Casting Technology and Information Fusion

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Abstract: The main focus in a lot of companies is the computer aided support of several tasks. Especially the work scheduling and the casting design in foundries are important aspects which are responsible for the economical survival on the world market. This paper contains proposals for a better support of the work scheduling and the casting design with help of modern computer techniques. At first a review of the research group "Information Fusion" is given, which develop a Workbench for Information Fusion. Thereafter the work scheduling is explained, which contains the state of the art and proposals for software solutions. Here aspects are considered, like the integrated process of the workout of offers and scheduling of the manufacturing, the in- and outgoing conditions at the workout of offers, checklists and databases for technical checks, etc. In order to manage these mentioned main points of the work scheduling, a Control-System, like Workflow Managemant Systems, is introduced. The paper presents several software solutions for the workout of offers associated with the elaboration of the work documents and the production start.

Keywords: Computer Aided Engineering, Offers for Castings, Information Fusion, Workflow Management

Introduction

The casting industry, e.g. automobile or maschine building industry, uses remarkable results oriented on computer aided solutions for technical tasks. CAD-Systems for casting construction, systems for stress and solidification simulation can be examplary mentioned [1, 2, 3]. The 50% quota of CAD-data and their processing in die casting plants is much higher than in steel and iron foundries. Here a quota of 10% was ascertained [4, 5]. An analyse of the development in foundries results in the fact, that there is no complex system which is able to integrate progressive technologies for information processing and communication oriented on requirements of the casting industry. In order to ensure a permanent coexistence of the casting industry in ensemble with the most efficient machine-building and equipment-building industry, an adaption to the progressive developments of the casting industry is necessary. The continuous and complex use of the information and communication technology in all sections of foundries is the future goal. In order to reach this, the scientific penetration of the company-own technological process is very important.

Presently the work about the casting design process is one application field of the DFG-Research Group "Workbench for Information Fusion". The part project "Casting Technology" analyzes the casting design process with the aim to get information in a new quality.

Information Fusion

The research group "Workbench for Information Fusion" combines the work of several part projects, in order to develop new techniques, concepts and methods for produce information in a better quality. There are six part projects which develop concepts for the workbench. Another three part projects establish the application areas. "Casting Technoloy" is one application field. Here some databases with foundry specific data and other auxiliary means are used, in order to qualify the casting design process with help of computer science. These days the conventionally method is used in foundries. During the processes of work scheduling the staff used the available databases directly. That means the employee get only the stored information of one specific database. With help of the concepts and techniques of the workbench it is tryed to get information in a new high quality. This is possible because all databases are used for decision making and the workbench filter the relevant information for specific tasks. Figure 1 shows a survey of the "Workbench for Information Fusion". The application profile "Casting Technology" works with a lot of different data. For instance, normal documents (e.g. norms and pictures), CAD-Data, and different technological data.

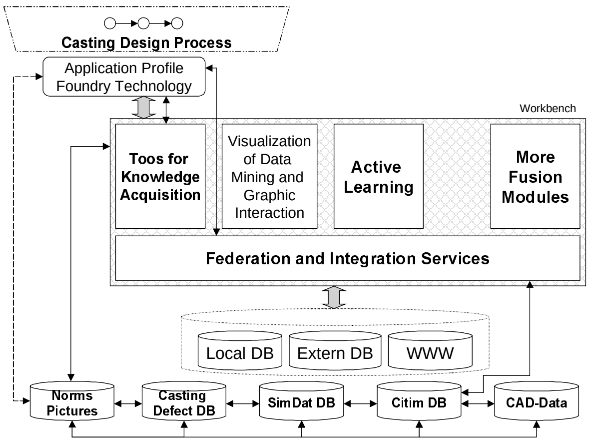

Figure 1: Workbench for Information Fusion

These Data support the decisions of the employee during the single worksteps. The data are distributed in heterogenous databases, technical manuals, or as expert knowledge. The last point is a very important fact in the casting design process. The expert knowledge is available in a fuzzy kind and it is very difficult to prepare the knowlegde for a computer aided processing.

Work Scheduling

Almost the complete knowledge of a company is normally combined at the work scheduling. For instance, information to economical questions, questions about material, logistic, operations, and equipment, as well as questions to the quality assurance are concentrated in foundries. Consequently the work scheduling is a core competence of the company. Already here the first decisions about the casting are made. Normally the work scheduling is executed in two steps. The process begins with Phase 2 (Figure 2), the workout of an exact offer, after an inquiry by a customer is received. In case of getting an order by the customer Phase 3 (Figure 2), the elaboration of the work documents, is executed. These steps differ from each other in level of detail. In context of the casting design process the work scheduling is expanded. This means, there is one phase more (Phase 1), the workout of a rough offer. Figure 2 shows the necessary work steps and clarifies the connection between the first two phases. The new strategy starts with Phase 1 (Figure 2), if the foundry would like take part in the product development process together with the customer. The decision must be deliberate by the foundry because the product development needs time and causes costs. But on this way the company tryed to get a good basic position in order to get the order. The rough offer comprehends the necessary product development information for a specific casting. If the foundry get the order for product development a final offer is create (Phase 2). The main focus is the cooperation with the customer during the casting design process. On this way it is possible to consider all necessary requirements for casting technical view. Phase 3 (elaboration of work documents) is uncoupled from the workout of offer. A lot of analyses were executed which comprise the conditions at begin, contents and course, strategic decisions of the company, available resources, and the qualification of the employees concerning the workout of offer.

An increasing interest in new techniques of computer science and communication is to find in casting industry. The practical experiences in range of expedient Workflow Management Systems in foundries confirm the necessary insert of these techniques [6]. Both reliable company-intern (e.g. information flows between workout of offer, marketing, and manufacturing) and company-extern (e.g. information flows between engineering offices, customer, cooperation partner, and so on) information flows are required, which are supported and warranted by adequate techniques [7].

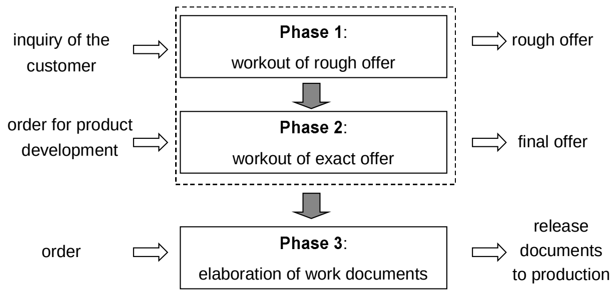

Figure 2: Phases of Work Scheduling in Foundries

The goal of expedient information processing systems is the storage and processing of different information types in only one system. This is required because the quantity and quality of information is relate to permanently changes by the simultaneous cooccurrence of heterogeneous information. Furthermore a utilization of these information at any time by planning engineers and by other competent employees is required. This point concerns the employees of the direct manufacturing process, which use the documented experiences in form of pictures and/or videos. Already nowadays it is recognizable that this approach causes a lot of advantages. For instance the avoidance of misjudgements during cost calculation, decreasing the loss of information and knowledge, the warranty of a high quality standard, of adherence to a time limit, and of a high productivity in work scheduling. Such an approach requires a demanding data management [8] and a high qualification and discipline oriented on the warranty of the actuality of data. All modifications have to be gathered and stored consequently by authorized staff. The major hurdle on this way is the insufficient scientific penetration of the technological processes in foundries (e.g. the control of the cavity fill process, in particular on complex castings) and the economic evaluation (e.g. ascertainment of the limits of economic manufacturing with available resources).

Reference Processes of the Work Scheduling

The precondition to a successfull existence of a company on the world market, which is bound on production, are qualified offers in a short term. Interviews in foundries results in an increasing number of submitted offers in the last years (35%). In the same time the success rate came under 30%. The necessary worksteps for workout of offers are shown in Figure 3. These steps are executed more or less detailled in the companies dependent on valence of the inquiry and the type of customer [14].

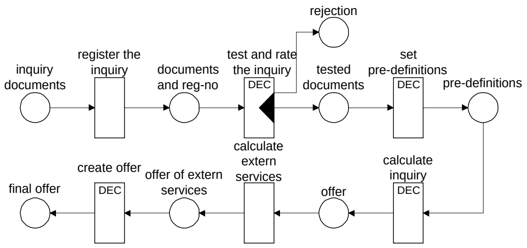

Figure 3: Sequence of Workout of Offers in Foundries

If the volume of trade of an inquiry is small, then no generation of the raw product is executed and data of similar calculation documents are used. In foundries auxiliary means for the workout of offers are used, like guiding principles, standards, several methods for checking the manufacturing oriented design, nomograms, casting classifications, regression equations for ascertainment of allowed times, material sheets and so on. Very often offers of already produced castings are used. These information are stored in file form or they are managed in specific production planning and control systems which are based on concepts like Material Resource Planning (MRP I) and Manufacturing Resource Planning (MRP II). A lot of software-suppliers for foundries are found, but no of the analyzed systems is conform with the major points of the sequence of Figure 3. For this reason at the Otto-von-Guericke-University Magdeburg in collaboration with a well-known foundry a concept for an efficient computer-aided solution was developed [9].

In order to model the identified process steps FunSoft-Nets [13] are used. The analyses during the research project contains the development of auxiliary means. The work contents of the single components, which are developed in [9, 12], are checklists for completeness check and verification of offers, the database "check the producibility of inquiries", and the algorithm for "generation the raw product". These components are introduced in the following.

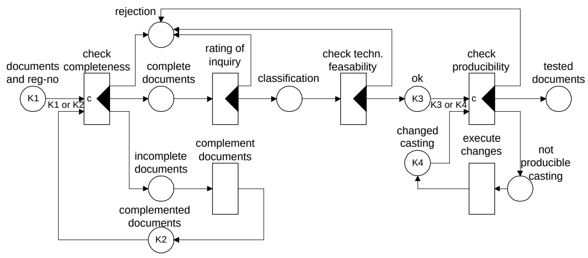

Figure 4: Subsequence "test and rate the inquiry"

For instance, the process step "test and rate the inquiry" of Figure 3 is subdivided in a subsequence (Figure 4). Here all necessary steps for testing the inquiry are executed. The workout of offers starts normally with a completeness check of the inquiry documents. As a rule there is a consultation with the customer in case of missing specifications. In order to represent the efficiency and the service of the foundry, the goal is the reduction of consultations with the customer. In collaboration with a well-known foundry a checklist was developed which completes missing information in dialogue with the employee.

The missing information are to differ in necessary and desired characteristics. Necessary characteristics are to understand as those which influence the technology of castings, the manufacturing costs, and the quality. The support of the checklist by completion of missing information is introduced as an example. For instance dependent on the piece number it is decided wheter automated or manual manufacturing means for production are used. Is the piece number not specified by the customer (5% of the inquires) the foundry submit an alternative offer, provided that several mechanized and automated form plans are available in the foundry. The *checklist* submit a manual mold for a piece number of 1. The proposal of automated mold plants is dependent on the minimal economic piece number. Not in each case the foundry elaborate an offer. It is also possible to eliminate an inquiry before the process "*check completeness*" of the inquiry documents is executed. Reasons for this can be a desiderative reliability of the customer, a small volume of trade, a small piece number (e.g. a new production line for the product is not advisable), and a cognizable compare of inquiries (e.g. the customer gets normally his products from another supplier).

Another very important point during the workout of offers is the weighting of the inquiries. In the context of the research group "Workbench for Informationfusion" a rule-based program for weighting the inquiries in foundries was developed. With help of the checklist several points were testet. Based on the tests the inquiry will evaluated and several possible kinds of cost calculations are proposed. These strategy is necessary because the customer is classified inquiry-oriented as A-, B-, or C-Customer. And the used cost calculation depends on these classification. The points of the checklist are divided in fundamental, technical and economical criteria. The evaluation of the fundamental criteria comprise the common relations, for instance customer-supplier-relations and the relations to the superior parent company. The technical criterias are related to available technologies, limits for technical feasibility, economical lot sizes and experiences with similar parts. Economical criterias verify the reliability of the customer, required price proposals of the customer, etc. Dependend on the test results, the program give possible kinds of cost calculations (Figure 5).

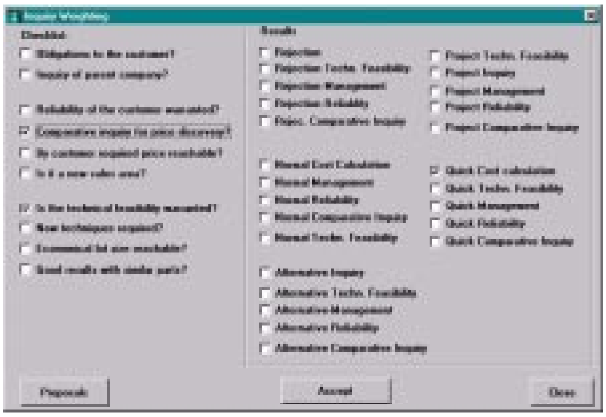

Figure 5: Weighting of Inquiries in Foundries

These are rough calculation, normal calculation, project calculation, alternative offers and rejection. Some proposals of the program have supplementals, so that in some cases the agreement of the management is required. Dependend on the result the next worksteps are executed. The program based on rules which are subdivided in superior and normal rules. An example for a superior rule is *“Is a new technology required then search an alternative offer!”* The rules are represented as decision tables. Table 1 showes an example.

Table 1: Expample for a Decision Table (Y-condition filled, N-condition not filled, X-action part will be executed)

		R	R	R	R
B	technical feasibility of the casting	Y	N	Y	N
B	comparison inquiry	Y	Y	N	N
A	quick calculation	X			
A	normal calculation			X	
A	alternative offer				X
A	rejection		X		

There are 2 rules and 4 alternative decisions. The complete checklist comprehends 10 criterias. The consideration of all rule-combinations leads to 2^{10} possibilities. But not all rule-combinations are expedient and redundancies are possible. So, in the decision table only some rules must be comprised.

One part of the Research Group “Workbench for Informationfusion“ comprises analyses about involvement of the results. That means, the results of the rule evaluation will be considered in furthermore weightings of future inquiries. In case of several proposals, e.g. normal cost calculation and rejection, the *human* decides dependend on the proposals and his experiences the furthermore procedure. With help of some techniques the checklist considered the decisions. That means, the choosed proposal influenced the priority of the rules. On this way rules with a high priority affect the rule evaluation and reflect as well the experiences of the worker.

In order to reduce wrong decisions during the workout of offers, a technical, organizational, and economical check of the technical feasibility of an inquiry is necessary. Currently, the compare of the characteristics of inquired castings with characteristics of manufacturing means is executed on the basis of expert knowlegde. In exceptional case documents of the available equipment and conditions of use are utilized. In preparation of software solutions for check the technical feasibility it was necessary to analyze the structure of the equipment, the flow path of castings through the single production units of the foundry, and the influence coefficients to choose from the equipment.

Table 2: Dependencies of Technical Feasibility (◈ Dependency, ◇ No Dependency)

Equipment for / *Input Data*	Melting	Casting	Molding	Core Molding	Cleaning Sand	Deburring	Separating	Heat Treatment	Analysis
Dimension	◇	◇	◈	◇	◈	◇	◇	◈	◈
Cores	◇	◇	◇	◈	◇	◇	◇	◇	◇
Section Thickness	◇	◇	◇	◇	◇	◇	◇	◇	◈
Weight	◈	◇	◈	◇	◈	◇	◇	◈	◇
Surface Quality	◇	◇	◈	◇	◇	◇	◇	◇	◇
Dimension Precision	◇	◇	◈	◇	◇	◇	◇	◇	◇
Material	◈	◈	◈	◇	◈	◈	◈	◈	◇
Quantity	◇	◇	◈	◈	◇	◇	◇	◇	◇

Within the scope of the investigations all substantially influence coefficients for the technical feasibility was identified. Based on these facts a database was designed which consider both the equipment and the casting specific aspects and the coherences between them. Table 2 showes the dependencies between the necessary input data and the equipment of the foundry. Information about conditions of use depend on the influence coefficients are evaluated, too. As a result of the elaborated algorithm the available equipments are showed which can used for production of a special casting. The result depends on casting characteristics (a selection of several ranges of casting characteristics is offered, like dimensions, material etc.). After the check of technical feasibility the search of similar castings respectively the generation of a raw product at a new inquiry is to be executed.

Casting Design Process

A very important part of the casting design process is the generation of the raw product. A foundry generate a raw product if no documents for similar or equal castings are available and the volume of trade is large. The generation of the raw product contains a scheme of allocation of sheets and the draft of the raw casting (e.g. 3D-Data). The goal is an exact predefinition of manufacturing costs. Thereby several aspects have to be considered, like position, number and shape of joint lines, of cores, and of the gating and feeding systems, allowances and drafts, as well as the precast of formfeatures.
There are various researches which contains the computer-aided generation of raw products [10, 11, 15] in the last years. The most solutions base on 3D-Data of the castings, but the available expert knowlegde of the foundries was not considered in these solutions.
In contrast to ancillary foundry industry for motor industry, which use computer-aided construction (CAD-Systems, like CATIA, ProEngineer, UNIGRAPHIX, etc.), the small foundries work with a manual generation of raw products which based on expert knowledge, like standards, guideline principles, and some other methods and equations for determining of gating and feeding.
Most expert knowledge oriented on the singularity of the foundry is normally not documented. Small foundries don't work with a 3D-CAD-System because the high costs. This can be a reason for a rejection of an inquiry, if the inquiry contains 3D-Data, or a collaboration with an engineer agency is necessary. The results of the researches shall support the small foundries with help of a partially realized solution, which based on expert knowledge in foundries and reasonable software with necessary interfaces to other applications. In preparation for the algorithm for generation of raw products all necessary molding processes and the particularities have been analyzed. Automated molding processes have many constraints, e.g. default mold joints of the molding boxes (horizontal, vertical) and the defined dimensions. In contrast to the automated molding process the manual molding process has nearly no limits. Furthermore different casting materials (e.g. cast iron, cast steel, aluminium) require various calculations for the gating and feeding system. Another important point was the analysis of possible theoretical schemes of allocation of sheets.

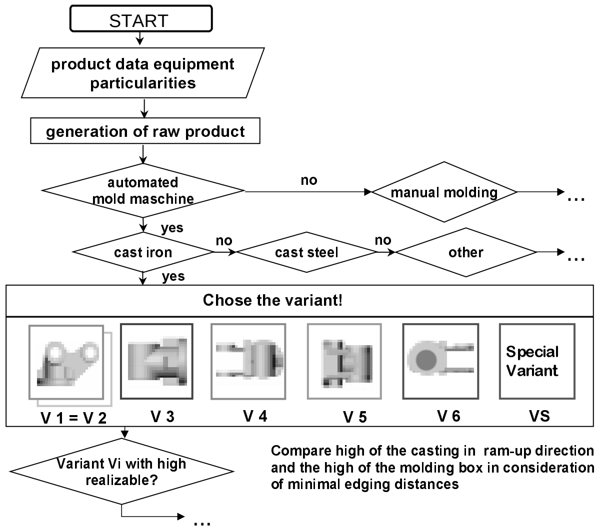

Figure 6: Part of an Algorithm for Generation of Raw Products for a Seiatsu Molding Maschine

Dependent on the developed algorithm 6 basis schemes was identified (Figure 6). The basis schemes are conform to the 6 views of casting. The reduction to 3 basis schemes is possible, if the casting is symmetrical. Special variants are possible, e.g. angular ram up of the casting. The algorithm was developed for a Seiatsu molding maschine. In Figure 6 a part of the algorithm is shown. During the execution of the algorithm the several positions for ram up the casting are eliminated because of illegitimate material encores (allowance, drafts, feeder) on particular casting parts. The residual positions for ram up the casting are to evaluate in consideration of economic criteria and the estimated costs have to be determined.

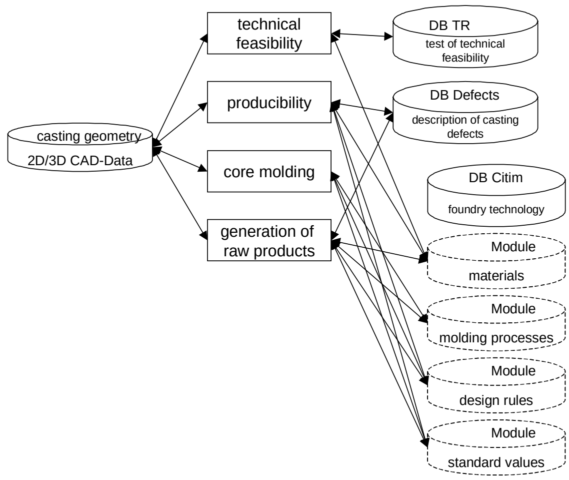

Figure 7: Databases of the Casting Design Process

The new strategy with help of the workbench contains the use of several databases. Each process step uses special infomation of different databases. With help of the databases the casting design process is supported so much as possible. Figure 7 showes the connections between process step and database. It is possible that the employee needs information of several databases for one task. In order to support this, the techniques of the workbench are used. During the check of producibility an access to the databases *DB Defects, DB CITIM – materials, DB CITIM – molding processes, DB CITIM – design rules* is necessary. These information are filtered by the workbench. The arising new data helps the employer by the execution of the single process steps.

Workflow Management and Work Scheduling

During the process of elaborating documents for offers and manufacturing for castings a lot of different 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. Under real conditions the documents for a casting have to pass through several departments (work scheduling, construction, sale, manufacturing, ...), which are often locally separated. Different foundries use different concepts for the development of castings. That means, there are different information and documents in different foundries and very often the documents go bidirectionally between two sections. The consequence of exchanging documents multiple times is a loss of information and time. It is ascertained, that the reason for the loss of information and time are the idle periods of the documents in the single sections. In order to introduct a Workflow Management System it is necessary to reengineer the departments of the company. Furthermore, there is a differentiation in inquiry oriented data and manufacturing oriented data. The inquiry oriented data consist of data about the customer, like name, address, customer number, and of casting oriented data which are provided through the customer resp. they result from the inquiry. The manufacturing oriented data result from the workout of offer. These data are organized in drafts for producing the casting, like draft for the casting, draft for the rought cast product with rough sizes, scheme of allocation of sheets, drafts for models, core boxes, chills, or pressure die tools. Furthermore, dates and prices of the tools are necessary. This comprises times for molding, for core manufacturing, assembly of molds, fusing time, casting time and time to empty the molds. More information for processing are times and operations for after treatment and dates and prices for mechanical manufacturing. Specifications for manufacturing are blueprints for the allocation of sheets, introductions for quality checks, predefinitions for mold boxes, coating, packing and forwarding. In order to prevent the loss of information and time a control for the workout of offers is suggested.

In the phase of workout an offer in foundries a Control-System has several tasks, like control of the identified processes, management and archiving of documents of the offer (2D/3D-Data, conventional drafts, pictures, motions, ...), management of technological data (material, requirements, tasks of the casting, ...), and elaboration of post calculations (used for offers of similar or equal parts). The reduction of product development times, the reaction on the increasing product variety, a better quality of the products, and the adherence to a time limit (e.g. date of delivery) are requirements for the Workflow Management Systems. These points are conform with the requirements of the foundry. Here it is necessary to react on the increasing complexity of the castings and to improve the quality of the offers, in order to increase the correctness of the calculations. On this way it is possible to reduce times and costs.

The use of modern workflow technology is leading to a lot of advantages. The employees are disburded by routine work and so the productivity increases and the pass-through times and the costs decrease. An improvement of quality is possible through an integration of services and quality-saving measures. A flexible reaction on customer desires and an effective monitoring of the sequences can be obtained, in order to analyze and solve problems very quickly with the goal to increase the satisfaction of the customer. The processes in a company are accelarated which contain important decisions. The reason is the availability of the current data. Another reason are the optimized or reorganized process sequences of the company and the use of an automated control. An advantage is a description of the processes, the execution and management of administrative and technical processes. So, the computer-aided coordination of the tasks reduces the number of subjective failures and it is possible to change the process sequences.

The base for the development of a control is a metamodell, which describe all necessary data. In the application field “Casting Technology“ exist two kinds of sequences. There are pre-modelled sequences, which are offered by the system, and normal sequences. That means, these pre-defined sequences contains activities which are repeated executed during the casting design process. A sequence, a pre-modelled sequence too, consist of processes. A process can be a sequence again or a process step. A process step is the smallest atomar unit which can be assigned to an activity. It is also possible to assign a refined process sequence instead an activity [12]. Figure 8 represents the metamodell. The Workflow Management in the application field distinguish two layers, the technical/technological and the information technological layer. The technical layer is used in order to model processes and sequences of the application field.

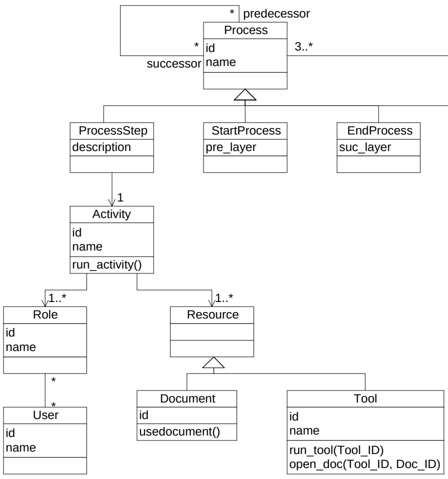

Figure 8: Metamodell for Sequences

A control system, which support especially the application field “Casting Technology“ was developed. Based on this control system the techniques of the workbench are used. These concepts and techniques are assigned to special processes and offered for instance as activities.

Conclusion

A multitude of analyses regarding efficient design of the workout of offers are executed. The aim is the reduction of the process time by increased quality. Some selected work steps of the workout of offers were profoundly analyzed, but not all particularities of foundries were considered. Contents of future works would be check the generality of the results in comparable companies. Independend on this work the analyses are to expand on the use of permanent molds.

This paper comprises multi-level analyses for technical/technological and information technological view. The technical/technological analyses contains the work scheduling in foundries. These investigations comprehends both the foundry equipment, the used techniques, and the casting design process and the used software solutions. The information technical analyses works with the available software and proposals for supportive software solutions were developed. Furthermore the casting design process with help of modern computer-aided techniques was a main point of this paper.

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