Process Control in the Work Scheduling

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Abstract: In modern companies the use of large information systems increases, in order to support the phases of the product development process. A main point of the paper is the introduction of fundamentals and the major processes of the work scheduling in foundries. It is described a process sequencial control based on a product structure of offer calculations and offers, which is explained by the example of the work scheduling in foundries. The aim is the support and automation of the process of preparation of offers for castings with focus on modelling and execution of the identified processes. The Institute of Production Technology and Quality Management and the Institute of Technical and Business Information Systems work together on a dynamic control, which use the product structure of EDM/PDM Systems, in order to react dynamical on varios conditions at run time. The paper contains a scenario, which explain the coherence between the sequence control of the processes and the structure of the offers.

Keywords: engineering systems, process sequencial control/workflow management, process modelling, workout of offers for castings, work scheduling

Motivation

In the companies more and more software systems are used in the product development. Applications like CAD solutions, systems for numeric control, systems for numeric and thermal sumulation, EDM- or PDM-Systems are used intensively. Thereby the introduction of new systems into the existing hard- and software environment of the companies is difficult and often realizable only through a considerable expense of time and costs. Furthermore a subdivision in several work areas is to observe, whereby the cooperation is often difficult. The example in this paper is the process of elaborating documents for offers and manufacturing of castings wherby a lot of differenciated information (geometry, material, process engineering, quality, deadline) have to be considered. The data shall be effective to gather, to archive, and to systematize. Thereby a cooperation of several software systems used in foundries is necessary. The executed analyses result in the fact that different concepts for development of castings are used in different foundries [5]. Under real conditions the documents for a casting has to pass through several sections (work scheduling, mechanical

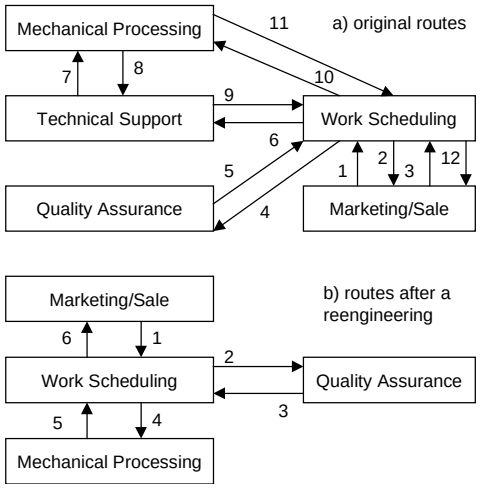

Figure 1: Routes of the Documents

processing, marketing/sale, manufacturing, quality assurance, etc.), which are often locally separated (Figure 1). The arrows and numbers between the boxes clarifies the routes of the documents through the sections of the company. It is to observed, the documents go bidirectional between two sections, like in Figure 1a the documents go four times between the section “Marketing/Sale“ and “Work Scheduling“. In Figure 1a the original ways of the documents and in Figure 1b the ways after a reengineering are shown. It is

to observed, that the reengineering results in a optimized way. There is a new disposition of the sections (section “Technical Support“ is assigned to section “Mechnical Processing“) and so only the necessary worksteps are executed. A reduction of the number of exchange steps is to observed.

The consequence of the procedure of repeated document exchange is a loss of information and time. It is ascertained, the main point of loss information are the idle periods of the documents in the single sections. With help of an automated control it is possible to reduce the idle periods. In order to increase the efficiency of the offer elaboration it is necessary to implement new concepts for the product data management, process modelling, and process controlling. Thereby it has to be considered that in the last years a lot of software systems for the development and manufacturing of castings has been developed, which have to be implemented expediently in a process sequential control and management. Consequently it is necessary to model processes, in order to reengineer and to rationalize the process sequences in companies. Another important condition is the acceptance of the control and new techniques through the employees which does not discuss in this paper.

Process Modelling and Sequence Control

In todays companies a cooperative work is recognizable. In order to realize this, it is necessary to model the executed sequences. Therefore, information about the tasks, the participants, the structure of the company, etc. must be provided. The engineering system must provide components for process modelling. The PACO-Integrationframework [2,12] realizes these components through the Process Layer, in order to integrate only the components needed during the execution of the modelled sequences [2]. In order to support the product development process, it must be worked with complex and interlocked processes. So parallel, iterative, or other structures in the sequences can be developed [6]. Another attribute of the product development process is the high, process-oriented information volume and the associated complex tasks for the project control. It is tried to develop concepts for the reduction of product development times on simultaneous assuring quality. Is the product development process supported by a process sequential control, a dynamic reaction on some situations is required.

Our sequence control is responsible for the flexible control of sequences, particularly the execution, the formation of the execution and the aspects of the processes (what, how, with what, who) are important. It is supposed that the control is independent of the data management, the product structure management (EDM/PDM), or the project management. The functionalities are provided by the available systems and the components are integrated on demand. These facts are dependent on a realization of the control, which is based on the PACO-Integrationframework [10]. In this paper only the Process Layer of the PACO-Integrationframework (Process Control Layer, Activity Layer, Configuration Layer, Object Management Layer) is explained. The control is located at the Process Control Layer, which is one part of the Process Layer. The other part is the Activity Layer. The user works with technical/technological processes of the Process Control Layer, which are only specified here. The Activity Layer realizes the transfer of the technical/technological processes into the

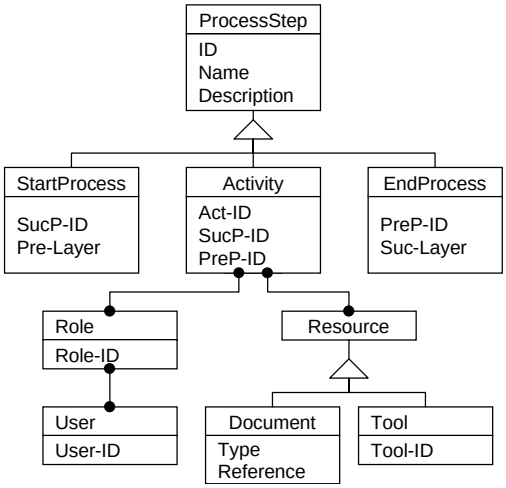

Figure 2: Object Model for the Process Step

(ID: unique identifier, Name/Description: of the ProcessStep, SucP-ID/Pre-Layer: successor/predecessor-layer of the StartProcess, Act-ID/SucP-ID/PreP-ID: identifier/successor/ predecessor of the Activity, Role-ID: identifier of the Role, U-ID: identifier of the User, Type/Reference: type/reference of the Document, Tool-ID: identifier of the Tool, PreP-ID/Suc-Layer: predecessor/sucessor-layer of the EndProcess)

informationtechnical processes (activities). Therefore the Activity Layer represents the connection between the technological and the informationtechnical layer. Each process step executed on the Process Control Layer can refer to several activities, which are executed on the Activity Layer. The Activity Layer combines abstract services from the Configuration Layer (e.g. “gear_wheel.slddrw”) to high-order services (e.g. “open “gear wheel“ with SolidWorks”). The Process Control Layer uses these high-order services.

The modelling of the necessary sequences is based on

the object model in Figure 2. A sequence consists of processes. Thereby it is distinguished between sequences, which are modelled by the user, and pre-defined sequences. Pre-defined sequences are already modelled and provided by the system. That means these pre-defined sequences contain calls of activities, which are often executed by the engineer or the draftsman during the product development process. The sequences are engineer-technical sequences of tasks, which can be used by the engineer during the modelling of new sequences. An example for a recurring sequence of tasks is the scheduling of times and operations for the manufacturing of castings. Another example is explained in chapter *Work Scheduling and Workout of Offers*. Sequences, including pre-defined sequences, consist of processes. A process can be a sequence or a process step. A process step is the smallest, atomic unit on the Process Control Layer. That means a process step is indivisible. There are three possible types of process steps (Figure 2): *StartProcess (SP)*, *EndProcess (EP)*, and the call of an *Activity (A)* of the Activity Layer. Roles, users, tools, and documents must be assigned to the process step. A user can be assigned to one or more roles and a role can be assigned to one or more users. The difference to conventional systems is the assignment of activities to the respective process steps. The activities are dependent on the used tools and can be selected from a list of available activities at runtime. For instance an activity with name “classify the casting“ and identifier “Act-ID A2_1“ could be offer on the Activity Layer, which allows to work after this scheme in order to classify the casting. By this means, the user is supported as far as possible. Is the *Pre_Layer* of a StartProcess „zero“, it is the highest layer and the total sequence starts there. In order to execute an activity on the Activity Layer, it is necessary to provide information about the user and the appropriated documents. The other information of the single process steps are used at the Process Control Layer only.

The support of a user during the development of new products requires the modelling of a coarse process scheme with the most important process steps or process sequences. It is possible to create processes, to connect processes to a sequence or simple constructions (e.g. sequences or loops), to assign pre-defined sequences to processes, and to set-up users. In order to make an assignment it is necessary that a pre-defined process sequence starts with a StartProcess and ends with an EndProcess. The total pre-defined sequence is assigned to a process as a sublayer. The demand for a dynamic control is based on the companies because it is not possible to model all sequences during the product development process in advance. The product development process is a repetitive development process which must be controlled dynamically. For example, if the sequence depends on the product structure problems occur. This paper understand an offer for a casting as a product with a structure. In order to realize a control depending on the product structure (on the structure of the offer), it is necessary to use the information and functionalities of the EDM/PDM-Systems. It is attempted to use dynamically prearranged recurrent processes. The execution of a rule depending sequence can be realized as follows. The first task is the identification of processes. That includes the recurrent processes of the workout of offers, which are mentioned in the next chapter. Based on an analysis and on the structure of the offer a multitude of rules must be defined, which can be evaluated. The rules contains the conditions which must be fulfilled, in order to execute a certain process. That means, all processes have certain conditions. At runtime, these rules determine which process executed as next, considering the product structure and whether the rules are completely fulfilled, partially fulfilled, or not fulfilled. Due to the fact, that the fulfillment of conditions depends on the results of the executed processes, a sequence is created and executed dynamically.

Work Scheduling and Workout of Offers

In order to explain an example the work scheduling in foundries is choosed. The work scheduling in foundries is splitted into two phases. In the following an approach to generate an offer is presented. In phase one the customer inquires a special casting. The work scheduling in the foundry creates an offer. In this phase the necessary documents for the inquiry are to elaborate, for instance working plan with costs, times, and quantity. The result of phase one is an offer which contains the necessary information for the customer, especially the final price. The customer get the final offer and dependent on the decision of the customer the foundry get the order or not. In case of obtaining the order through the customer, phase two starts and the work documents are to elaborate. These work documents are drawings (like finished machine drawing and drawing of the raw product), scheme of allocation the sheets, working plans and so on. The worksteps of phase one (create an offer) and phase two (elaborate the work documents) are similar. The difference is the level of abstract. The center of this paper and of the carried out researches is the phase of workout of offers. During the two phases a lot of information must be considered. For instance geometry (drawings of the casting), specification of the material (cast iron, cast steel, ...), process engineering (method of casting, quantity), quality (micro structure, mechanical properties, ...) and not at last the deadline. These data shall be effective to gather, to archive, and to systemize [3,13].

The present general method for workout of offers in foundries is execute as follows. In the first step an already calculated offer for a similar or an equal part is searched. Is an offer found then the data are to be updated or adapted. It is possible to create a completely new offer with the available documents or post calculations, which based on expert knowledge. Another point of view is the furthermore use of the expert knowledge for generation of cast pattern and raw products. In any case it is necessary, so far as possible to automate and to support the approach with the mentioned auxiliary means.

Figure 3 shows a part of a possible pre-defined sequence for the workout of offers for castings. In the praxis the draftsman or engineer attemps to adapt available solutions or partsolutions and only in 15 % of all cases a new construction has to be [1]. Another point is the result of the analysis about information in foundries. The information about the range of workout of offers in the companies are very often unstructured and uncomplete, so that the most decisions based on experiences of the employees. In order to use the created sequences it is necessary to cooperate with engineers at the beginning of development and modelling. The main processes of the sequences are the technical/technological processes. The assignment of activities in this case is not performed by the engineer at build time, but some pre-defined sequences are provide by the engineering system. Such static, pre-defined sequences are possible because at the workout of offers in foundries recurrent work-steps do exist.

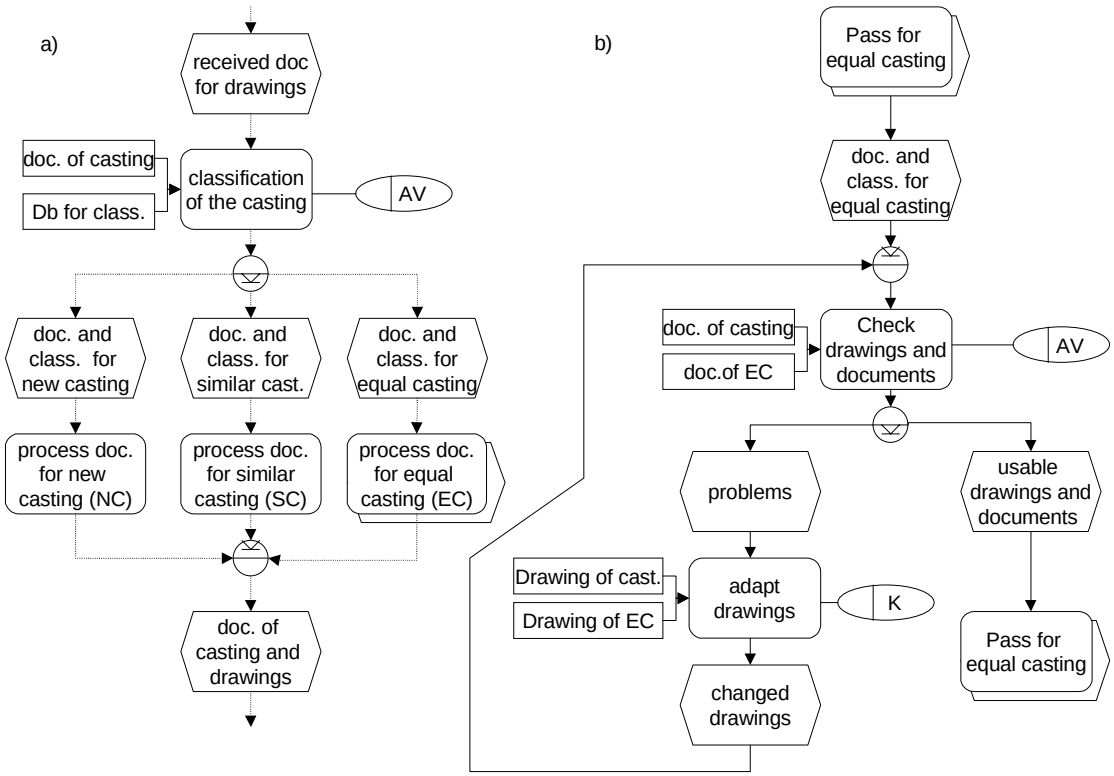

Figure 3: Part of the Sequence „Drawings“ (Event-Driven Process Chain – EPK)

In order to realize an automated control for the workout of offers, a type of Petri-Net has been proposed. The Process Layer of the integrationframework with the control is a link between the engineer and the engineering system and consequently it must be possible to react on dynamic situations. That means, not every possible sequence must be known at the beginning and therefore it is not necessary to model the sequences at that time. During runtime the sequences are dynamical defined [9]. Examples are sequences for construction or design, for the generation of part lists, or for the workout of offers. These pre-defined sequences self can be repeat or worksteps or processes of the sequences can be repeat.

The sequence (Figure 3) is modeled as an event-driven process chain [11]. In the following the basic fundamentals are explained. *Events* initiate one or more functions respectively events are the results of the functions. Functions are activities, which describe the aim of the execution, and they need time. Dependend on the results of the functions several branches and rear

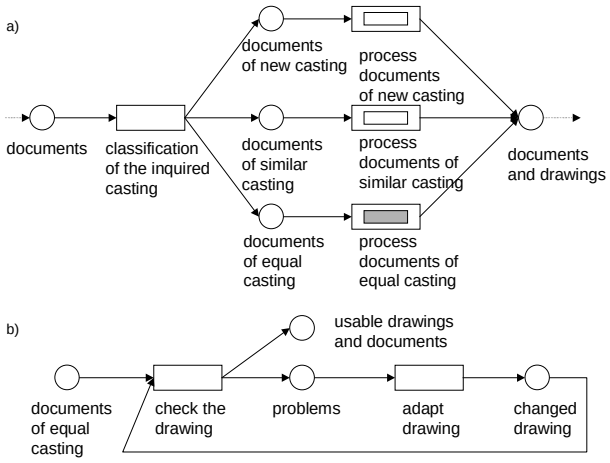

Figure 4: Sequence for the Process "PREPARATION OF DRAWINGS" (Workflow)

jumps are possible. Branches are presented through connectors (logic operators are AND, OR, XOR). The timing is described with help of the control flow. Also organization units are available, in order to present sections of the company, and it is possible to assign information objects to the functions, which represent the information flow. Based on the inquiry a classifcation of the casting is carry out (Figure 3a). The function „classification of the casting" uses the documents of the casting and a database with necessary foundry specific information. Three events are possible. Figure 3b shows the refined sequence "process doc. for equal casting (EC)", which must be executed if the result of the classification is a repeated part.

In the following the sequence of Figure 3 is transfered in another sequence (Figure 4). During the phase of analysis, a modelling as an event-driven process chain (EPK) was necessary because of the unstructured and incomplete information in foundries. With the help of event-driven process chains it is possible to clearly present the necessary information. In Figure 4 a kind of petri-net is used [4]. Compared with Figure 3 no necessary input or output information for the processes are presented. The transitions are represented as rectangles and they are comparable with the process steps of the event-driven process chains. The objects are conditions, which are necessary for executing, and they are represented as circles. Rectangles with a double frame are processes, which contains a refined process sequence.

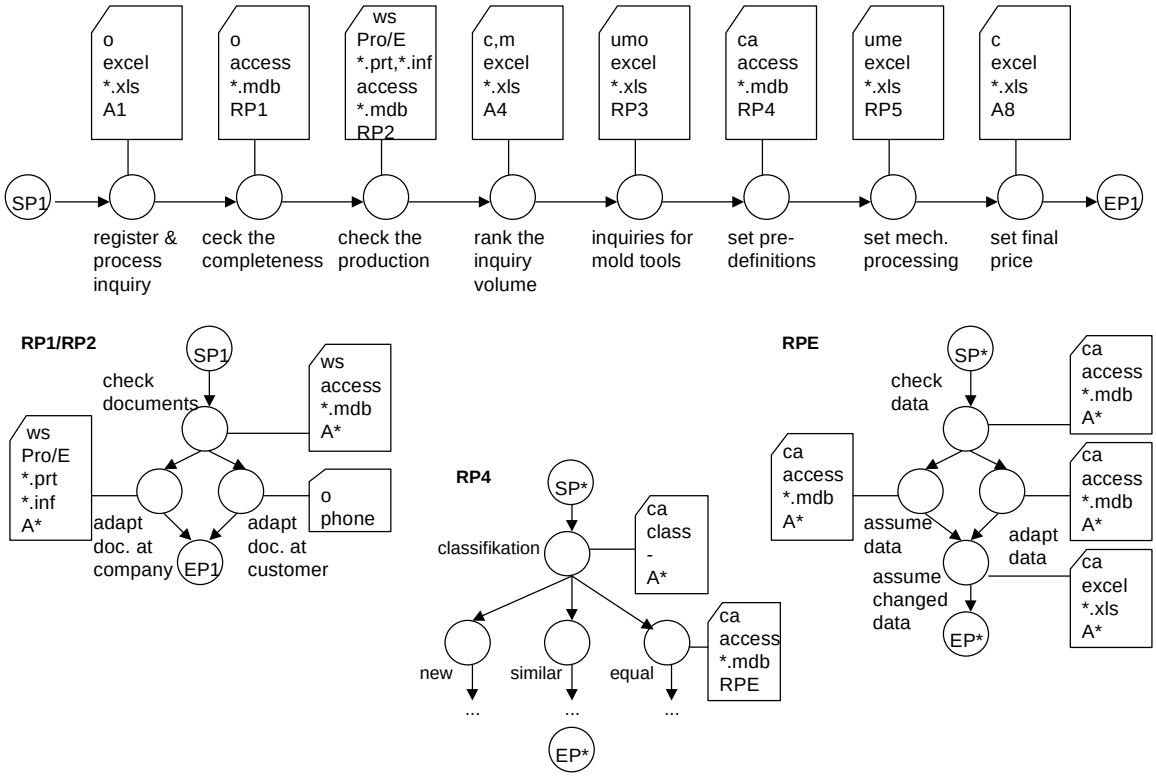

Figure 5: Reference Processes During the Workout of Offers

(o: marketing/sale – official in charge, c: marketing/sale – chief, m: manager, ws: work scheduling – engineer , ca: work scheduling – assistant for calculation, umo: modelling – official in charge for modelling, ume: mech. processing – official in charge for mech. processing)

The process sequence of Figure 4 is executable by a control granted that information, like role, user, tool and so on, are assigned to the single process step. The example of Figure 4 contains only a few samples of major processes, which can be executed during the workout of offer. In order to develop a process sequence, which contains all important process steps, the results of the explorations in eight foundries are to analyse. From the result of the analyses follows another sequence (Figure 5). This sequence contains only the major processes (reference processes) of the workout of offers without the information flow. Roles, tools, documents, and activities or references to refined process sequences are exemplary assigned to each process step. The order of the processes is different in each foundry. For example in Figure 5 a possible order is proposed, but the position of process „*rank the inquiry volume*“ varied. At the beginning and at the end of each sequence the process steps „SP*“ and „EP*“ are called. That is necessary for identifying the refinement level. „*SP0*“ and „*EP0*“ fix the highest layer.

In order to distinguish this approach from the available process controls the focus is the product structure-driven (dynamic) control. In this paper the workflows of the Workflow Managment Systems [7,8] are not the crucial point, but here are the technical processes of the product development are considered. The process is controlled depending on the information contained in the EDM/PDM-System. The existing prototype PACO has to be expanded, in order to realize a dynamic control, which depends on the executed user tasks, the product structure, and the requirements. That is, based on the product structure (e.g. information for the offers) the system choses the process steps which are offered to the engineer as the next process. For instance, during the workout of offers the user works with an EDM/PDM-System and searched documents for the offer. Depending on this information and possible supplements the pre-definitions are set. The evaluation of the results of the executed processes leads to automated decisions about the further sequence (e.g. pre-definitions for new, similar, or equal parts). Depending on the decision, the user is offered a list of additional pre-defined sequences (e.g. „set postprocessing“ or „set assurance control“) and he can choose from.

Scenario

In this chapter a scenario is explained, which contains the coherence between the control of the processes and the structure of the offer. Based on the fact that the control used an EDM/PDM-System, in order to realize a dynamic control, in Figure 6 a possible scenario is shown. The direct strategy in order to workout an offer starts with the input data of the inquiry, like geometry, material, process engineering and so on. As a result the necessary data are calculate. This calculation data are the real data and they are compose to an offer with the final prices. The analyses result in the fact, that sometimes there are big differences between the final and the real prices, the profit margin. In order to rationalize this approach, a support with help of a control is suggested. That means the control takes over all necessary processes of the workout of offers and a indirect way is carried out.

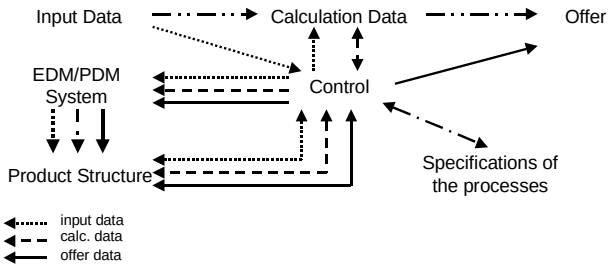

Figure 6: Coherence Between Control and Structure of the Offer

At first the input data of the inquiry are managed by the control. The control call the EDM/PDM-System and there the information are stored in the product structure. Only one time it is necessary to store the data via the EDM/PDM-System. On this way it is possible that the control have an access to the input data at any time. During the processing of the sequences the necessary current data are available. The control uses the data and information of the product structure directly, without accessing the EDM/PDM-System. The specifications of the processes, which are executed by the control, are stored in an own database. Here all necessary information of the processes are available, e.g. roles, users, documents, tools and so on. It can be said that the control based on the previously modelled processes of the workout of offer and the structure of the offer. The calculation data arise during the execution of these processes (run time). The order of the processes depends on the structure of the offer calculation, which is stored in the product strucure, and is composed during run time. Thereby a repeated access to the product structure data is possible. Finally the complete calculation data are the basis for the offer. The creation of the offer depends on the product structure, too. That means the product structure contains the structure of the offer in different versions and dependent on the version the offer is to workout. The result of the process control is the final offer, which based on the product structure.

Conclusion

The number of the systems which are used for the product development process in companies is increasing constantly. As yet a multitude of analyses with the point of view of an efficiant formation of the workout of offers has been carried out. The goal of furthermore analyses is the checking of generality in comparable companies. Another main focus is the analysis of the job processing in foundries. A connection to the workout of offer is to elaborate, in order to develop a continuous handling of the work scheduling. The main point of this paper lie in preparing the processes of workout of offer, in order to use an automated control. For this it was necessary to analyse the structures of several companies, information and documents which must be managed. By means of an example the sequences are modelled as event-driven process chains and as a kind of petri nets, in order to consider all problems during workout of offers.

In evaluation of the results a process sequence is developed which contains the reference processes of the workout of offers. These reference processes are the most important processes which are identified during the analysis. It was tried to generalize the processes, in order to use the sequences in similar foundries with the goal to use a control, in order to support the workout of offers with information technical means. Further works contain the development of a sequence control, which is tailored to a special industrial branch, e.g. foundries. With the control it is possible to reduce times and costs for developing a product. The goal for the future is an automated support of the work scheduling with the possibility to draw conclusions from manufacturing and use the experiences by new developments.

References

[1] S. Krötzsch, I. Hofmann, F. Kreutzmann, E. Ambos and G.Paul: Economic Supply of Information During the Workout of Offers for Castings. GIESSEREI 84(10):15-21, 1997. (in german)

[2] S. Krötzsch, I. Hofmann, G. Paul, E. Ambos: Process Modelling During the Workout of Offers for Castings. In: International Conference for Processmodelling, 22.02.-24.02.1999, Cottbus. Appear in: B. Scholz-Reiter, H-D. Stahlmann, A. Nethe: Process Modelling, Springer-Verlag, 1999.

[3] F. Schiffer, K.-H. Tempelhof: Fertigungsprozeß-gestaltung im Maschinen- und Gerätebau, Verlag Technik Berlin, 1981. (in german)

[4] B. Baumgarten: Petri-Netze, Wissenschaftsverlag, 1990. (in german)

[5] M. Rohloff: Produktionsmanagement in modularen Organisationsstrukturen, R. Oldenbourg Verlag München Wien, 1995. (in german)

[6] B. Scholz-Reiter, E. Stickel (editors): Business Process Modelling, Springer Verlag, 1996.

[7] G. Vossen, J. Becker: Geschäftsprozeßmodellierung und Workflow-Management, Thomson Publishing, 1996. (in german)

[8] St. Jablonski: Workflow-Management-Systeme, Thomson Publishing, 1995. (in german)

[9] M. Reichert, P. Dadam: $ADEPT_{flex}$ - Supporting Dynamic Changes of Workflows Without Loosing Cotrol, University of Ulm, Computer Science Reports of Ulm, No. 97-07, 1997.

[10] M. Endig, S. Krötzsch, D. Jesko, G. Paul, I. Hofmann, and E. Ambos: Framework für ein verteiltes Prozeßmanagement in der Angebotserarbeitung in Gießereien, Erschienen in: Tagungsband zur 4. Magdeburger Maschinenbau-Tage, Logos Verlag Berlin, 22.- 23. September 1999. (in german)

[11] J. Staud: Geschäftsprozeßanalyse mit Ereignisgesteuerten Prozeßketten. Springer Verlag Inc., 1999. (in german)

[12] S. Krötzsch, I. Hofmann, G. Paul: Using of Process Modelling in the Work Scheduling, Erschienen in: Q. Yang. Proceedings of the ISCA “12th International Conference on Computer Applications in Industry and Engineering (CAINE-99)”, Atlanta, Georgia USA, November 4-6, 1999.

[13] St. Morschheuser: Integriertes Dokumenten- und Workflow-Management, Deutscher Universitätsverlag, 1997. (in german)