THE SPC APPLICATION
IN THE PRODUCTION AND USE OF ALUMINIUM BASED MASTER ALLOYS

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Statistical methods have been used to control the critical processing steps in the production of aluminium based master alloys. Implementing this statistical process control (SPC) offers much more advantages than the control function alone, since it provides opportunities for process optimization. The methods used result in an improved product performance which as such is an objective that can be justified and, in the end, is clearly detectable. With SPC it is possible to demonstrate the distinct differences (cleanliness, performance) between the various grain refiner master alloys.

INTRODUCTION

Statistical process control is the modern way for efficient and quality conscious thinking nowadays. In order to successfully introduce SPC the following conditions are mandatory:

- management commitment
- process control system
- statistical education

To implement SPC successfully a start-up time of one to two years has to be taken into account. The approach to the process needs to be redetermined. Optimization has to be achieved by means of the process control function. The control function should be a separate entity with its own responsabilities, seperate from production.

QUALITY COSTS

A well known quality costs calculation model given by Juran (1) and plotted in a graph (see Fig. 1.), shows the relation between the quality of conformance versus costs per good product unit.

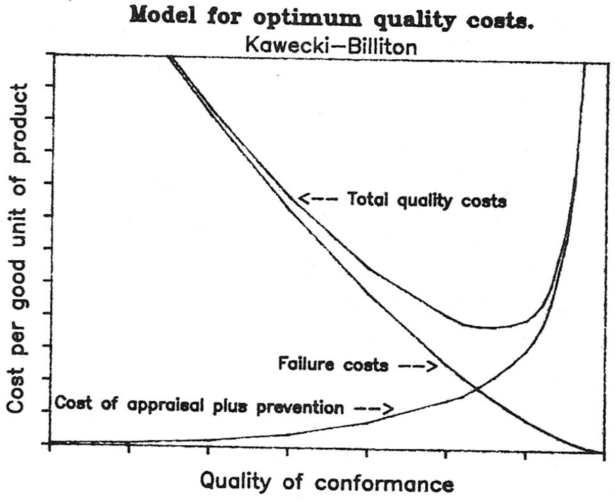

Figure 1. Relation between the cost of appraisal and the failure costs.

SPC can, with a slight extra effort, reduce the failure costs because of controlled fluctuation. It can also optimize composition, yield, dimensions, production time, costs and last but not least, product performance.

PROCESS CONTROL SYSTEM

The system for controlling the process is the most important SPC element. The main elements are illustrated in the following scheme (see Fig. 2.):

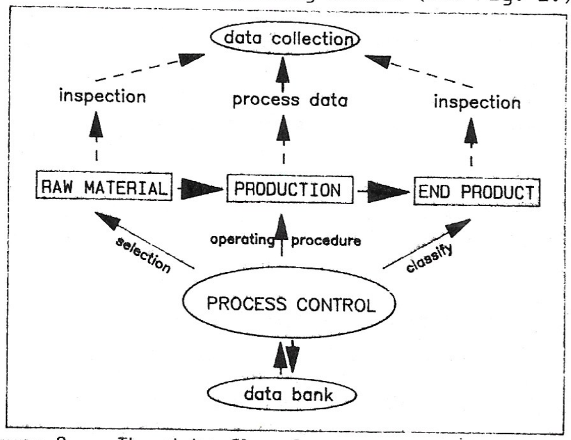

Figure 2. The data flow for process control.

It is important that process control has immediate access to data from raw material in stock, process information and product produced. Process control will indicate the material to be used, the most suitable production procedure and will classify the end product produced. In a daily confrontation with Production and the Warehouse Manager, a feedback can be obtained in which process control can justify optimization and changes. Incidents can be traced. This point, in particular, is a vital steering tool in optimization. Input of all the people involved in the process can be treated in a structured manner. It is of utmost importance that the information be kept as concise as possible and the data be kept simple.

STATISTICS

Proven statistical tools are necessary to evaluate the data obtained. The support of a statistical consultant is important, especially during the start-up phase. Statistical packages should be readily available. All the normal statistical tests and pre-designing like; e.g. testing on significance, setting the level of confidence, making correlations etc., have to become a normal practice. Skilled personnel with a sound understanding of the process conditions, will provide the set-up for the experimental designs. Such evaluation tests will have to become incorporated in the statistical process control.

RESULTS OF SPC APPLICATION

The results of the application of SPC are demonstrated by improved process control, product optimization and product performance.

Process Control

Critical process parameters are monitored on control charts with the objective to:
- reduce fluctuations and
- establish an optimal mean value

This is illustrated in Fig. 3.

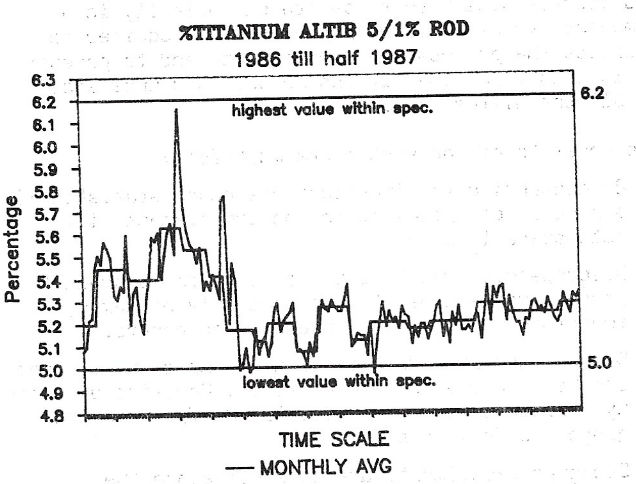

Figure 3. The Titanium content in AlTiB grain refiner versus time.

Product Optimization

The factor to be dealt with in our case is: the cleanliness figure (CF). In order to judge the effect of an improved control, reference has to be made to the pre-SPC period by tracing back into past performance. Application of the scheme indicated in Fig. 2. allows the start-up, as well as the continuation, of an improvement program. A survey of the results of this continuous effect is given in Fig. 4. and 5.

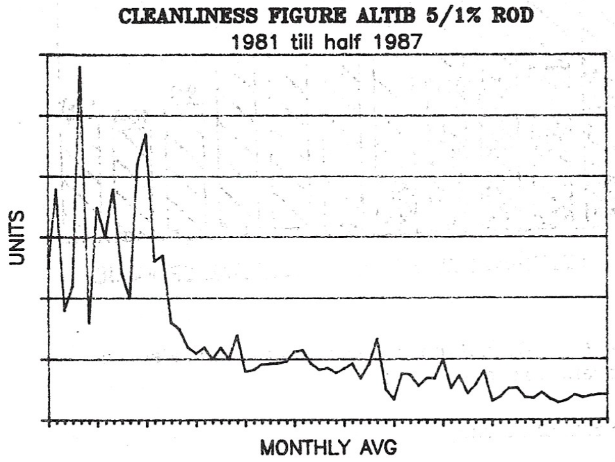

Figure 4. The monthly average of the cleanliness figure.

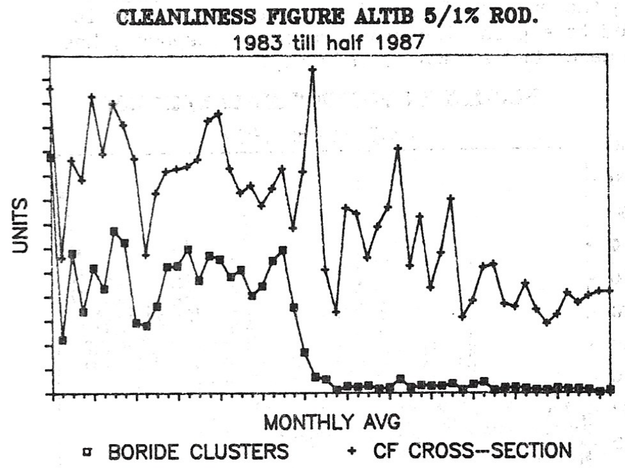

Figure 5. Detailed part of Fig. 4. with the contribution of boride clusters indicated as part of the total cleanliness figure.

Significant changes in the production process can be made visible (see Fig. 6.) which is necessary to verify whether or not the target is attained and aids to steer subsequent improvements. Evaluation of the investments vis à vis the obtained effect can then be carried out.

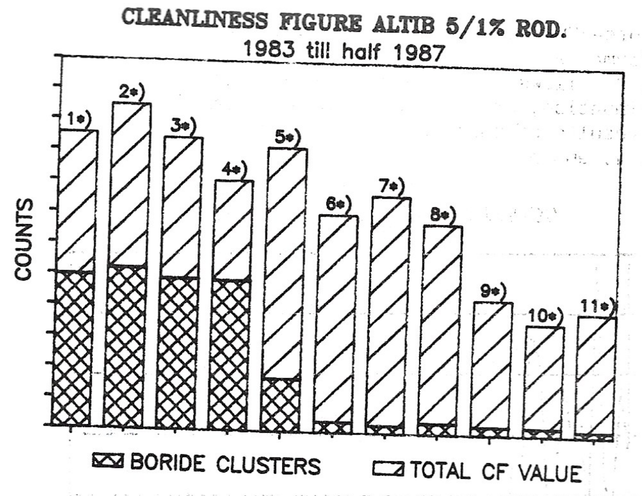

Figure 6. Cleanliness improvement dependent on subsequent process changes.

Product Performance

The product performance must be observed continuously. Again improvement programs can be judged against other important factors such as grain refining response (see Fig. 7.). The advantage of using the number of nuclei per unit value that is needed to express the grain refining response, has been described elsewhere, see (4).

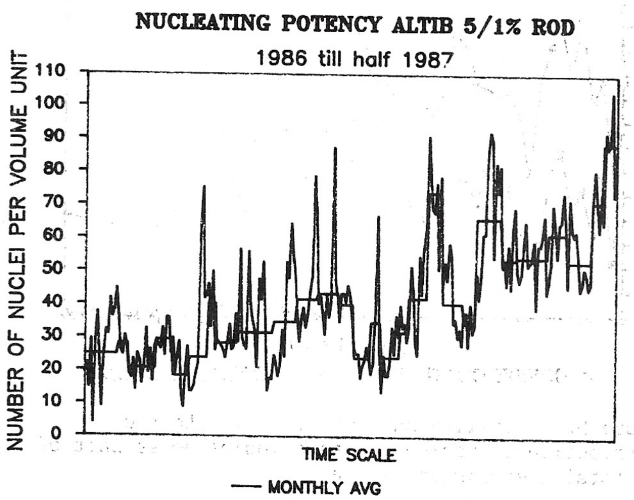

Figure 7. The improvement in time for the grain refining response of AlTiB 5/1% rod.

Fractional Factorial Design

Real benefit can be obtained when the entire data collection process, that was started and justified by the abovementioned factors, is used for fractional factorial design (FFD).
What is FFD ? With regard to the non-staticians, one of the best and most understandable articles is "What every technologist should know about experimental design" by Charles D. Hendrix (2). FFD can be applied successfully to a defined and controlled process. One has to realize that process parameter setting can always be set more optimally and also that process parameters are interrelated.
The basic principle in FFD is the variation of the process parameter setting within acceptable limits.

The variations have to be carried out in a designed matrix experiment. As a result of the chosen matrix, the main effects of the given variations will become visible in the responses.
An example of the most simple matrix experiment for varying two interrelated process parameters X and Y with resp. $\pm\Delta$ and $\pm\lambda$ is illustrated in Fig. 8. The response is plotted in units.

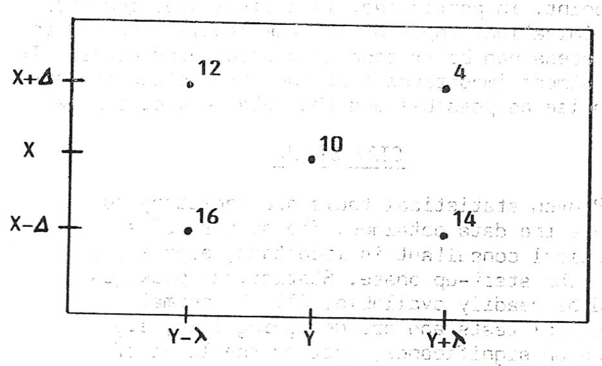

Figure 8. A two factorial matrix with a given variation of $\pm\Delta$ and $\pm\lambda$.

It is necessary to identify, in co-operation with the process specialists, the most important process parameters and the responses to be aimed for. The experiment should be planned by someone with experience in this field. Parameter setting should be repeated as often as is necessary to obtain significant differences. See also "Plant Experimentation" by William J. Hill and Robert A. Wiles (3). The fractional factorial design can be made to work by means of the complete data collection system and the statistical knowledge of those involved in SPC.

CONCLUSION

In order to implement SPC, an effective system for process control has to be available. The process and product data have to be stored logically in a computer system. Skilled personnel are required to evaluate the process and product data and to present it in such a way that it can be used and understood by all the different disciplines.

The benefits of the system are multifold:

- By presenting the important responses statistically a process of optimization and improvement will automatically start.
- Discrepancies which occur can be matched against process variations. Action need only be taken, therefore, when a real interruption occurs.
- Discussions on justification of improvement steps can be supported by proven facts. Benefits obtained by improvements can be calculated afterwards to judge the decisions taken.
- Designed experiments are possible since the typical variation of the system is known and a controlled system of varying process parameters based on FFD is provided.
- Discussions with suppliers and customers can be supported with statistical data. Reality of specifications can be judged against the product quality obtained from recent data.

The application of SPC has culminated into an improved process control, product optimization and product performance and in addition leads to a reduction of the total quality costs.

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4. M. Vader, J. Noordegraaf and E. Klein Nagelvoort, "Interrelations Between Aluminium Grain Refining Using Aluminium-Titanium-Boron And The Number Of Growth Centres", (Paper presented at the 8th International Light Metals Congress, Leoben-Vienna, 22nd. June 1987).