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REDUCTION OF DEFECTIVE PRODUCTS IN THE PRODUCTION OF VIBRATION DAMPER

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Abstract: Due to the constantly growing competition on the market, enterprises are looking for a way to improve the quality of their products and services. The quality of the product is largely dependent on the number of defects present, so efforts should be made to minimize them. The article presents a method of limiting the formation of defective products, in this case, vehicle components – vibration dampers. The method was developed using selected quality management methods and tools.

Keywords: vibration damper, defect in the production.

1. Introduction – characteristics of the production process of vibration damper

The purpose of the article is to show how to detect the causes of a recurring problem. The example problem is a large amount of nonconforming products, the item being vibration dampers. The task of the vibration damper is to dampen the vibrations generated by the crankshaft, to protect it and to aid power transmission using a ribbed belt.

The vibration damper consists of an outer aluminum ring produced via the casting process. The cast is then processed, where the appropriate tooth shape is provided (referred to as "poly V"). Subsequently, anodizing is performed, which gives the ring adequate corrosion protection and an aesthetic appearance. The hub is made of hot-rolled steel. The last component of the vibration damper is the rubber ring used for vibration damping. The production process is performed on vulcanizing presses. On the press, the outer ring is connected with the hub by pressing a rubber ring between them.

The purpose of balancing the damper is to shave off material in a place, where there is too much of it in order to unify its mass or to add weight to where there is too little of it. To ensure protection against corrosion, parts are coated with an anti-corrosion agent.

Figure 1 shows the structure of the damper.

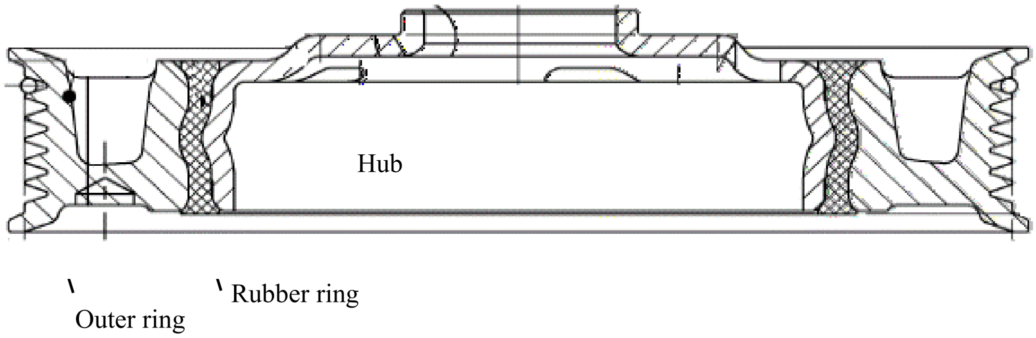

Figure 1. Structure of a model vibration damper.

A block diagram of the production process of vibration damper is shown in Figure 2.

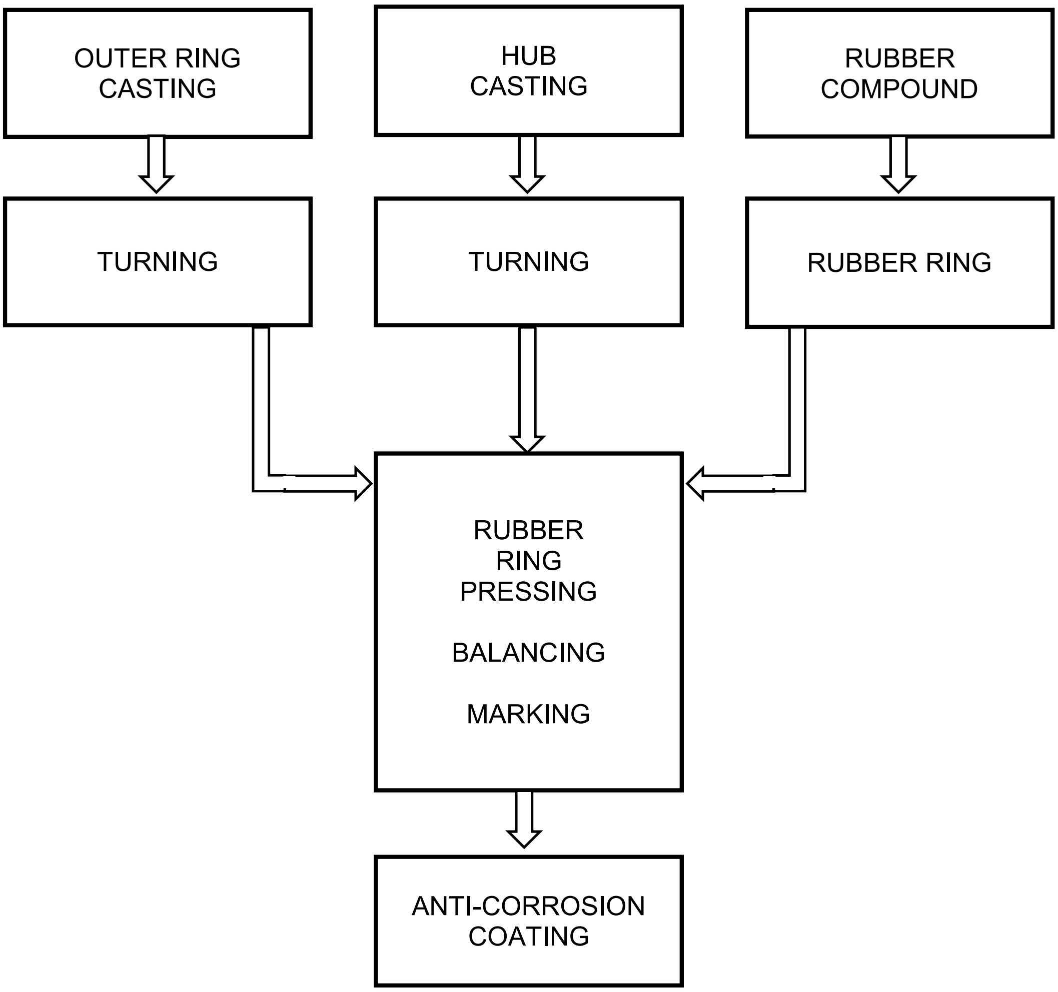

Figure 2. A block diagram of the vibration damper production process.

2. Defect characteristics in the production of vibration dampers

Each production process is affected by various factors, as a result of which the process is disrupted. The reasons of variation in the process can be as follows:

- systemic (random) – being part of the process, which is very difficult to determine,
- determinable – possible to define and eliminate.

Variation in the production process is an undesirable phenomenon, and it leads to formation of defective products, and thus generates additional costs.

Costs in relation to the described issue can be divided into following parts:

- conformity costs – incurred in order to obtain the required quality, quality conformity checks held for verifying the obtained quality in relation to the required quality,
- non-conformity costs – arising from the generated non-conformity, i.e. between the quality obtained and the required quality (Molenda, Hąbek, and Szczęśniak, 2016; Zasadzień, et al., 2017).

In order to identify non-conforming products, a list of the most frequent defects along with codes assigned to them was developed, e.g. offset (F1), cast defect – pit (F2), cut teeth (F5), incorrect diameter (F7), incorrect position of holes (G1), imbalance (G2), radial run-out (G5), mechanical surface damage (G7), axial run-out (H7), badly pressed rubber (I1), corrosion on surface of the part (J4), pressing force out of tolerance (J5). Examples of defective components are shown in Figure 3.

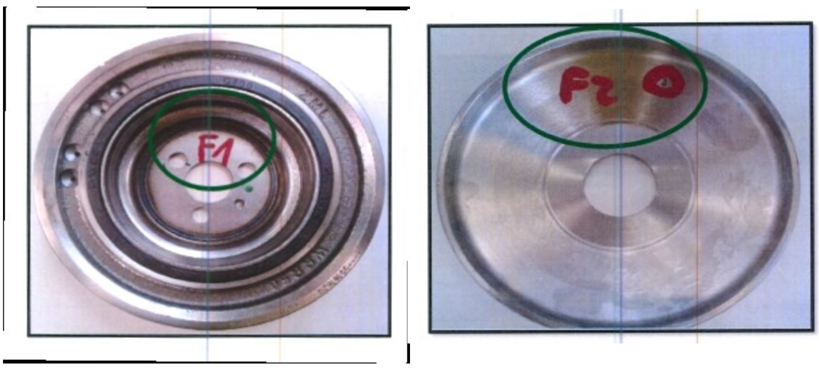

Figure 3. Examples of defects occurring in the production of the vibration damper, described with the codes a) F1 – offset, b) F2 – cast defect.

It is crucial to determine which production area generates the largest amount of non-conforming products. In order to obtain better control over the cost for scrap and to identify the places where the largest amount of non-conforming products occurs, each production area has been assigned with its own CC (Cost Center) number (Figure 4).

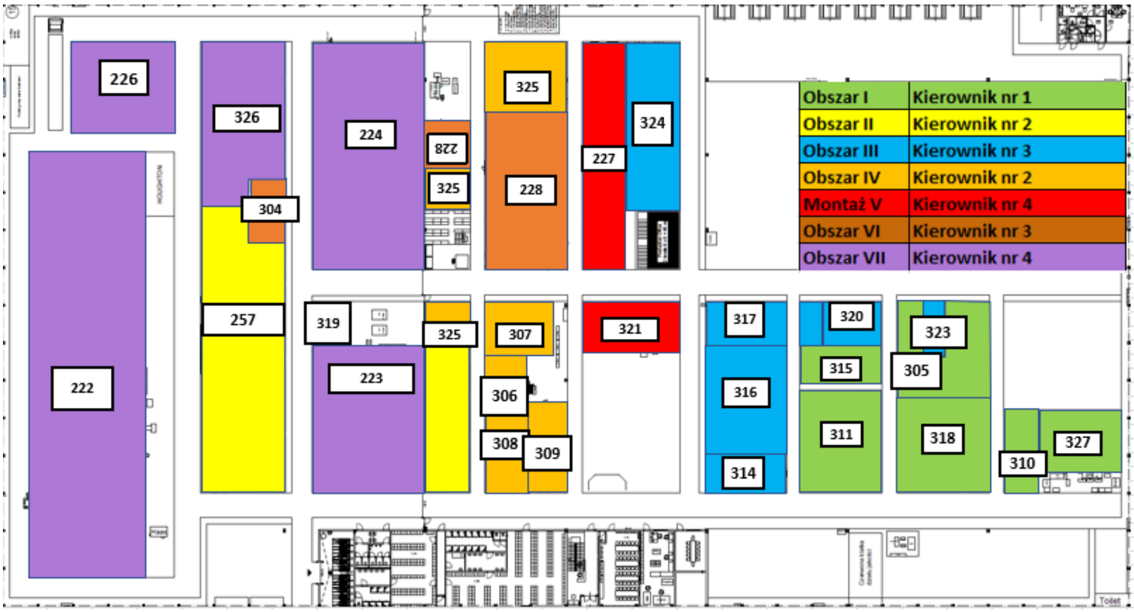

Figure 4. Division of the company's production area into CCs.

The division of the production area into CCs enables the preparation of a Pareto analysis, which will indicate the area generating the highest costs.

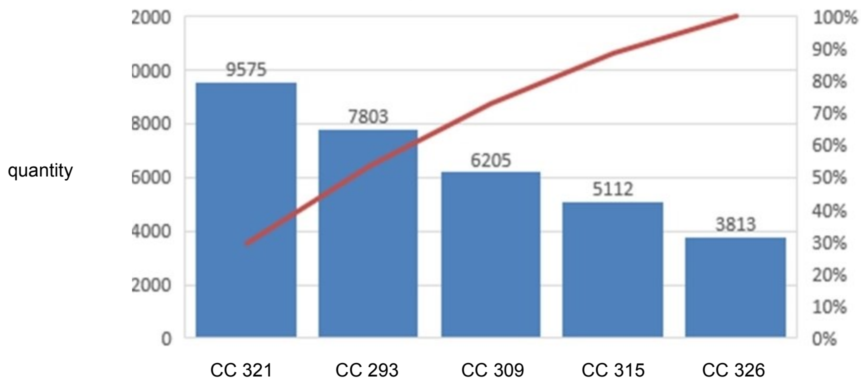

Figure 5. Pareto diagram – quantitative amount of non-conforming products by CC.

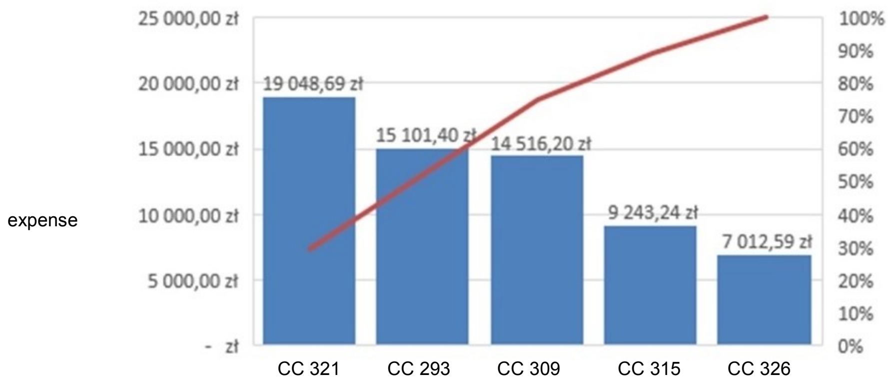

Figure 6. Pareto diagram – costs of non-conforming products by CC.

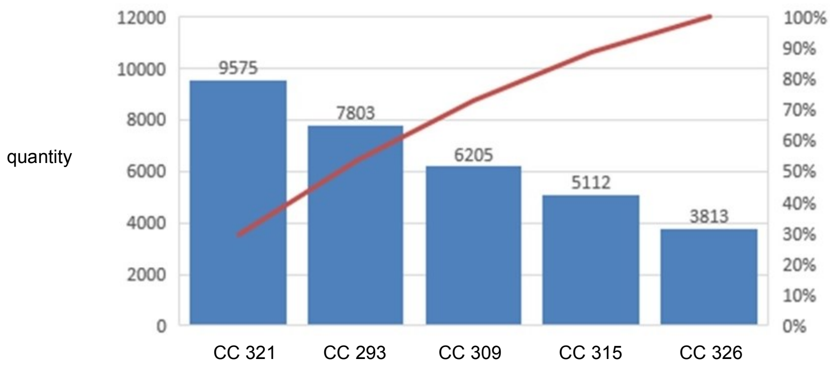

Figure 7. Pareto diagram – quantitative amount of non-conforming products by codes.

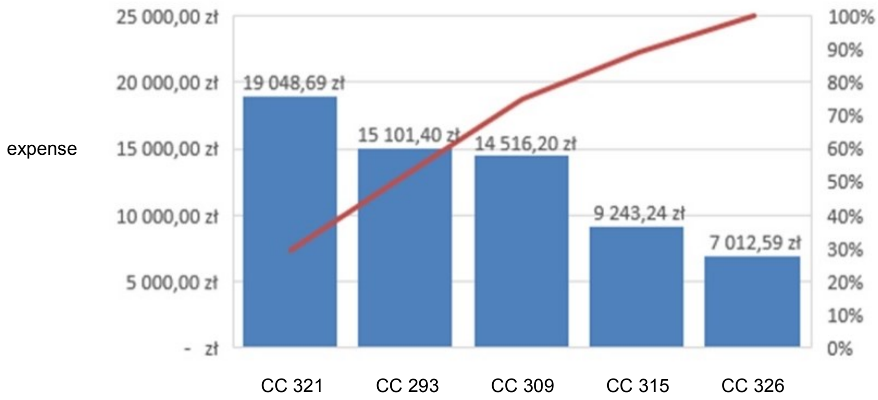

Figure 8. Pareto diagram – costs of non-conforming products by codes.

In the process examined, non-conforming products from the line caused excessive axial run-out. Axial run-out is the difference between the largest and smallest distances of the points of the real facing surface at a specific R radius from any plane perpendicular to the reference axis (rotation)

The axial run-out in the analyzed vibration damper constitute differences measured on the first teeth called poly V along the circumference in relation to the reference planes, which are the Y base plane.

3. Failure Modes and Effect Analysis (FMEA) on the axial run-out

The next step in the analysis was to check how the axial run-out was assessed in FMEA and what risks are associated with it.

Table 2.
Assessment of the axial run-out in the FMEA

Operation	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s) Mechanism(s) of Failure	Oc	Current Process Controls
Rubber ring pressing	Axial run-out not conformant with specifications	Fast wear, noise	7	Incorrect, worn out tooling, improper setup	2	One psc every one hour, three pcs for approval, 100% final inspection

Axial run-out occurs during pressing of a rubber ring between the outer ring and the hub, and it may be a result of a non-conforming connection. A potential effect of the axial run-out can be faster wear of the ribbed belt and noise.

Axial run-out is a critical characteristic; therefore its severity (Sev) was rated as high (7). The severity refers to the degree of consequences of the failure that occurred at the customer's site or within subsequent stages of the process.

Occurrence (Oc) can be assessed based on statistical data that shows how many times a given defect occurred in the process. In the analyzed cases, the frequency of occurrence of such a defect was assessed as LOW (2).

Table 2.
Occurrence assessment for FMEA

Probability of Failure Occurrence	Assessment of occurrence of a defect
LOW probability of failure occurrence. Cases detected sporadically over the past year in similar processes.	**2**

This rate is definitely too low, given the fact that the occurrence of failure (axial run-out) in the analyzed period was detected very often and even systematically. Rating of occurrence should be changed to 8 or 9 due to the intensity of the occurrence of non-conforming products.

Table 3.
Occurrence assessment for FMEA

Probability of Failure Occurrence	Assessment of occurrence of a defect
VERY HIGH likelihood of failure. Cases detected almost systematically over the past year in similar processes.	**9**
HIGH probability of failure occurrence. Cases detected very often over the past year in similar processes.	**8**

Detectability (Det) constitutes an assessment of effectiveness of the control system in identifying potential vulnerabilities or defects of a project before allowing the production or anomalies and their effects on the product in the production process, before the product reaches the customer or another production stage.

Detectability was rated 3, parts (frequency 100%) are measured automatically in line.

4. Failure Modes and Effect Analysis (FMEA) on the axial run-out

In In order to analyze and identify all possible causes of the issue of axial run-out, a cause and effect diagram, known as the Ishikawa diagram, was used (Figure 9) (Skotnicka-Zasadzień, 2012; Wolniak, Skotnicka, 2005; Zdanowicz, Kost, 2001).

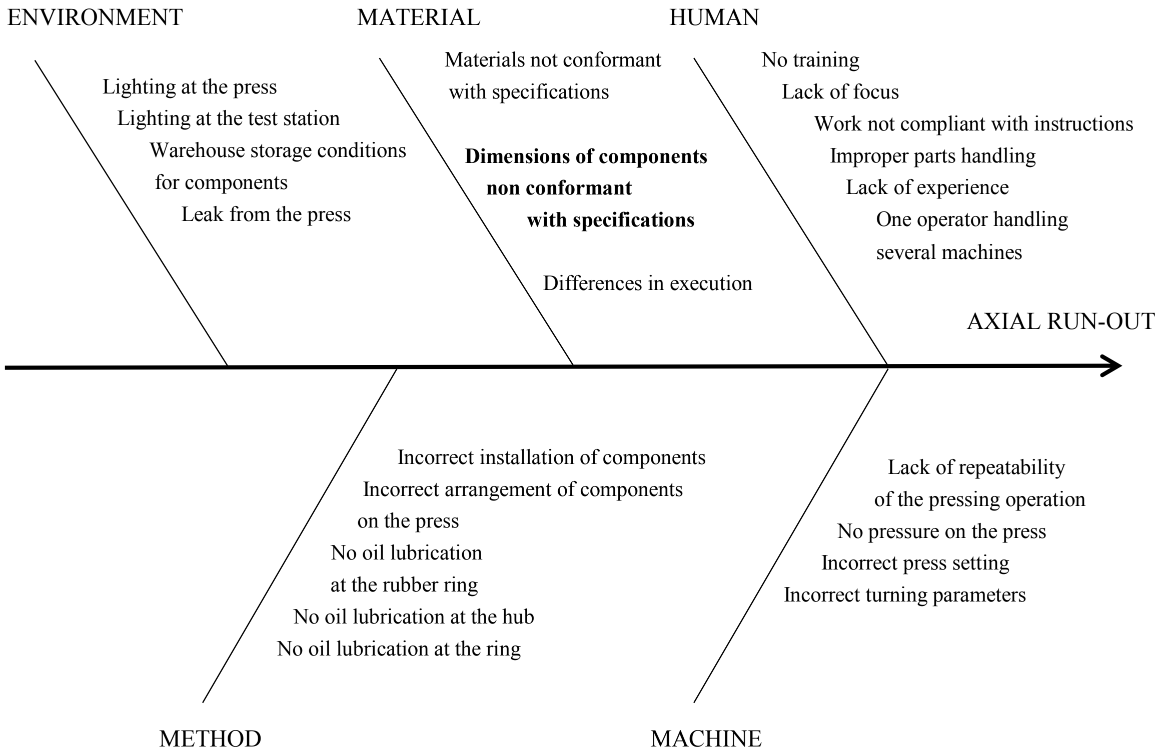

Figure 9. Ishikawa diagram for axial run-out.

For each "axis", the following potential causes that may cause axial run-out have been noted:

1. Environment: lighting at the press, lighting at the test station, warehouse storage conditions for components, leaks from the press.
2. Materials (hub, outer ring, rubber ring) are not conformant with specifications (diameter), outer ring not conformant with specifications, rubber ring not conformant with specifications, differences in execution.
3. Human: no training, no focus on operations performed, work not compliant with instructions, improper parts handling, lack of operator's experience, one operator handling several machines.
4. Method: no oil lubrication at the hub, no oil lubrication at the ring, no oil lubrication at the rubber ring, incorrect arrangement of components on the press.
5. Machine: no pressure on the press, incorrect press setting, lack of repeatability of the pressing operation, non-conformant tooling geometry, incorrect turning parameters.

5. Axial run-out analysis using the 5Why tool

The next step in the analysis is to estimate which of the following reasons may have a significant impact on the creation of the axial run-out.

Hub diameter out of specifications

1. Occurrence

   The diameter has been turned out of tolerance – why? → the turning operation was carried out incorrectly – why? → the cutting insert became loose during turning – why? → the cutting insert is not screwed correctly – why? → the insert is screwed with an Allen wrench – why?

2. Detection

   The insert is screwed with an Allen wrench – why? → lack of checking the correct screwing of the insert – why? → lack of data on problems with the insert tightening – why? → checking after the insert replacement was connected only with the dimensions turned by it – why? → checking the dimensions after replacing the insert is insufficient to verify its screwing – why?

3. System

   Checking the dimensions after replacing the insert is insufficient to verify its screwing – why? → lack of procedure to verify insert's screwing – why? → the procedure was not important – why? → lack of occurrence of similar situations in the past – why? → such a situation was not foreseen

The presented 5Why analysis aims to find the root cause in 3 aspects:

1. Why did the problem occur?
2. Why was the problem not detected?
3. Why did the system not protect against the problem?

One of the reasons that was chosen for the 5Why analysis is "hub diameter out of specifications".

5Why analysis on occurrence: hub diameter out of specifications, diameter turned out of tolerance, turning operation was carried out incorrectly, insert was loose during turning, insert was not properly screwed, insert screwed in with an Allen wrench.

A potential cause of the problem is "the insert screwed in with an Allen wrench".

5Why analysis on detection: insert screwed with an Allen wrench, lack of control on proper screwing of the insert, no data on problems with tightening the insert, checking after replacement of the insert concerned only dimensions turned by it, dimensional checking after replacement of the insert is not sufficient to verify its screwing.

A potential reason for detecting the problem is "dimensional checking after replacement of the insert is not sufficient to verify its screwing".

5Why analysis on the system: dimensional checking after replacement of the insert is not sufficient to verify its screwing, lack of procedure to verify the screwing, historically, the procedure was not important, lack of similar situation in the past, no information in FMEA.

A potential reason why the system did not detect the problem was "lack of information on similar events in the system".

7. Conclusion

The fiscal report was used in the analysis. The report covers the period: March to February next year, and there is a negative trend evident in the analyzed period, as the number of non-conforming products has increased during this period. The percentage of non-conforming products was 2,9%. Hence, 321 Cost Center generated the highest costs (19048,69 PLN). The largest number of non-conforming products was caused by axial run-out (code H7) – 682 products that cost 2880,75 PLN. Frequency of occurrence of such a defect was assessed as LOW (2).

The cause of the non-compliant product was the dimensions of components (hub) being non-conformant with specifications. The hub diameter was out of specification due to improper clamping of the cutting tool. Cutting tool attachment control is a solution that was immediately implemented.

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