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Process Control Systems in the Mixing Facilities[1]

Computer based process control systems within mixing facilities of rubber factories have developed since the 1980s from autarkic automation systems to complex comprehensive management systems, which integrate in other IT worlds (like ERP-systems or laboratory systems) harmonically. Moreover there are more and new possibilities for analyses, which include not only the pure technical data, but also commercial and economical treatments of all activities within the production.

History of process control systems

In the 1980s was the beginning of IT systems for the control of single machines and processes at the production of rubber compounds. First of all the most important ambitions were to increase the production quality of the main unit – the internal mixer.

From the customers point of view it was adequate to control the mixer itself with all belonging dosing and loading systems in use of miscellaneous processing instructions. Thereby was presumed, that all batches could be mixed with nearly regularity.

That is why the developers of process control systems pushed the automation of internal mixers mainly. However it was recognized quickly, that all processes within mixing facilities has to be considered for a constant production quality. The software engineers did not want to regard the mixer as a stand-alone system. They wanted to keep the option to control and supervise all processes within the mixing facilities with IT systems.
Quickly this clear-sighted view resulted in the expansion of the functionalities of process control systems. At first there was the control and connection to downstream equipment like open mills and batch off machines. With that complete mixer lines were equipped with IT systems. In addition to the mixer manual or semi-automatic or full-automatic weighing systems followed shortly, which did not have to be in the line character of the mixer.

In 1993 first requirements for the backtracing of materials were realized. This was the first step away from the straight production technology to the control and documentation of logistic aspects. So the Material Tracking/ Tracing System (MTS) was developed. In connection with this also first solutions for the warehouse management were found from providers for process control systems. Thereby the warehouse management was restricted always to the core competence: the mixing facilities and the warehouse for mixing production.

With the introduction of the first warehouse management systems for mixing rooms it came to an unavoidable contact with other IT-systems. It was the business systems (ERP) which had to be communicated with in terms of materials, to provide the companies with a harmonic overall functionality in the IT area.

Actual state – Controlling

A current process control system is characterized mainly by its flexibility and modularity. It is adaptable to the various situations in the factories. For example old machines can also be equipped with a new control system as well as a completely new factory. Thereby it does not matter who is the manufacturer of the machines or the supplier of the PLC.

The modularity is given by a range of control and monitoring solutions for the separate aggregates which can be added with various evaluation and analyzing programs or with different interfaces to other systems. Through this the user can imagine a complete computerized system for all possible use cases with the linking of all the machines in the mixing room. In practice the user begins to use the process control system perhaps with a small solution e.g. with the control of a single manual weighing station. Later on, this installation could be enhanced by additional weighing stations or in a next step with the control of a mixer line with a belt scale at which the weighed materials from the manual weighing stations could be verified.
Through this step-by-step introduction of a process control system it is provided that the users do not have too much changes instead of a complete modernization in one huge step. The users can gradually get used to the new opportunities to gain experience of the modern IT environment according to their own individual desires and needs.

The process control system always consists of a strong core with extensive configurability. In the IT the production infrastructure is mapped. The advantage of this configurability is created especially for changes and/or additions to the equipment or processes: the new conditions are configured and does not need to be programmed complicatetly.
Despite 20 years of experience and collection of more or less typical characteristics of mixing facilities, the customers have individual wishes which are not included in the product and which are not mapped in the configurability. These very special requirements then are developed individually for the customer. Hereby it will be achieved that the process control system adapts to the client or user and not vice versa.

Regarding to two technical points of a modern system, I would like to introduce below:

Power related oil injection

Admitting and dosing of plasticizers and oils does not necessarily has to be done after certain times or steps within a mixer step program. With a power related oil injection the oil is injected when needed. This possibility is not new, but it is only used rarely by the users.
A lower and upper power threshold would be set. The first injection takes place until the power has dropped to the lower threshold. The oil pump turns off and will be reactivated only when the upper power threshold is reached.
To ensure that the complete quantity of oil will be injected, which is definded in the recipe, it is possible to define a maximum waiting time after the injection is activated when the upper power threshold should not be achieved. Remaining quantities of oil in the way from oil scale respectively oil hopper are given after a defined lag time of the injection phase safely into the mix.

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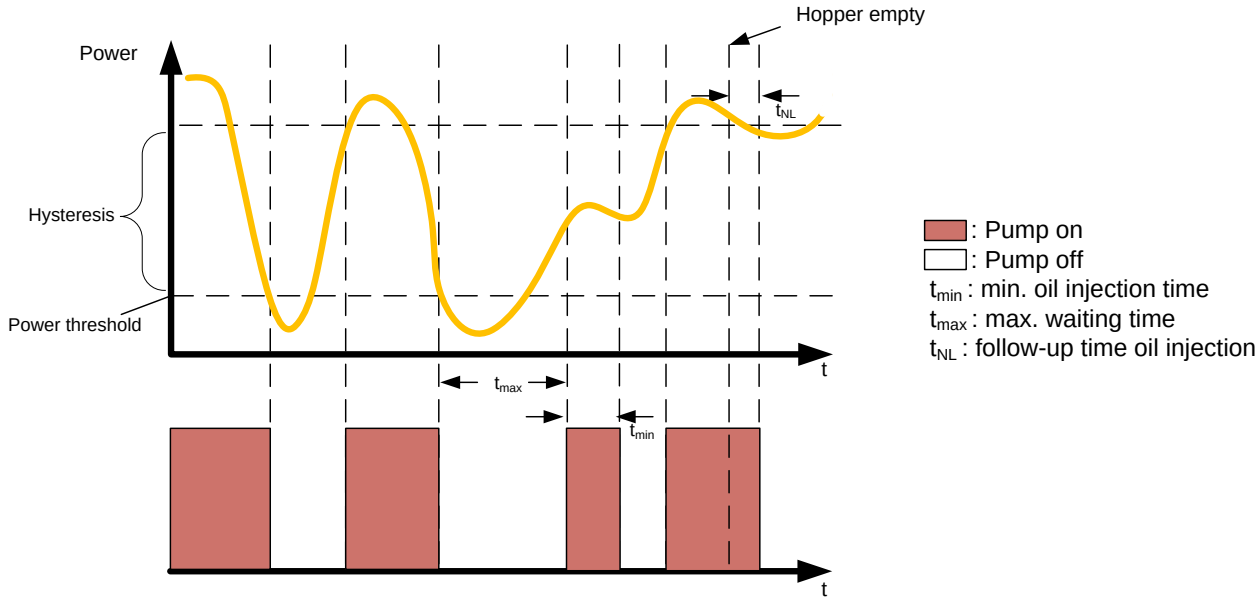

Picture 1: Power related oil injection

Self optimizing PID-controller

The target of a control operation is generally the controlling of the mixing process, so that a certain mixing temperature is held or a temperature curve is generally traced along as precisely as possible.

The quality of a controller is determined by the behavior of the track (here the mixer) and the recruitment of the controller. For optimum correction of controlling differences today mostly PID-controllers are used. The behavior of the controller is set by the propotional, the integral and the derivative values. A manual optimization of these parameters for controlling a mixing process has long been theoretically possible. These optimizations are very extensive.
Therefore this optimization is been done automatically in a modern mixer control module of a process control system. The system creates a disturbance, and registers the response within the mixing process. For this behavior the controller parameters and the amplification can be calculated.

Example 1: A defined set-temperature should be reached and maintained. With the rotor speed and the ram pressure the actual-temperature is raised to the set-temperature. This temperature level is maintained as long as required, until an additional criteria is reached. For example this could be the reaching of a specific energy, a specific ram level or a defined power level. In the simplest case the step program switches to the next step after a defined time.

Example 2: In control mode a predertermined master curve (set-temperature-curve), which is saved in the mixer step program, will be reproduced. The mixer program reproduces this master curve by changing the rotor speed and/or ram pressure.

Ram position control

On the research project "ram position control" of the DKG (Deutsche Kautschuk Gesellschaft), which was organized not long ago, we were actively involved. To avoid dust dispersion, the lowering of the ram can be slowed down before touchdown. This makes it possible to save a cleaning step.
The process control system is ready for further use-cases. The ram way can be controlled in relation to periods, events or within defined steps in the mixer instruction. There is a function editor, in which the process engineer can define formulas according to which the ram is to be controlled.

Actual state – material tracking

The tracking and tracing of materials in the mixing room is covered completely for many years. The customer requirements tend to rise on the development of transitions and interfaces to processes that are before or after the mixing.
Incoming raw materials are so clearly recognized at the labeling and marking and all relevant data will be transferred into the process control system. Important data can be for example: unique material name, lot or batch number, expiry date, quantity. [2]

The marking of materials, products and containers in circulation is in most companies done by barcode. This is very inexpensive to print and very reliable. The RFID technology, which is already used often in other industrial sectors, has kept in rubber mixing plants so far only in small areas of entry. For example, the identification of multiple containers to be used in circulation (buckets, boxes, containers) have been frequently used RFID. As a labeling system for unique applications the RFIDs were not used often until now, presumably for cost reasons.

Relatively new are requirements for hiding the real material names and trade names. The wishes for this come primarily from the Asian region, where the risk of loss of know-how (e.g. recipes) is particularly high. For the material tracking this means, that the operator does only have restriced or no knowledge about the materials which are used. The materials come already with coded and encrypted names in the mixing room. For the operators in manual weighing in the process control system is only shown from which containers the materials have to be weighed.

Actual state – analyzing

Regarding to the interpretation and analysis of the processes in the mixing room, the requirements are constantly increasing. On the one hand we want the simplest possible tools to detect outliers and errors in production and on the other hand these information are needed over all locations of the company, e.g. within a consolidated group.

A basic requirement is the individuality of the evaluations. For example, the user reports can be self-configured and designed. Thus, material tickets and tabular information are created, that meet the unique requirements exactly.
In addition to tabular reports the graphical representation and analysis of technical process data is extremely important. Here the actual values (e.g. temperature, power, ram way) will be summarized and they could result in a fingerprint of the batch. This can be added by characteristical figures which can characterize the mixture.
Process data of a particular batch can be compared to other batches of the same production order or they can be compared with batches from other orders. When overlaying the curves, a trigger

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function helps to compare the measurement curves by setting all curves with one process step to the same date. With this outliers can be located very fast.

In addition to the process data the customers and auditors are asking for the data from the laboratory. Both data (process and laboratory data) should be presented together. This involvement and acquisition of laboratory data takes place via computer interface, so that the data could be shown in the same evaluation program, both process and laboratory data. So the important data that describe the properties of the mixture are available summarized via the process control system.

Picture 2: Simultaneous presentation of laboratory data with process data

There are also improvements for finding specific information and answers to individual questions. Similar to popular internet search engines the operator can formulate complete search queries, to which he immediately receives a reply. This search queries have to orientate themselves to the database structure, but this is very easy for the user after a very light training and instruction.
This search function is popular in the so-called "Journal". Here are all the operations logged which are performed by users of the process control system. It creates a kind of logbook or history function that stores who, what, how and when was made or amended. These logs are nothing new, but the enlarged and diversified search possibilities for the entries and events.
Search queries can be for example: "Who and how a recipe has been amended?". "When user XY has logged on and off to the system and what programs did he use?".
If one defines not only persons as a user but also other systems or internal services, the information what these systems have been done are also available in the system. This possibility is very interesting for example for interfaces to external systems. In adjustments between the two computing platforms, one can immediately understand which system has written which data into the interface or which system has picked up the data. The collaboration between IT service providers will be so much easier.

Production data aquisition and analyzing (PDA)

Solutions for compliance and documentation of high quality and production standards are established within the process control system since many years. Increasingly, attention is now being placed on increasing productivity by optimization and avoidance of mistakes. We often find that more often the business view on the mixing process is more important. Over the process control system the production data should reliably obtained.

Definition of production data

For the following descriptions we must define the term "production data" at first. They describe actual data from the commercial and economic production process. Examples of production data are numbers, quantities, working hours, downtimes, events. Production data in this context are not technical process data such as speed, power, temperature, etc. Other definitions of production data are available and differ often from company to company, depending on the usage.

Motivation

Reasons for the introduction of production data acquisition and analysis systems are - in addition to the general pressure to improve efficiency, to avoid downtime and eliminate weak points in the process - an appropriate description and statistical evaluation of the respective operating states. So far, downtime, disruption and similar events often have been recorded manually in labels and lists, which were collected and analyzed manually. This time and message data collecting was difficult, the reliability of these notes is not always accurate.
With the introduction of computer-guided systems to both, the collection of production data and the quality of evaluations should be raised to high quality.

Acquisition at the process

Events that occur during the production, can be automatically recorded in part, if a link is from the computer control system to the machine is provided. Examples of automated messages for a mixer: order changes, recipe changes, mixing door open,...
Some messages, for example organizational or some technical problems can not be independently identified by the system. Here a manual collection of the data by the operator is required, which however, should require a negligible effort and it should fit into the normal working process of the

operator. Therefore it is sensible, to integrate the production data acquisition into an existing computer control system. New hardware is not required. Examples of manual messages: setup time, break time, lack of material, following machines not ready,…
To simplify the entering process for the operator the PDA data would be categorized in meaningful groups and maybe sub-groups, during the introduction of the PDA system. The finding of these message texts and the groups is carried out individually for each customer. Characteristics of the plant and its own linguistic usage and definitions of types of time and accidents are thus incorporated into the system.

For a mixer line the production data acquisition is usually based on the machine. It is collected, how the system is running and whether interference occurred.
Different to a mixer line is the collection of production data to semi-automatic or manual weighing stations that are not directly linked to a mixer line, based on the person and / or the weighing place. This is due to the fact that people often change within the weighing stations, sometimes even while a running shift. The customer would mainly also like to collect the performance of individual employees.

Analyzing

Technically, evaluations of production data can be analyzed in various ways. For example, a web-based remote access from any workstation or reports can be distributed via email.
Presentation of individual data: Production data can be shown in various protocols, which reflect all the events chronologically with date and time of start and end. This analysis is useful for a very detailed analysis of individual machines. Alternatively, the individual data are taken in a colored bar graph, so that operating conditions can be visually analyzed on a timeline.
Summarized individual data: A summary of individual data is the base for further statistical analysis. The durations of the production data will be displayed summed, for example for a shift, one day, a week or a month.
Statistical analysis: For a chosen duration (e.g. one month) the data will be displayed in a percentage overview of productive times, malfunction periods and downtimes. These evaluations provide a quick overview, where errors happen often. Furthermore, different business metrics can be calculated, and their long-term development can be observed.
Transfer to external systems: Of course performance figures may be passed on to third party systems. One possible application is the transfer of performances to the payroll office to be used to calculate piecework wages.

Benefits

Of course acquisitions and evaluations of the production data can never take off the management task to take measures for fault fixes or efficiency increase. But they give the leaders a very good support for the targeted and secured finding for inadequateness in its own production.

Legitimacy

The legitimacy of computer technical collection and analysis of performance and productivity data needs to be clarified in each company for each case. Often agreements with the work council are necessary or, in some countries, computer counting of the productivity are not or only partially allowed!

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Interfaces

Process control systems are increasingly seen not as stand-alone solution, but to integrate harmonically into existing IT environments and others.

ERP-interfaces

The most common interfaces are between ERP systems (e.g. SAP, Sage, MS Dynamics, Infor) and the process control system. Before the development of the interfaces first comprehensive analysis and definitions are needed. Together with the customer and the ERP system suppliers the supplier of the process control system will determine which business processes are running on which system. This results in use-cases and individual interfaces. Examples:

- Exchange and synchronization of master data (materials, products, names, number ranges)
- Exchange of inventories and material movements (material receipts, stocks or requirements from the mixing room, output of finished or semi-finished products)
- Exchange of order data (orders, state of production, message of finished goods)
- Exchange of material lists and recipes
- Notification of PDA data to the payroll office

Laboratory interfaces

Interfaces to laboratory systems (e.g. MonTech, Scarabaeus , Eclipse) can be attractive in various ways:
Unless the recipe development should not be done on the process control system, recipe data from the laboratory or development system may be taken over. So they are available in the production system in a comfortable manner.
Another - and increasingly more interesting - interface development to laboratory systems is the combination of laboratory measurements and data from the technical process of production. The laboratory values are archived together with the process data and are available for a common data representation and analysis, as well as for passing on to following processes (extrusion, injection molding, etc.).

Summary and outlook

Within the mixing room in the rubber industry the process control systems are no longer just stand-alone automating systems. It is increasingly necessary to combine different production sites and data between other computerized systems. There are also increased requirements for commercial and business considerations of the events in the mixing room.
This will change the tasks and business for suppliers of process control systems. The technical know-how for the actual production automation is still very important, but not enough so far. In addition commercial knowledge and extensive analysis and discussions are necessary to get a complete overview of all processes, even the processes which are not included directly in the mixing room. Only in this way the customer can get a system which is not an isolated application. The developer for a process control system is getting more and more to an advisory service.

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