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APPLICATION OF THE STATISTICAL CONTROL OF THE PRODUCTION PROCESSES IN ORGANISATION

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Abstract:
All recent experiences confirm the fact that the main tasks of quality management are guaranteed only with the high skilled employees. Employees are responsible for the production plan and development, services and processes. The series of standards called ISO 9000 [8, 9] help to establish quality management in organization. Usage of the quality management with statistical process control is also very important for the company. Companies are spending all human, material and financial resources to improve quality management [7]. The objective of the paper is to outline the statistical process control in production company Finalcast Ltd. Žiar nad Hronom.

Key words: *statistical process control, production organization, regulation processes, process capability, statistical control, control chart*

INTRODUCTION

Organisations that use statistical control of the production processes have the main goal to achieve profitable production, products quality and to keep the measures, production facilities and processes under the statistical control [1, 2, 6].

Statistical control of the production processes helps to minimize failures in the process and emphasizes the maximum prevention of defects arising from human and technical reasons in processes. The goal is to achieve high production process capability from the statistical point of view [5].

The goal of the paper is to propose a solution for the non-conformity reduction in a machining of cylinder heads using statistical control of the processes. As the machining process of cylinder heads is demanding in terms of finishing operations, this paper is devoted to the most critical point in the finishing of the cylinder heads production [3, 4].

MATERIAL AND METHODS

Two technologies are used for the aluminium alloys casting production in chosen organisation:

- gravity mould casting – flexibility is the main advantage of this technology, allowing production of the advanced shape castings production and the formation of the internal shapes using sand cores produced using CT, CB and CRONING methods. Castings with the weight up to 50 kg can be produced,
- low pressure casting – it allows production of the large-scale casting with the higher demands on dimensions and weight as well as oil-tightness or water -tightness. Aluminium and aluminium alloys castings can be produced using this technology up to diameter 1.2 m and weight 35 kg.

Analysis of the present state of cylinder heads wastage on the machining line

To determine the most critical point in the cylinder head machining on the machining line, one of the statistical control tools had to be used. The most suitable method is Pareto analysis regarding to particular operations demands and amount of the failures occurring in the process.

The most critical point in machining of the cylinder heads is manufacturing of the adjustment holes according to Pareto analysis mentioned above (Fig. 1). This article is dealing with improvement in the production segment of the cylinder heads machining for Deutz engines.

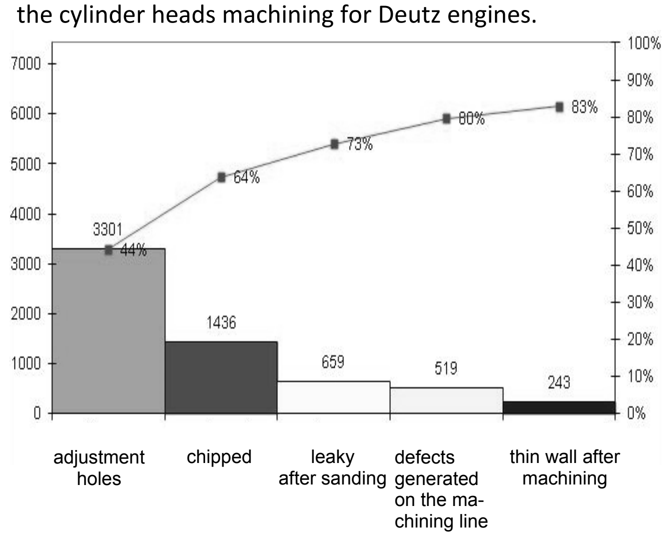

Fig. 1 Pareto analysis of the faiures on the cylinder heads in year 2013

Analysis of the process capability using indices C_p and C_{pk}

Adjustment hole (Fig. 2) is very important point on the cast produced with the respect of further processing by customer. It is positioning point for the final machining and assembling into engine, so the dimensions and position of this point determine the waste production, in case that required tolerances are not adhered. Data were recorded using form 1.

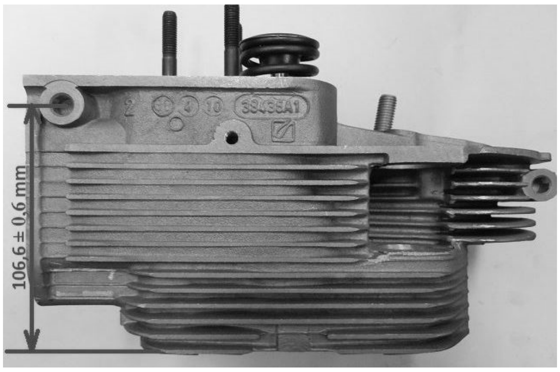

Fig. 2 The distance from the casting base to adjustment hole

Distance from the casting base to adjustment hole 106.6 ± 0.6 mm appears to be the most critical dimension, see Figure 2.

Corrective actions

Considering the result of the process capability test (Form 1), which does not satisfy desired state, corrective actions have been proposed in order to achieve a correspondence of the equipment condition with the customer requirements, or the drawing specifications. All aspects were respected in the proposal affecting a quality of the machining of the cylinder heads produced as well as the operational safety. A description of corrective actions is recorded in Table 1.

It has to be said, described corrective actions were proposed regarding to the contemporary financial sources of the organisation and time stress in the operation.

Capability of the production facility – machining line.

Non-stop operation of the machining line for cylinder heads for Deutz engines is the most advantageous and profitable method of the operation. Production capacity of

Form 1
Values measured in process of the cylinder heads machining

		PROCESS CAPABILITY TEST INDEX - Cpk	**Date: 21.3.2014**
MACHINE		**CASTING**	
Name:	Mould nr. 10	Name:	Cylinder head 38 436
Technologist nr.:	5	Mould nr.:	1-8-1787 / E pos. 2.
Manufacturer:	Finalcast. s.r.o. ZH	Customer:	Deutz Germany
CHECKED PARAMETER: adjustment holes			
TOLERANCES DESIGNED: Th = 107.20 Td = 106.00			
Measured by: Maroš Petruš Date: 21.03.2014 Sign:			

Measured and calculated values:	Nr.	Measured value	Nr.	Measured value	Nr.	Measured value
Tolerance: T = Th – Td	1	106.57	18	106.05	35	106.55
T = 1.200	2	106.58	19	106.56	36	106.58
	3	106.57	20	106.58	37	106.54
Mean value:	4	106.52	21	106.57	38	106.54
Xa = 106.54	5	106.52	22	106.85	39	106.52
Standard deviation:	6	106.23	23	106.54	40	106.55
Sw = 0.173784	7	106.33	24	106.54	41	106.55
	8	106.85	25	106.55	42	106.53
	9	106.52	26	106.54	43	106.85
	10	106.23	27	106.53	44	106.57
	11	106.28	28	106.23	45	106.32
	12	106.57	29	106.87	46	106.52
	13	106.57	30	106.32	47	106.57
	14	106.55	31	106.88	48	106.54
	15	106.66	32	106.21	49	106.85
	16	106.66	33	106.58	50	106.53
	17	106.32	34	106.55	**Nr. of measur.: 50**	
Index of the process capability Cp **Cp = T / (6 . Sw)**			**Cp = 1.15**			
Index of the process capabilityCpk = min(Zu . Zl) **Zu = (Th – Xa) / 3 . Sw** **Zl = (Xa - Td) / 3 . Sw**				**Zu = 1.27** **Zl = 1.03** **Cpk = 1.03**		
Minimum value of Cp a Cpk required 1.33 **Process: not capable** **Name:**		**Sign:**				

Table 1
Corrective actions description

Equipment	Part	Failure	Correction method		Notice
			repair	change	
Adjustment table	table air cleaning	inoperative	repair		
	spindles	excessive clearances		change	
	locating pins and bushes on the clamping table	excessive clearances		change	
	clamping base	excessive clearances		change	
	door lock	inoperative		change	operational health and safety
	support beds (horizontal and vertical)	excessive clearances		change	regrind
Boring and turning mill	hydraulic unit	leaking	repair		
	horizontal unit	not steady position	repair		
	cooling tank	leaking	repair		
	bottom clamping cylinder	excessive clearances		change	
	greasing	clogged		change	filter
	fixtures	excessive clearances	repair		
	vertical milling machine	clearance in bed	repair		
Machine no.1	setting nut at the side milling machine	broken		change	
	hydraulic unit	worn box of feed control of the mill		change	
	locating pins and bushes on the clamping table	excessive clearances		change	
	milling heads	broken screws	repair		
	spindles	excessive clearances		change	
Machine no. 2	cooling	clogged	repair		clean
	clamping	non-uniform distribution of the clamping pressures on clamping and positioning cylinders		to change electromagnetic boxes	
Machine no. 3	protective grid door	Inoperative	repair		operational health and safety
	stop cover	Broken		change	
Manipulators no. 1 and 2	travels	excessive clearances		change	shafts
	clamping gearbox	excessive clearances	repair		

the line is 320 to 350 heads at one 8-hours shift. Non-unnecessary wastages occur because of the machines' setting-up during the shift.

Correctness and completeness of an equipment of the production centre was checked in machining line verification. Above-mentioned corrective actions were undertaken. The most critical point of the line was adjusted, a distance of the adjustment hole from the casting base to 106.6 ± 0.6 mm.

Measurement time framework was 5 hours. 10 pieces of cylinder heads in-line were measured each hour. Table 2 presents measured values.

Table 2
Measured values of the adjustment holes distance

Nr.	x_1	x_2	x_3	x_4	x_5	Mean	Range
1	106.86	106.49	106.6	106.61	106.33	106.578	0.53
2	106.64	106.35	106.59	106.59	106.27	106.488	0.37
3	106.76	106.62	106.56	106.47	106.35	106.552	0.41
4	106.61	106.45	106.47	106.49	106.25	106.454	0.36
5	106.69	106.67	106.7	106.5	106.35	106.582	0.35
6	106.64	106.7	106.69	106.7	106.36	106.618	0.34
7	106.4	106.92	106.73	106.66	106.4	106.622	0.52
8	106.63	106.78	106.6	106.79	106.68	106.696	0.19
9	106.66	106.77	106.69	106.8	106.48	106.68	0.32
10	106.38	106.63	106.57	106.79	106.55	106.584	0.41

Figure 3 presents control chart of the capability for measured values of the machining line for range.

Subgroups of n = 5 measurements were created from the measured values of 50 cylinder heads (5 hours, 10 pieces each hour).

Mean value $\overline{X}_i$ and standard deviation s_i were calculated. Then common mean value $\overline{\overline{X}}$ = 106.585 was calculated from the measured values. Average standard deviation was $\overline{s}$ = 0.1634. Neither upper, nor lower specification limit was exceeded, the values $\overline{\overline{X}}$ and $\overline{s}$ can be regarded as stable. The variance was depicted by the histogram (Fig. 4) with a symmetric shape. Its bell shape indicates the normality of distribution. The histogram was balanced using the probability density function $f_{(x)}$ for normal Gaussian distribution.

As the mean value $\overline{\overline{X}}$ and standard deviation $\overline{s}$ stability was achieved and the normality was proven, the capability indices C_m and C_{mk} can be calculated. C_m value was 1.693 and C_{mk} values were 1.648 and 1.794. Because the indices are higher than the minimum value 1.66, it can be declared that machining line for Deutz engines cylinder heads is capable and appropriate for machining of the adjustment holes.

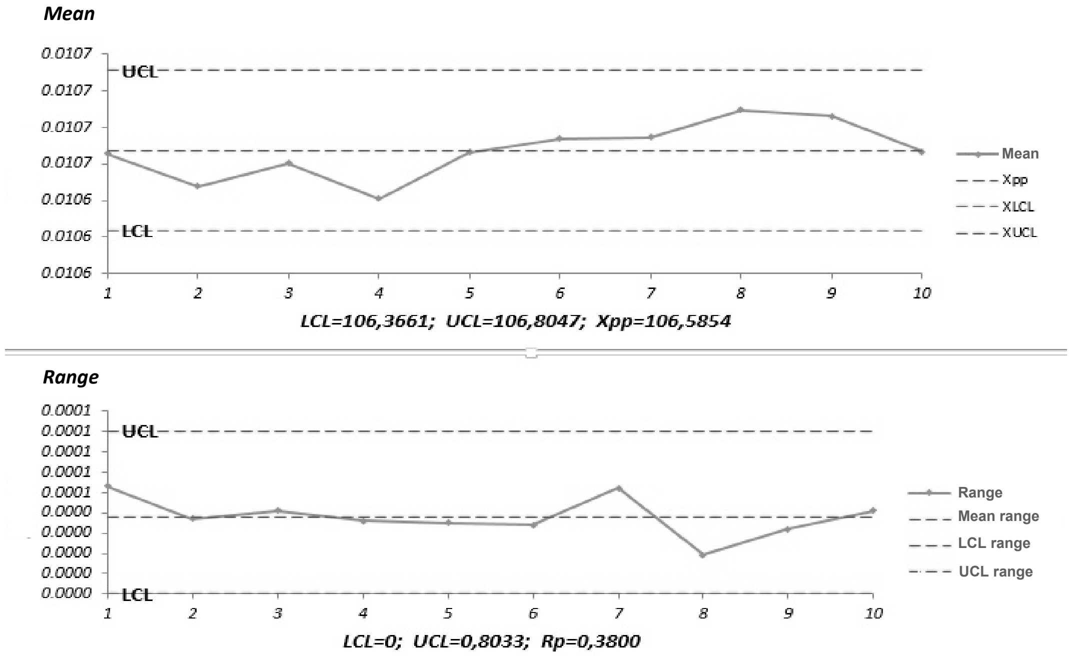

Fig. 3 Control chart for mean and range

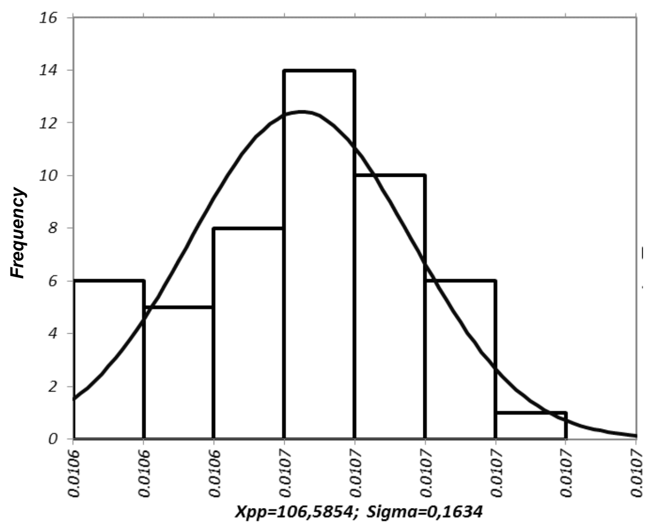

Fig. 4 Histogram of machining line capability

Production process capability – machining of the adjustment hole of the cylinder head

Control charts for mean $\overline{X}$ and range R were used to determine the production process capability. The charts help to explain the values obtained from the process, regarding the dispersion and location. Therefore, control charts are made and analysed in couples. The first chart describes the location while the second one describes the variance.

This couple $(\overline{X}, R)$ is created by measurement of the selected attribute of quality at the process output. Totally 200 pieces of the cylinder heads were measured.

Measurements were carried out within one-hour periods, during which the sample of 5 cylinder heads was taken. Calculated values of the means $\overline{X}_i$ and ranges R_i are used in control charts. Central lines $\overline{R}$ and $\overline{X}$ as well as control limits were calculated using measured data.

Values calculated for the control chart $\overline{X}$ and $\overline{R}$:

- process mean $\overline{\overline{X}}$ = 106.60 mm,
- $UCL_{\overline{x}}$ (HZM) = 106.82 mm,
- $LCL_{\overline{x}}$ (DZM) = 106.34 mm,
- mean range $\overline{R}$ = 0.365 mm,
- UCL_R (HZM) = 0.77 mm.

It results from control charts (Figure 5) that process is under statistical control. None of the characteristics $\overline{X}_i$ and R_i breaks the control limits and no trend has been observed.

Histogram and the function of probability density *f(x)* for normal (Gaussian) distribution are visible in Figure 6.

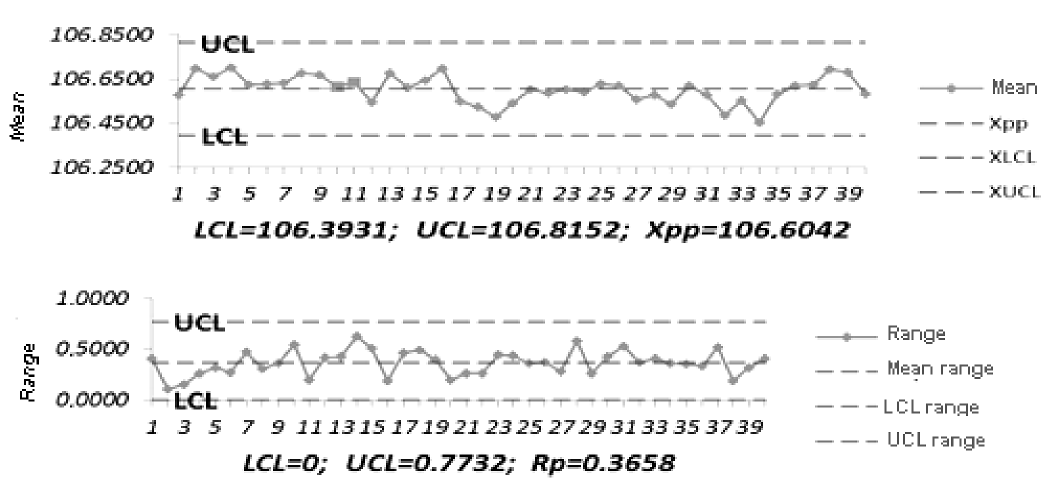

Fig. 5 Control charts for mean and range of the adjustment holes position

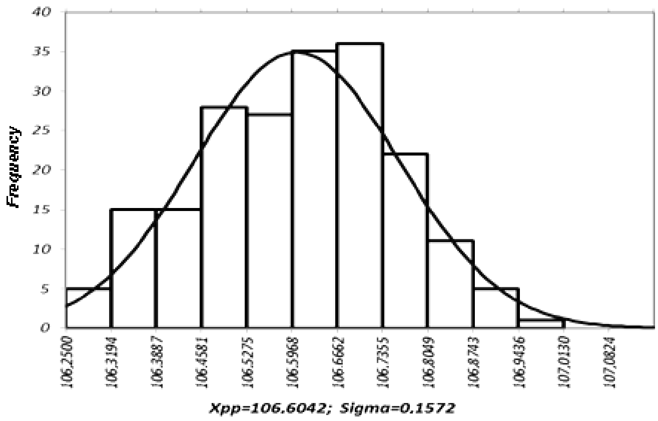

Fig. 6 Histogram of the process capability

Histogram describes the production process variance. Histogram has symmetric shape with a peak near to the nominal value.

Indices of the production process capability C_p and C_{pk} were used for production process capability calculation.

Values C_p **= 1.44** and C_{pk} **= 1.38** are greater than the minimum value 1.33. We can state that production process is capable.

The process meets the customer's requirements (specifications) after corrective actions and the machining of the adjustment hole can continue in these conditions.

DISCUSSION AND CONCLUSION

The solution of the problems in the company Finalcast Ltd. significantly contributed to improvement of the process of cylinder heads machining. Necessity of the solved problem was confirmed by the equipment analysis prior to corrective actions application. An unsatisfactory condition of the manufacturing equipment resulted in numerous returns by customers, which significantly influenced financial situation of the company and as well as our decision to solve this problem.

Management of the company Finalcast Ltd. has decided to invest to the changes proposed in the forthcoming time for condition of the manufacturing line for the cylinder head castings machining, which does not respond to present time requirements.

Statistic control methods proved to be powerful tool for identifying questionable points as well as the feasible way to specific problem solving.

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