

Six Sigma process improvements in automotive parts production

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ABSTRACT

Purpose: of this paper: In the paper is presented a Six Sigma project, undertaken within company for production automotive parts, which deals with identification and reduction of production cost in the deburring process for gravity die-castings and improvement of quality level of produced parts.

Design/methodology/approach: The objectives are achieved by application of Six Sigma approach to quality improvement project in automotive industry. The applied Six Sigma approach includes team works through several phases: Define, Measure, Analyze, Improve, and Control (DMAIC).

Findings: Systematic application of Six Sigma DMAIC tools and methodology within an automotive parts production results with several achievements such are reduction of tools expenses, cost of poor quality and labours expenses.

It was shown that Six sigma is an effective way to find out where are the greatest process needs and which are the softest points of the process. Also, Six sigma provide measurable indicators and adequate data for analytical analysis.

Research implications: The possibility of application of several Six Sigma tools such are thought process mapping, Pareto diagrams, process mapping, cause and effect matrix, and analysis of variation and capability studies.

Practical implications: Improvements through reduced Production time, Control time, Material and Internal scrap have been yield significant financial. Furthermore, this pilot project enabled introduction of Six Sigma methodology in wider range of manufacturer activities.

Originality/value: The paper researches the possibility of Six Sigma application within manufacturing process. This paper is of the value to researcher in the field of quality management and quality improvement, as well as to professionals in the manufacturing industry, wherever the quality improvement is an issue.

Keywords: Quality management; Six Sigma; Capability analysis; Measurement system analysis

1. Introduction

Six Sigma is new, emerging, approach to quality assurance and quality management with emphasis on continuous quality improvements. The main goal of this approach is reaching level of

quality and reliability that will satisfy and even exceed demands and expectations of today's demanding customer [1].

A term Sigma Quality Level is used as an indicator of a process goodness. Lower Sigma quality level means greater possibility of defective products, while, higher Sigma quality level means smaller possibility of defective products within process [2,3].

If Sigma quality level equals six, chances for defective products are 3,4 ppm. Achieving Six Sigma quality level involves leadership, infrastructure, appropriate tools and methods, while quality have to become a part of corporate business plan [4,5].

The main objective of Six Sigma initiative is to aggressively attack costs of a quality. Overall costs of quality are, usually, divided in tangible and intangible part. The tangible or visible part of costs of quality, e.g. inspection and warranty costs, scrap, rework and reject, can be approximated with only 10–15 % of overall costs of quality. Remaining 85-90 % of quality costs are usually intangible and, therefore, overlooked and neglected in companies quality costs analyses.

Tools and methodology within Six Sigma [6,7] deal with overall costs of quality, both tangible and intangible parts, trying to minimize it, while, in the same time, increasing overall quality level contribute to company business success and profitability.

2. Six Sigma methodology

A Six Sigma project, which deals with identification and reduction of production cost in the deburring process for gravity die-casting turbo compressor housing, was undertaken within company for production automotive parts [8,9]. In this project the Six Sigma approach, based on team, works through the structured DMAIC methodology (Define, Measure, Analyze, Improve, and Control phases), Figure 1 [9,10].

2.1. Define phase

Within *Define phase* are articulated problem descriptions, objectives and metrics as well as solution strategy.

The main goal was to identify and decrease expenses in the deburring department for aluminium castings through times and scrap reduction for at least 30% [8]. There were several major causes for the high expenses variability in castings quality, to many handcrafts, and to long control time.

The main objectives of undertaken projects were to identify areas in the process where extra expenses exist, identify the biggest impact on production expenses, introduce appropriate measurement system, improve process and reduce expenses on production times, and implement improvements.

An adequate metrics for evaluating projects success should be established. These metrics includes ratio volume/cost, labour cost, tool cost, scrap cost, number of nonconforming or defect parts per million (ppm), and Rolled Throughput Yield (RTY), the probability that a part will pass through multiple process steps without a defect.

When the project was started, few useful historical data were available, so the first step was to collect and select these data in the deburring processes. On the base of the collected data decision about selection of process for improvement should be made, all process phases should be screened and appropriate action plan for minimizing variability within the process as well as reduction of production times prepared.

In accordance to Six Sigma philosophy, Define, Measure, Analyse, Improve and Control strategy approach was employed. In accordance with DMAIC methodology, project goals should be defined, cross-functional teams formed including individuals with adequate process knowledge, historical information collected, and appropriate process selected for improvements. Furthermore, process map and cause and effect diagram should be define, process FMEA conducted and, based on obtained results, required actions and tools for process analysis selected. Appropriate action plans and design of experiment methods should be employed, and diverse control charts used for success monitoring.

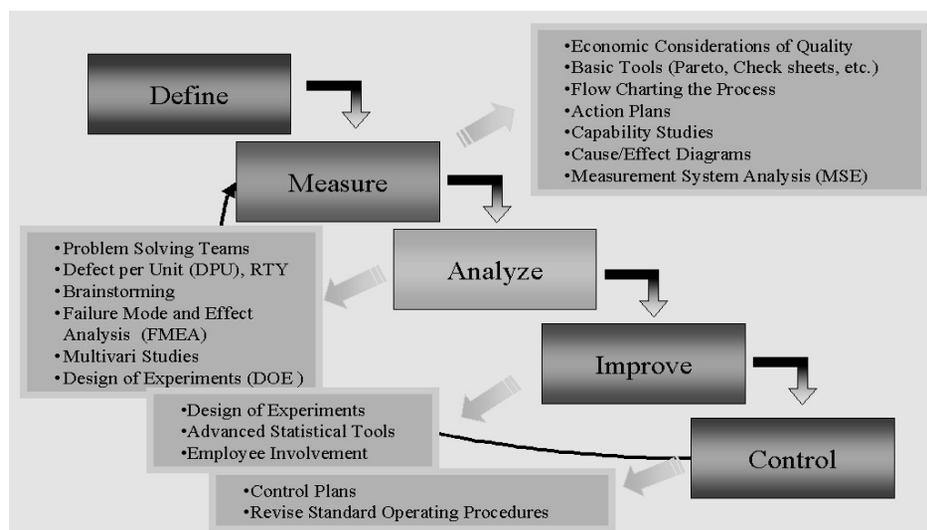


Fig. 1. DMAIC methodology for running Six Sigma projects [9]

2.2. Measurement phase

One of the objectives of project was to identify major process variables impacting the high expenses. Pareto chart for total expenses, Figure 2, shows that the highest impact has labour costs with 42,6%, following by production centre and headquarter costs, but the last two, as well as production service costs, were successfully reduced with internal system reorganization of company [11].

Based on Pareto chart, formed team made decision to analyze and make improvements within labour and tools cost area, which together have amount of 48% of total expenses. Also, there were submitted that quality improvement and reduction of quality costs within process are achievable.

The significant improvement could be accomplished by:

- Reduction of cycle time,
- Reduction of control time,
- Reduction of tool costs, and
- Minimizing or eliminating scrap.

The deburring process for compressor housing no. 434.807 was chosen because Pareto diagram showed that the part number have the biggest volume of production, which was 40 % while the first following, has 15 %.

The first undertaken team task was to completion of a **thought process map (TMAP)**, Figure 3 [8]. Team approach and idea how to solve the problem was elaborated through the TMAP.

The chosen deburring processes for compressor housing involves following production steps:

- Sawing residual of feeding system,
- Drilling,
- Burrs removal – cleaning bases for clamping on machining area,
- Rough grinding – burrs removal in the dividing plain, and
- Control – material defects and simulation of machining clamping system.

Process map was drawn for all operations in the deburring process, and a list of the input and output variables were completed. The input variables were ranked as, *Critical, Noise,*

Controllable and *Standard operating procedures variable* and, furthermore, non-value added operations are defined and marked.

Team decision was that all variables should be analyzed using a cause and effect matrix to identify the key critical input variables for further study. The product diameter and tube length non-conformance, deformation of parts, quality of surface as well as scrap are evaluated using cause and effect matrix. Each team member filled in a questionnaire scoring influence of input variables on non-conformance and defects. Team decided that the main variables for further analyzing are Grossly burr, Material and Operator from Press operation, Control operation and, Sawing and Drilling operation.

Moreover, during period from nine months actual data for observed process were collected and ppm and RTY indices are calculated.

As Pareto diagram showed the highest volume of material scrap was in the Press operation because 60 % of scrap was in the direct relationship with removal burr on the press. Also, based on Pareto diagram of material scrap, conclusion was that the Material in the Sawing and Drilling operation has minor impact on the expenses level. So, at the end of this phase, decision was that Press and Control operations should be main objectives of further improvements

2.3. Analyse phase

Firstly, FMEA for the deburring process was made. The most critical operations were the *Control operation* and the *Press operation*. Conducted analyse showed that data before Press operation were normal distributed while, after operation data were non-normal distributed, Figure 4.

The measurement system analysis for controlling the most important dimension of compressor housing ($4,7 \text{ min}$) with two Operator and two trials per Operator was conducted. The result showed that Operator #1 needs some training, while Operator #2 has good measuring results. In addition, the measurement gages are reliable.

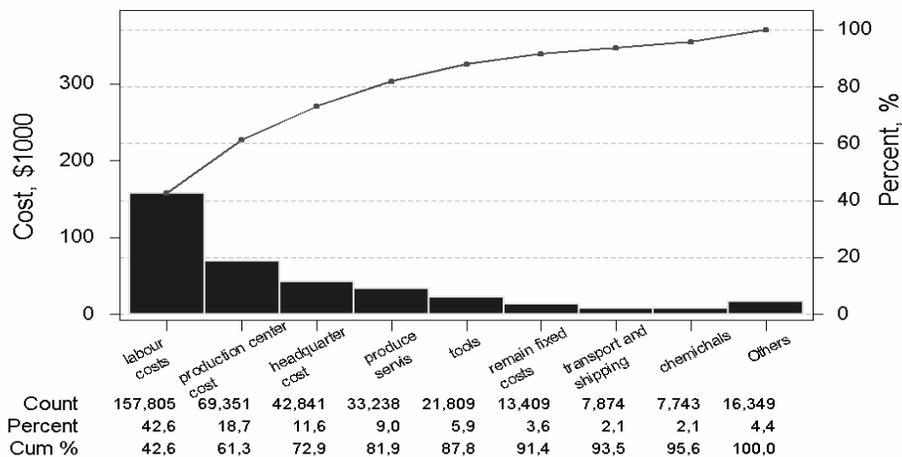


Fig. 2. Pareto chart for total expenses in the deburring department

At the end of this phase the Multi-vary analysis was conducted to check drawn conclusion, as is show on the Figure 9. Multi-vary analysis showed that the biggest variation was in the N1 and minimal variation in the N3. Also, castings with bigger burrs have smaller dimension after burrs removal. Analyses of parts construction explain the reason for different deformation in the squeezer operation in the different positioning points. The lateral section of part isn't constant and the part is less loaded in N1 then in other two points

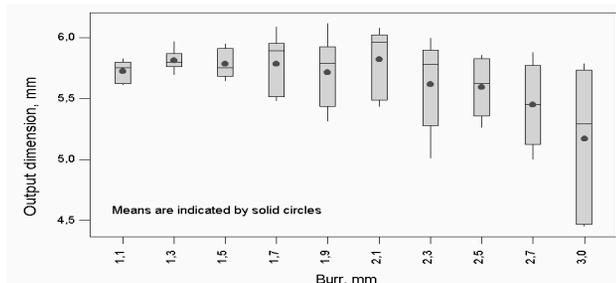


Fig. 7. Box-plot analysis

Correlations: burr mm; N1; N2; N3			
burr mm	N1	N2	N3
N1	-0,880	0,000	0,000
N2	-0,584	0,702	0,001
N3	-0,249	0,420	0,728
	0,184	0,021	0,000

Fig. 8. Correlation matrix

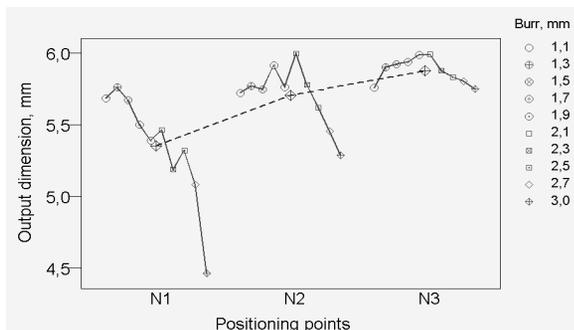


Fig. 9. Multi-vary analysis

2.4.Improvement phase

Through followed brainstorming session decision was made that tool modification is needed to reduce cutting forces and avoid scrap appearance. Modification was applied and significant results were obtained, primarily in scrap and tool wearing reduction.

Although, significant improvements where achieved, defined goals where not jet met, so further experimentation where conducted with different clamping system in the machining area.

Obtained results lead the way to made some amendments in the clamping system to avoid or decrease impact of material scrap and automatically decrease scrap expenses. After appropriate tool construction, several experiments with external clamping were done with process capability study and measurement system analysis (Gage R&R analyses), Figure 10 [8,12].

2.5.Control phase

The analyses results showed that there weren't any significant differences on the critical dimensions, but the most important fact was that the radial accuracy in the defined diameters was unsatisfied. Experiment was repeated with external clamping system, but this time with burr classification, and controlling surface for clamping on parts. Results were analyzed and final decision made about external clamping system application in the machining area.

After repeated experiment with external clamping system better results were obtained while, in the same time, all critical and functional dimensions had good capability. The most important conclusion was that dimension of burr hadn't any important impact on machining area.

Final decision was that the external clamping system will be applied on one production line and, if proved acceptable, after certain period of time will be applied on others production lines and map this solution on the similar castings.

To make that possible some simple modifications was needed on the casting die to secure quality surface on the castings for external clamping.

In this, final phase of DMAIC methodology, a control plan was developed to ensure that processes and products consistently meets our and customer requirements, and to check how external clamping system impact on quality production level [13, 14, 15].

3.Discussion and conclusion

Six sigma is an effective way to find out where are the greatest process needs and which are the softest points of the process. Also, Six sigma provide measurable indicators and adequate data for analytical analysis.

Systematic application of Six Sigma DMAIC tools and methodology within an automotive parts production results with several achievements.

As is shown on Figure 11, the achieved results are:

- Reduced tool expenses for 40 %,
- Reduced costs of poor quality (CORQ) for 55 %, and
- Reduced labours expenses for 59 %.

Also, the significant results are achieved by two indexes that are not dependent on the volume of production:

- Production time reduction for 38 %, and
- Index cost/volume reduction for 31 %.

Generally, improvements through reduced *Production time*, *Control time*, *Material* and *Internal scrap* will give annual benefits of \$ 72 000.

Expected annual benefits of external clamping system application is \$100 000.

Gage R&R (ANOVA) for MARPOSS 434808

Gage name: Mjerna naprava MARPOSS
 Date of study: 27.12.2000.
 Reported by: Krulic E.
 Tolerance: 94.16 +0.08
 Misc:

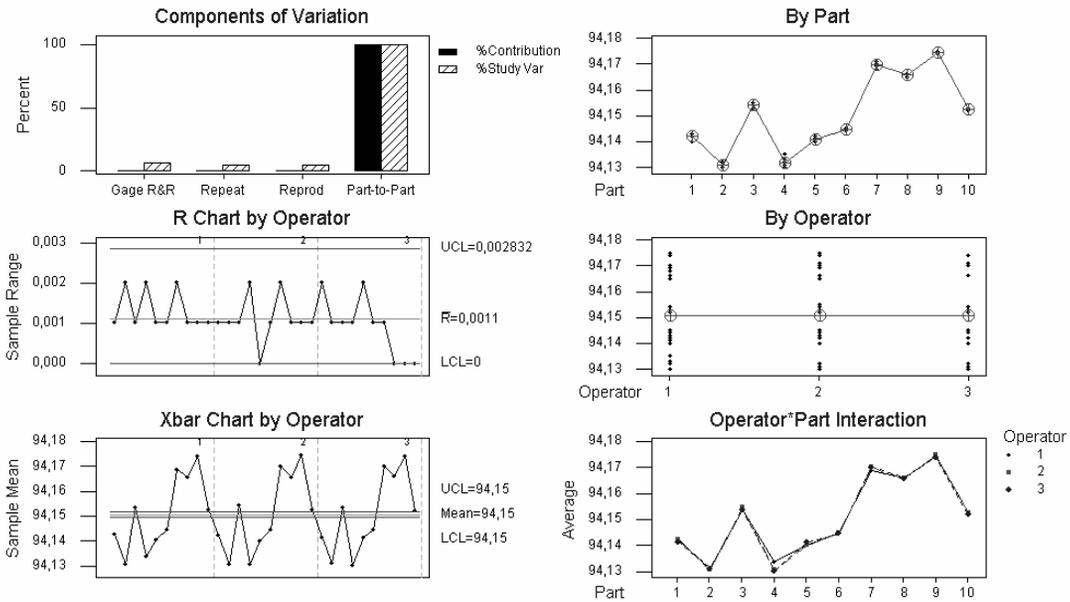


Fig. 10. Measurement system analysis

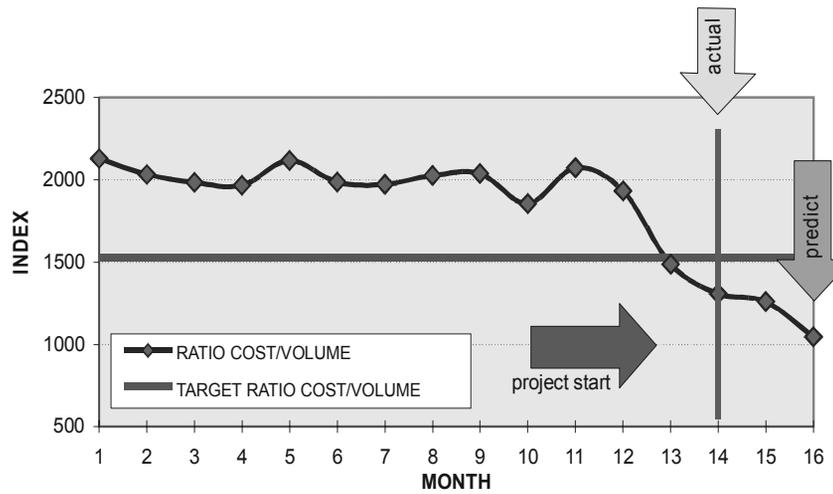


Fig. 11. Actual and predict value of ratio volume/cost

Conducted improvement project based on Six Sigma methodology provides close acquaintance with all phases of process while Six Sigma tools enables right decisions and the most significant improvements.

Besides the appropriate methodology implementation, it is also essentially to develop an infrastructure that will initiate and support Six Sigma projects and initiatives [11, 13]. Definitely, Six Sigma is a powerful methodology that can, properly implemented, result with significance savings and improvements.

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