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Knowledge integration in CAD-CAM process chain

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ABSTRACT

Many conscious or unconscious decisions of the designer directly sets manufacturing steps. Currently the information for the steps have to be recreated by the production planner. In other cases the manufacturability is not guaranteed. This paper will show, how a manufacturing knowledge integration in CAD systems will support the planning and work preparation. This knowledge is distinguishable between conventional and additive manufacturing. This paper shows how knowledge can be implemented in CAD systems with different integration depths to reuse them in CAM systems. For this, the knowledge will be extracted from structured text files (such as XML files) by an expert system. Another possible source is a database with company and international standards, which can be accessed directly or through a web service. Furthermore the benefits of web services in that field will be analyzed.

KEYWORDS

Knowledge based engineering; linking of knowledge domains; integration of knowledge; API programming; web services; databases; conventional and additive manufacturing

1. Introduction

Knowledge Based Engineering is an omnipresent topic in the CAx environment. Engineers of different departments are trying to define their knowledge to implement this in CAx systems (e.g. CAD or CAM systems) [2]. The aim is to minimize routine design time for recurring task or following tasks. With this the creative design time can be increased (Fig. 1). [6] For recurring tasks, the system the Engineers are using doesn't change. To support this tasks the CAx systems has to be modified. For increasing the following tasks, the interfaces between CAx systems has to be analyzed. In both cases an expert system is necessary to implement the functionalities to the CAx systems. In this paper knowledge transfer examples are shown between design and manufacturing.

Many tasks the designer has to do can be automatized. But the current CAD systems doesn't offers all needed functionalities. For e.g. if a keyway has to be attached to a shaft, the designer gets at best a user defined feature to attach and (s)he has to look for the right size by checking the shafts diameter. Then (s)he has to look in the standards, which key can be used. If the company and international standards are digitalized and saved in a database, an expert system can analyze the possible various sizes and let the designer just select one of them. The tasks of diligence can be done automated. In this step the template of such features has to be more intelligent. The information which are needed for manufacturing are determined with the selection of the size. The data, required by the production planner, has to give him as a suggestion, so that (s)he can use this data or discard it, but not has to look for it once again.

By looking at the process chain design and manufacturing in additive manufacturing, the conditions differ from conventional manufacturing. The designing process is very dependent from the additive manufacturing system and the settings for the specific build process. Also in this area there are benefits by supporting the designer with knowledge to reduce the queries to the production planner.

2. CAx systems knowledge integration

Almost each department has different knowledge domains. These differentiate for the data and information which the domain contains and in the way these are stored. The first step is to think about possibilities of linking knowledge domains.

2.1. Extracting knowledge for integration

Initially the knowledge of an expert has to be defined and stored in a structured way, so that the expert system can access this data correctly. This step can nearly be done independent of the expert system. Just the extracted data has to be saved in a way that is readable by several systems. The data of company and international

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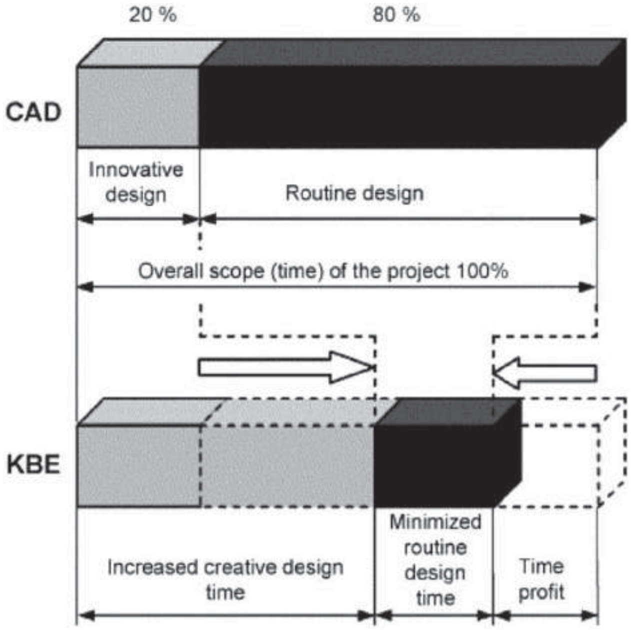

Figure 1. Advantage of using KBE in design process [6].

standards are usually saved in tables. The information about the logic of using and connecting the data can't be saved into a table easily. Regarding the conventional and additive manufacturing, the required process data is not the same.

While designing parts to build with conventional manufacturing, the designer doesn't need to know which machine will manufacture this part. The production planner knows the information about required cutter etc. Most important difference, the machine and cutter are selected after designing the model. In conventional manufacturing each part is manufactured alone. All these data can be saved in tables easily, for e.g. machine or cutter parameters [4].

While manufacturing parts in the additive way (like Selective Laser Sintering (SLS) or Selective Laser Melting (SLM)), many (same or different) parts are built together to make use of the whole build space. So the process settings define the design parameters. For e.g. the reachable surface roughness is dependent from possibly added supports or the slightest gap between materials is depended from the process settings. For this an AMP-XML file was created to define all process parameters including machine data. This file can be filled by the production planner with the AMP-Tool [5]. Fig. 2 shows the application and interfaces between engineering and work preparation in additive manufacturing.

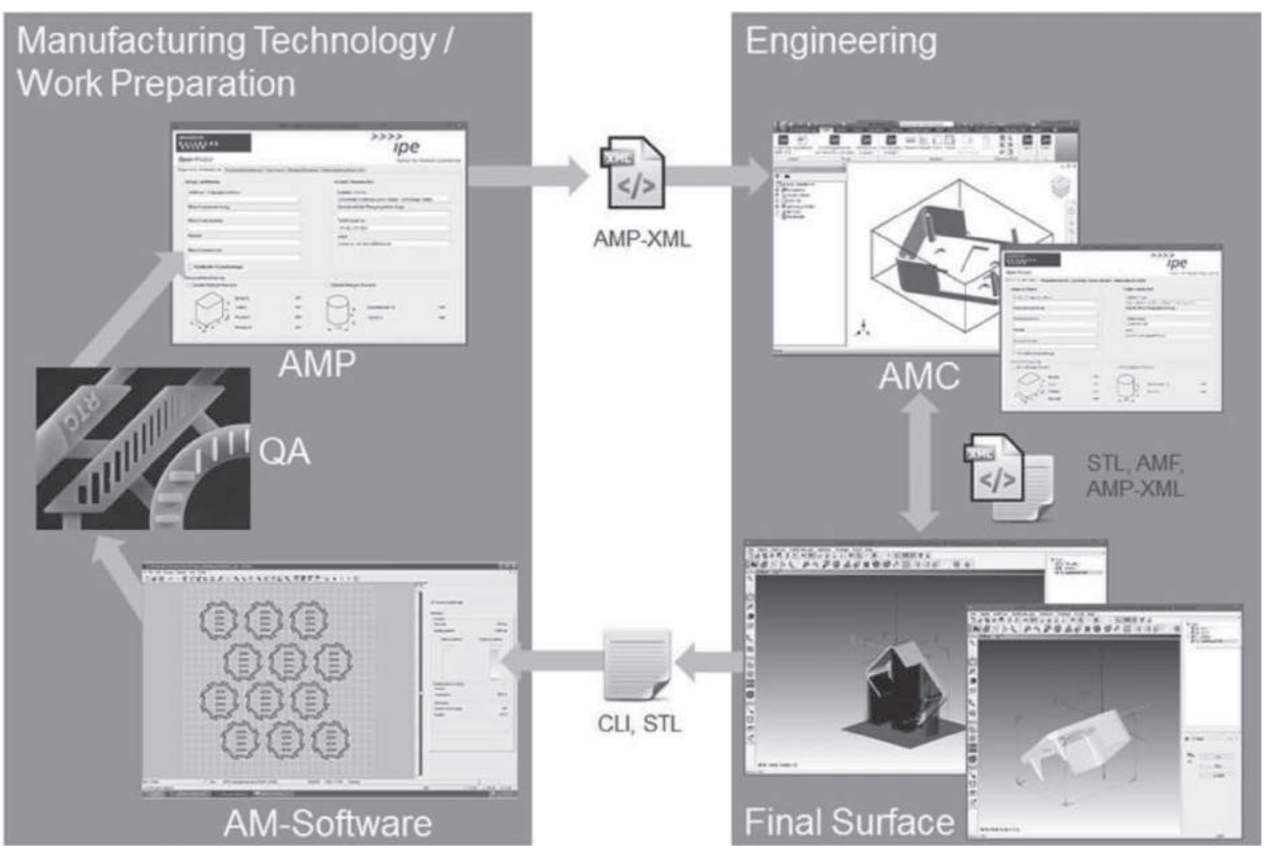

Figure 2. Application and interfaces in additive manufacturing [5].

2.2. Expert system

To implement knowledge into the CAD system without additionally burdening the designer, it is necessary to use an expert system. There are different types of expert systems which can be distinguished between the integration depths in the CAD system. To implement manufacturing knowledge into the CAD system, an integrated KBE system is necessary, especially when disturbing the workflow of the designer is not desired. In this depth of integration the design of the expert system is very much dependent of the application program interfaces (API) of the CAD system. The expert system can offer functionalities over the view layer or let functionalities act on specific events. The knowledge technology reads the relevant data into the repository, handles these depending on the request and transfers it into the CAD model (Fig. 3).

For conventional manufacturing the expert system offers functionalities to set geometry, semantic information and manufacturing information for standard elements like undercuts, center hole, circlip groove etc. Compared to the additive manufacturing functionalities, these functions can be used without explicit connecting the knowledge data. In additive manufacturing each CAD model has to be linked to the specific AMP-XML file by the designer. Here functions are included like showing Bounding Box of the parts or the Build Space of the specific additive manufacturing system with or without shrinking. The designed part can be analyzed with the process information saved in the AMP-XML file by the production planner.

2.3. Accessing data

The knowledge saved as data in the XML files, similarly simple text files or JSON files can be read with different parsers in nearly each programming language. XML and JSON are structured files and should be preferred. The data can extracted by the keywords. By using simple text file the structure of the file has to be known by every expert system. The validity of XML and JSON files can simply checked with XML Schema [1].

With equal ease the data of a database can be read. Nearly each programming language offers database connectors to request data by sending a SQL Select statement. But for this each expert system has to know the structure of the database and the needed SQL strings. In most

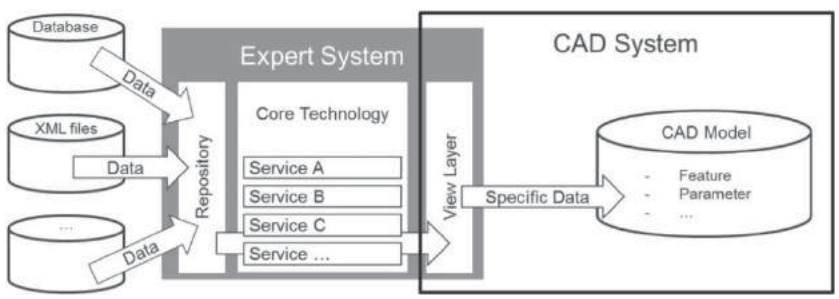

Figure 3. Integrated KBE system.

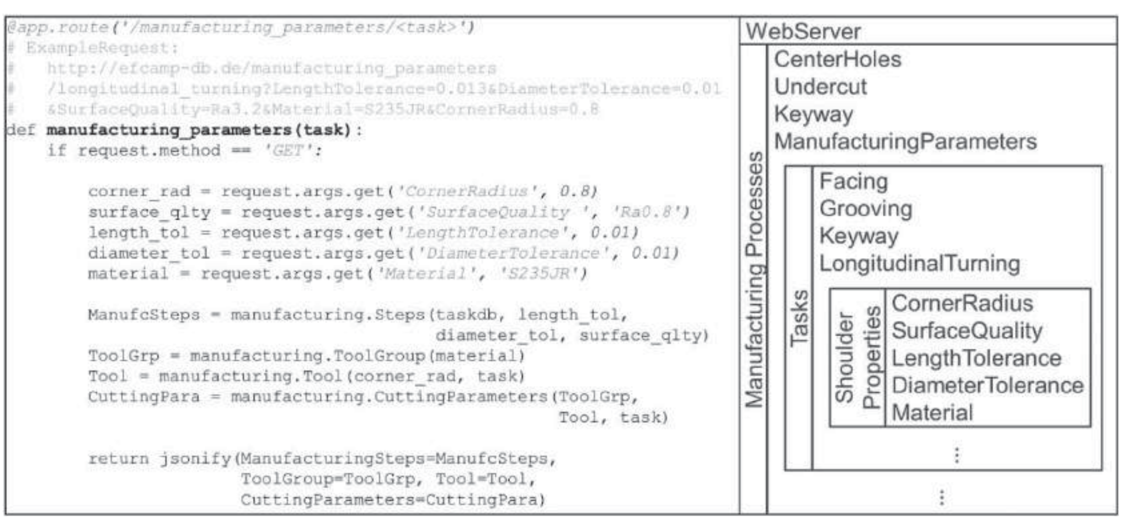

Figure 4. Structure of web service.

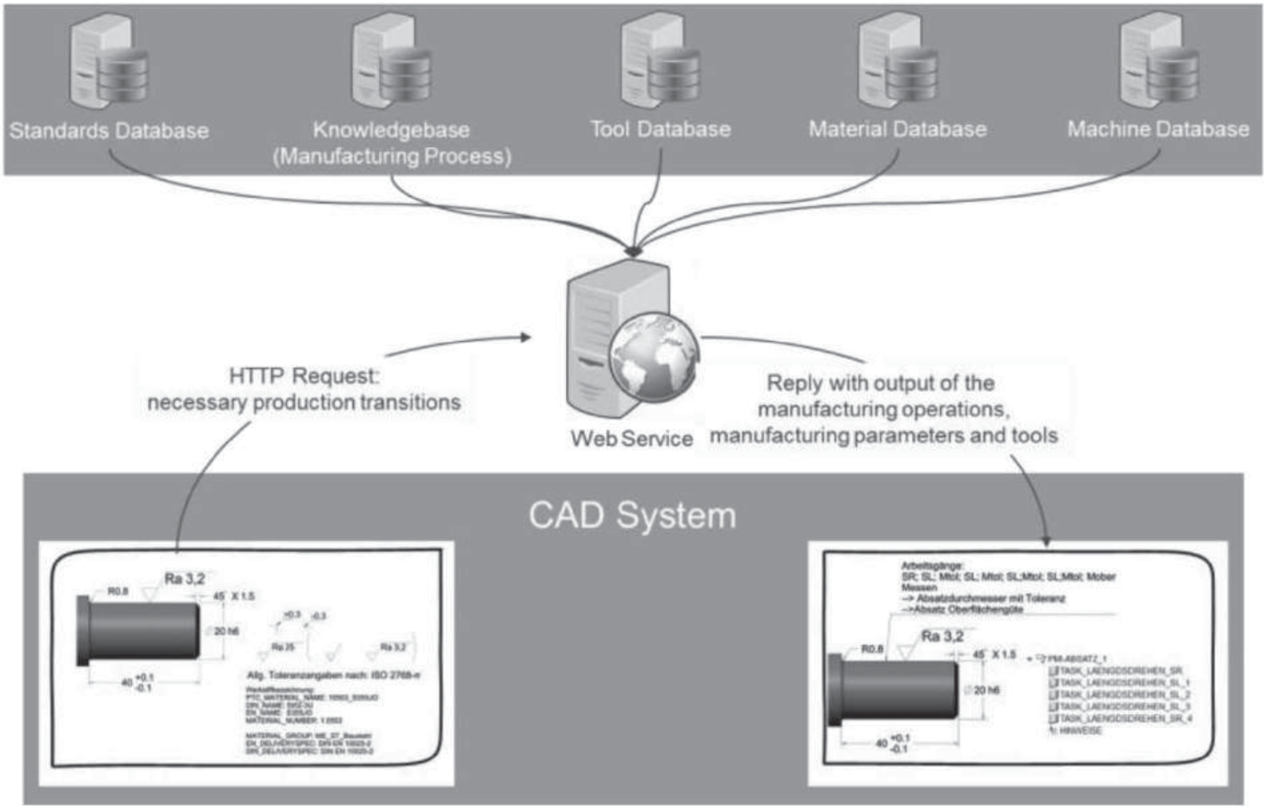

Figure 5. Web service to get database information in CAD system.

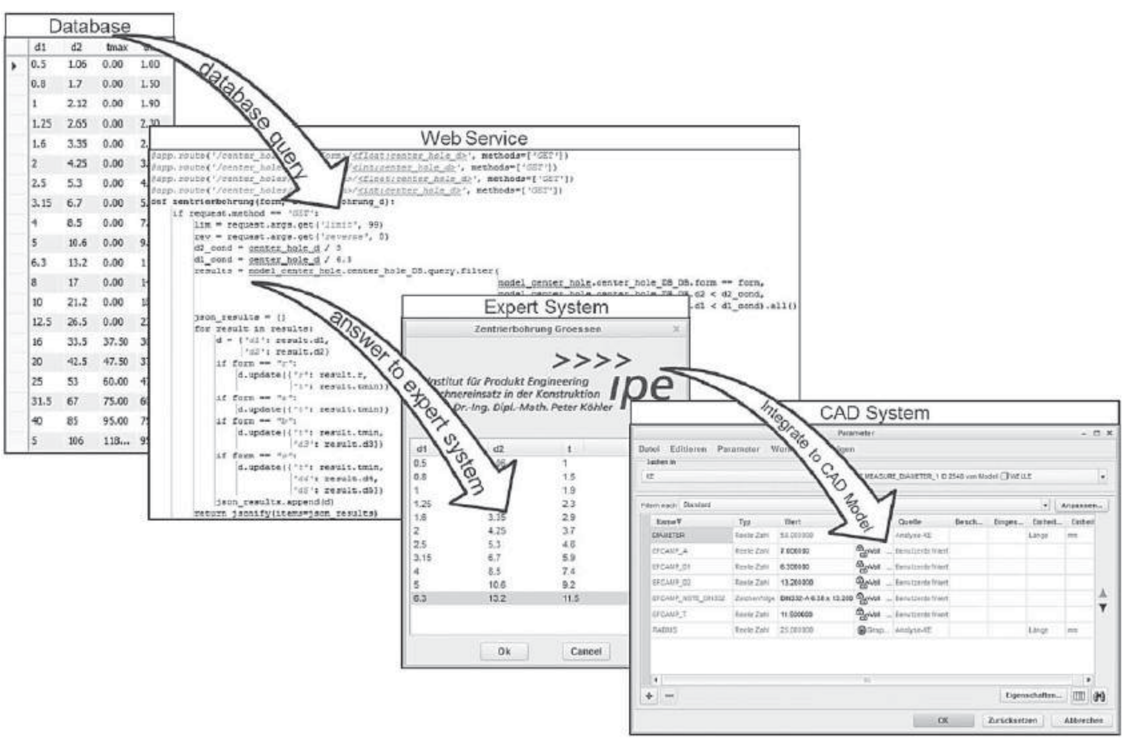

Figure 6. Workflow of knowledge integration.

cases the standards are dependent of many information, which are connected with other standards or tables. Just filtering a table of standards is not enough to get a form of a standard. For this database function are necessary or the logic of the data dependence or every special case has to be defined in each expert system. In that case the database cannot be changed in its design or source. For example switching from an international to a company standard requires changing all expert systems of each CAx system using this standard.

For this the access to the data is managed by a RESTful web service [7]. By using web services the needed information can be obtained by a HTTP request. The URL contains all information that is necessary to get the answer from the web service (Fig. 4). The web service contains the logic to get the data of the table or other sources like files etc. and to connect these in the right way. Depending on the web service the answer can be a JSON, XML, HTML or other formats. The expert system can validate this answer with the schema and read the data with the parser (Fig. 5).

In case of changing the structure of a database or similar, it's just necessary to adjust the web service. There is no need to change the expert system in that case.

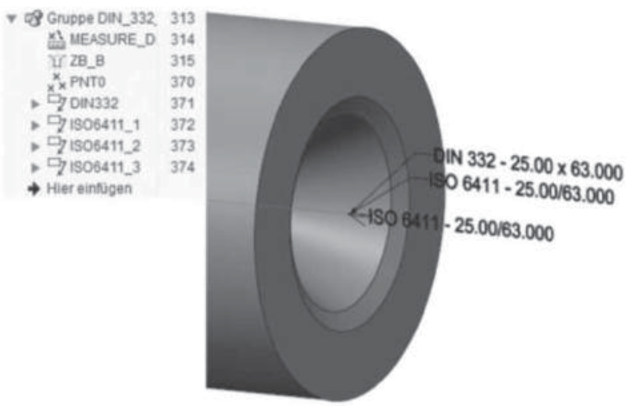

Figure 7. User defined feature to implement knowledge in feature.

2.4. Knowledge integration

The expert system has to implement the knowledge into the CAD system. The integration depth depends on the

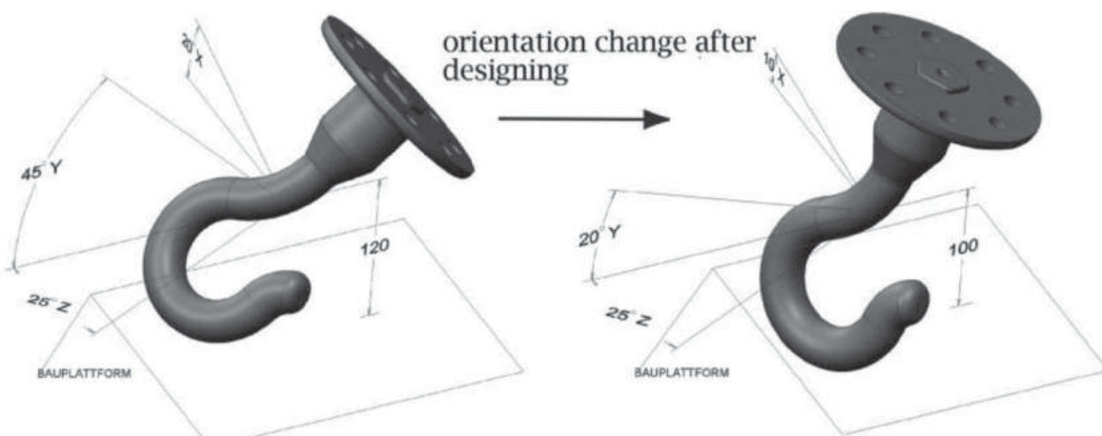

Figure 8. Changing orientation and position after designing.

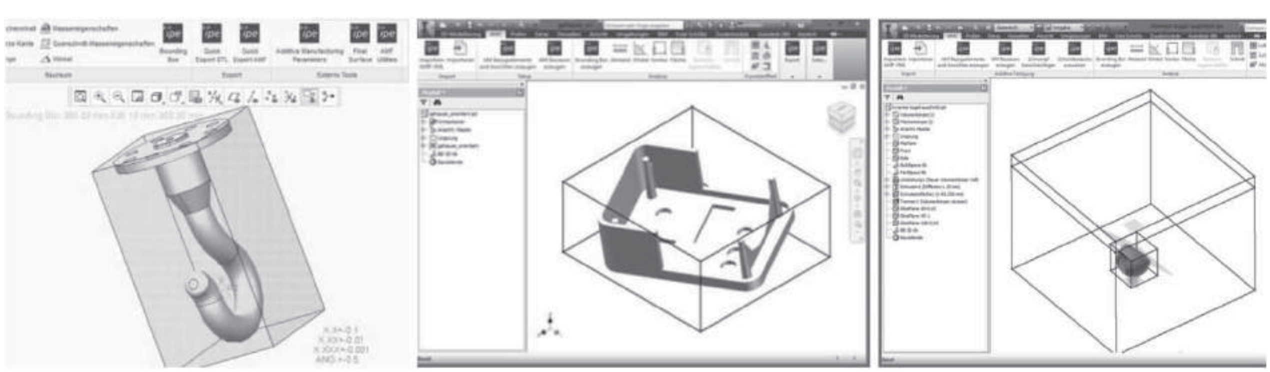

Figure 9. Knowledge integration in additive manufacturing: (a) Bounding Box in Creo, (b) Bounding Box in Inventor, (c) Build Space with and without shrink in Inventor.

type of information. Most of the data extracted are saved as parameter in model or in feature. Here it is not enough to save the data only, a time stamp and the version of the standard has to be saved also as information for better traceability. According to this, the designer has to decide if the expert system should keep the knowledge on the current status of the database or leave it at the last state. Fig. 6 shows an example of knowledge integration

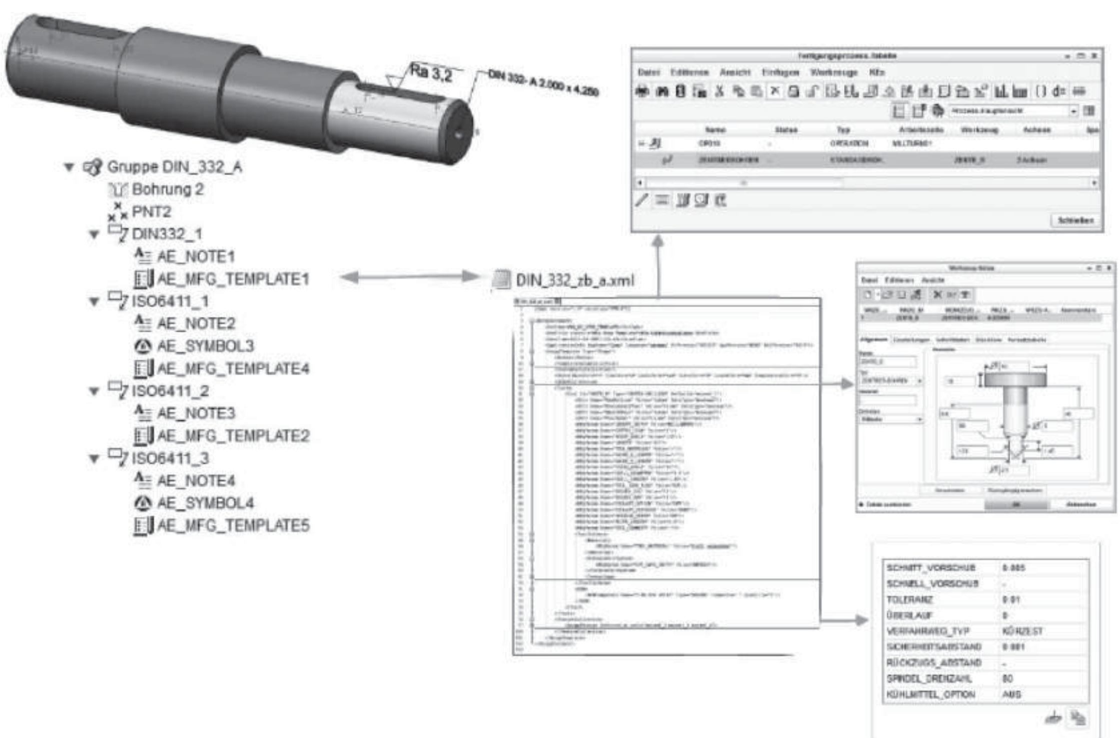

Figure 10. Extracting manufacturing information from feature to CAM module.

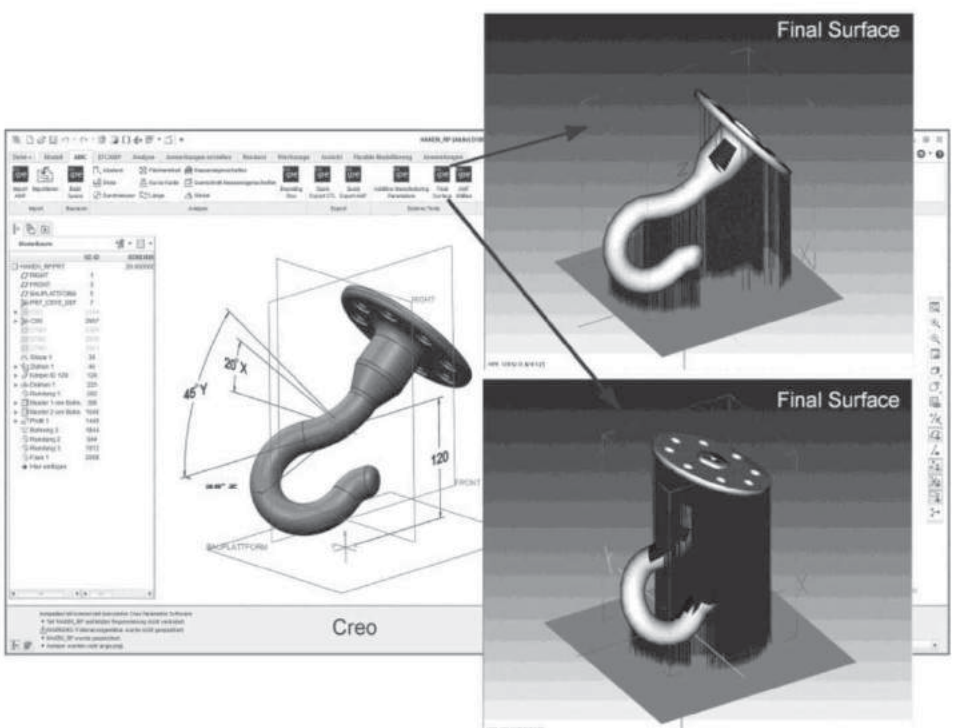

Figure 11. In-design evaluation of support structures in Final Surface (GFaI Berlin, www.final-surface.de).

in Creo. First the expert system starts a query from the database and filters data to the possible forms. The designer gets an offer of possible sizes. After selection one set, these parameters are transferred to the feature in the CAD system.

Anyway a preparation of the model is a basic prerequisite. Either the preparation has to be done manually before integration or it has to be done by the expert system. In conventional manufacturing the feature are prepared and saved as user defined features (Fig. 7). These individual groups always contains an analysis feature with all information which are required for the query. If it is not just a semantic feature, then there are feature to create the geometry. Finally there is always at least on note feature. This note contains different manufacturing templates, where manufacturing information can be saved [4].

In additive manufacturing the only prepared item is the part template. One of the most important function is changing orientation after designing the part. So the part can be brought to the position and orientation of the build process in the machine after designing the part (Fig. 8). Depending on the build orientation the quality of the part and the build time directly changes [3].

All other information are implemented directly by the expert system without preparing the model. Examples are the build space of the additive manufacturing machine, bounding box of model or slice data (Fig. 9). These functions can help the designer to check the model manufacturability without consult each time the production planner.

2.5. Using knowledge in pursuing CAx systems

In conventional manufacturing the knowledge can be extracted automatically from the CAM module of the CAD system, by reading the information from the manufacturing template (Fig. 10). In other CAx systems constellations the transfer of knowledge has to be done by expert systems which convert the knowledge from one domain into another. In some cases the knowledge can't transferred directly. Then a structured text file, for example JSON file, is needed to provide the implemented knowledge for other systems [4].

For additive manufacturing a direct transfer trough the expert system is realized, where the process and model information are transferred to Final Surface (Fig. 11) [5]. Here the geometry is transferred in an intermediate data exchange format. Additionally the orientation, the slice data and other information are submitted.

3. Summary

This paper shows how a knowledge integration in the CAD model can increase the own but also following tasks. Mainly the knowledge integration should help the designer to create parts or feature which can be produced without recurring demand. The production planner gets additionally to the geometry of the model a suggestion of manufacturing parameters. The production planner can accept, refine or discard these.

The implementation has shown, that connecting different information in one point is useful. In that case changes should not require changes in the CAD system or in the database. Just the adjustment of the web service is required.

Just in comparing conventional and additive manufacturing it can be seen, that the approaches are different. Conventional manufacturing require company specific manufacturing parameters, when additive manufacturing require process specific parameters which can provided by the production planner with the AMP-XML file. The main benefit is to reduce the constant iteration between current and following tasks.

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