangements

Change of the "fundamental position" of the robot - the measurements showed that the additional time savings would be possible at a different start of removing the casting from the die. The initial position of the robot to the longitudinal axis of the die casting machine is not at right angle, thus it is not optimal for removing. Robot performs rotation movement of the main carousel to get into position perpendicular to the longitudinal axis of the machine after opening the door of casting machine. After that, the drive into the die and removing follows. Total savings would offset 0.75 sec.

The time savings after optimisation was for different casting in interval from 2 to 8 s (from total time cycle from 35 to 80 s).

Opening the door of casting machine - if the proposal of displacement of the "basic position" of the robot was denied, change in removing process is obvious. This could be different settings of the doors movement if management system allows it. The current situation is such that the die opens, and then the doors of casting machine begin to open. Opening of the doors at the same time or even ahead of the opening of a die, to allow robot to remove casting immediately should be the solution.

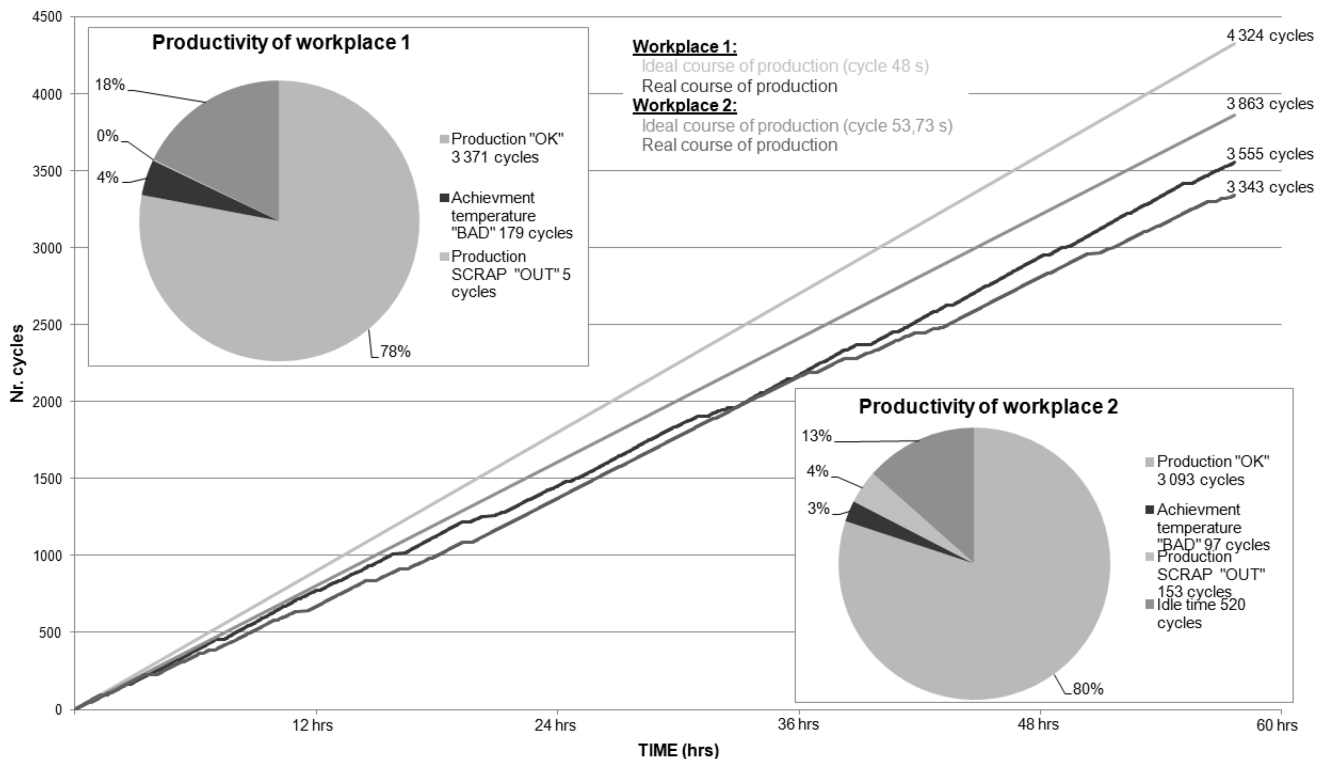


Fig. 5. Total productivity after optimization

5. Conclusion

The experimental part is focused on the rationalization of the current work cycle time for die casting of aluminium alloy. The working place was described in detail in the project. The measurements were carried out in detail with the help of charts and graphs mapped cycle of casting workplace. Other parameters and settings have been identified.

The proposals for improvements were made after the first measurements and these improvements were subsequently verified. The main actions were mainly software modifications of casting centre. It is for the reason that today's sophisticated workplaces have the option of a relatively wide range of modifications without any physical harm to machines themselves. It is possible to change settings or unlock some unsatisfactory parameters.

Finally, two types of evaluation of proposed adjustments were carried out by calculating the cost. In the first case, the costs were calculated from actual measured times and different scrap in given period was included in this calculation. This means that it were calculated time and scrap-reducing savings, but also to a partial extension of the cycle time. The overall impact of the cycle adjustment to the calculation was therefore assessed. Only the benefit from implemented time measures was evaluated in the second calculation. The scrap was taken as constant in this second calculation. In the first method of evaluation was found that due to all the undertaken modifications were substantially spared the production cost. In summary, the benefits of these modifications means 1 months free capacity of automatic units per year Total

time saving is ca 9 %.. Total productivity for all workplace is around 80%. after optimisation.

Acknowledgements

This post was created with the support of the project FR-T11/028 "Optimising and controlling the cost and quality systems in the foundry POLAK Ltd. "Announced by the Ministry of Trade and Industry with the support of a project launched by the TIP program.

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