Technique for analysis of defects of products machine building according to IATF 16949:2016 standard requirements

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Abstract. Correct techniques of and approaches to the analysis of production stability and measuring systems and management of products quality are significant for the tasks of development and improvement of a mechanical engineering enterprise quality control system. More opportunities arise for production quality managers enabling their dealing with claims and defects, elaboration of corrective actions and application of statistical methods for the analysis of quality of products. In this article, a technique for the analysis of defects of mechanical engineering products based on the system approach is suggested, and an example of its practical application is described. The main distinctive feature of the suggested technique consists in a description of each part or component of an assembly or a unit in the form of formulas offered at one of the stages. Application of the technique for the analysis of defects allows systematizing data on potential defects, probable causes and possible consequences of them, thus that leading to improvement of the management process and quality of products of mechanical engineering.

1. Introduction
The approach to the task of management of products quality has changed recently. More attention is now paid to prevention of defects instead of remedial works. The methodology for Advanced Product Quality Planning (APQP) is widely applied. This methodology helps to organize the effective process of quality management aimed at prevention of potential defects.

“Advanced Product Quality Planning” is the most important and the most difficult procedure included in IATF 16949:2016 international standard [1]. Most machine-building enterprises perform their works according to design documentation developed by a consuming enterprise. It means that it is impossible simply to implement the procedure just as it is represented in the standard. Very often enterprises leave implementation of the APQP procedure till the last moment considering it to be the most difficult procedure. And later they find out that it was necessary to begin the process of product quality improvement using this procedure [2].

The process of Advanced Product Quality Planning can be successful only if general information or the “consumer's voice” is made use of correctly. In this regard, special attention needs to be paid to the analysis of consumer claims.

2. Statistical analysis of claims on truck defects
The statistical analysis of defects stated in claims from external consumers of autocomponents is carried out for the purpose of finding the most defective unit of a truck. 15000 claims were considered in this research (table 1).

The truck consists of three main parts: engine, body, and chassis. The chassis is subdivided into the following systems: transmission, running gear, steering gear and brake system [3]. The revealed defects were distributed according to their belonging to a certain mechanism (system).
Table 1. Major defects of the truck.

| Type of defect                                                                 | Number, pcs. |
|-------------------------------------------------------------------------------|--------------|
| Flow of oil through cylinder of rear wheel brake                              | 3451         |
| Flow of oil through drive gear cuff                                           | 3338         |
| High level of gearbox noise                                                   | 1647         |
| Oil leakage through hub cuff                                                  | 1325         |
| High level of hub bearing noise of front axle                                | 959          |
| Backlash of the upper hinge of the front drive                               | 682          |
| Breakage of an arm of fastening of the shock-absorber of the forward bridge   | 607          |
| High level of hub bearing noise of rear axle                                 | 583          |
| Vibration when braking the car                                                | 461          |
| Backlash of a hinge of a cross-section steering draft                         | 447          |
| Noise (destruction) of the bearing of a nave of a forward axis                | 400          |
| Slapping noise in the gearbox                                                 | 359          |
| Oil leakage through brake clamp                                               | 281          |
| Gearbox differential breakdown                                                | 172          |
| Low-quality brake clamp                                                       | 153          |
| Noise of hinge                                                                | 135          |
| **Total:**                                                                    | **15000**    |

After that, the distribution of defects was analyzed and a diagram was constructed (figure 1).

The final diagram shows that the greatest number of defects is revealed in transmission. The rear axle proved to be the most defective among all the mechanisms included in the transmission.

The rear axle is one of the main units of the rear-wheel drive car, which connects the rear wheels of one axle to each other. It also transfers the torque from the engine through the propshaft to the drive wheels and with the help of the differential allows you to rotate the wheels of the car at different angular speeds [4].

It can be concluded based on the diagram that claims on defects of the rear axle represent 49.2%, thus making about a half of the total quantity of claims.
The research objective is definition of potential causes for defects to prevent them and reduce the level of defects of the rear axle of the truck.

3. Description of the technique for the analysis of defects of mechanical engineering products

The technique for the analysis of defects of mechanical engineering products includes the following stages:

- analysis of forms and carried-out functions of parts;
- analysis of probable causes for and possible consequences of potential defects;
- development of potential defects qualifier;
- development of a qualifier of probable causes for defects;
- development of a qualifier of possible consequences of defects;
- setting of formulas to describe potential defects of the studied parts;
- systematization of data on the revealed defects and their potential causes;
- building of a cause-and-effect diagram.

We will exemplify its practical application by analyzing defects of the rear axle of the truck. A vehicle is a complex functional system. Interaction of different parts of the vehicle design for certain functional purposes represents functional influences. Therefore certain defects result in failures of other parts of the unit.

A study of functional impacts of parts of the unit on other parts is necessary for development of a system of preventive measures for the rear axle potential defects.

The first stage suggests analysis of the form and the carried-out functions of parts of the studied unit. We will examine the structure of a banjo rear axle of the truck.

The results of the carried-out analysis of the form and the carried-out functions are set up as a table, a fragment of which is represented in table 2.

| Name of part       | Part form description and image | Function                                                                 |
|--------------------|---------------------------------|--------------------------------------------------------------------------|
| Rear wheel hub     | Rotary-body-type part with an external rim with openings and an internal opening of a complex configuration | Provides to a wheel an opportunity to rotate round its pivot-center and to keep strongly on the suspender; transfers rotational motion from transmission to a wheel if it is the driving wheel |
The painted table contains detailed information about the components of the rear axle, their structure and functions. This helps to understand the relationship of parts between themselves.

During the work with claims, the approach consisting in the analysis of potential defects, identification of the probable causes and assessment of possible consequences, instead of total control of defects and constant corrective actions, is considered appropriate. According to IATF 16949:2016, such approach is called "Failure Mode and Effects Analysis" (FMEA) [5, 6]. As a rule, most enterprises dealing with production of auto components use this method of the potential defects analysis as a separate procedure and rarely perform this procedure as a stage interconnected with other processes of APQP. Without admitting the importance of the analysis of potential defects, some employees calculate priority number of risk, formally observing the procedure and placing points of relevance, appearance and detection. This results in incorrect assessment of risks and probable consequence. That is why a system analysis of potential defects is used in this research.

The results of the carried-out analysis of potential defects of the rear axle of the truck and their probable consequences are set up as a table, a fragment of which is represented in table 3.

**Table 3. Potential defects, their causes and consequences.**

| Name of part | Potential defect | Consequences | Probable defect causes |
|--------------|------------------|--------------|------------------------|
| Hub          | Corrosion        | Fixing ring with a cracked radius | The influence of atmospheric factors (e.g. salt, moisture) |
| Damages      |                  | Brake drum fixing ring torn off | Loose hub bolts |

Types of defects were defined using facet classification, the results are set up as a table, a fragment of which is represented in table 4.

**Table 4. Defects qualifier example.**

| Designation | Type of defect |
|-------------|----------------|
| D1          | Corrosion      |
| D2          | Damages        |

Qualifiers of the probable causes and possible consequences are similarly developed. Their fragments are represented in tables 5 and 6 respectively.

**Table 5. Example possible defect causes qualifier.**

| Designation | Cause                                           |
|-------------|-------------------------------------------------|
| S1          | The influence of atmospheric factors (e.g. salt, moisture) |
| S2          | Loose hub bolts                                 |
Table 6. Possible consequences qualifier.

| Designation | Consequence                          |
|-------------|--------------------------------------|
| P1          | Fixing ring with a cracked radius    |
| P2          | Brake drum fixing ring torn off      |

Setting of formulas of the description of potential defects of the studied parts is executed based on tables 4, 5 and 6. The fragment of results is set up as table 7. The final formulas can be used during the work with the database for information support of the Advanced Product Quality Planning procedure.

Table 7. Formulas of the description of potential defects.

| Name of part | Formula of the description of potential defects |
|--------------|-----------------------------------------------|
| Hub          | \{S1[D1P1]\} \{S2[D2P2]\}                    |

Interconnected causes, defects and consequences are marked with braces \{\}. Square brackets are used for defects and consequences arising from a single cause. The formula presented in the table means that potential causes of defects in the rear wheel hub are corrosion and damage. According to this formula, you can determine which defects can occur and what consequences they can cause.

The graphic representation of the formula is shown in figure 2. Such a scheme can have a more complex structure. For example, the scheme of defects of the driven gear of the main gear (figure 3).

Figure 2. Scheme of rear wheel hub defects.  Figure 3. Scheme of the driven gear of the main gear.

The provided formulas have scientific novelty and have practical value for quality management of products of mechanical engineering. Feature of the received formulas is that at their application in an information system of maintenance of processes of the analysis of defects of a formula allow:
1. To carry out fast search of all possible reasons S defects established during production or in use in a parameter D code.
2. To carry out fast search and prevention of all probable effects P appearance of defects by a parameter D code.
3. To define potential defects of D which can arise at emergence of any reason by a parameter S code.
4. To define and to warn timely possible effects of P on the basis of information on the established reasons of defects of S.
5. To define possible defects of D which was led to emergence of P effects found in use devices.
All these opportunities allow preventing emergence of the reasons corresponding to category of the revealed defects by future production. Thereby, they help to improve work with claims and to reduce risks according to requirements of the international standard ISO 9001:2015 [7].

On the basis of the developed formulas of the description of potential defects and the constructed schemes of defects the analysis according to claims from external consumers of autocomponents was carried out.

The results of the research of probable causes of the defects of the rear axle of the truck specified in claims from external consumers are represented in table 8.

**Table 8. Results of the research of probable causes of the defects of the rear axle.**

| Name of defect                            | Probable cause                                   | Designation |
|-------------------------------------------|--------------------------------------------------|-------------|
| Flow of oil through drive gear cuff       | Excessive oil pressure                           | S43         |
| High level of gearbox noise               | Improper punch of nut                            | S14         |
|                                           | Transmission oil which is used does not comply with specifications | S22         |
|                                           | Improper adjustment of differential gear wheels  | S29         |
|                                           | Non-compliance with temperature conditions       | S30         |
|                                           | Loose fixture of driven gear wheel to the differential box | S36         |
|                                           | Wrong side clearance                             | S37         |
|                                           | Loss of preload by drive gear                    | S40         |
| Oil leakage through hub cuff              | Exceeding service life                           | S9          |
|                                           | Hub damage                                       | S10         |
| High level of hub bearing noise           | Increased load on bearings                       | S12         |
|                                           | Deformation of axle shaft                        | S13         |
| Slapping noise in the gearbox             | Satellites axis breakdown                       | S20         |
|                                           | Transmission oil which is used does not comply with specifications | S22         |
|                                           | Loose fixture of driven gear wheel to the differential box | S36         |
|                                           | Wrong side clearance                             | S37         |
| Gearbox differential breakdown            | Satellites axis breakdown                       | S20         |

The cause-and-effect diagram which shows the defects of the rear axle specified in claims and potential origins of defects is represented in figure 4.
Claims about the quality of the rear axle

- High level of gearbox noise
- Slapping noise in the gearbox
- High level of hub bearing noise
- Flow of oil through drive gear cuff
- Oil leakage through hub cuff
- Gearbox differential breakdown

Figure 4. Cause-and-effect diagram of the claims.

The resulting cause-effect diagram will prevent the occurrence of detected defects in the future and improve the quality of manufactured auto components.

The effective product quality management begins with the analysis of "incoming information" and ends with the collection of information on the quality of the output from the consumer.

4. Conclusion

The technique suggested in this article allowed systematizing data on potential defects, probable causes and possible consequences. The potential causes for defects were defined to prevent and reduce the defect level of the rear axle of the truck. This technique can be applied to the analysis of various assemblies or units of the machine-building industry.

References

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