Estimating the warranty returns and proving root causes using statistical analysis of archived parameters measurements for an automotive mechatronic device

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Abstract. In the mass production of the automotive industry, there are many cases in which a problem is not detected in the production processes of the supplier, but after delivery, in the customer's assembly line. As a result, it is necessary to know both root causes to prevent them, but especially, if it cannot be detected even in the customer's processes, to estimate the probability of occurrence in the warranty period. The paper's aim is to present the analysis of the measurements of the mechatronic devices indirect parameters linked with the effect of the failure and by statistical correlation to prove the root causes. A study case will be used to understand the failure first occurrence and the duration of its effect, as the symptom description as well, in that way it will support the estimation of the warranty return number of parts, eventually, the accounting department can establish the provisions based on the output data.

1. Introduction

Nowadays, the automobile contains a lot of more electronic components and systems and those are present in almost all the parts from a car: the body uses systems such as power door, power window, climate control and mirror wiper, the chassis uses suspension, differential and drive shaft, the power train uses systems such as engine control and transmission, the safety systems such as EPS, ABS, airbags, traction control and tire pressure monitor and the examples can go on.

![Figure 1. Electronic systems as % of total car cost.](image)
A study regarding the future of the electronic systems in the cars shows that currently, the percentage of the total cost coming from these electronics is bigger than 35% and this will increase in the next ten years to 50% from the total cost of the car, as is presented in figure 1 [1].

One system present in all the new cars is the Infotainment or well known as the official term IVI, In Vehicle – Infotainment. This is a term that describes the set of systems used for entertainment and information management available in a car. IVI devices can provide entertainment services such as radio, TV, games, but also navigation and various services that are connected to mobile devices through technologies, for instance the phones via Bluetooth [2].

Now, the suppliers of these products are not out of the warranty liability [3], as the recalls campaign as well, the more so as the product is linked with the safety systems in the car. In the 2019 report analysis of Stout based on the department of transportation from NHTSA, National Highway Traffic Safety Administration and many other international recall data bases can be seen in figure 2 the trend from the ten years monitoring (starting to the 2009 year) of the electronic components which contain the software embedded [4].

![Figure 2. Unique campaigns recalls of electronic components by year.](image)

From the previous report cannot be seen the last period, 2019-2020, but taken into consideration the number of total recalls from 2019 and the total number of the vehicles plus the equipment recalled, as is presented in figure 3, can be understood that the curve was switched in the wrong direction and the number increased [5].

![Figure 3. Motor Vehicle and Equipment Recalls – Source: NHTSA, 2019 Annual recall report.](image)
Therefore, the suppliers of these mechatronic devices in the mass-production must take seriously the analysis of the risks in the development phases [6], as in the serial production as well, as long as the cost with the warranty returns and the analysis of those parts is increasing daily [7]. Moreover, the new standard IATF 16949 applicable in the automotive industry [8] is focused on the same topic: analysis, risk mitigation and reduction of the warranty return.

2. Study case in an automotive mechatronic device manufacturer

The study case is based on the analysis of a mechatronic devices which is part of the IVI system, a device from the category HMI, Human Machine Interface, in fact, the device that support the driver to handle with the infotainment panel and to navigate in menu or to connect the mobile phone and find the contact in the agenda.

This device consist in an assembly from the plastic injection moulded components together with a PCBA, Printed Circuit Board Assembled, containing the microprocessors and the software embedded, as the LEDs, Light Emitting Diodes, for the night vision as well, a rubber which will give the tactile feedback from the normal pushing buttons made from plastic injection moulded components, screwed together, and a joystick which will be used to navigate in the direction of north-south or in the direction of east-west.

The joystick itself is assembled from the metallic parts with the glued magnets and a stop element from rubber material which is pressed into the plastic axe will define the way of the travel on those two directions – see figure 4.

![Joystick components](image)

**Figure 4.** Joystick components.

As the customer tactile feedback recognition for the parts, are defined the following characteristics: a curve generated by the travel ways, S, and the forces, F, as can be seen in figure 5. Also, the report between the F1 and F2, named Snap, calculated as the difference between F1 and F2, split to F2, with a result in percentages.
Figure 5. Travel ways and forces curves to describe the correspondent feeling of the user.

Those characteristics are tested and measured in an end-of-line test bench by using a dynamometer EDM20 050EL handled by a robotic arm and the auto-calibrating cycle is started when the pusher of the dynamometer starts to push over the device’s joystick, in that way, the system will reach the travel start-end, in order to measure within the expected range. The robotic arm will return the travel way and, eventually, by using a LabView interface the program will present on display the curves, as the data are archived in the comma-shifted-value format in the machine hard-drive.

2.1. Problem description
The issue started with a complaint from the customer and was claimed the fact that the travel way in direction of west is not according to the specification. As result of investigation, the stop element was detected in a moved position after the disassembly of the device. This stop element is inserted by the operator in the axe, then a semi-automatic machine will press it until the end position. The correct position of the stop element into the axe is ensured at this workstation, but a dedicated checking or measurement of the position is not performed in the next operation or the end of line testing machine. Moreover, if the rubber stop element will change its position in time, this effect cannot be detected as the testing step procedure is running almost immediately after the assembly (perhaps a small inventory level could be in some situations, still not enough to let the rubber to go out) and the vibration from the transport of the parts with the truck to the final facility will augment the possibility of the occurrence.

2.2. Investigation, analysis of the data and the result
On the affected claimed part was assembled a stop element which has a burr on the split line from the injected tool, as can be seen in figure 6 by microscopy analysis. Due to this, the stop element didn’t arrive in the end position into the axe, therefore the rubber components was kept in the position as should be and the final test at the end-of-line bench can’t detect such a failure in travel way.
The stop element is delivered by a supplier out of a toll with one hundred cavities, therefore, an investigation regarding the possibility of the affected batches and cavities was completed. A batch from a certain incoming date in week two was detected as suspect, but there was not at all the possibility to see when and at which line (out of three production lines of the joystick) were delivered these affected parts with burr because of the logistic supply method which require to split the same batch on all lines at the time.

Consequently, an analysis of the parameters from the archived data out of end-of-line hard drive was performed and the snap for the joystick in the west direction was deeply investigated. The result can be seen in figure 7 and figure 8, conclusion leading to a certain period of the suspected parts escaped and susceptible of the warranty return.

The target line is the minimum value of the snap which is 20% (in the plot chart being 20.000 as converted from the archived csv files) and the period of the suspected escaped parts is within a time frame of twelve weeks.

Eventually, the statistical analysis using Minitab 19 [9] was performed and the correlation analysis between three samples was used to prove the hypothesis of snap influence and possible detection in the end-of-line test. The first test performed was between two series of three hundred measurements, C1 and C2, and the result shows a correlation between – see figure 9.
The second test performed was between two series of three hundred measurements as well, C1 and C3, C3 being the period of detected snap variation due to burr on the stop element, and the result shows not a correlation between – see figure 10. As a result, the collected and archived data are referring to certain characteristics and their related measurements, but not direct data regarding the insertion of the stop element or position of it, because the test bench specification was established according to the customer requirements and the risk assessments from the development phases.

Due to all these facts, the paper study case proposed the possibility of using the analysis of the data concerning indirect measured characteristics, therefore, the necessity of validation from the statistical point of view was requested. Based on the information presented above, primarily, the statistical significance was proved and secondarily, the factors linked with the root causes as the period of the suspected escaped parts as well have been identified.

### 3. Conclusion

The study was initiated due to concern of the affected parts in field and the risk to overpass the provision established at the initial budget, as the image in front of the customer as well. As the effect was generated by a characteristic of the single part out of specification, the rubber stop element, and as...
the multi-cavities tool and the receiving inspection method based on the validation of the supplier through process audit capability and not an AQL level acceptance, was not possible to detect such a failure earlier, therefore, a batch of timeframe of twelve weeks was susceptible to be delivered with a certain percentage of the filed return risks. Based on the method selected, the root cause was proven by statistical analysis because the reproduction of the bad parts it is not quite possible at this level of the mass production.

The future research will follow, and the statistical analysis will be performed to allow a better estimation of the parts in field to be returned and the provision calculation to be accurate.

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