

CHAPTER 10

Examples for Application

10.1 Mixed Processes

In the course of research for this book, many examples were examined. A complete integrated manufacturing execution system (MES) as is presented in this book could not be found in any company. Although the need for integrated production management is increasingly recognized, generally, only function-specific isolated solutions for partial areas were found. A clear division according to the production forms

- Discrete manufacturing.
- Process-oriented manufacturing.
- Continuous manufacturing is rather the exception. Generally, mixed processes, that is, process-oriented *and* discrete processes, are needed. The production of roll material, with its refinement process and use-optimized format creation, represents a special form. If we look at the standardized approach for an integrated MES, the borders between the aforementioned production form blur completely. The core topics of the MES always remain the same irrespective of the production form.
- Mapping products in a work plan as a sequence of a combination of work processes and machines/equipment.
- Operative sequence planning across the entire process chain.
- Controlling the production process with
 - Material management (i.e., raw materials, articles produced in-house, and purchased parts).
 - Recording operating data and/or machine data, usually with statistical process control (SPC) functionality.

- Instruction management in various functions.
- Maintenance management for machines and equipment.
- Quality management for machines and laboratory.
- Order traceability.
- Performance monitoring.

The weighting and degree of detail of these requirements differ hugely in individual companies. The examples selected here therefore can only show a small part of the many possible versions. The first example contains a process-oriented mixed process with products being filled into various packing quantities. The second example looks at the characteristics of the production of roll material.

10.2 Sensient Technologies: Emulsions

10.2.1 Information on Sensient Technologies Corporation

Sensient Technologies Corporation is one of the world's leading suppliers of flavors, fragrances, and colors, which are used in a wide variety of products within the food, pharmaceutical, cosmetic, and information technology (IT) sectors. The products are manufactured at various locations worldwide and stand for the highest possible quality. The German location of the company has been certified in accordance with DIN EN ISO 9001:2000 and the International Food Standard.

10.2.2 Description of the Production Process

Emulsion: General Description

An *emulsion* is a semistable solution composed of two liquids that cannot (or only to a limited extent) be mixed with each other. The basic components are water or water-soluble substances and oils or oil-soluble substances. In the emulsion, one of the two liquids is distributed into the other liquid in the form of very fine drops. The dispersed drops of liquid form the *inner phase*, and the liquid that surrounds them forms the *closed* or *outer phase*. These basic substances are also known as *oil phase* and *water phase*.

Since water and oil do not mix by nature, it is necessary to use an *emulsifier* in order to lend the emulsion stability. The emulsifier makes it possible to form a permanent mixture of the water and oil phases by removing the surface tension between both phases.

Production Process for Manufacturing an Emulsion

The water and oil phases are manufactured in-house as preliminary products. There is a similar manufacturing process with a similar method for both preliminary products (Fig. 10.1).

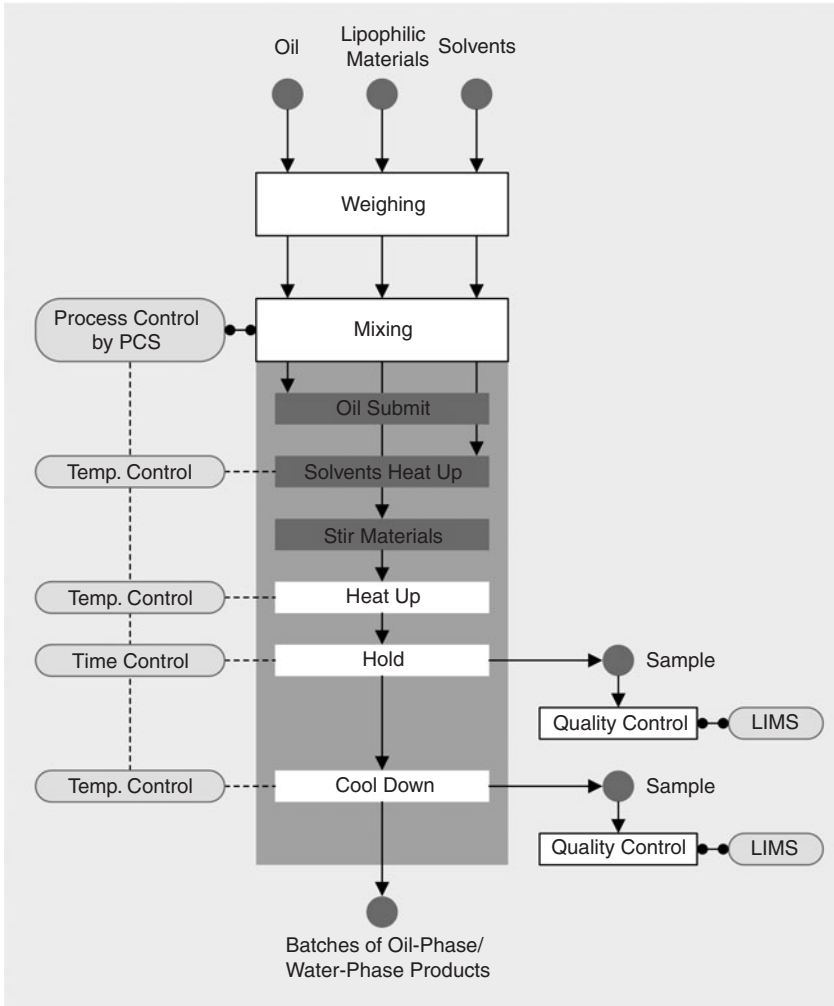


FIGURE 10.1 Process for creating the preliminary product oil phase (the preliminary product water phase is produced in a similar manner).

After the raw materials are weighed, the oil, various lipophilic substances, and solvents are added to a mixing process. This mixing process is carried out and monitored semiautomatically by a process management system (see Sec. 3.4.3) in several stages. At various stages of the process, tests are carried out and checked in a laboratory with the aid of a *laboratory information management system* (LIMS).

Manufacturing these preliminary products occurs in the form of *batches*, which then form the basis for the preparation of the actual emulsion. This production is carried out on special emulsion equipment,

which is also controlled by the process control system in the following order:

- Adding the water phase
- Heating the water phase
- Adding the oil phase
- Heating the oil phase
- Mixing the oil phase
- Adding the emulsifier
- Mixing the preliminary products with the emulsifier into a “pre-emulsion”
- Cooling
- Homogenizing
- Pasteurizing
- Cooling
- Filtering (Fig. 10.2)

The finished emulsion then is processed in a bottling system. The actual end product is not achieved until the substance is filled into various container types in the last step; that is, the various articles are determined only through packaging.

10.2.3 Basic Quantity Units and Production Units

The preliminary products water phase and oil phase are produced in the unit of measurement kilograms as a *batch*. Every batch is produced in charges. A *charge* is defined as a *batch lot* and receives a unique ID for control and tracing purposes.

The emulsion is also produced in the unit kilograms in batches with unique IDs. The batches of the emulsion (liters) then are filled into various container forms (e.g., 0.3-liter bottles). Here, then, the unit of measurement changes from liters to pieces. These containers are then packed into boxes, whereby a different number of containers can be used for different packaging types (1 piece to x pieces).

10.2.4 Production Process Plan

The overall production process is mapped in three work plans (for the preliminary products oil phase and water phase and the end product emulsion) by an MES (Fig. 10.3).

10.2.5 Challenges for the MES

Overview

Mixing processes on the basis of recipes are central here. A recipe contains the individual components and their percentages and a process

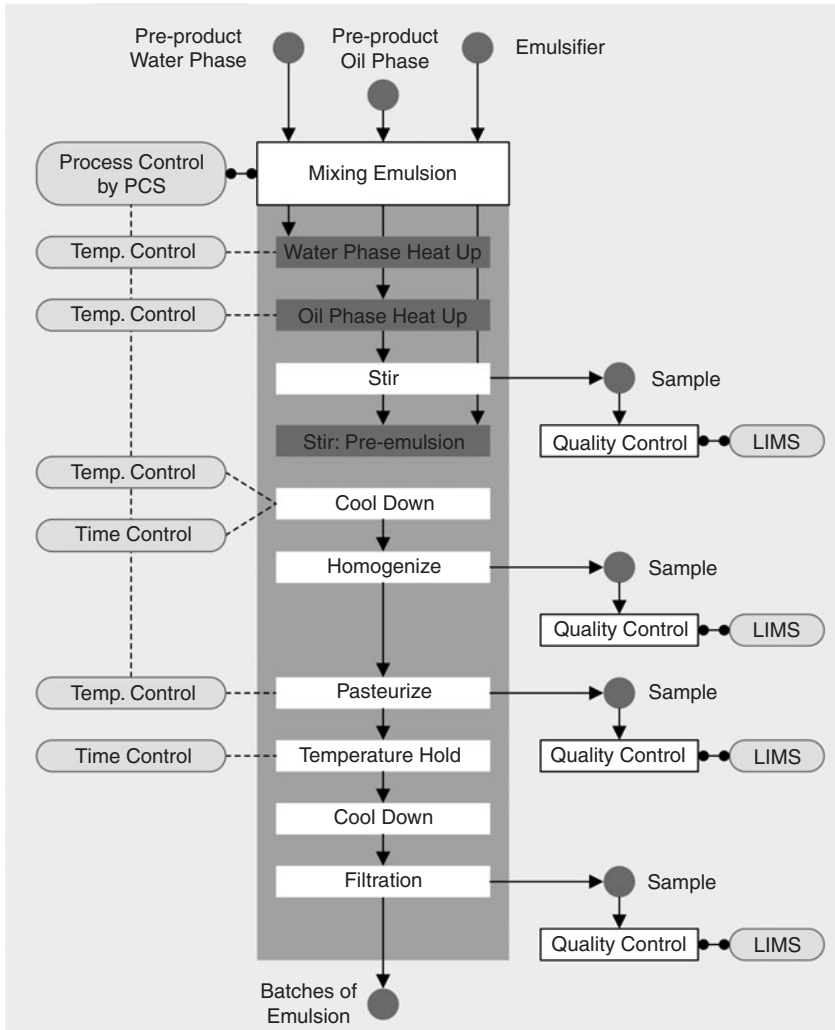


FIGURE 10.2 Process for producing the emulsion on the basis of the preliminary products.

sequence plan, which controls the mixing process. The overall process described is not very complex—the challenge is rather to control the partial systems (e.g., mixer). Here, it is really a partial MES that is used in the sense of ISA S88 (see Sec. 3.2.1). Successive individual raw materials are compounded and added, and the process steps are controlled using a process sequence plan. Because of volume limitations, the quantity is often established and defined in terms of what are known as *charges*. The output arising from a charge then is termed a *batch*.

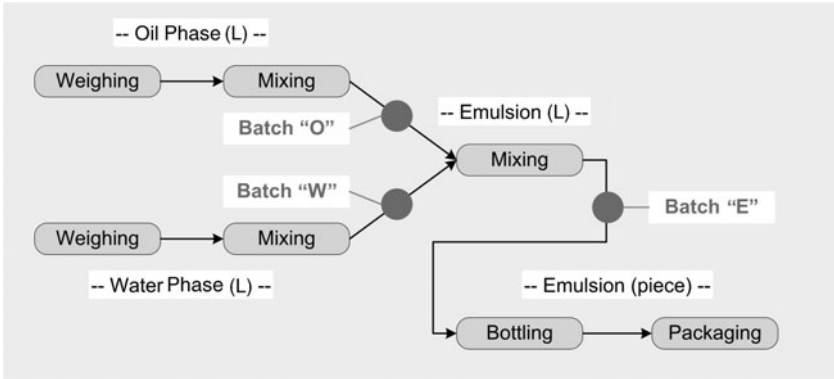


FIGURE 10.3 Macro structure of the production process with production units and quantity units.

In addition to automated control and monitoring of the performance process, samples are taken at certain stages in the process, which then go to the laboratory for testing. If the samples pass the test, the next step is released; otherwise, corrections are carried out.

Special aspects within mixing processes include, for example, waiting periods between individual process stages to allow the product to “mature.” Especially for food products, cleaning processes are required that must be carried out precisely according to the Food and Drug Administration (FDA) Directive 21 CFR Part 11 (see Sec. 3.2.4) and confirmed electronically.

These mixing processes generally are preceded by weighing processes in which the individual components as a percentage of the recipe are weighed precisely. For this, regular monitoring of the scales equipment is important to guarantee correct results for the process.

The mixing products generally are filled into a wide range of packing units, which means that a mixture charge is used for several filling charges, differing in packing sizes, labeling, and packaging form.

Although the process steps in process-oriented production generally are highly automated, a superordinate management system is necessary for planning orders and for the order-specific storage, documentation, and evaluation of performance data in a production management system.

In the example described, implementing an MES pursues the following goals:

- Product traceability
- Cycle times—transparent comparison between target and actual times, reduction of cycle times

- Increasing first-pass yield (FPY)
- Increasing capacity
- Increasing overall efficiency (OEE)
- Improving transparency through tracking work-in-process (WIP) stock and the current demand data
- Measurement of deviations from the process sequence plan
- Analysis and evaluation of process parameters (i.e., SPC or 6Sigma)
- Consumption planning and reducing energy consumption
- Detailed resource planning
- Measuring actual production costs online
- Online stock management for warehouse stock, including evaluation
- Maintenance management with assessment of inspection findings and maintenance material
- Increasing planning effectiveness (i.e., planned production versus actual turnover)

The achievement of these goals is closely linked with integration of the process management level, which already exists today in the sense of a collaborative production management system.

Monitoring Function as an Extension of the Automation Level

The mixed results of the individual batches, the associated material application costs, and other performance data with target/actual comparisons with regard to times, energy consumption, and various process parameters must be measured and monitored through the MES. The MES is therefore the superstructure of process automation. The condition for this is a stable and high-performance data interface between the automation and the MES.

Product Traceability

The entire process chain must be documented together with all raw materials used, packing materials, etc. and the relevant process values for the end product produced. By resolving this process chain, starting with the end product, the delivery charges, such as for the raw materials used, can be recorded.

Online Cost Control

A detailed consideration of the cost situation should be carried out for the production of an emulsion, that is, direct production costs, costs for secondary products, warehousing costs, power consumption costs, and overhead.

Performance Recording

For the filling process, an entire overview of the performance situation of the filling system must be provided. This includes target/actual comparisons for quantities, times, and costs, as well as key figures (KPIs) on the efficiency of the system and on the condition of the machines/equipment. In addition, data on the staff employed and on violations of limit values, especially based on statistical quality control (SQC) tests, are also recorded. Individual measurement data can be called up for further analysis.

10.2.6 Realization and Implementation

At the moment, requirements for the MES are being processed as the basis for an evaluation process. The process management systems for the various mixing processes are already in use. A simulation of the process with the aid of an MES gave rise to the following three main requirements:

- Superordinate management and control of the process
- Online cost control
- Performance measurement

These can be mapped with ease. The connection of the existing automation technology is linked with additional outlay.

10.3 Acker: Synthetic Fiber Fabrics

10.3.1 Information on the Company

The company, Acker, was founded in 1949 in Seligenstadt, Germany. From a product line that initially consisted of curtains, technical fabrics were developed beginning in the 1960s. Since the start of the 1970s, these have composed the main branch of production at Acker. Acker is one of the leading manufacturers of technical fabrics.

Acker products generally are supplied to other companies (e.g., automotive suppliers) and then processed further to form products for the end customer (usually not yet the consumer). Examples from the product range are car nets, luggage compartment covers, and fabrics for adhesive plasters and sun screens.

10.3.2 Description of the Production Process

Overview

The production of technical fabrics is carried out entirely in-house at Acker. It generally begins based on an existing need for refinement with the manufacture of what are known as *gray good pieces* (i.e., warping and knitting). Every gray good piece is allocated to an *article*



FIGURE 10.4 Creels with spools of thread as raw material for production.

family and can take on any defined variant (identity = article) within the family in the course of production. The article family establishes the fiber and the construction required for manufacturing the gray good pieces by means of a suitable knitting machine. Production control is handled by sales using what are known as *block orders*. Block orders are, by definition, not article-based (Fig. 10.4).

Refinement collects suitable gray good pieces into *lots*. Sales and marketing assumes production control within the refining process with the aid of *allocation orders*. These are allocated permanently to an article (and therefore have an article identity), but these can be changed throughout the course of production as needed. When a lot is being put together, the kilogram goods are converted to running meters (meterage) using a target key figure. This parameter is based on the periodical recording of actual values.

The batch runs through various production steps within the refining process on the basis of the definition in the *article master*. If necessary, data in the allocation order can be added to the workflow (e.g., the dyeing process step). Each individual step in the workflow is classified using one of the permanently indicated process types (e.g., laundering, napping, and final finishing). The article master data determine with which concrete work cards (i.e., work instructions) the production of a step is to be carried out. The selection of potential production resources is indicated by matching the work card to the concrete production machine.

Accordingly, a work card describes the instructions for the process and the process data for execution of a process step on a particular machine (i.e., equipment). The respective production planning establishes which work card should be used for a concrete production step. Planning is suggested by the MES (i.e., preplanning) and is refined by the production manager (i.e., fine planning or final planning). Manual fine planning is monitored by the MES in order to point out errors or risks. As a result of the planning, production receives the work processes to be executed for the necessary process steps (i.e., sequence of steps).

Depending on the new planning of demand for articles through changes in stock and the content of allocation orders, the article identity of a batch can be adjusted depending on the current production step. Extraordinary planned or omitted production steps to the batch can lead to a change in the article identity.

Warping

If the knitting section orders the warping section to provide chains (i.e., rows of several partial-warp beams), the warping section manufactures these chains and the partial-warp beams needed for the chains on warping machines (Fig. 10.5). Each chain provides several fibers for the knitting process, from which the gray good piece then is manufactured for subsequent refining of the technical fabric through the knitting production step. Eight warping machines are available for warping the partial-warp beams.



FIGURE 10.5 Warping machine.



FIGURE 10.6 Knitting machine.

Knitting

In the knitting section, several partial-warp beams are collected into a chain. A knitting machine is loaded with one or several chains. The production manager assumes planning of the right knitting machine in fine planning. There are 50 knitting machines of different types available (Fig. 10.6). Positioning the fibers into the guide tracks and steering the movement of the guide tracks are done manually. The knitting machine then produces gray good pieces of a particular length and width by means of a meshing technique; these pieces are needed for an article family. The respective gray good pieces are weighed (unit: kilograms) and recorded and called up by refining.

Refinement

The processes of refining involve a lot (a type of batch) composed of several gray good pieces for the required article. The following process steps are (optionally) possible during this process:

- *Pretesting.* The raw material pieces of a lot are subjected to a visual test with the aid of a cloth inspection machine. Flaws in the fabric are marked and recorded statistically. If necessary, various raw material pieces are sewn together.
- *Napping.* In the napping process, the surface of the technical fabric is napped to velour.
- *Laundering.* The gray good piece is cleaned through laundering.
- *Dyeing.* The raw material pieces of a batch are dyed in this dyeing machine.

- *Drying.* A washed/dyed batch is relieved of water residue before the actual refinement process in a stentering frame with the aid of heated air.
- *Finishing.* Finishing refers to treatment of the fiber using a recipe of chemical water-based additives. The finish is applied to the fabric by dipping with subsequent wringing to a defined remaining moisture. In a maximum of five dyeing fields, the goods are then spread out and condensed out with hot air.

The finish can be used to achieve various effects, for example, a stiffer or softer feel or flame-retardant effects. It is carried out simultaneously with the process on the stentering frame through a computer-controlled dosing system (Fig. 10.7). The dosing equipment continually provides the stentering frame with the required quantity of finish. The finished goods can be cut optionally in length at the outlet of the stentering frame (symmetric and asymmetric).

- *Fixing.* Fixing is the name given to thermal treatment of the goods with or without finish. It serves in particular to ensure that the goods do not shrink when in use.
- *Final finishing.* The last of one or several work processes is referred to as *final finish*.

Processes on the stentering frame are controlled, recorded, and monitored fully automatically with the aid of the MES (for quality control). The finished pieces resulting from the



FIGURE 10.7 Dosing equipment.

stentering frame are forwarded to the shipping section for second inspection and tailoring.

- *Shipping.* The workflow for the production of an article ends in refining with final finishing on the stentering frame. Afterwards the lot is sent for shipping. If no second inspection is carried out on the stentering frame, this is performed during a wrapping process on the cloth inspection machine. Flaws are marked and recorded, and the customer is reimbursed for them, if necessary. In the worst case, parts of a lot may be blocked (blocked stock). The finished goods are loaded onto a particular spool type and packed as per the customer's requirements.
- *Laboratory.* In parallel with shipping, a sample piece taken from the lot is forwarded to the laboratory for quality testing. The laboratory checks the characteristics that are specified in the customer order. Inspection criteria such as burning behavior, stretch behavior, and tear strength are also tested in the sample. The actual values measured here are evaluated based on the targets against the tolerances established there (OK/NOK testing). If samples from a lot are tested, shipping waits for the lot to be released before the shipment is released.

10.3.3 Basic Quantity Units and Production Units

See Fig. 10.8 for interrelationships between production units gray good pieces, lots, finished pieces, and spools.

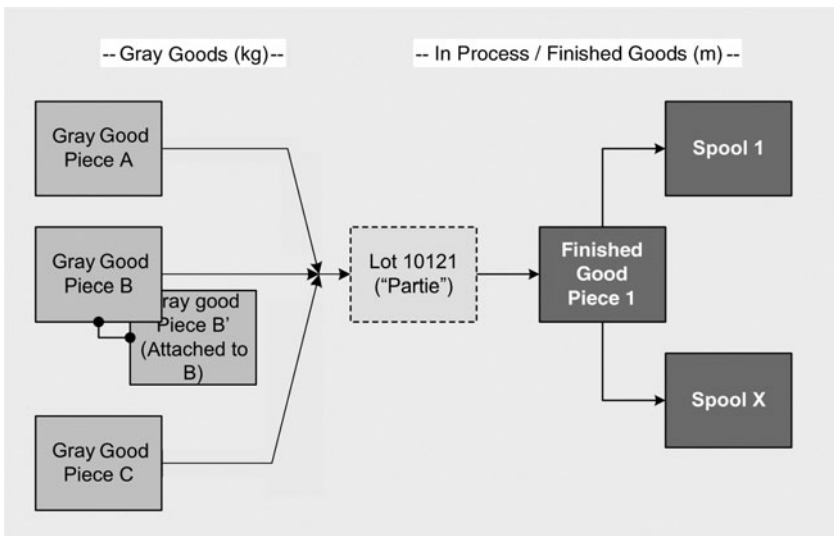


FIGURE 10.8 Interrelationships between production units gray good pieces, lots, finished pieces, and spools.

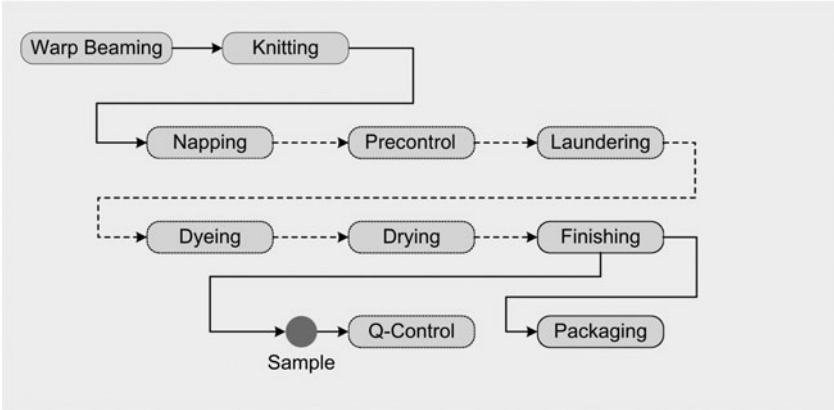


FIGURE 10.9 Macro structure of production flow with production units (i.e., warp beaming, knitting, napping, laundering, and dyeing).

10.3.4 Production Flow Plan

The entire production flow is mapped by the MES in two work plans (for gray good production and refining) (Fig. 10.9).

10.3.5 Tasks of the MES

In addition to increasing transparency and reproducibility of processes and safeguarding processes, the following tasks are also covered by MES.

Master Data Administration

- Article administration with
 - Finishes
 - Work cards for all production departments

Order Monitoring and Confirmation Data

- Order monitoring:
 - Confirmation of operations on production steps
 - Recording of duration of operations
- Resource monitoring:
 - Monitoring of the consumption of raw materials and additives (dosing system)
 - Monitoring of the usage of resources (e.g., spools, dyeing beams)

Operational Data Acquisition (ODA/MDA)

- Linking knitting machines for recording knitting defects (fiber tears) and for the monitoring revolutions
- Linking stentering frames to production management, capture and recording of process values, and usage of finishes
- Linking dosing equipment with usage monitoring of additives and supply of stentering frame
- Linking the drainage system to process recording in order to prove compliance with regulations (for environmental authorities)

Quality Assurance

- Fiber monitoring on warping machine
- Identification of defects on warping machine
- Identification of defects on stentering frame
- Identification of defects in second inspection
- Tests in laboratory and evaluating testing criteria for articles using statistical methods and determining actual values based on customer's testing plans for an article
- Evaluation of test results (laboratory)
- Article-related evaluation
- Customer-related evaluation
- Batch-related (lot) evaluation

Fine Planning and Control

- Production planning for all production departments
- Technical process control

Product Tracing

For the end product produced, the entire process chain with all materials used and the relevant processes must be documented. Tracing will be done with the aid of consistent labeling and monitored process control and recording (e.g., partial-warp beams, chains, gray goods, lots, finished pieces, and reels). Then, for example, it is possible to trace back to the yarn delivery batch used through resolving the process chain, beginning with the end product.

Maintenance (TPM)

- Maintenance and monitoring of mechanical units (roller bearings, etc.) based on recurring examinations
- Carrying out maintenance based on maintenance schedules

- Management of a replacement part warehouse
- Management of testing methods

Recording Production Performance

Identification of the fastest, average, and highest cycle times of the article for all production units

Material Management

- Management of stock quantities for
 - Yarn
 - Warp-beam stock
 - Gray good stock
 - Finished goods stock
 - Blocked stock
 - Additives (dosing system)
 - Work piece carrier/means of transport (reels, beams, etc.)

10.3.6 Challenges

The production described is very challenging, especially because of the wide variety and dynamics this requires. The following boundary conditions must be taken into consideration by the MES:

- Up to the final finishing production stage, however, a lot or part of a lot can take on a different article identity (in the form of a variant) at any time. This is achieved through dynamic redirection within the refining process on instruction. This means, for example, that a lot can be planned under article identity A and take on article identities B and C in part or as a whole in the end result (e.g., through modification of the finish or color).
- The production has both the character of discrete-parts manufacturing (i.e., production of the gray good pieces at the knitting section) and batch manufacturing (i.e., lot), from which packaged goods (finished pieces or reels) result.
- The production may require finishes that are acquired in a continuous process (dosing system) for the manufacture of particular articles. From the point of view of the stentering frame, supply is continual. The dosing system itself, however, can produce the finish only in defined individual quantities (charges). Supply is automatic, and use of the finish with regard to the article must be monitored and recorded (in a calculatory and quality-relevant manner).
- From the preceding, it follows that an existing workflow for an article can be transferred dynamically to the workflow of

another article in accordance with particular criteria. The MES must suggest a transfer where necessary and also must monitor the correct transfer.

- Production is in the form of classic line production. Individual sequences in the workflow can, however, be interpreted as line production (e.g., sequences on the stentering frame).
- Theoretically, the MES must include two partial areas—on the one hand, the knitting section, which provides gray good pieces to refining at the proper time and, on the other, the refining section, which together with the shipping section is responsible for timely delivery of the goods. Within these units, independent coordination is carried out on the basis of internal control.

10.3.7 Realization and Implementation

For realization, a step-by-step process is selected. In the first step, already existing isolated solutions [e.g., production planning and scheduling (PPS) partial systems for scheduling the stentering frame] are extended to integration in the MES interconnections. This migration was urgently needed to retain the existing data records, even if ultimately realization involved replacing some isolated solutions completely with the MES. The tasks of the laboratory are realized in its own software module with its own database owing to its very special nature. This module can be integrated completely into the final MES via a common database.

In the second step, uniform software front ends (based on the .NET framework 2.0) were created for all task areas (i.e., departments) that offer professional customer-specific business processes with the aid of their own databases.

Together with the second step, a standard product for the core of the complete MES was introduced. This standard product assumes, among other things, the required information management, data acquisition (i.e., ODA or MDA), and process linking to controls. Tasks of the standard product also include tracking and tracing, total productive maintenance (TPM) tasks, and resource management. The individual MES terminals use the Web technology of the standard product to implement the required information management. Thus all information and queries are available via Web visualization in the front end on every computer.

In further stages in the process, it is planned to integrate the individual business processes analyzed in advance into the MES system. The number of databases then is reduced from five to two (the MES standard database and a customer-oriented database).

Through the mixture of customer-oriented software development and standard software used, Acker has an optimally adjusted, future-oriented system for its operations. The maintenance costs of the system are manageable owing to the high degree of standard components.

10.4 Summary

In order to illustrate the theoretical content of this book, two application examples were provided from real life. Generally, mixed processes, that is, process-oriented and discrete processes, are required for industrial applications.

The first example includes a process-oriented mixing process that includes filling the products into various packing units. Sensient Technologies Corporation manufactures flavors, fragrances, and dyes that are used in a wide variety of food, pharmaceutical, cosmetic, and IT products. The manufacturing process for an emulsion was described as an example.

The second example examines the characteristics of the production of reel material. The company, Acker, also manufactures products that are used in the production of other products. Examples of some of the company's products are dividing nets for vehicles, luggage compartment covers, textiles for wound strips, and sun screens for cars.