## Chapter 2

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# APPLYING THE ISHIKAWA DIAGRAM IN THE PROCESS OF IMPROVING THE PRODUCTION OF DRIVE HALF-SHAFTS

**Abstract:** Nowadays, companies from the automotive sector are faced with huge financial problems. They are often forced to reduce production costs and / or administrative ones, however none of them can afford to reduce the costs related to the area of product's quality. The activities undertaken by the companies to improve their production processes can help to increase their competitiveness.
The company that will be presented in this analysis produces half-shafts for various types of cars and constantly analyzes, verifies, and undertakes corrective and preventative action to remedy the occurring inconsistencies. For this purpose, the company uses, among other means, various quality tools. The object of the following research is the application of the Ishikawa diagram in the process of improving the half-shaft production.

**Key words:** Ishikawa diagram, half-shafts, improvement, automotive sector.

## 2.1. Introduction

More than 8 million people worldwide are employed in the fifty largest factories that are producing more than 80 million vehicles annually (LUCZAK, 2008). The automotive industry is also a well-developed network of suppliers providing components directly to OEM (OEM - Original Equipment Manufacturer) or supplying service stations and replacement parts aftermarket. Suppliers of the automotive industry are a highly

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diverse group. The smallest companies employ a few people, and the biggest ones are international concerns employing thousands of people. Enterprises are also taking various positions in rows of the so-called suppliers pyramid; which include direct suppliers (1st row) second-row suppliers (subcontractors) and the further rows (indirect suppliers). Suppliers also differ in their competence profile; they can be identified as mass components manufacturers or the system integrators. Engineering companies, which offer their research and development services, as well as the enterprises that equip factories, are among companies that supply the automotive industry (Berlin.trade.gov.pl).

Suppliers of automotive parts are obliged to meet a number of requirements - e.g., economic, qualitative, including trade requirements as well as individual ones, that are defined by the customer. In the production process it is particularly important to control the key parameters as well as to control the quality of products, which will have direct impact on the safety of their users (LUCZAK J. 2008, BORKOWSKI S., STASIAK-BETLEJEWSKA R. 2011).

The analysed company is an automotive half-shafts' manufacturer, the half-shafts provide a connection between the drive wheel and the engine. Their function is to transfer the drive and allow wheel turning during the movements of suspension and vibrations. Each shaft contains two homo-kinetic joints, one of which is fixed and is located on the wheel's side and a second, which has a wide angle of shaft tilt, and is located on the side of the gearbox. They are connected using the connecting shaft (materials obtained from the researched company 2012).

Drive half-shafts have a huge impact on: a) the dynamics of the vehicle b) durability of mechanical systems c) performance d) NVH-Noise Vibration Harshness e) noise, f) efficiency they also have the main role in increasing the engine power and car maintenance. Therefore, the new generation of half-shafts produced by this company is the result of an ongoing commitment to research and develop new ways of improving and optimizing the overall performance of half-shafts (BORKOWSKI S.,

KRYNKE M., STASIAK-BETLEJEWSKA R. 2011, materials obtained from the researched company 2012).

## 2.2. The aim and methodology of the research

The aim of the study was to use the cause-effect Ishikawa diagram as a research tool that will help to improve the half-shaft's manufacturing process. To accomplish the goal of the research the following methods were used: a) observation method, b) induction method. c) descriptive method and d) the technical methods of data presentation.

## 2.3. Research tool characteristics

The basic tools in quality management, which are also called classical, elementary or traditional, ensure solving most of the companies' quality problems. The effectiveness of the tools used by employees is dependent on their knowledge, skill and the complexity of their application as well as on the interpretation of the results (HAMROL A. 2007, PIEKARA A., DZIUBA S. T., KOPEC B. 2012).

We can identify the following tools ('Great Seven' tools):

- Pareto - Lorenz Diagram, Histogram, Block Diagram, Check sheet, W. Shewhart's control charts, Correlation Graph, Ishikawa Diagram.
- Ishikawa's diagram was developed and used for the first time in Sumitomo Electrics factories in Japan (Oakland 1994).

Because of its shape it is also known as the "fish-axis". It is used primarily to identify the causes of various phenomena, among others: errors, problems and irregularities that occur during the work organization processes. The main principle of Ishikawa diagram is to analyze and find a place (cause) where the mistake has occurred and then to eliminate the mistake and apply measures that will prevent the re-emergence of the mistake (NIERZWICKI 1999, DZIUBA S. T., PIEKARA A., MALAS W., KOZIOL P. 2013).

It is assumed that solving the problem using the cause - effect method is implemented by the whole team, preferably with the use of "brainstorming." Most often the specific problems is worked on by specialists of one specialty, however sometimes the team comprises of people having various specialties, in accordance with the principle of Japanese quality circles. The success of a particular task, the aim of which is to investigate the causes of the specific phenomenon, is determined by the interest and involvement of the members of the task team, as well as by a real desire to determine the causes for the non-compliance and for the shortcomings of processes that it involves (Nierzwicki 1999, Dziuba S. T., Piekara A., Malas W., Koziol P. 2013). It has to be clear that sole use of the Ishikawa diagram does not allow for a rapid solution of the problem. Creation of the diagram is supposed to result in the situation in which all of the possible causes of errors are known, to subsequently rule out the least likely causes. From a practical point of view, when you create an Ishikawa diagram, it is correct to adopt the principle that the most important causes are located closest to the main axis, and the least probable causes are placed further away from the main axis. Reading the diagram, you will notice right away which problems are relevant and which are of less importance. Further elimination of causes (e.g. using "brainstorming") allows focusing on the most important reasons for non-compliance and increases the chance to detect and remove them (KINDLARSKI 1993, NIERZWICKI 1999, SELEJDAK J., KONSTANCIAK M. 2012).

## 2.4. Identification of the problem

In the event that the product manufactured by the company does not meet the requirements of the customers, immediate corrective action should be implemented, to determine the causes of the non-compliance, and measures to prevent its recurrence should be applied. At this stage it is important to apply a suitable tool that is used in quality management.

The figure number one (Figure 2.1) shows an example of front drive half-shaft : (1) produced in the studied company, which consists of the following components: (2) band / bands, (3) housing, under which a sufficient amount of grease can be found, (4) labels, (5) joint located on the wheel's side, and (6) tulip. The left side of the drive half-shaft is located on the wheel's side, while the right side is located on the gearbox' side. Preliminary analysis of the production process showed that a falling band located on the side of the wheel causes the problem. The problem occurred at the work stand of the first assembly line operator (Figure 2.2).

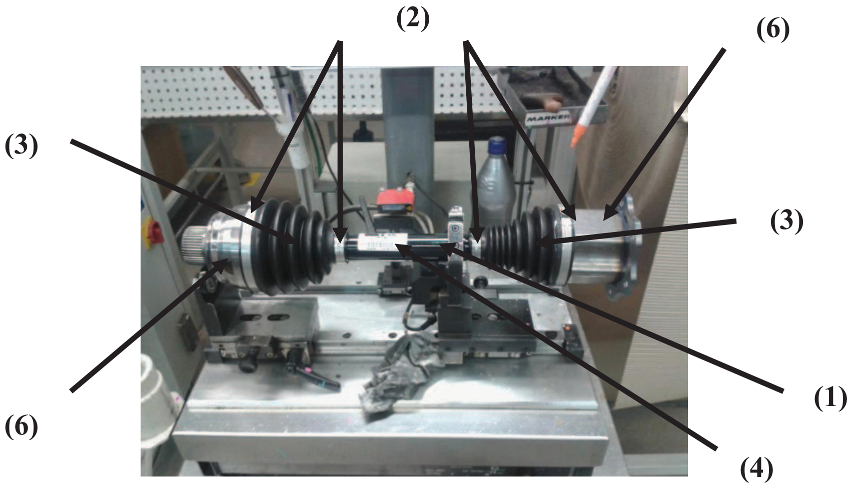



***Fig. 2.1. Example of the front drive half-shaft.***

*Source: personal research*

The scope of action of the assembly line first operator:

- collection of the band and the housing,
- installation of these components on the assembly head,
- collection of shafts and inserting them into the housing assembly station,
- sticking labels on the shaft,
- mounting the housing on the shaft, by means of the station,
- fastening a band using pneumatic pliers,

– taking the item out of the station and installing the retaining ring on the shaft,
– collection of joints , inserting them into the machine and assembly,
– placing the finished product at a specified spot, where it is taken over by the second operator.

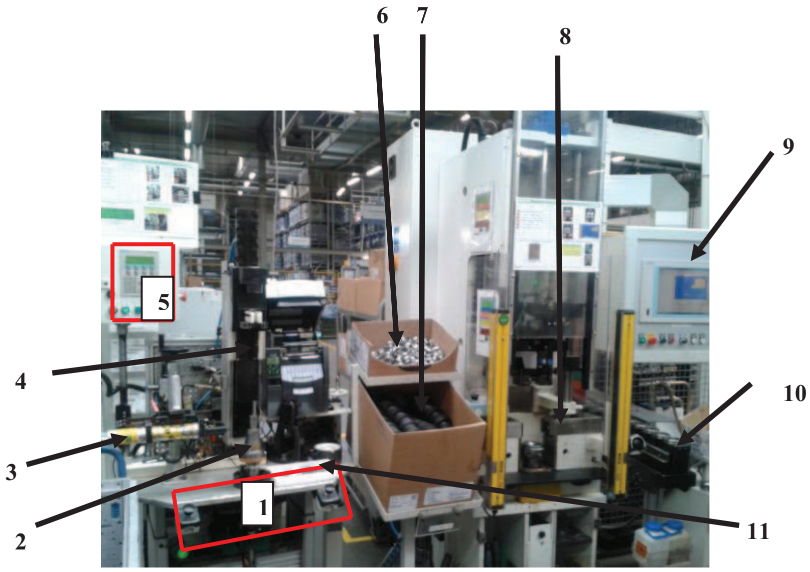



***Fig. 2.2. The work stand of the first assembly line operator.***

*Source: Personal research*

Figure number 2 (Fig. 2) presents the work stand of the first assembly line operator, which can be divided into the following elements: (1) buttons that start up the housing assembly station, (2) assembly head, (3) pneumatic pliers, (4) the station responsible for assembly of the housing. (5) Control Panel (used to operate the housing assembly station as well as pneumatic pliers), (6) bands, (7) housings, (8) the machine that is used to put the shaft together with the joint, (9) Control Panel (machine control panel), (10) joint (11) retaining rings.

## 2.5. Description of non-compliances

The client received the half-shafts, which were mounted in the vehicle. The issue concerning them was that the small bands located on the wheel's side were sliding of automatically from the housing of the drive shaft as a result of rotation, the result of this situation was the unsealing as well as leaking of grease- that could have been the cause of bearing seizure. In the picture (Figure 2.3) the band is located in the correct spot on the housing , while in the picture (Figure 2.4) the band, on the wheel's side, is sliding of

***Fig. 2.3. Band installed properly.***

*Source: personal research*

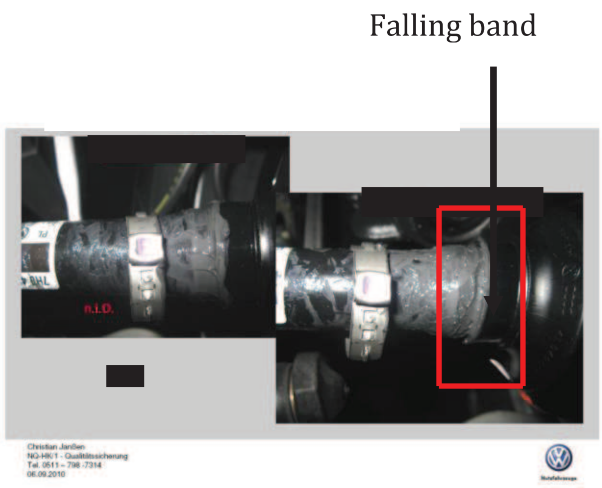



***Fig. 2.4. Falling band located on the wheel's side.***

*Source: personal research based on the materials acquired from the company*

## 2.6. Analysis of non-compliance conducted using the cause-effect Ishikawa Diagram

To analyse the issue, the cause - effect Ishikawa diagram was selected, as it is the most widely used tool for the detection of quality in the automotive industry. Its main principle is to determine the causes of the problem, and then eliminate the problem and then use appropriate measures that will allow preventing the re-emergence of non-compliance.

In the Figure 2.5 the non-compliance, that is the falling band located on the drive half-shaft on the wheel's side, is presented in the form of the Ishikawa diagram.

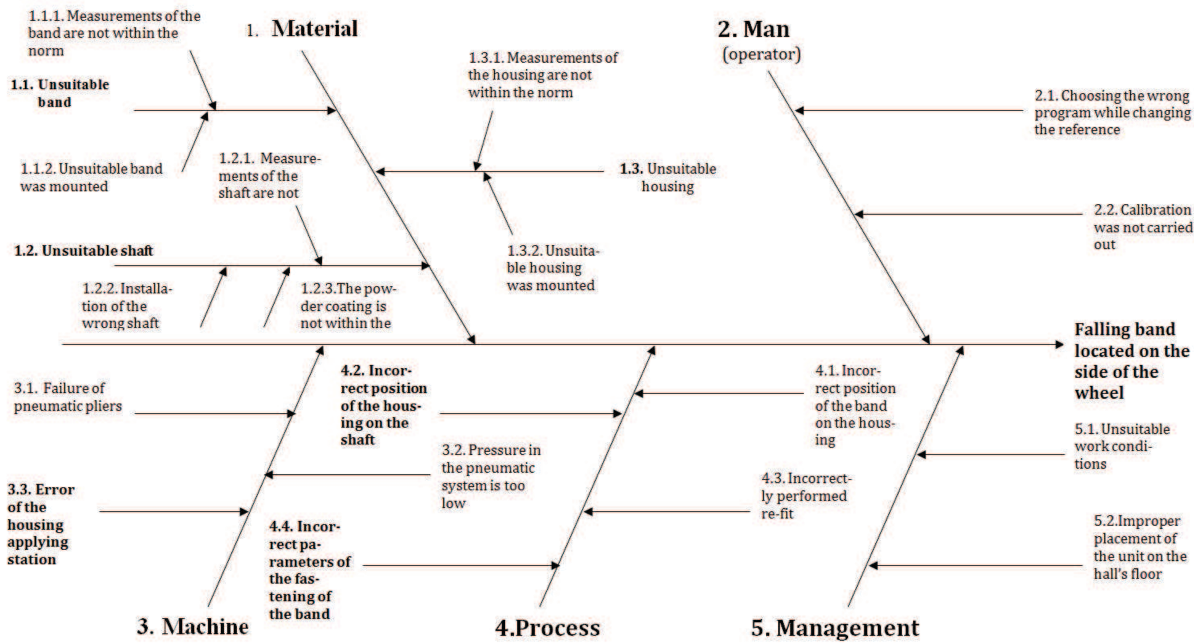



***Fig. 2.5. Ishikawa Diagram.***

*Source: personal research*

Table 2.1. The analytical description of the causes based on (Fig. 2.5).

**Table 2.1. Analytical description of the non-compliance's causes, the falling band located on the drive half-shaft on the wheel's side**

**1. Category of causes: the material**

**1.1. Cause: unsuitable band**

1.1.1. Sub-cause: the dimensions of the band do not meet the standards.

To verify this cause the following measurements were taken:

- thickness of the band,
- width of the band,
- firmness of the band,
- gaps of the band's fastening.

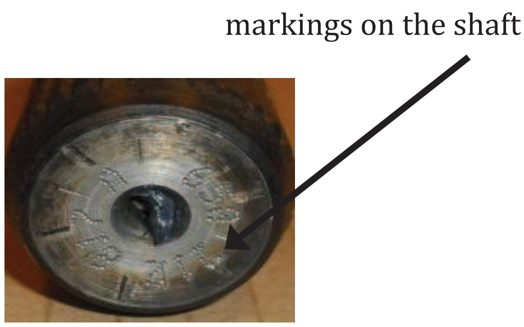
After taking the above measurements it was concluded that the size of the band is suitable and meets the requirements of the company

1.1.2. Sub-cause: wrong band was installed

The study shows that all of the bands, produced on the day when the complaint was issued, measured 37.5 mm (Fig. 2.6), which is in line with technological documentation. Therefore, this sub-cause does not have any effect on the analyzed problem.


***Fig. 2.6. Band measuring 37.5 mm.***

*Source: personal study based on the materials acquired from the company*

| **1.2. Cause: unsuitable band** |
|---|
| 1.2.1. Sub-cause: the measurements of the shaft do not meet the norms.<br>This cause does not affect the analyzed problem, as on the basis of the performed tests it can be concluded that the shaft has the correct dimensions - complying with the standard. |
| 1.2.2. Sub-cause: wrong shaft was installed.<br>During the production of shafts each of them is labeled Based on the performed analysis, the markings on the shaft indicate that correct parts were used and that the parts were in accordance with the technological documentation, it is therefore necessary to eliminate this cause, as it does not affect the analyzed problem. The markings on the shaft prove that the correct part was installed (Figure 2.7).<br><br><br>***Fig. 2.7. Labeled shaft.***<br>*Source: personal study based on the materials acquired from the company* |
| 1.2.3. Sub-cause: the powder coating not meeting the standards<br>The tested shaft had a coating of 64 m, which means that it was appropriate, as the standard in this case range is from 60 to 150 microns. This is not a cause that affects the main problem. |

**1.3. Cause: unsuitable housing**

1.3.1. Sub-cause: the dimensions of the housing not meeting the standards.

The faulty components, in the researched company, were tested and the results of the tests showed that the dimensions were in line with the norm, and therefore should be ruled out as the cause.

1.3.2. Sub-cause: installation of the wrong housing

The markings located on the housing show that they have been fitted correctly - the number is in line with technological documentation, as shown in Figure 2.8.


***Fig. 2.8. The markings on the housing.***

*Source: personal study based on the materials acquired from the company*

**2. Category of causes: man triggered causes (human factor)**

2.1. Cause: choosing the wrong program while changing the reference

This cause can be eliminated, because on the basis of the study it can be concluded that on the day of producing defective parts operators chose the correct program.

2.2. Cause: calibration was not carried out

The tests show that the calibration (process of setting the parameters of force and the gap of the pneumatic pliers) was carried out correctly. Viewing the check forms that are available in the database of the company proved the above.

**3. Category of causes: machine triggered causes**

3.1. Cause: failure of pneumatic pliers

On the basis of the analysis that was carried out in the establishment, on the day of the complaint there has been no information related to the malfunctioning of the machine (operators did not report any failure of pneumatic pliers), thus this cause should be ruled out.

3.2. Cause: air pressure being too low in the pneumatic system.

As with the previous cause, there is no information about issues with the clamping tool. The minimum pressure, recorded on the day when the defective elements were manufactured, was 7.9 bars, which means that it was normal, as it is required for the pressure to reach the minimum of 6 bars. Thus, the low air pressure is not the cause of the problem.

3.3. Cause: error of the housing applying station.

This may be one of the reasons why the problem has occurred, as holding the start button for too short of a time could have resulted in the error of the station.

**4. Category of causes: technological process**

4.1. Cause: The incorrect position of band on the housing.

Based on the research carried out in the company it can be concluded that the marks on the housing of the defective parts indicate that the band was tightened in the correct position, the proof of this are the images presented in Figure 2.9.Therefore, this cause can be eliminated.

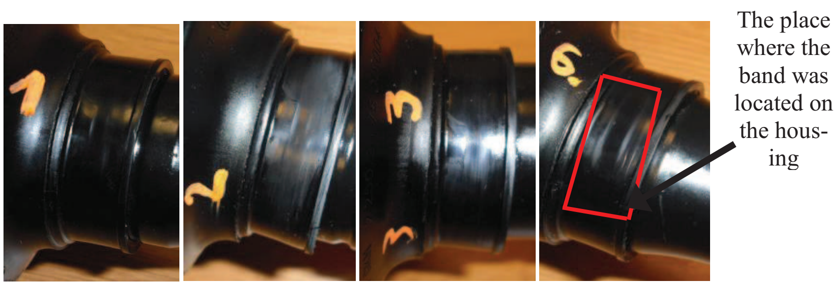



***Fig. 2.9. The place where the band was located on the housing.***

*Source: personal study based on the materials acquired from the company*

4.2. Cause: incorrect position of the housing on the shaft.

This may be a potential cause to the problem, as there is a risk of the retaining ring (element used in the manufacturing of a shaft) getting into the assembly head( on which a housing with a band is placed, and then using the housing applying station the shaft is pushed into the housing) causing the housing to be in the incorrect position during assembly.

The Figure 2.10 presents the assembly head inside of which the retaining ring is located.

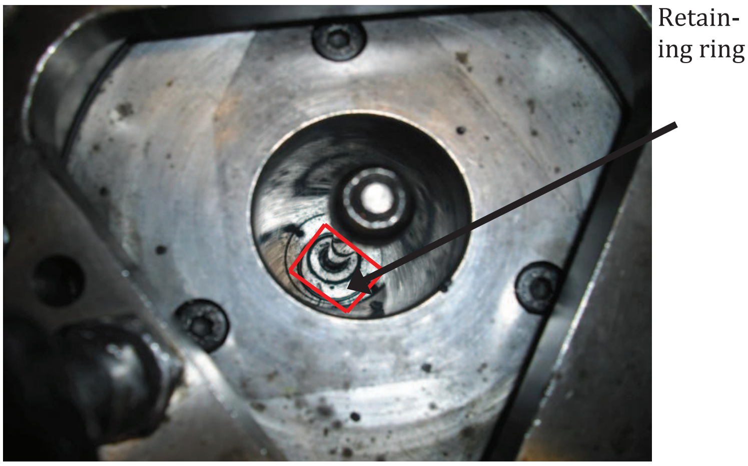



***Fig. 2.10. Assembly head.***

*Source: personal study based on the materials acquired from the company*

4.3. Cause: incorrectly performed re-fit

Based on the analysis performed in the company, we can gather that the production database does not show any alterations that were made on the day of producing the defective shafts. That means that this cause has no effect on the analyzed problem.

4.4. Cause: incorrect parameters of the band's fastening.

This unit (the control panel of pneumatic pliers), which is used to change parameters while the work is being performed, is not secure, which is equivalent to the fact that everyone has access to it and, therefore, there is a potential risk of changes in the parameters introduced by the operator. This cause may have had an influence on the issue being analyzed.

Figure 2.11 presents the device , which can be used to change the parameters.

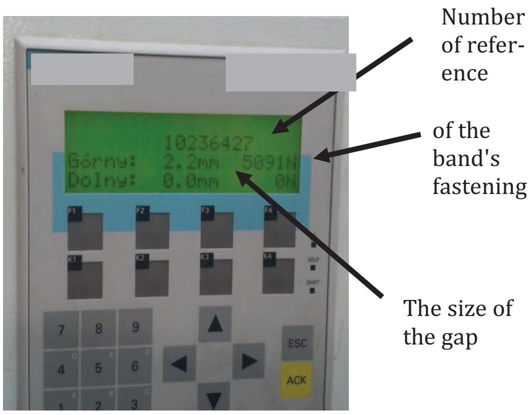



***Fig. 2.11. The control panel.***

*Source: personal research*

| 5. Category of causes: management |
|---|
| 5.1. Cause: unsuitable work conditions.<br>For the work carried out by the operators to be correct, it is necessary to have the right work conditions. The study shows that in the audited company there is a three-shift system of work, where one shift lasts eight hours. The employee is entitled to two breaks, each lasting fifteen minutes. The production hall is spacious and properly lit. Operators have protective glasses, gloves and safety shoes as well as earplugs, which muffle the noise occurring in the production hall. Based on the above analysis, it can be concluded that working conditions are adequate, and therefore it is not a cause that affects the analyzed problem. |
| 5.2. Cause: improper placement of the unit on the hall's floor.<br>On the basis of the analysis carried out in the factory, we can conclude that all the machines are located in the right places. It is therefore necessary to eliminate this cause, since it has no impact on the analyzed problem. |

Based on the analysis of the cause - effect Ishikawa diagram three causes were selected that had the greatest influence on the issue being analyzed and need to be improved. These are: 1) Error of the housing applying station; 2) Incorrect position of the housing on the shaft; 3) Incorrect parameters of the band's fastening.

## 2.7. Summary

On the basis of the performed research the three main causes that influenced the analyzed problem, were found: Therefore, to eliminate:

1. The error of the housing applying station the station should undergo inspection, as well as the housing applying station's programming should be improved. In the case of this station, it will be necessary to add one-second time period (the operator must hold the station's' turn on' button for not less than one second), which will allow the opera-

tor to know, after hearing a sound signal, that the housing is correctly mounted on the shaft when the button is pressed for too short of a time an error message will be displayed to notify the station's operator.
2. Incorrect position of the housing on the shaft. A ban that concerns placing the bands loosely on the station's table should be issued, as well as installation of the dish to keep the bands in that would have its designated place. Moreover, an additional confirmation of the correct position of the housing on the shaft can be introduced using a special chip placed in the head and connected to the control panel. If the housing is installed in the wrong position on the shaft then the station will not start and you will see an information about irregularity appear.
3. Incorrect parameters of the band's fastening it is necessary to restrict the access to the parameters of bands' fastening by introducing an additional security measures in the form of card readers in the audited company - only authorized employees will have access to the parameters, namely, the leaders, the station leader, process engineers and automation engineers. In addition, the operator should measure the gaps of every band that has been mounted, using a gap gauge.

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