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Application of Quality Tools in Solving a Production Problem

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Abstract: The article focuses on the issue of automotive products. The product is a component necessary for the proper functioning of the engine in a car. The application of various quality tools represents the identification and subsequent elimination of defects to improve the manufacturing process. The aim was to reduce the proportion of complaints related to product malfunction and to increase the overall control of the manufacturing process. This includes activities such as identification, analysis, and elimination of the root cause of the claimed product function. Standard tools used to identify and analyse the root cause of the problem such as Ishikawa, Pareto, 4Wh1 were used. It usually focuses on inventory reduction, machine optimization, process synchronization. In addition to basic quality tools, process capability or microscopic analyses were also used. The system quality management tool of auditing was also used. The root cause of the problem was identified. Measures were subsequently taken and savings of more than EUR 50,000 were achieved.

Keywords: quality tools, analysis, improvement, root cause, process capability, production.

1. Introduction

The automotive industry is important for every country where cars or car components are manufactured. They make an important contribution to the GDP (Gross Domestic Product) of such a country. The Slovak Republic is a country that is one of the most visible countries in the world in terms of its automotive production. There are four manufacturing OEM (Original Equipment Manufacturer) plants and several hundred suppliers of various components that are assembled in these OEM plants or shipped to other OEM plants around the world. The problem solved below concerns a component that is part of a throttle valve. The problem solved was an air leak from the actuator. The air leak was negatively affecting the functionality of the actuator and thus the throttle valve control. Identification of the cause causing the undesired air leakage was preceded by a broader analysis of the problem to better understand it.

Defining the problem: actuator leakage test failure again at the measuring station, exceeding the allowable air leakage specification of 3.5 cm^3/min.

Objective: to identify, eliminate and prevent the recurrence of air leakage above the allowable specification at the measuring station. Prevent customer complaints and increase control and process.

Benefit: Customer protection, reduction of costs associated with problem occurrence, control over actuator manufacturing process management.

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The 8D methodology was not used to address this issue.

2. Experimental Section

The actuator (Figure 1) is a mechatronic component that is used to control the throttle valve in a car engine. The role of the throttle valve is to regulate the performance of the car depending on the position of the accelerator pedal.

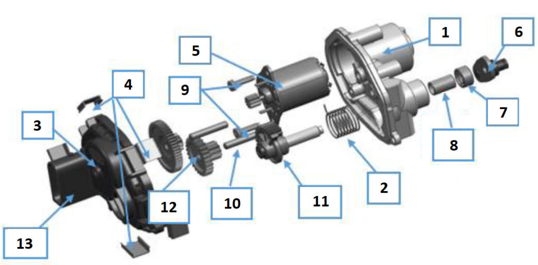

Figure 1: Actuator. ***(1) Aluminium kinematic housing. (2) Spring. (3) Plastic cover. (4) Clip – 5pcs. (5) CMD engine. (6) Output lever. (7) Gasket. (8) Roller. (9) Screws. (10) Pins – 2pcs. (11) Shaft with gearing. (12) Two gears. (13) Connector.***

Manufacturing of the actuator consists of the following activities:

1. *Manual insertion of CMD motor and spring (Workstation A).*
2. *Automatic insertion of roller (Workstation B).*
3. *Automatic pin insertion (Workstation C).*
4. *CMD engine screwing (Workstation D).*
5. *Gear insertion (Workstation E).*
6. *Air leak test (Workstation F).*
7. *End-of-line test (Workstation G).*
8. *Engraving (Workstation H).*

A leak was detected at the air leak testing station. This leak exceeded the permissible limit (3.5 cm^3/min.) specified by the customer. In the months of May, June and July 2021, defects were recorded and are summarized in the table below (Table 1).

The marking of identified defects is as follows:

- *N1 Incorrect additional pressing of the roller*
- *N2 Incorrectly executed housing press*
- *N3 Incorrect pin setting*
- *N4 Twisting beyond permissible limit*
- *N5 Improper small motor test*
- *N6 Weld defect*
- *N7 Incorrect shaft insertion*
- *N8 Clip 1 check*
- *N9 Bent connectors of the pin*
- *N10 Air leakage above permissible limit*

In terms of frequency of occurrence using Pareto analysis, the 3 most important defects that contributed significantly to production problems were identified. Another analysis used was the Defect Priority Map. The Defect Priority Map analyses the defects from 4 aspects [1]. These are the aspect of defect occurrence, cost, severity, and the possibility of detecting the defect. The resulting priority index (PI) value is calculated according to the following equation (1).

$$PI = O \cdot C \cdot S \cdot D \tag{1}$$

O - occurrence is a frequency indicating how often the defect occurred during the monitoring period (Tab.2); C - cost is the sum of the cost of the material and the cost of the labour related to the product defect (Tab.3); S - severity is the degree to which a given product defect is significant to the customer (Tab.4); D - detection is the way in which a defect can be caught, detected (Tab.5).

Table 2: Occurrence determination

Occurrence	***Quantity***	
Points	***Range***	
5	130	104
4	103	78
3	77	52
2	51	26
1	25	1

Table 3: Cost determinantion

Occurrence	***Quantity***	
Points	***Range***	
5	7 760,00 €	6 208,00 €
4	6 207,00 €	4 656,00 €
3	4 655,00 €	3 104,00 €
2	3 103,00 €	1 552,00 €
1	1 551,00 €	1,00 €

Table 1: Number of defects for 3 months of observation (in 2021)

	Defect										
Month	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**N7**	**N8**	**N9**	**N10**	**Total**
May	68	35	27	25	14	42	30	25	35	120	421
June	78	32	25	24	13	41	12	21	32	112	390
July	75	37	28	30	17	47	22	29	28	132	445
Total	221	104	80	79	44	130	64	75	95	364	**1256**

Table 4: Severity determination

Severity	*Range*
5	Safety
4	Recurring problem
3	Significant problem for the customer
2	Less significant problem for the customer
1	Irrelevant to the customer

Table 5: Detection determination

Detection	*Locality*
1	During production
3	End of line
6	By audit
9	Scrap customer
13	Customer complaint

The calculated priority indices over the analysis period for each defect are shown in the following graph (Figure 2).

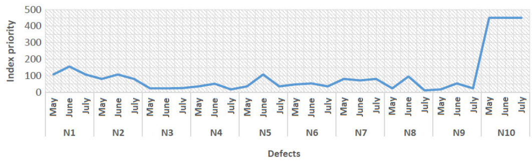

Figure 2: Defect's priority index

From the Pareto analysis, it was clear that the most frequent defect was the N10 defect. Calculation of the defect priority index determined its value to be 450. It was important to investigate further by analysis what the root cause of its occurrence was.

The question arose: Is the root cause an error in the air leakage measurement itself or is it a defect directly related to the product (the actuator)? If it is the product, the root cause may be a leak in the product itself (improper design) or human error.

First, the 4W1H analytical instrument was used. It is an instrument that is often used in practice in the standard 5W2H form [2,3]. However, organizations modify this tool according to their needs. This tool uses analysis based on simple questions aimed at better understanding - analysing the problem [4].

Where is the problem? Air leak detection is located at the control station - Air Leak Test. The test is performed fully automatically.

Why is air leakage a problem? The size of the air leak exceeds the customer defined tolerance. The measured air leakage exceeds the upper air leakage tolerance = 3.5 cm^3/min.

What is the problem? It is clear from the measurement records at the control station that the actuator air leakage had a variable course.

When does the problem occur? The control station for the air leak test is fully automated. There is no worker intervention during the measurement. The worker only sets the input parameters of the measurement process. As air leakage was detected in every working shift, the influence of the worker performing the testing can be excluded. A more accurate picture of the occurrence of air leakage detected at the control station is shown in the following figure (Figure3). The occurrence of exceeding the customer specification (3.5 cm^3/min.) relates to both morning and night shifts.

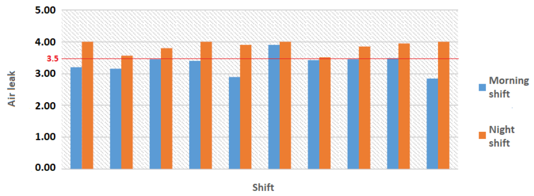

Figure 3: Air leak measurement

What is the problem? The problem is serious if the air leakage at the control measuring station is shown to be within the upper permissible limit for a long period of time. An analysis of the measurement results was carried out. The individual value graph describes the measured leakage values (Figure 4).

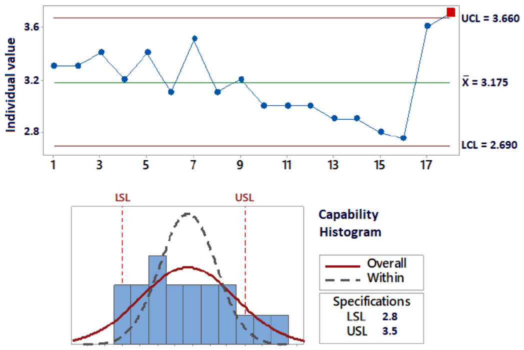

Figure 4: Analysis of measurement results

This is a sampling for the months of May, June, July. As can be seen the air leakage values range from 2.7 to 3.8 cm^3/min. The Capability Histogram

(Figure 4, right hand side) shows that this is an incapacitated process. The value of CP and CPK < 1.33 confirms it. The upward jumps in air leakage values are alarming.

The analysis focused on confirming the reliability of the test itself at the control station. This validation was performed through the procedural capability of the input air leakage measurement values. Thus, it is a validation of whether the measurement is correct, and the cause of the leakage is a measurement error of the station or a leakage on the monitored actuator itself. To perform the validation, a sample piece of actuator was inserted into the testing device and measurements were taken. The results obtained were evaluated and the measuring station was found to be capable, both in the measurement process itself and in the chamber pressure (Tab.6).

Table 6: Assessment of the capability of the measurement process

	Minimal	*Normativ*	*Maximal*	*Cp, Cpk*	*Conclusion*
Leak measuring device	2.8	3	3.5	Cp=4.16 Cpk=2.78	Capable
Chamber pressure force	1000	1500	2000	Cp=4.16 Cpk=2.78	Capable

Based on the analyses performed so far, the attention was directed to the product itself, i.e., to the actuator. The detected air leakage outside the customer's specification was caused by the product itself. Further analysis was needed to determine where the leak location was. A "bubble test" was performed to determine the location of the air leak [5]. This is a test the essence of which is to locate the leak through the emission of bubbles [6]. A bubble test was performed on the non-conforming product, the result of which can be seen in the following figures (Figure 5).

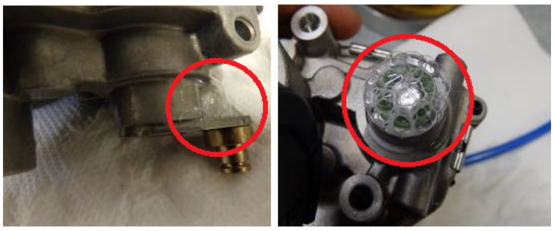

Figure 5: Bubble test result

The figure shows the air leakage points on the actuator. The test confirmed that the air leakage is related to the product (actuator) itself. The air leak is caused by a leak at the junction of the kinematic housing and the output lever. An elementary tool for finding the root cause is the Ishikawa diagram [7,8,9]. Therefore, it was used in the next step.

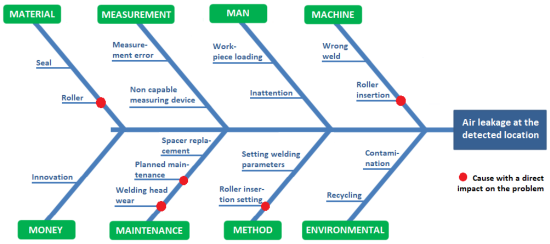

Figure 6: Ishikawa diagram application

By applying the Ishikawa diagram, it was found that the problem can be observed at Workstation B - Automatic Roller Insertion. This workstation is fully automated. The activities of this workstation include insertion of roller and seal. It was therefore necessary to analyse the activities of this workstation. An analysis of the product itself and the location of the air leak detected by the bubble test was performed. A microscope was used to analyse the site in detail. This confirmed contamination with plastic particles (Figure 7).

Figure 7: Microscopic analysis

This contamination caused a misalignment at the joint between the housing and the output lever. This had an impact on the leakiness of the product and the air leak itself. This finding initiated an audit at this site. The result of the audit at Workstation B - Automatic Roller Insertion revealed a serious problem. The surface of the delimiting head extension was badly worn (Figure 8). The wear of the delimiting head was occurring faster than expected. The surface of the worn head was causing its worn surface to push off into the roller. The roller thus gained unwanted relief, which caused the leakage of the actuator after it was assembled.

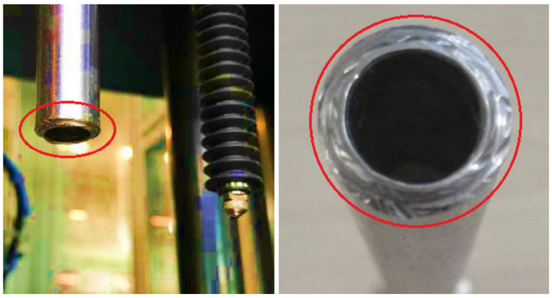

Figure 8 Wear delimiting head

3. Results and Discussion

The worn surface of the extension was the root cause of the actuator air leak. The wear occurred because the maintenance interval of this extension was not set appropriately. Thus, rapid wear was not anticipated. Based on this knowledge, the following measures were taken:

– *Immediate replacement of a worn-out delimiting head.*
– *Inclusion of the delimiting head in the list of spare parts of the line with increased frequency of replacement.*
– *Development of a control action plan for Workstation B (Figure 9).*

Date:	1.8.2021	ACTION PLAN FOR AIR LEAK				
Revision:	2nd					
Workplace:	B					
No.	Description	Specification	Measurement technique	Priority	Frequency	Complete
1.	Analysis of rejected products	< 1%	Test analysis	2	Weekly	Complete? ☐
2.	Component measurement	< 1%	Test analysis	1	Weekly	Complete? ☐
3.	Contamination analysis	No contamination	Visual inspection	2	Weekly	Complete? ☐
4.	Occurrence of plastic particles	No occurrence	Visual inspection	1	Weekly	Complete? ☐

Figure 9: Action plan for air leak from the actuator

By introducing the above measures, the incidence of air leakage from the actuator has been reduced by up to seven times! Actuator air leakage still occurs, but the root cause was substantially reduced. The overall control of the roller pressing process was improved. The benefit of the measures introduced can be expressed in financial terms. Savings of more than 50,000 Euros per year were achieved because of these measures! The investment required by the measures introduced represents a negligible fraction (1%) of the amount achieved by their introduction.

4. Conclusions

The MSA methodology was not used for the solution. A rational problem-solving procedure was used. The priority index has identified which issues need to be addressed. The problem was an actuator air leak out of customer specification. This leak was causing improper operation of the car's engine throttle valve. The goal was to identify the root cause and fix the actuator air leak. By applying various analyses, the root cause was identified. The root cause was a faster wearing tool that was pressing the actuator roller during assembly. By implementing the measures, significant financial savings were achieved for the organization.

Acknowledgments

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