

# Reengineering of Permanent Mould Casting with Lean Manufacturing Methods

R. Władysław

Department of Materials Engineering and Production Systems, Technical University of Lodz,  
Stefanowskiego Str. 1/15, 90-924 Łódź, Poland  
e-mail: ryszard.wladyslaw@p.lodz.pl

Received on 25.04.2007; Approved for printing on: 27.04.2007

## Abstract

At the work were introduced main areas of production system project of casts produced in permanent moulds, that constitutes reengineering of conventional production system according to Lean Manufacturing (LM) methods. New resolution of cooling of dies with water mist was shown to casting of car wheels made from aluminium alloys in low pressure casting process. It was implemented as a part of goal-oriented project in R.H. Alurad Sp.z o.o. in Gorzyce. Its using intensifies solidification and self-cooling of casts shortening the time of casting cycle by the 30%. It was described reorganizing casting stations into multi-machines cells production and the process of their fast tool's exchange with applying the SMED method. A project of the system was described controlling the production of the foundry with the computer aided light Kanban system. A visualization of the process was shown the production of casts with use the value stream mapping method. They proved that applying casting new method in the technology and LM methods allowed to eliminate downtimes, to reduce the level of stocks, to increase the productivity and the flow of the castings production.

**Keywords:** Innovative materials and casting technologies, Cooling with water mist, Computer aiding the casting production, Lean Manufacturing, SMED, Kanban, Die casting

## 1. Introduction

The implementation of the technological cooling water system of dies in the process of casting car wheels made from aluminium alloys in the R.H Alurad Sp.z o.o. foundry in Gorzyce was the inspiration to elaborate the project of the production improvement in the model foundry factory [1-4].

Conducted then examinations required analysis of technological and production factors on stations of casts production. They suggested implementing changes outside field written in the project, and also in the organization of functioning of the department.

A purpose of the work which designing changes of the conventional system was results from this experience of silumin casts production produced with method of casting in permanent moulds, leading for increasing the effectiveness productions of foundry. In the project was applied a methodology of producing

improving systems in accordance with Lean Manufacturing. The principle and the way of implementations for the technology lost-wax process was described by the author in the earlier publication [5].

## 2. Main areas of reengineering

Fundamental aspects of the improvement in the production require implementing changes in basic areas of the production system:

- of casting in the technology: shortening the cycle by fast cooling dies and casts,
- in changing-over casting stations,
- in the organization of production cells,
- in the system of steering a production process.

## 2.1. Improvement of technology – fast cooling of die and cast

A view of the industrial station for producing casts with low pressure casting process was presented in figure 1.

Casting in the conventional system takes place with natural convection self-cooling of the die or with applying additional chilling with stream of compressed air pointed to the exterior surface of the die while solidification and self-cooling of the cast.

In order to intensify the process of cooling casts on the station a system of cooling dies with use of water mist was implemented. The device for generating the water mist was shown in figure 2 [2]. It was designed and made as a part of the intentional project.



Fig. 1. Low pressure casting station of car wheels castings [2]

The device – Automatic Cooling Servo lets the die simultaneous cooling to eight different areas with water mist about set value: of the stream, the pressure, beginning the time and cooling lasting.

In picture 3 comparing chilling the total time for cooling examined variants was described. From carried out examinations results that cooling with the water mist makes shorter a production cycle and biggest shortening of the cycle of car wheels casting process was achieved at applying cooling with mixture of air and the water mist for 0,35/0,40 MPa pressure.



Fig. 2. Water mist cooling device [2]

Cooling the die with the help of the water mist is more effective than cooling with only an air. It lets influence the productivity of cooling individual zones of the cast the quality of the cast in reality through regulations, it provides with the greatest effectiveness of cooling 0.45 MPa of air at the pressure and 0.50 MPa of water as well as it is shortening the cycle of the die casting about the 30% at reducing using air up.

One should apply described above effects of the intensification of cooling dies in the designed system also for cooling casts outside the casting machine. In picture 4 research findings of changes of the temperature of the chill and the cast were presented while casting the cycle out with using cooling with air and the water mist. It results from research, that the temperature of the cast and mould (2mm from the surface of the cast) in the moment of removing it from the chill is taking turns in a wide range from 100°C to 480°C depending on method of cooling the die and area of the cast. The stream of the water mist evenly is directed for the casting in the state in a few till a dozen or so seconds to lower its temperature to <50°C. It will cause the improvement in the resistance of casts to damage during preliminary cleaning and the transport hence he will reduce the number of gaps, a transport will hasten them for next operations as well as he will increase the safety of the functioning of machines and people in the foundry.

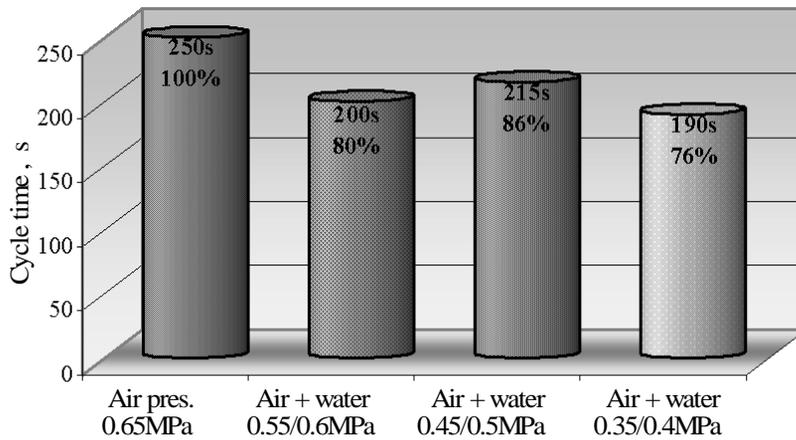


Fig. 3. Effect of cooling method on casting cycle [2]

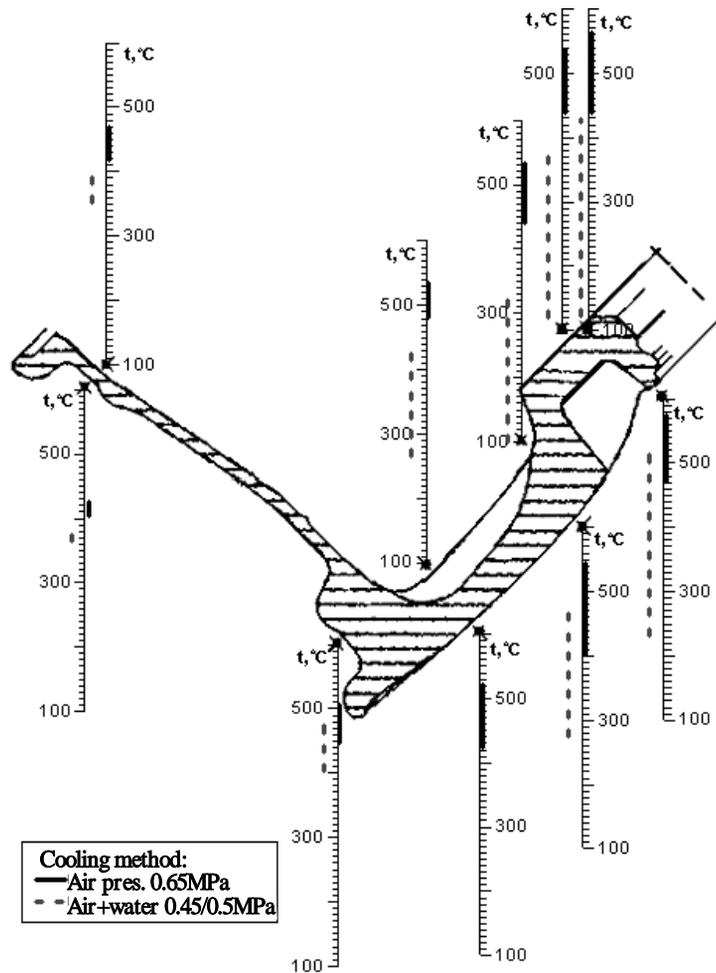


Fig. 4. Temperature range of cast and die in cooling process with 0.65 MPa pressure air and with water mist 0,45/0,50 MPa [2]

## 2.2. Organization of production cells

Choice of the appropriate form organizational of production cells one should precede by analysis of current state in the foundry with applying the mappings of the value stream method. The visualisation of the entire process and the thanks ago simpler finding all bottlenecks or stoppages is an idea of creating the map of the present state against the background of entire production process. Their being results from burdening stands with stoppages or with bad steering supplies. Map with the help of appropriate symbols is showing the process, the route of worker and of material or semi-finished product in the entire production system. Between individual processes momentary buffers as well as magazines of longer storing are appearing. The manufacturing process is also described with such sizes as: *c/c* - time of the tact = available time / size of the order, *c/p* - time of changeover, *NVA* - time, in which value isn't being added to the product, the *Wyd.*-productivity of the machine [6].

As a result of analysis was designed the combining stands of

No.	PLACE	OPERATOR TIME	Machine TIME	ROUTE TIME
		s	s	s
10	Machine 1	15s	228s	2s
20	Machine 2	15s	180s	
30	Machine 3	15s	185s	
40	Machine 4	15s	176s	
	Σ	60s	769s	8s

casting machines into cells. It was shown schematically in picture 5. The production at the same time a few production orders by one operator is optimizing time of its work. During solidification and self-cooling of the cast in the die He is able to supervise the functioning of machines, to make the visual control of casts and die and preliminary cleaning casts.

Arranging machines by the optimum and establishing non-crossing ways of passages of the operator is confirmed with method of the Spaghetti diagram [7].

The Hazard Alarm appearing in the central part of the cell of the is giving the possibility of sudden stopping a production process by the operator in the case of noticing by it threats to the safety of the work or the imperfect completion of the production. This authorizing the operator of every station of the production process constitutes the realization of the - Andon principle essential for Lean Manufacturing.

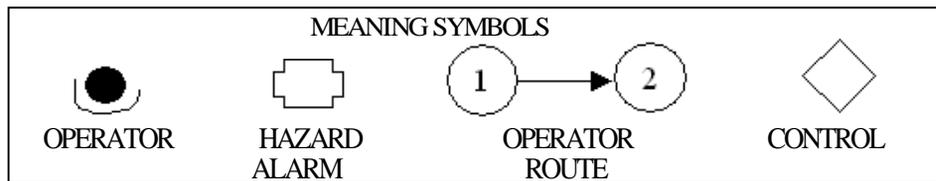
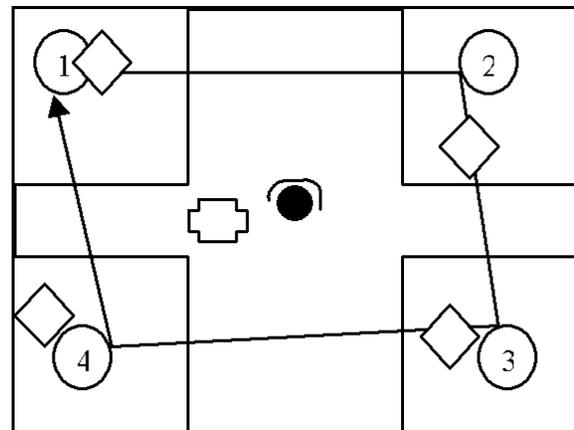


Fig. 5. Reorganization of casting machines into production cells

## 2.3. Fast changeover of casting machines with SMED method

An idea of the SMED method was presented in figure 6.

From comparing rearming basic stages in the conventional version with the version after applying changes results the reduction of the changeover time in a production cycle. It is an effect of outside, internal preparing the stands' activity separating and simultaneous moving the preparing activities beyond called *tpz* area, it's mean beyond production station [7].

Switching the machine off for the duration of the completion of the preparatory action is extending the *tpz* time much, mainly because of the more late start-up of the machine and preparing it for the work (of making so-called working test series). Therefore SMED method of inventively separates outside preparation from internal and enables the exchange of the part of the preparatory action from inside to outside. They later are making streamlining both types of the operation their in order to shorten times of realization.

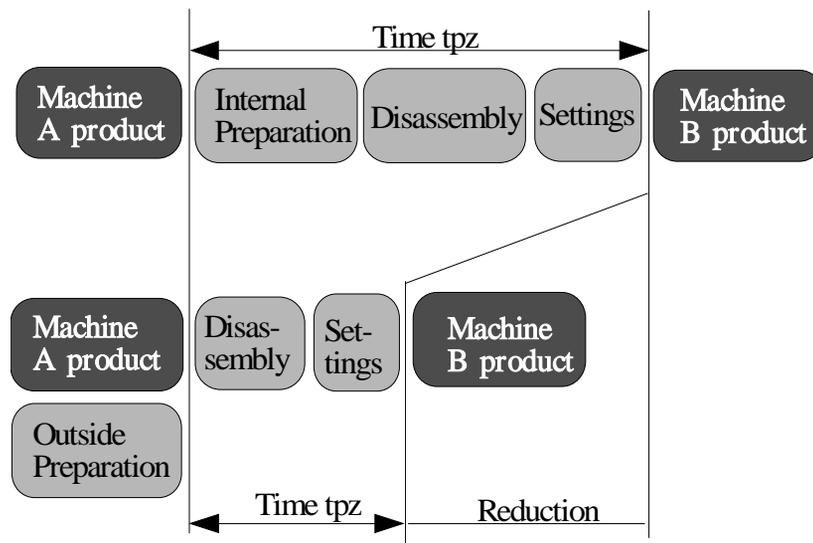


Fig. 6. Reduction of changeover time with SMED method [7]

It is possible, in accordance with SMED principles to carry out transforming to much shorter from the existing technique of changeover in three steps [5].

#### Step 1 - separation of internal and outside activities

The preparation and the transport of tools and devices during the work of a machine allow to reduce the time of internal operations about the 30% up to the 50%.

#### Step 2 – transforming the internal preparation into to outside one

It consists, for first on the new assessment of the activity for reason of rating to the type and for seeking ways of transforming the internal arrangements to outside. It is possible thanks to analysis of the real course and the realized purpose of preparatory action.

#### Step 3 - streamlining the preparatory action for activities

Preparatory are making up:

- the preparation, the regulation after trial, control of materials and tools - activities guaranteeing correct situating and appropriate functioning of devices and tools (constitute the 30% of all preparatory action) - realized as internal arrangements,
- the assembly and disassembly of tools and devices - activities including removing devices and tools after the realization of the production party and preparing devices and tools for the next product (constitute the 5% of all preparatory action) - realized as in-house arrangements,
- the measurement, settings and the calibration – the activities must be made to the purpose of the correct accomplishment of production tasks e.g. the centring, the

dimensioning, the measurement of the temperature or pressure and like that (constitute the 15% of all preparatory action) - realized as internal arrangements or outside,

- test series and the adjustment of the machine - last of activities carried out while traditional preparing, adjustment of the machine in the destination of appropriate making the product (constitute the 50% of all preparatory action) - realized as in-house arrangements, since to as long as the machine isn't actually set not perhaps correctly to perform production tasks.

In table 1 next activities were described made while rearming the casting machine after applying the SMED method. The percentage participation of lasting for their time in rearming was shown in picture 7.

After applying SMED techniques the time of preliminary heating up the form was reduced to 10 minutes and he can more be reduced only through more distant standardizations of the activity. Disassembly of the previous form together with delivering new is filling the 15% of changeover the total time. In the future appropriate organizing additional trained human resources for changeover will allow to save consecutive minutes and the entire process will do safer.

His total time amounts to 34 minutes and it means the shortening over the half in comparing to the state before changes.

Table 1. Activities and their time of lasting while changeover the machine after applying the SMED method

	Activities	Time		
		min	%	Cumul.,%
1.	Start of changing-over	0	0	0
2.	Disassembly of the current die / delivering the new heated one from covering with put ceramic layer	5	15	15
3.	Fastening the die / Assembly of side jaws	4	12	26
4.	Assembly the cornet and the burner	3	9	35
5.	Assembly of the getting cornet on the plate of the machine	2	6	41
6.	Assembly the burner	1	3	44
7.	Heating of the die	10	29	74
8.	Connecting of cooling system	1	3	76
9.	Checking and starting the cycle	1	3	79
10.	First cast	4	12	91
11.	Good cast onto Rtg checking	3	9	100
	<b>Suma <math>\Sigma</math></b>	<b>34</b>		<b>100%</b>

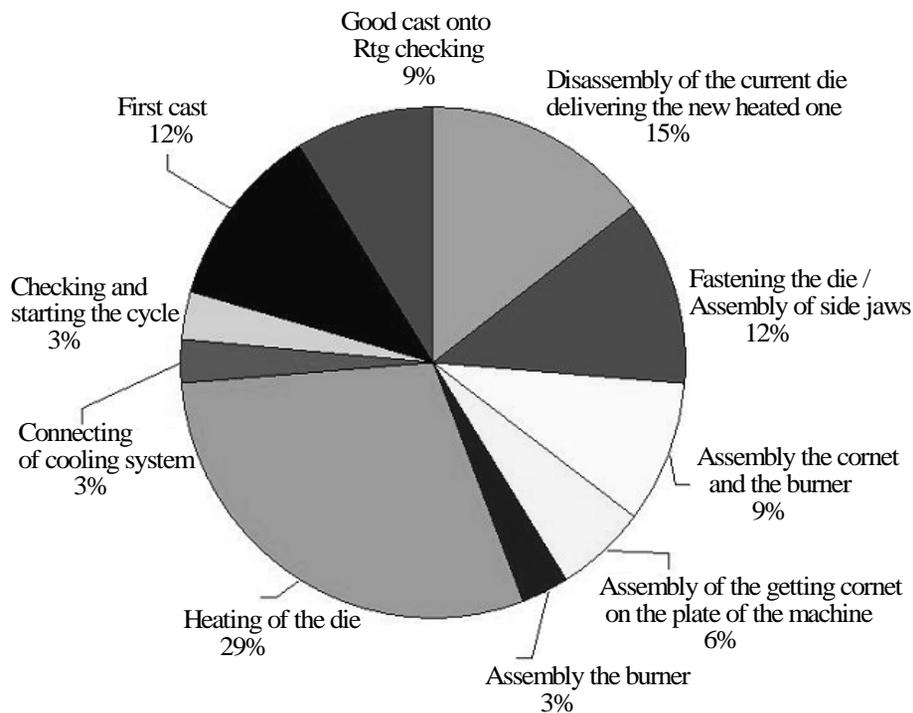


Fig.7. Percentage participation of the activity in changeover the machine after applying the SMED method

## 2.4. Value stream map of future state of production process

In picture 8 a visualisation of the designed production system was presented with the help of map of the future state. It includes an entire production process of the foundry, for which the production is a reply to the demand of the customer of the - department of mechanical processing. It's describing with use of special symbols and the text, the elements of project, raw material

sailing across the stream and semi-finished products and the time of the realization and waiting for the technological operation. It was shown order of the casting operations (of positions) according to the principle „pull” is cleaning and packing, the control with X-rays, casting in dies and preparing liquid casting alloys. From calculated production parameters results, that total NVA time (of storing) to value 1.5 day but the VA time were minimized (productive) to 34 minutes. The production capacities achieved 4700 casts per month for 2 shifts of work system.

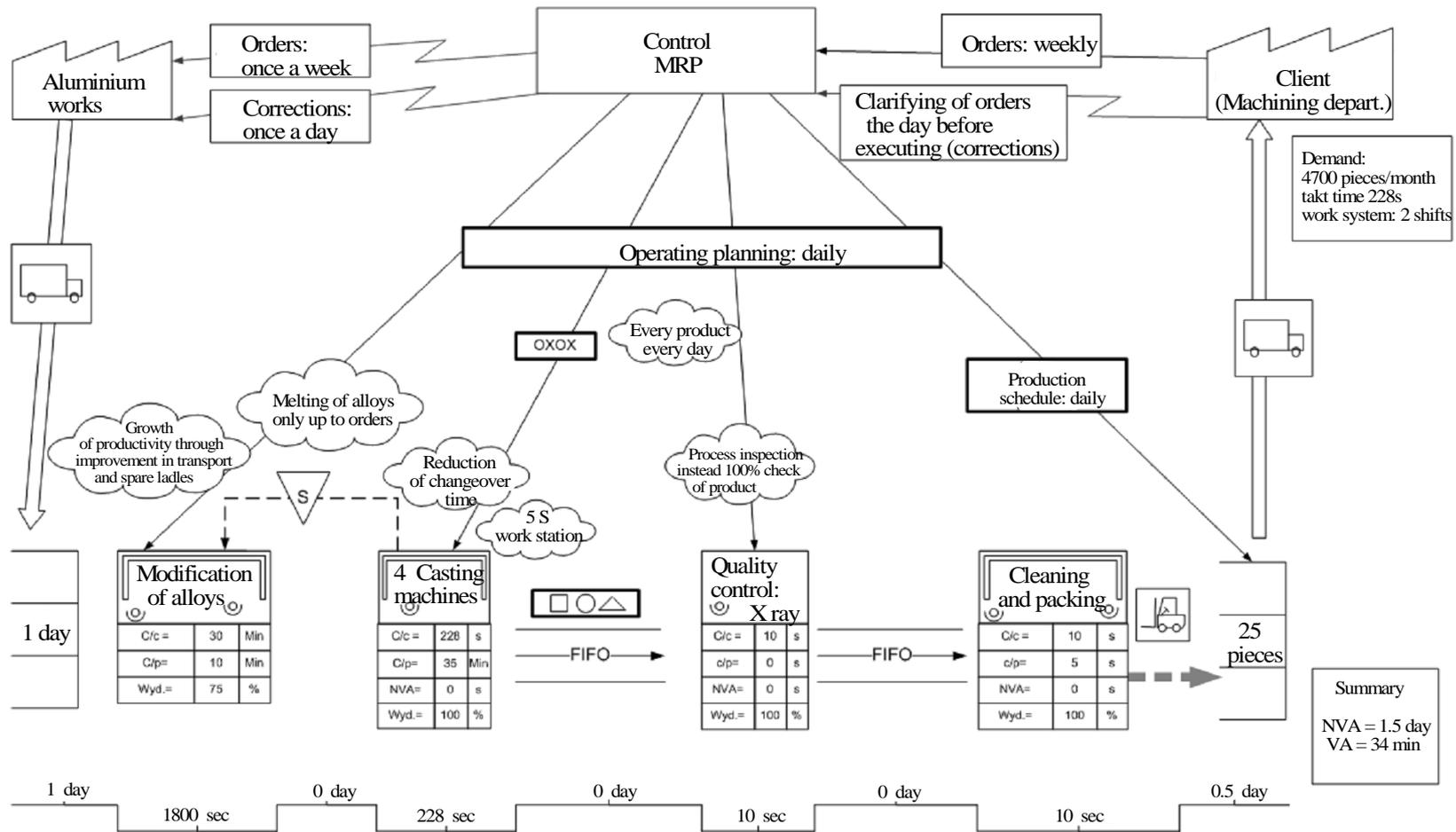


Fig. 8. Value stream map of future state of designed production system of castings

## 2.5. System of production control - computer aided light Kanban

Kanban – the system of monitoring and controlling of production most often is realized with the help of cards and with Kanban magazines suiting them. On account of difficult conditions of the environment of the work appearing in the foundry a light Kanban system is much better solution. In picture 9 an example of the luminous Kanban board for the toolroom was shown. Designed system with use of the computer dispatcher position, luminous information boards, standby light indicators, sensors of the liquid metal level and scanners of the stream of the products will supervise realizing the production schedule in according to the principle „pull” of Kanban system.

Machine	Goal	At present
9	0950	540
10	1040	620
11	0500	430
12	0720	310

Changeover of Machine 11 in 4 hours and 40 min

Fig. 9. Light Table of Kanban for toolroom

He realizes the system of steering the following functions:

- planning the operation,
- monitoring the amount of raw materials and semi-finished products on stands,
- coordinating of the functioning of domestic and outside suppliers a production process (changeover of stands, feeding with liquid alloy etc.),
- holding the pace of production,
- registering realized production orders, - informing workers of the foundry of the state of the production.

A dispatcher of carrying out a plan is steering the system, which with the help of the computer stand is loads the list of instructions in the determined order for production cells. Operators at the beginning of the change agree with the dispatcher on all details and they are solving appearing problems.

Implemented production orders are solved by the computer system which is generating the information about the apt demand and the time of the realization shown on boards: of casting cells, melting plant, of the toolroom and the magazine of alloys. Additional applying colours of the shown information and signals (green, yellow, red) is grading the importance of the transmitted information.

Carrying orders out is being recorded by the computer system freeing the ability to plan the system. This solving next running down the inserted list by the dispatcher loaded at the beginning of the planning period (the day, the week).

## 3. Conclusions

To sum up get research findings one should state that designing the production system according to Lean Manufacturing principles lets more effectively to use existing resources of the enterprise. To eliminate existing stoppages and to reduce the size of store stocks and work in progress. The designed system of controlling the production is increasing the fluidity of the flow of the material stream and a workload of single production cells. It is transferring, first of all for producing casts in the higher and stable quality, more productively and without exaggerated burdens for the worker.

As concrete achievements of designed production system of silumin casts in permanent moulds one should rank:

- shortening the cycle time of casting by the 30%,
- shortening the changeover time to 35 minutes,
- improvement in the organization of the work thanks to the consistent system of controlling the production,
- freeing human resources in the foundry and the improvement in exploiting them,
- the greater competitiveness and shortening the time of the completion of an customer order.

## References

- [1] Pietrowski S., Władysław R.: Working out and implementing technological water system of cooling dies in process of casting car wheels from aluminium alloys. Goal-oriented Project No 6T08 080 2004C/06487. 2004-2006 (in Polish).
- [2] Władysław R.: Implementation of water mist in car wheels casting process, Archives of Foundry, No. 22, (2006) 552-561 (in Polish).
- [3] Władysław R.: Intensification of die casting of car wheels process - Conference proceedings „Polish Metallurgy in Years 2002-2006”, Comitee of Metallurgy, 2006 359-366 (in Polish).
- [4] Pietrowski S., Władysław R.: Low pressure casting process análisis of Al-Si car wheels cast, Archives of Foundry, No. 22, (2006) 376-391 (in Polish).
- [5] Władysław R.: Reengineering of precision castings production system – Archives of Foundry, vol. 6, No 19, (2006) 413-424 (in Polish).
- [6] Duggan K.J.: Creating mixed model value streams, Productivity Press, NY,2002.
- [7] Garner W., Goodyer J.: Lean Manufacturing, Coventry University, 2005.