Improving the process of setting-up the extrusion line based on a systematic approach

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Abstract. The article is devoted to the description of the application of a systems approach with the aim of improving the process of setting-up the equipment of cable manufacturing, namely, the extrusion line. First, a risk-based approach was used to identify the bottlenecks of the setting-up process using the FMEA methodology. Secondly, the most critical operations of the setting-up process were considered in terms of measurement authenticity. In this context, the analysis of the stability of the measuring process, an analysis of the bias linearity and an analysis of repeatability and reproducibility were carried out. Using the measurement system analysis, it was managed to reveal four main factors influencing the variation of the measuring process and recommendations were made to improve each of them. Corrective actions have been developed, after the implementation of which the level of general repeatability and reproducibility of the measurement process has passed into the category of acceptable. Thus, applying the principles of a systematic approach and using the tools recommended by IATF 16949 "Measurement system analysis" and "Potential failure mode and effects analysis", we managed to achieve a new level of quality of the process setting-up an cable manufacturing, reduce the risk level of the process and minimize costs.

1. Introduction
A number of works by Russian researchers are devoted to the implementation of the quality management system in the enterprise and its improvement in various areas of industry. Through the introduction of various methods of quality management, important issues of improving the quality of the final product are solved. As a result, enterprises are attaining to improve the efficiency of the quality management system, production efficiency and reduce costs.

Activities to implement and comply with the requirements of the international standards ISO 9000 and 14000, ISO 45001 and IATF 16949, as well as quality management methods such as "Potential failure mode and effects analysis" (FMEA), "Measurement system analysis" (MSA) and many others is organizational innovation. The purpose of this activity is to assist the organization in the development and improvement of the basic management system to ensure its continuous improvement.

A systematic approach to quality management means an ordered set of interrelated and interacting elements, designed to create the conditions that provide the required level of product or process quality at minimal cost.

The quality management system of an enterprise includes various subsystems, the functioning of which at the proper level ensures the quality of the final product, on which customer satisfaction
depends. In this paper, we consider the supporting process subsystem, or rather its separate element - the process of setting-up.

In terms of cable production, the setting-up process is an important element of the manufacturing process. This process should be considered in the context of applying a risk-based approach to reduce the level of risk and reduce the influence of variation factors affecting this process.

2. Description of the process of setting-up the extrusion line from a system point of view
A systematic approach is a powerful tool that is used to make management decisions.

A systems approach is a comprehensive study of a phenomenon or process as a whole from the standpoint of system analysis, that is, clarifying a complex problem and structuring it into a series of tasks solved using economic and mathematical methods, finding criteria for solving them, detailing goals, designing an effective organization to achieve goals [1-6].

To improve the process of setting-up, we will consider setting-up in terms of its systematic and set a number of goals. First, we will conduct a risk analysis of the setting-up process. Secondly, we will analyze the measuring system of the key characteristics of the setting-up process. Finally, thirdly, we will conclude on the results of the analysis.

The process of setting-up the extrusion line in cable production consists of several stages:
- analysis of the technical condition of the line;
- checking the quality of products produced by previous shifts;
- Assembly extrusion head and the installation of the mandrel and the die;
- replacement of filtering grids;
- product quality control and transfer to the master in production.

3. Risk assessment of the process of setting-up the extrusion line
For risk assessment, we chose the FMEA (Failure Mode and Effects Analysis) methodology. FMEA is an analytical methodology that is used to ensure that potential problems throughout the production process are reviewed and studied. The most obvious result of the methodology is the documentation of collective knowledge of multi-functional teams. The results are presented in the table. [7-9]

The analysis showed that two of the three process characteristics studied are critical, which suggests that the setting-up process is an important stage in the production process. The distribution of the final risk level for each of potential failure mode is graphically presented in Figure 1.

![Figure 1 Distribution of risk by potential failure modes](image-url)
### Table 1. Risk analysis of the setting-up process using FMEA methodology

| Process Steps/Function | Requirement | Process | Potential Failure Mode | Potential Effect of Failure | Severity | Causes of Failure | Controls | Occurrence | Controls | Detection | RPN | Recommended Action | Responsibility & Target Completion Date | Action Results | Action Taken | Completion Date | Severity | Occurrence | Detection | RPN |
|------------------------|-------------|---------|------------------------|----------------------------|----------|------------------|----------|-------------|----------|-----------|-----|-------------------|----------------------------------------|---------------|-------------|-------------------|---------|-----------|----------|-----|
| Extrusion line setting-up process: Preparation of process equipment and tooling to perform a process operation | 1 - no mass leak | Process | Local insulation thinning | 1 mass flow | 9 | 1.1.1 The distance between the mandrel and the die is small | Assembling the head and installing the tool in accordance with the requirements of H1 | 2 | Visual inspection by the process operator at the beginning of work | 5 | 30 | Preventive maintenance of equipment; setting-up in accordance with the requirements of the instructions H1 | | 4 | 5 | 9 | 5 | 80 | 6 | 5 | 9 | 5 | 80 |
| Extrusion line setting-up process: Preparation of process equipment and tooling to perform a process operation | 2 - Tool size in accordance with the process documentation | Process | Loss of insulation | 2.1 The size of the tool is higher than that established in the process documentation, the discrepancy of the wire diameter (higher than the established) | 8 | 2.1.1 extruder speed and thrust mismatch | Preventive maintenance of equipment, setting-up in accordance with the requirements of the instructions H1 | 2 | Visually by marking on the instrument | 5 | 30 | | | | 8 | 2 | 5 | 80 |
| Extrusion line setting-up process: Preparation of process equipment and tooling to perform a process operation | 3 - Tool size in accordance with the requirements of technological documentation | Process | Difficult or impossible recycling wires at the consumer | 2.2.1 extruder speed and thrust mismatch | 8 | 2.2.1.1 extruder speed and thrust mismatch | Preventive maintenance of equipment, setting-up in accordance with the requirements of the instructions H1 | 2 | Visually by marking on the instrument | 5 | 30 | | | | 8 | 2 | 5 | 80 |
| Extrusion line setting-up process: Preparation of process equipment and tooling to perform a process operation | 4 - The frequency of replacement nets 1 time per day | Process | Wire appearance mismatch | 3. Foreign inclusions in isolation | 5 | 3.1 Incomplete processing of plastic granules due to defects in filtering grid | Replacing grid every shift | 3 | Checking the grid change by masters according to the H1 instruction every shift | 6 | 90 | | | | 3 | 5 | 6 | 90 |

**Symbol**  
- critical characteristic
4. Measurement system analysis of the key characteristic of the process of setting-up the extrusion line

For modern Russian manufacturers of automotive components, there are at least three reasons for applying statistical analysis of measuring processes:
- meeting the requirements of foreign consumers;
- reducing the cost of calibration of measuring equipment;
- development of measuring equipment.

MSA (Measurement System Analysis) is a method whose goal is to give an opinion on the acceptability of a measuring system through a quantitative expression of its characteristics. [10-13]

The IATF 16949 standard, together with ISO 9001, establishes requirements for a quality management system in the design and development, production and, if applicable, in the installation and maintenance of products related to the automotive industry.

For conducting an experiment on the analysis of the measuring system, the characteristic was chosen - diameter of the mandrel. This characteristic aroused interest as a result of the FMEA process, as the discrepancy in diameter leads immediately to two failures out of three, which were analyzed in FMEA - to a mass leak and to inconsistency in the diameter of the finished wire.

4.1. Stages for measuring mandrel diameter

The diameter of the mandrel is a geometric characteristic that affects the quality of the process of imposing insulation, ensures its concentricity. This fact determines the importance of measuring accuracy. Therefore, we consider in more detail the practical part of the experiment. [14-17]

For the planning, preparation and conduct of the experiment, a working group of experts was created, which included a specialist from the technical control department and an engineer for quality. They compiled a description of the measurement process with the following data:
- about the parameter being measured, including the part number and its name, the parameter being measured, the nominal size and the parameter tolerance;
- about the measuring instrument, including the name, date of the last calibration / verification and measuring resolution;
- about operators, including information on their number and qualification requirements (education, category).

4.1.1 Analysis of the measurement process stability

It consists in the implementation of nine cycles of experiments with one operator, two measurements of the sample in each cycle. The results are recorded in the “Medium and span control chart of the measuring process” using the Minitab software package.

Figure 2 Medium and span control chart to determine process stability
Specialists working with the study of this process, decided to consider the process stable, since there are no signs of process instability. Medium and span control chart obtained from the results of experiments is shown in Figure 2.

4.1.2 Linear displacement measurement process analysis

As part of this experiment, five samples were selected with supposed true values. Each of the selected samples was measured nine times by one operator. As a result, the linear displacement of the measurement process was plotted (Figure 3).

If we consider the displacement compared with the tolerance on the measured parameter, we can conclude that the displacement of the measuring process is insignificant compared to the tolerance on the parameter and even on the scale of 1/10 of the tolerance can be considered almost constant. Therefore, the displacement of the measurement process can be neglected, that is, it is assumed that the displacement of the measurement process within the tolerance of the measured parameter is constant and zero.

4.1.3 Analysis of the repeatability and reproducibility of the measuring process

Then was held an Analysis of the repeatability and reproducibility of measurements was carried out using the statistical software Minitab. The results showed (Figure 4) that the measurement process is unacceptable because the observed repeatability and reproducibility is unacceptable.

Therefore, it is necessary to develop and implement corrective actions aimed at reducing the risks of these types of variability and eliminating the corresponding causes.
5. Conclusion

As a result, the following corrective actions were proposed:
- development of technique for measuring the diameter of the holes of the mandrel on the used measuring instrument;
- develop a controller's work instruction based on the methodology;
- to conduct training and certification of operators involved in the measurements;
- continue to study the factors - operator, measuring instrument, environment, method with the aim of developing recommendations for improving these factors.

Ultimately, the application of the analysis of measuring systems helped to identify four main factors affecting the variability of the measuring process. As a result, recommendations were given to improve each of them:
- when conducting MSA, to attract operators who are not regular executors of this operation and keep in stock of trained specialists;
- conduct MSA indoors with air conditioning, to ensure the temperature in the specified range. In addition, it is necessary to use equipment that does not conduct heat to ensure the accuracy of measurements;
- replace the measurement tool with a more accurate one. The resolution of the measurement tool used is 0,005 mm and is unacceptable according to the rule of thumb, as more than one-tenth of the tolerance for the measured parameter;
- to develop a measurement procedure based on the passport data of the measurement tool used and the controller's experience, as well as a visualized work instruction of the controller, which will help eliminate the option of measurement error.

Having introduced the proposed corrective measures, the MSA was repeated, the results of which were used to reduce the convergence and reproducibility of the measuring system to a level ranging from 10% to 30%.

It should be noted the importance of applying a systematic approach to eliminate the risks of the setting-up process. By dividing the setting-up process into individual operations, we were able to identify the most important among them using the FMEA methodology. This characteristic — the mandrel diameter was studied using the MSA methodology. As a result of the implementation of the developed corrective measures for the identified problems, it was possible to reduce the overall repeatability and reproducibility of the measurement process to an acceptable level.

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