Statistical control algorithm for the process of rapid solidification rate of the melt

V A Vasiliev and S A Odinokov
Moscow Aviation Institute (National Research University), 121552, Moscow, Russia
E-mail: vasiliev@mati.ru

Abstract. To improve the efficiency and quality of the process of rapid solidification rate of the melt, it is necessary to improve its controllability. This can be done using a set of statistical methods. It is proposed to use the algorithm for consistent application of statistical methods and improve product quality. It enables data collection, processing and analysis, including process stability analysis, process capability analysis, trend analysis and evaluation of relationships between parameters. The algorithm can be used to fulfill requirements in a quality management system.

The article deals with the application of statistical methods for consistent analysis of the quality of the process of rapid solidification rate of the melt. The obtained results are supposed to be used in the structure of the quality management system.

The process of rapid solidification rate of the melt have been developed in Moscow Aviation Technological Institute (currently included in the Moscow aviation Institute) since the eighties. Serious results are obtained in the development of the process theory. The technology is developing in the direction of obtaining materials with new properties that are difficult or impossible to obtain by other methods [1–3]. First of all, it should be noted the production of materials for the manufacture of solders, filters, magnets, catalysts, reinforcing elements, etc. The process of rapid solidification rate of the melt is aimed at obtaining a wide range of products in the form of fiber, wire, tape with unique special properties and intended for wide use in the engineering industry.

Application of technology of high-speed solidification of melt and obtaining the corresponding original properties of production is economically expedient only in case of realization of the set results. It is necessary to ensure the stability of the quality and increase the capacity of the process. This applies to product quality and quantity. The consistent application of a group of statistical methods is a means of assessing such problems. They are designed to collect, process, analyze data and make appropriate management decisions. It is proposed to use the algorithm of statistical process control (figure 1). It provides the ability to meet the requirements of ISO 9001:2015 data analysis for process monitoring.

This algorithm was developed as a result of research of properties of a wire of solders on the basis of copper and fiber of steel of austenitic class. However, it is universal and can be applied to other materials.

It is necessary to create a system of indicators for monitoring and measurement. The presence of an automated system practically does not limit the number of parameters. But at the initial stage it is necessary to limit the key parameters of the process.
Figure 1. Algorithm of statistical control of the process of rapid solidification rate of the melt.
As a rule, this is the speed of the crystallizer disk, the material feed rate and the melt temperature [4].

Product quality indicators – geometrical parameters of fiber or wire cross-section-are controlled.

Statistical data collection includes planning and execution of control operations, including primary processing. Particular emphasis is placed on checking for outliers. This step includes the following elements:

1. selection of metal fibre and process quality indicators;
2. development of a plan for statistical control of the process;
3. statistical observation of the process;
4. exception of sharply allocated values of results of control.

The quality indicators include geometric fiber quality indicators and the corresponding technological indicators of the process of rapid solidification rate of the melt: the speed of rotation of the crystallizer disk, the feed rate of the molten metal, the thermal conditions of the melt, etc. Construction of the variation series is caused by the presence of different values of the trait in the aggregate. Variation occurs as a result of the fact that the individual values of the trait are formed under the combined influence of various factors (conditions), which are combined in different ways in each case. For example, hydrodynamic and temperature conditions, values of geometric characteristics of the fiber section, etc. the presence of variation is the main prerequisite for statistical research.

There are two groups of factors that affect mass phenomena and processes and are a source of variation: General and random factors. Common factors (common to all units of the mass population) act equally (permanently) for each unit of the population. They make these units similar to each other, create common patterns for them, form a typical level for the units of a qualitatively homogeneous population. Random factors are individual, they act on individual units of the mass population and form deviations of individual values of the characteristic from the typical level [5].

Construction of statistical variation series allows to make a preliminary analysis of the quality of the process. Measures of Central tendency need to be identified. These include the arithmetic mean, mode, and median of the distribution. The level of variation in the statistical population should also be assessed. In this case, the scope is used for the preliminary estimate and the standard deviation as the main measure. It should be borne in mind that in the process of high-speed solidification, batches with different but similar characteristics can be obtained. In this case, it is necessary to apply the coefficient of variation, which is a relative indicator [6].

Statistical hypothesis tests include testing the normality of the distribution. It allows you to get a preliminary result about the stability of the process. We determine the presence of special factors during the implementation of the process. At this stage, it is necessary to eliminate or reduce their impact. In addition, statistical hypothesis testing allows for a comparative analysis of individual batches of raw materials and final products.

To obtain the specified parameters of the wire or fiber affects several indicators of the process. The degree of influence they have different. This should be considered for management. Multivariate correlation and regression analysis should be used to analyze and then predict the results. The presence of strong dependencies will increase the efficiency of decision – making and improve the quality of management. In the process of rapid solidification rate of the melt, not just correlation analysis, but rather multiple correlation plays an important role, as a number of interacting product characteristics need to be taken into account simultaneously and the process is controlled through the use of several technical parameters. A multiple is the correlation between a dependent variable y and a set of independent variables x1,x2,...,xk. However, in the vast majority of studies, there is an effect of intercorrelation, and sometimes even multicollinearity, which makes a direct approach to measuring multiple correlation difficult. We need a new approach that allows you to quickly and reasonably obtain information for subsequent management decisions and actions. For this purpose it is proposed to apply numerical methods.

The process must be stable. However, often at the process of rapid solidification rate of the melt the statistical tendency of results is observed. For example, it can occur due to insufficient resistance of the disk-crystallizer. The statistical time series should be analyzed. Identify trends or variations in
results. You should consider the trend for process management. For example, you can predict the replacement of the crystallizer disk. To assess the process of rapid solidification rate of the melt and identify trends, a mechanical or analytical alignment is proposed, as well as the use of a set of statistical indicators, including absolute level increases, growth rates and other absolute, relative and average indicators.

In the manufacture of products, the main instrument of analysis remains the control chart. It is necessary to select the control card, conduct a preliminary analysis of the process and conduct subsequent management. As a rule, a double control map is used, which includes a map of arithmetic means and a map of standard deviations. If the results are unstable, median maps are used in the samples. A span control map can be used to simplify the processing of the results. Experience with the control chart shows the importance of control at the initial stage of hardening. This is due to the instability of the process at the start. Features of the process do not allow to do with traditional control cards. The presence of trends leads to the need to use cumulative sum maps that provide an assessment of constant shifts in the values of quality indicators. The specified requirements for the fiber cross-section and the need for constant monitoring of their implementation is a prerequisite for the use of acceptance control cards that provide analysis of two aspects: the stability of the process and its ability to perform the task. One of the advantages of the acceptance control card is that there is no unnecessary control, i.e., no need to unnecessary adjustments to the process when it takes place in the "process acceptance zone", i.e. in a satisfactory condition in terms of ensuring tolerance.

To analyze the capabilities of the process to meet the specified requirements, the $C_p$ and $C_{pk}$ coefficients should be used to assess the accuracy and configuration of the process. For normal operation of the process it is necessary to obtain a value greater than one. It is also possible to estimate the number of suspected inconsistencies in the wire or fiber. This makes it possible to evaluate the efficiency of the process of rapid solidification rate of the melt and its economic feasibility. $P_p$ and $P_{pk}$ coefficients can be used to analyze production conditions

The final action, in accordance with the requirements of ISO 9001:2015, is the continuous improvement of the process. As a rule, this is due to the requirements of the consumer. After that, the cycle repeats. Improving the process of rapid solidification rate of the melt involves a serial connection to the analysis of the most significant factors. The main tool is the correlation and regression analysis with visualization through the use of Pareto diagrams. Evaluation of the effectiveness of the measures taken is to increase the coefficient of determination in the study of the relationship between technological parameters and quality indicators.

This algorithm allows to implement the principle of quality management - making decisions based on facts. As a rule, it consists in selecting a quality indicator, data collection, data processing and data analysis and making a decision [7]. Extensive experience in the use of this technology determines the main indicators. Other actions are implemented using the proposed algorithm. Decision-making in this case can be implemented automatically.

Thus, the paper proposes an algorithm for the complex application of statistical methods. It allows you to analyze and control the process of high-speed solidification of the melt. The algorithm has great versatility. It can be used for other technologies. The algorithm complies with the requirements of ISO 9001:2015 and provides data monitoring and analysis. The algorithm allows to improve customer satisfaction, to assess the conformity of products, assess process capability. This allows for corrective and preventive measures. Implementation of the algorithm in the quality management system will improve the effectiveness and efficiency of the system.

References

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