

Value adding process chain by Rapid Prototyping and Tele Engineering

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ABSTRACT

Advanced Rapid Product and Process Development (RPPD) is distinguished more and more by a high level of division of labour between different partners. Especially for aesthetically sophisticated and geometrically complicated parts the possibilities of Rapid Prototyping are widely used. The necessary 3D-CAD-Modeling, Rapid Prototyping applications and selected secondary processes are realized by specialized Service Bureaus. However, usually the customer requires complex solutions including product design, tool design and different secondary processes. Therefore the need for cooperation between Small and Medium sized Enterprises (SME) on a high communication level is given. The paper describes practical experiences of advanced Rapid Product and Process Development by means of Rapid Prototyping and Tele Engineering.

1. INTRODUCTION

Cooperation along value adding process chains is a general requirement for companies of all sizes – small, medium or large sized enterprises. Especially the automotive industry has got a high level of specialization and division of labour. More than 50 % of all components and parts are manufactured by subcontractors. This requirement for all companies developing and manufacturing new products can be characterized as follows:

- technical progress
- dynamic changing of the entire manufacturing process chain
- new technologies and processes
- increased complexity of the manufactured products and offered services
- consequent and efficient orientation on different and changing customer needs
- continuing improvement of the value adding process

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Based on these requirements the general goal of cooperative value adding processes consists of two main factors:

- Ability and willingness for an improvement of the company's performance – including the best possible utilization of newest technological experiences
- Networking and division of labour with competent partners

The dynamical development of the Rapid Prototyping & Manufacturing technologies during the last 10 years arose new requirements for the industry to incorporate these technologies and to utilize the given opportunities in the best possible way.

Currently more than 3,300 systems, based on 10 different physical principles and procedures, are available worldwide. Depending on the specific demands upon the RP models (design evaluation, functional testing or pre-series manufacturing) different systems can be used. Specialized service bureaus often take the part of 3D-CAD modeling, RP building process and selected secondary operations. In demand for secondary processes are especially Plastic Molding and Metal Casting.

Pre-selection and evaluation of suitable process chains for a specific manufacturing task should include several variants considering both the technological and the economical point of view.

Based on this more or less theoretical approach some typical problems in the Rapid Product and Process Development are shown in the following, using the development of some typical die casting parts as an example.

2. DEVELOPMENTAL STEPS OF DIE CASTING PARTS

So-called "system suppliers" for manufacturers of final products (e.g. cars complex automotive components like e.g. die casting companies) get more and more included into the design and development of new parts. To do so several tasks have to be solved. A general overview is given in figure 1.

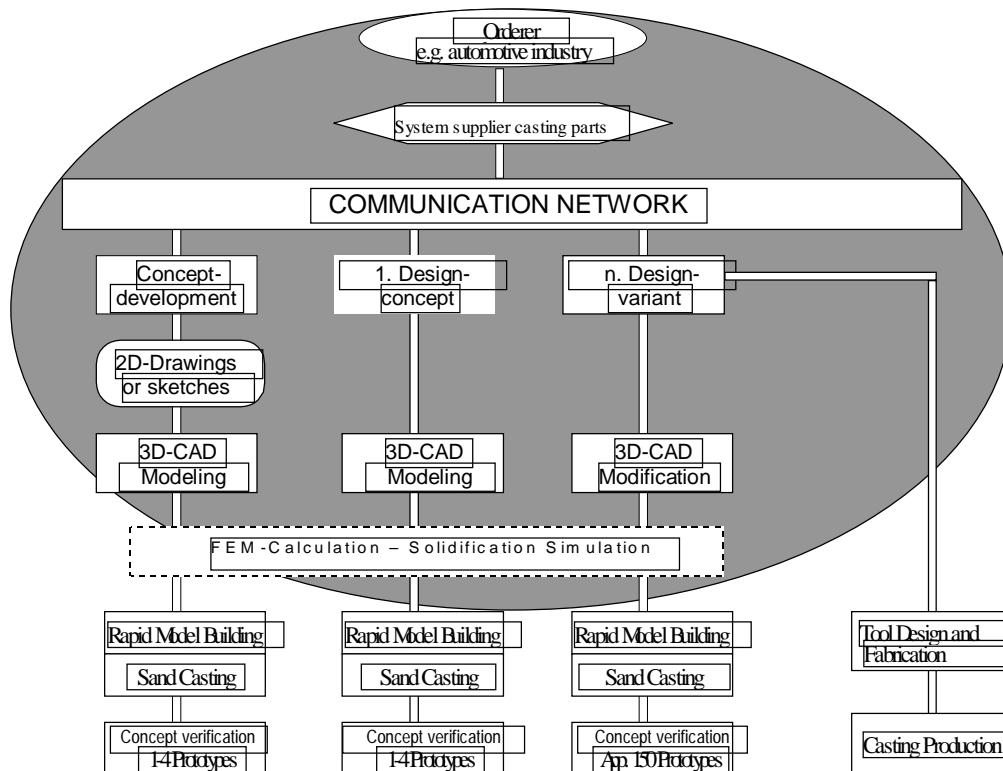


Figure 1: Communication network for the optimizing of the value-adding process chain

The practical realization will be demonstrated by an example "housing". The task includes the following process steps.

- Data transfer
- Data conversion
- Correction of the input data
- Data preparation for casting
- Rapid Model Building
- Sand casting
- Finish processing

2.1 Data transfer

The respective data, mainly 3D-interface-files like VDA or IGES are transferred using typical media such as streamer, network, modem and ISDN. In this case the files were sent by a 4 mm data cartridge. In order to avoid complications it seems necessary to record data exchange information. For this, the following protocol was developed.

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Data Exchange Information				
		Your Data		Our Data
Company				SFM GmbH
Street				Bertolt-Brecht-Allee 24
ZIP-code / City				01309 Dresden
Telephone				0351-3199-2365
Fax				0351-3199-2361
Videoconferencing number				0351-3119-806
Order Number				
File Names				
Contact Person				
CAD – Data Exchange				T. Himmer
CAD – Systems				T. Himmer
Network / Data Transfer				T. Himmer
Multimedia				T. Himmer
CAD Systems		CAD Version	Operating System Version	CAD Version Operating System Version
Pro/Engineer				Version 16 HP-UX 9.05
Strim 100				Version 2.1 IRIX 4.0.5
Other:				
System / Interface				
Pro/Engineer				
IGES / VDAFS / STEP / Direct				
Strim 100				
IGES / VDAFS / STEP / Direct				
Other				
IGES / VDAFS / STEP / Direct				
Media				
4 mm Data Cartridge				2 GB
1/4" Data Cartridge				150 MB
CD-ROM				yes
3,5" Floppy disk (1,44 MB)				yes
UNIX (tar, compress)				tar
DOS (copy, zip, arj, lharc)				
Encoding				
UNIX (binary, ASCII)				binary
DOS (binary, ASCII)				
Parameter for Data transfer				
Email address				
ISDN-number				
Transfer System				Fritz Data 2.03
Protocol				Eurofile, ID Trans
Multimedia				
System (ProShare, Netmeeting)				ProShare Version 2.1
ISDN-number				0351-3119-806
Data transfer				possible
Image transfer				possible
Shared Access to Applications				possible

Table 1: Data Transfer Protocol

As can be seen from Table 1 the Multimedia System "ProShare" is able to send data as well for example 3D-CAD, helper programs or viewer software. Such information are important for building time calculation or other process parameters.

2.2 Data conversion and correction of the input data

Data conversion means the translation of CAD-interface data into CAD-system internal data, quasi the import of VDA / IGES files. Now, errors resulting from the interface have to be corrected. This can be a time consuming process. For example it took one week to make all corrections.

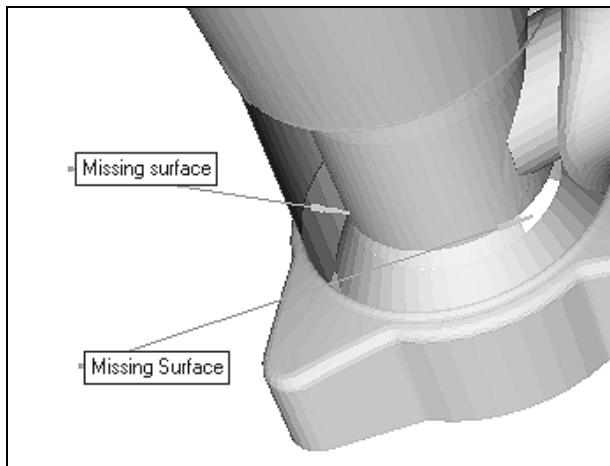


Figure 2: Input data

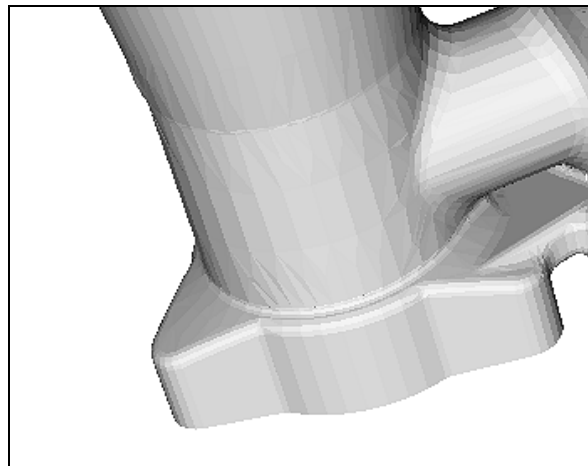


Figure 3: Corrected data

Especially shells or surfaces are missing as can be seen from figure 2. Gaps and holes must be closed and shells have to be regenerated. Holes which are drilled afterwards are closed as well. After this operation the result is a closed volume.

2.3 Data preparation for casting

In this process step the corrected files are prepared for the casting application. In particular, draft angles, roundings / fillets and allowances must be added, undercuts have to be removed and the parting surface is decided.

Using the Multimedia equipment occurring problems can be discussed "online" with suppliers, partners or customers. This will be shown with the undercut given in figure 4. Both sides of the video conference have access to the opened application, here an viewer software and can discuss the problem. Moreover, remarks and comments can be made from the video conferencing participants in different colors. The discussed changes can be saved as a notebook file for recording.

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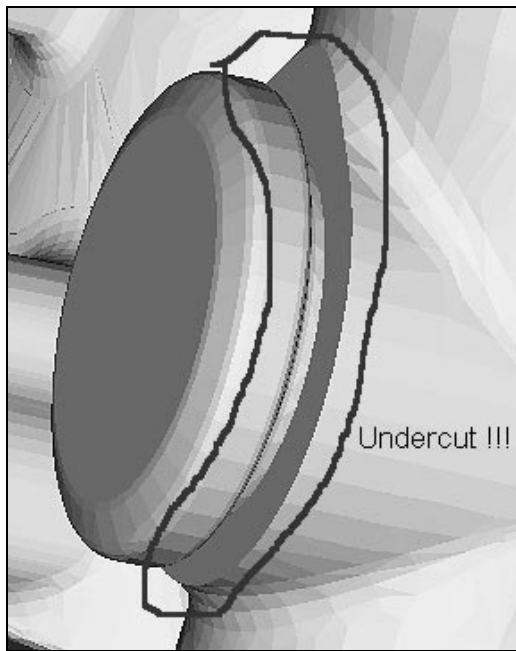


Figure 4: Undercut

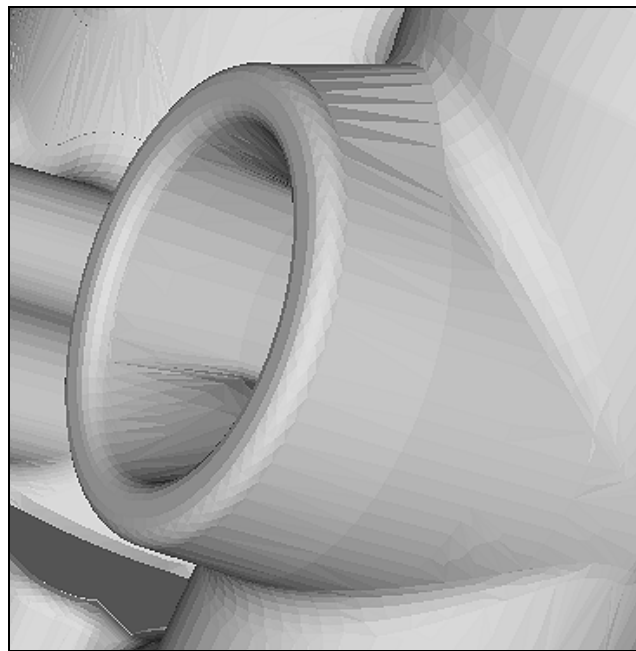


Figure 5: Undercut removed

The entire Multimedia / Tele-engineering system embraces 2 video cameras. One camera is called document camera. In case only technical drawings or sketches exist, the document camera is very useful to clear up technical details just in minutes without any faxes or scanned pictures. The drawings or sketches are put on the camera table and problems are discussed “online”. Making a snapshot with the same camera, discussed changes can be saved as well. Figure 6 shows the document camera and figures 7 one snapshot.

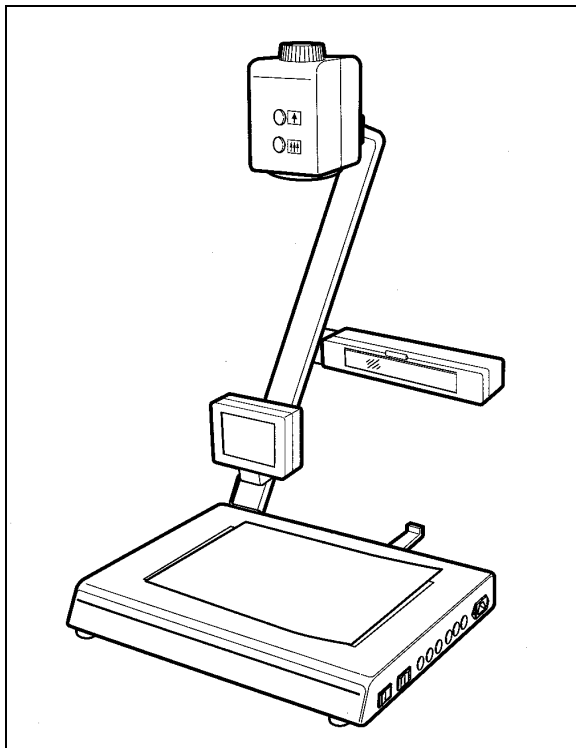


Figure 6: Document camera

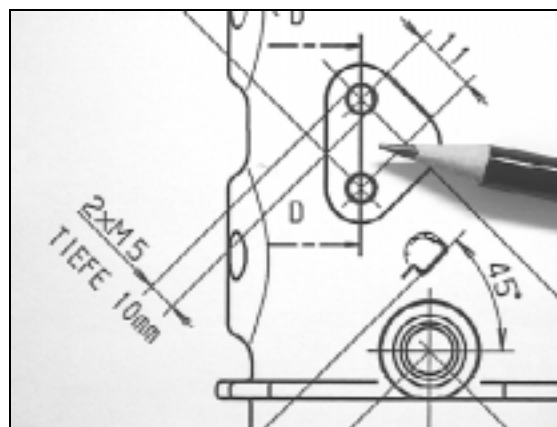


Figure 7: Snapshot of a technical drawing

2.4 Rapid Model Building

After the 3D CAD data is prepared, the casting models and core boxes can be manufactured. Here the LOM (Laminated Object Manufacturing) technology was used. Then, the fabricated models are finished by coating and surface treatments. Again, the document camera is useful to discuss questions "online". With zoom even very small details can be seen (figure 8). The stair stepped structure of the LOM model is clear visible. One advantage is, that the model remains in the company, thus the security is higher.

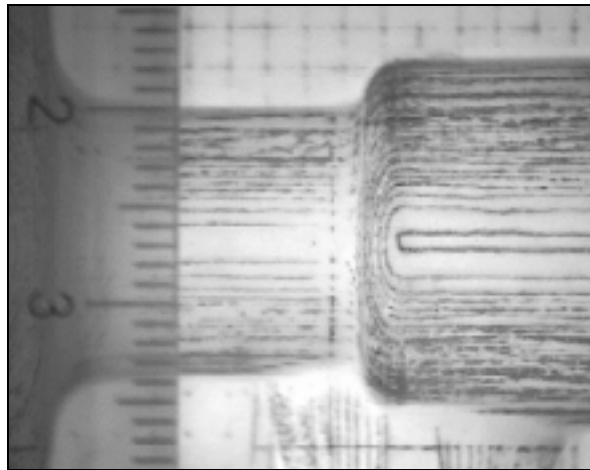


Figure 8: Detail of the LOM model

2.5 Sand Casting and Finish Processing

Similar as described above, manufacturing details can be analyzed using the Multimedia system. From the casted part digital images can be taken and transferred to the partners or directly discussed by Tele-engineering. Figure 9 and 10 show pictures of sand cast errors.

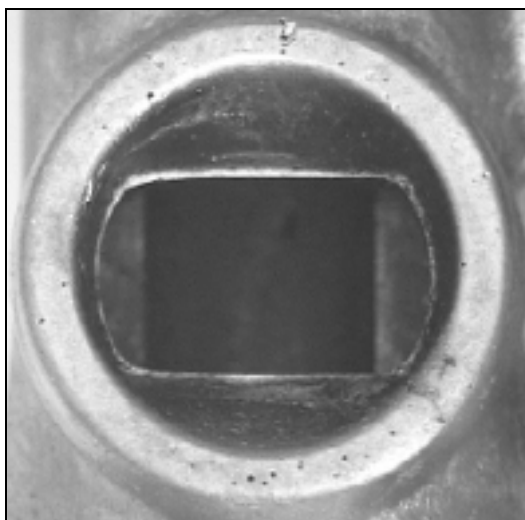


Figure 9: Air voids



Figure 10: Parting edge

If the final processing/machining provides a partner, good cooperation is essential. For better comprehension, the 3D-CAD data of the casting can be transferred with the Multimedia system. In addition, these data can be used for NC machining.

3. METHODOICAL SUPPORT FOR DECISION MAKING

When the foundry company receives the inquiry – either directly from the customer or from the RP service bureau – the foundry engineer starts with deciding on the casting technology for the enquired part. The following has to be determined in the named order:

1. casting process (sand casting, investment casting, die casting or other)
2. non-castable features (undercuts, extremely thin-walled sections, small drillings and others), modifying them into castable ones or deciding on leaving them for machining (includes consultation of the part's actual designer on possible modifications that don't influence the part's functionality)
3. raw casting design, marking of all features to be machined in the drawing (to be able to enquire a competent partner about machining)
4. pattern and core box design (roundings, parting line, core marks) including parameter settings (shrinkage factor, draft angle, machining allowances and more)

At this time it is done only roughly to be able to determine manufacturing costs and delivery time. The RP service bureau has to determine the CAD modeling effort for the casting design modifications, the number and size of all Rapid Prototypes to built (split pattern, multi-part core boxes, shaped follow board to determine the parting line). The NC machining specialist has to determine the machining costs.

When the customer's 3D CAD data arrive at the RP service bureau via interface (IGES, VDAFS, STEP or other) the work starts with repairing of the received data. This is due to a loss of geometrical and topological information that always occurs when using neutral interfaces. Depending on the CAD systems used by the customer and the PR service bureau this loss might be insignificant or serious what results in more or less time consuming CAD work.

When the original 3D model is restored the actual design modification to meet casting demands starts. From this point the close cooperation between the CAD designer (RP service bureau) and the foundry engineer is very important for the success of the project. Methods of Tele Engineering and utilization of the newest telecommunication technology described in the following chapter play a key role in this cooperation. The methodical support of the CAD designer by the foundry engineer starts with a check list. The general „check list for the CAD designer“ containing design rules for casting parts, patterns and molds which is described in

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[ⁱ] has to be adjusted to the actual part. Table 1 shows this for an example part – a housing for the automotive industry.

Modification of part design to meet casting demands	<input checked="" type="checkbox"/>
<i>generally:</i>	
1. shrinkage factor +1.0 %	<input type="checkbox"/>
2. draft angle 1°	<input type="checkbox"/>
3. machining allowance 2.0 mm where marked in drawing (details ① - ⑦)	<input type="checkbox"/>
4. matching bolts and nuts implemented in the pattern and core box halves for positioning the halves to one another	<input type="checkbox"/>
5. replace sharp edges with roundings	
6. ...	<input type="checkbox"/>
<i>patterns:</i>	
1. solid (massive)	<input type="checkbox"/>
2. split pattern (2 halves, bending parting line, see sketch 1)	<input type="checkbox"/>
3. close drillings M8 and 3/8'' (see sketch 1)	<input type="checkbox"/>
4. remove undercuts at 2 of 4 cuttings at the torus (see sketch 1)	<input type="checkbox"/>
5. dimensions of core marks see sketch 1, front side draft angle 5°	
6. draw the two features Ø16 in its full length down to parting line	<input type="checkbox"/>
7. modeling a shaped follow board that defines the parting line (height emerges, juts out 20 mm on all sides of the pattern – sketch 2)	<input type="checkbox"/>
8. ...	<input type="checkbox"/>
<i>core boxes:</i>	
1. split core box C1, bending parting line (see sketch 1), 3 core marks (at ④, ⑤ and ⑦)	<input type="checkbox"/>
2. split core box C2, 3 parts (2 halves, 1 basic plate), even parting line	<input type="checkbox"/>
3. simplify inner diameter 30 - 41H7	<input type="checkbox"/>
4. adopt core marks from the pattern	<input type="checkbox"/>

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5. filling orifices marked with „⊗“ (see sketch 1) – no inclining of these core marks	<input type="checkbox"/>
6. core-in-core marks at ③: draft angle 2°, changing the cross section's shape from round to angular (core lock), raw diameter 10 mm (i.e. less than 2 mm machining allowance)	<input type="checkbox"/>
7. ...	<input type="checkbox"/>

Table 2: Specific check list for the CAD designer to modify the part design to a complex casting pattern design for a housing from the automotive industry

The CAD designer uses this check list as a guideline for his design modification and works it off step by step. Questions during this work have to be answered by the foundry engineer (by telephone, fax, Email and data transfer, video conference, other means of telecommunication or personal). After that a first draft of the casting pattern has been created. Proceeding simulation of pattern removal and core box opening (draft check) in the CAD system or other software helps determining undercuts, insufficient draft angle or other problems. Especially when the parting line is bending or otherwise uneven it is often very difficult to ensure a pattern and core boxes free of even the slightest undercuts.

Another important step is to determine and minimize necessary machining allowances. It is often uneconomical or even not possible to apply machining allowances according to German standard DIN 1688, part 1. In the case of the housing machining allowances were set to 2 mm, at a pre-cast drilling even as low as 1 mm.

In some cases the casting technology has to be modified because of design features which become visible during the pattern design process. In the case of the housing the splitting of one core box had to be changed significantly.

Some problems come up just after the RP generative process. Using the LOM technology for Rapid Prototype Casting Patterns makes it possible to modify the finished model by traditional pattern making methods [11]. For the housing the following modifications were done:

- adding material to the shaped follow board (LOM waste material and epoxy resin)
- sanding material off the board to create a draft angle not considered during CAD design
- adding draft to both pattern halves to a feature with an undercut (epoxy resin)
- mounting wooden top plates onto the core boxes to make them serviceable on a sand core injection machine

4. APPLICATION OF TELE-ENGINEERING AND ADVANTAGES

Multimedia can be applied in any engineering sector. The specific application may differ, but many functions of the Multimedia equipment are useful not only for technical purposes.

It can be concluded that video-conferencing systems such as ProShare are very practicable for engineering purposes. Several video conferences with casting companies have shown the potential of Tele-engineering.

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For example, the entire data preparation for casting applications can be done "online", without spending a lot of money and time for traveling. 3D-CAD files, pictures, sketches, video sequences or sound files can be transferred, shared and recorded. Moreover, it is possible to do Tele-engineering "online", because many applications can be shared. That means, both sides have access to the application, e.g. Word, Excel, 2D-Modelling software or 3D-Modelling software like SolidWorks. In other words, design changes can be made with two or more participants of one video session.

2D and 3D "Online Tele-engineering" was successfully tested, however the hardware requirements are quite high. Upgrading the hardware, especially memory (128 MB) is essential to improve the system performance. The next step is "online" training (usage/handling of the software) in the field 3D-CAD Modeling.

Security issues like installation of "fire-walls", encoding, recording of video sessions are further tasks that have to be solved.

5. SUMMARY

Better work division and cooperation between different companies can be supported by Tele-engineering.

The paper described first experiences for application of Rapid Prototyping and Tele-engineering in the foundry industry.

The practical results demonstrate some effects for efficient problem solving.

6. LITERATURE

- [i] Müller, Bernhard: Casting design in the age of 3D modeling; *Gießerei* 85 (1998) Nr. 2, 10 Februar, pp. 56 – 60
- [ii] Kochan, Detlef; Müller, Bernhard: Better casting quality by the use of improved LOM patterns; *Gießerei* 84 (1998) Nr. 13, 30 Juni, pp. 17 – 22

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 - [ii] Kochan, Detlef; Müller, Bernhard: Better casting quality by the use of improved LOM patterns; *Giesserei* 84 (1998) Nr. 13, 30 June, pp. 17 - 22