THE CHALLENGE OF HANDLING MATERIAL INFORMATION FROM DIFFERENT SOURCES

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ABSTRACT
Nowadays there are a lot of different kinds of material information needed in the product development process. This article will analyze the challenge of handling material information from different sources and different phases in the development process of the automotive industry. The needs for various kinds of material information are analyzed by different subjects (legislative regulations, construction design, strategically requirements). The information sources are examined in order to understand the differences and the reasons for the difficulties that occur when integrating the material information into the systems and sources. As a result the main problem will be identified, which is the different semantics or naming of the materials.
Two possible solutions to overcome the difficulties and to make the available information accessible are evaluated and compared. These approaches are a data warehouse and an intelligent search engine. On the basis of the evaluation the search engine approach will be identified as the preferred one. While a more sufficient solution to solve the problem of the many sources is presented, this article also provides a solution to overcome the problem of the different semantics.

Keywords: Material information; heterogeneous systems; integrating material information; semantic problems

1. SCHEME OF THE PRODUCT DEVELOPMENT PROCESS
The basic process scheme is divided into different phases (see figure 1). Some of the phases are divided into several sub phases which are not shown in figure 1.

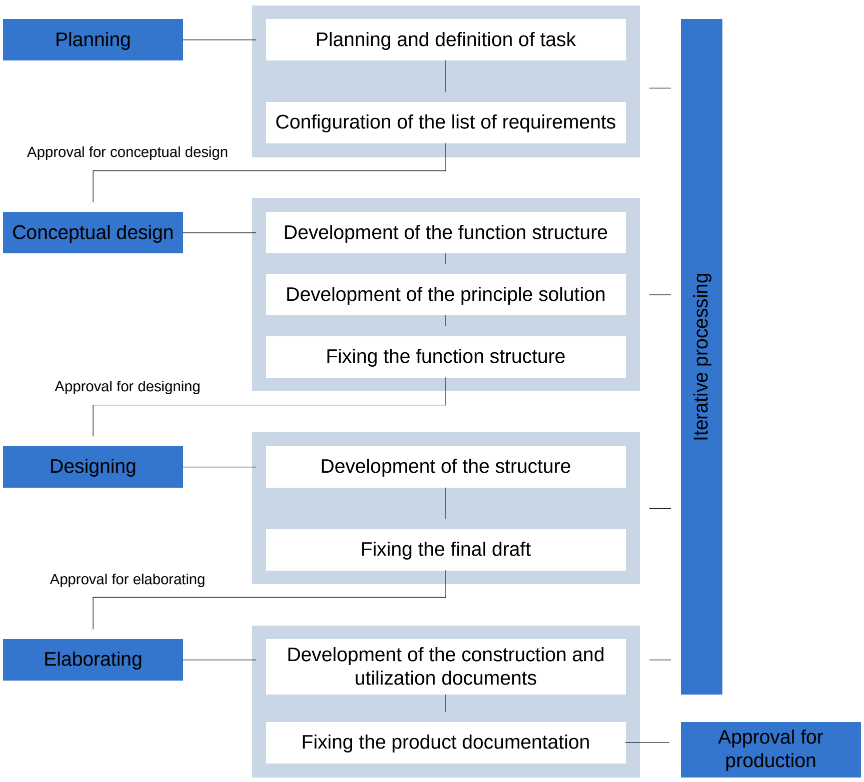

Figure 1: Basic phases of the product development process [10]

The phases of the development process are in chronological order, so after one phase is finished, the next one starts. At the end of every phase a catalog of criteria has to be fulfilled in order to proceed to the next phase. These catalogs contain checklists of certain decisions that have to be made up to that point (e.g. exterior design, material composition, validation of parts). The selection and validation of the materials is part of the criteria. The available information is increasing throughout the process in quality and quantity [3].
During the product development process numerous external partners are involved. This collaboration between BMW as the OEM (original equipment manufacturer) and the suppliers can have three major forms:

- One or more parts are developed completely by the supplier. So the supplier is responsible for the development of that part but is integrated in the development of the whole product (e.g. a car). The documentation is provided by the supplier.
- One or more parts are developed by the OEM but in close collaboration with the supplier that will produce and deliver the part. The documentation of the development data is provided by the OEM.
- One or more parts are developed by employees of a supplier by order of the OEM. The documentation has to be done at the OEM but by the employees of the supplier.

The development data includes all data regarding the materials. The material data consists of the name of the chosen material, incl. the standard, and all data that led to the choice of the material. This data consists of the simulation data, the results of test runs and the properties of the material (physical and chemical).
Because the data is provided by different sources the occurrence of semantic differences is a common consequence. In this work the focus is on the different semantics regarding material information.

2. EXAMPLES FOR INFORMATION NEEDED

The reasons for the need of new and completely integrated material information is divided in two different origins: One reason is the obligation to be able to report detailed material information by law, the other reason is the requirement of the development process, also influenced by newer strategically motivated reports, that need a lot of material information such as environmental life cycle assessments. In order to fulfill all these requirements some new material information is needed.
Integrated material information means in this case that the material information of the various sources are matching and complementing each other. That consists the same naming in the different sources opening the ability to analyze the material information from different sources automatically.

2.1. Development process

In the “traditional” fields of product development the following standard set of material information is needed:

- Design: Designing the parts with individual materials to make sure, that all requests (stability, design aspects, weight, etc.) to this part are fulfilled.
- Simulation (finite element analysis): Verifying the chosen materials in an early phase of the development process regarding strength and durability.
- Compliance: Information for proper documentation (tests, naming, assembly instructions, etc.) of the chosen materials.

Construction and simulation data is punctually needed during the development phase. In regards to compliance it is important that all the information leading to the choice of a certain material is available for a long time period. In case of functional failure in a part the manufacturer has to proof that he did everything possible to exclude the material or design as cause of the failure.
Additionally there are more and more new fields in the development process that need a very specific set of material information. These fields are for example:

- E-mobility: Information like magnetic properties or conductivity is necessary. In addition knowledge in battery design and materials is necessary and wasn’t common in the past in the automotive industry.

- Lightweight construction: Using innovative materials as carbon fiber. Building up expertise in fields of process ability or safety issues is required. Of course, this includes the individual material properties.
- Environmental lifetime assessments: Regarding the environmental lifetime assessments information like the global warming potential (GWP) for the materials are needed.

Because of the above shown complexity in these individual topics, there are several departments involved, including one department specialized in the material information.

2.2. Regulations by law

Regarding the automotive industry in Europe, there are two important regulations (2000/53/EG and 2005/64/EG) by the European Union [7,8]. These regulations require two reports: the material composition in seven categories (metal, polymers, rubber, modified organic natural materials, glass, liquids, other) to guarantee the recycling quotes and the compliance with the prohibited materials. This information has to be presented along with the start of the production and is a requirement for the type approval. To fit these requirements the material information has to include the chemical composition of every part build in the sold cars. Currently the four substances Chromium(VI), Cadmium, Lead and Mercury are prohibited in the regulation 2000/53/EG.

To fulfill the requirements of the ELV directive 2000/53/EG regarding the recycling quotes, the reuse and recovery has to be at least 95 % and the reuse and recycling has to be at least 85 % of the vehicle weight [8].

There is an emerging field that requires completely integrated but still very specific material information. This field is the REACh (Registration, Evaluation, Authorisation and Restriction of Chemicals) legislative. REACh needs the chemical composition for every single produced part and sold article. The major difference to the prohibited substances by 2000/53/EG is that potentially the usage of every substance can be restricted by REACh [11].

As a result the monitoring of the used substances is not restricted to the individual components of the product but affects everything that is sold by the company. The new challenge coming up with REACh for a vehicle manufacturer is the fact that also the accessories and merchandising articles have to be monitored. So the amount of material information is increased significantly as does the number of suppliers providing material information.

The EU is not the only market with regulations like the above mentioned ones. There are more and more markets with similar laws (e.g. Japan, Korea, China).

Considering the complex requirements by law, the need for integrated material information gets crucial. If the legislative requirements can’t be satisfied the consequences will be significant. It can be high fines or even the denial of a type approval.

3. DATA SOURCES

3.1. Groups of possible information sources

The material information needed to fit the information requirements mentioned in chapter 2 is stored in different sources. In order to analyze the possible sources, they were assigned to four different groups.

PDM systems

The first group is the product-data-management systems. These systems are used to handle the master data of the parts. In contradiction to the two other groups, the main PDM systems within the examined environment are connected. The system landscape consists of the main ERP based systems and some other (mostly older) systems based on other platforms. These systems are integrated in the system landscape of the PDM systems, to make sure that the master data (like part number, naming, etc.) for each part is consistent in all systems. So most of the systems are connected, but only a small part of the contained information is integrated. Because the material data isn’t part of the master data yet, this information is not consistently displayed within the already connected systems.

Information provided by supplier

Focusing on the internal information handling is not sufficient, because often the cooperation with suppliers starts in the early phases of the product development. So the second group of material information is the information provided by suppliers. As described in chapter one, if the supplier takes the responsibility for development process, the information (all but the master data) is stored and designed fitting the supplier's systems. In these cases the information (including the material information) is transferred at the end of the development process with the rest of the documentation. This kind of formalization may cause inconsistent material information.

To exchange detailed material information (chemical composition) between the OEM's and the suppliers a standard platform to transfer the information was developed within the German automotive industry and is now used worldwide. This platform is the IMDS (International Material Data System). The IMDS is a web based program in which material information can be uploaded and published to a list of recipients. In that way the supplier can give the information regarding a part that is bought by several customers to all customers at once [12]. Because most of the suppliers work for more than one OEM they don't use the OEM specific semantic or material naming, they use their own.

Unstructured information

The third group of sources for material information is unstructured information located on the different file servers, the internet or the local hard drive. Unstructured information is information that is not stored in a strict or fixed structure like a database or some sort of system. Through surveying employees working in different functions along the development process it became apparent that these unsorted files are a very important knowledge source regarding material information, especially in the early stages of the development process [3]. Locating this information is very difficult, because the search possibilities are very limited. You have to know at least approximately where you have to look for the information and you have to know the exact phrases to use to find the desired information. Thinking of the semantic differences, it is obvious that the present situation is not satisfying and should be improved [3,5].

Information in software tools

The last category of sources for material information consists of the databases that are part of a software tool. Especially calculation and simulation programs are often equipped with their own set of material information. Because of the origin of the data (the software supplier), the possible semantic differences to the other systems seem to be quite obvious. Another difference to the other groups to be thought of is that this data is not connected to the system landscape of the company. Even if technically possible the company wide usage of this information has to be checked with the software supplier. It may be necessary to change the license agreement, which can possibly be very expensive.

3.2. Evolving new sources

With the new requirements for material information the need for new systems and tools for data acquisition and administration arises. Analyzing the used PDM (Product-Data-Management)-systems in use it was recognized, that the main PDM system is based on ERP. Nevertheless there is a certain amount of systems developed independently from the used ERP because of different reasons.

One example is the MDS System (Material Data Sheet System) which is the company's in-house-tool for handling the IMDS data. At the beginning it was developed to monitor the material data sheets for the parts delivered by suppliers as part of the initial sample inspection. But nowadays it is one of the most important tools regarding material information for reports requested by laws. When the tasks of the system were expanded, it was thought of integrating the MDS in the PDM landscape by integrating it in SAP. The decision to use Oracle further on as the system platform was first of all made by the higher flexibility to customize the tool easily [6].

Another reason for creating a new system to gather certain data is posed through legislative or intra organizational requirements. There are certain types of information that have to be separated from the rest of the systems and where the access is only granted selected employees. Cost information for example must not be published in the company, because this information is highly confidential since they contain sensitive information of the suppliers like hourly rates and other internal costing information. Software licenses are another reason to separate respectively not integrate information. Not every software program can be used in the whole company, because a lot of software is licensed

for only a handful of users. So the information contained in that software has to be constricted to the actual users.
The need to transfer information to an external partner can be also a reason to store information separated from the other PDM-systems. Especially in the construction departments a lot of external engineering offices operate as partners to do the designing in CATIA or a similar program or to do different kinds of calculations and simulation (finite elements analysis). Ensuring that all external work is based on the same data like the internal work, the internal material data needs to be provided to the external partners.

4. DATA QUALITY AND DIVERSITY

The stated facts concerning the information sources influence the data quality. Because the diverse systems developed over time and out of individual motivations, the stored information is independent (except the master data, see chapter 3.1.). This is one main reason for the occurrence of semantic differences regarding the material information between the systems [4]. These differences are in most cases different labeling systems so that an automatic comparison between sources is not possible. Sometimes the same terms have different meanings for certain departments, e.g. development and purchasing departments.
The stated semantic differences between the systems are responsible for the difficulties to join the information of the sources. Manually, quite often there is no problem recognized, because the users working with the information are capable of distinguishing the differences in the used semantics, sometimes even without recognizing. Even if the users don't recognize the semantic differences, they have to search in each system respectively each information source separately. That has some disadvantages: first of all it is very time consuming [9] to get more than one kind of information for a certain material. Another point is that you have to compare the different information manually to make sure that there are no inconsistencies or misunderstandings because of semantic differences.
For integrating the different sources the semantic differences are very problematic and until now there is no general solution [4]. Also it may happen that the information in one single system does not follow the same semantic rules. For example the IMDS: because every supplier and OEM creates their own data, using their own, internal rules, names and notations, there are a lot of different semantics in this one information source. So if this information is supposed to be used to create a consistent information set, it has to be done manually. This problem was recognized when trying to use the IMDS data to do certain analyzes concerning prohibited materials. Because of semantic differences it was impossible to order and group the material data by the given material name. It is possible to analyze the data by the VDA classification [6].
The various origin sources can be external or internal. External sources are for example standards like ISO or AISI describing the requirements to the individual materials. Possible internal sources can be records from test plants or expert knowledge.
Especially the problem of using different semantics in different information sources has been observed repeatedly [2, 4]. Nevertheless the employees working with different tools and systems should be able to compare the tool internal material data with the company wide used material data to avoid the possibility of misunderstandings and to focus on extending the tool's material information via one central department.

5. THE SOLUTION: DATA WAREHOUSE VS. SEARCH ENGINE

Two possible answers to the question, how to manage all these different material information out of all are generating a "master-database", e.g. a data warehouse, or generating a possibility to look into all the sources with one central search engine.

5.1. Data Warehouse

A very obvious way to solve the problem is to build a classical data warehouse, which is connected to the different sources. The data warehouse is based on the idea to collect specific information from different systems and to store this information in a structure that makes the evaluation of the data more effective. Regularly new information is generated by combining the different sources. The collection of the data is done by a script searching the different sources on the basis of defined and static rules [1].

Thinking of the different systems containing material information, this solution seems to be very practicable and solid. Under certain circumstances, it appears to be the most suitable approach to this problem. The advantages of the data warehouse can be summarized as follows:

- Consistent and valid rules to merge the data of different sources.
- Possibility to analyze the data in various ways.
- Very good system performance.
- Easy to apply security requirements in regards of information security.

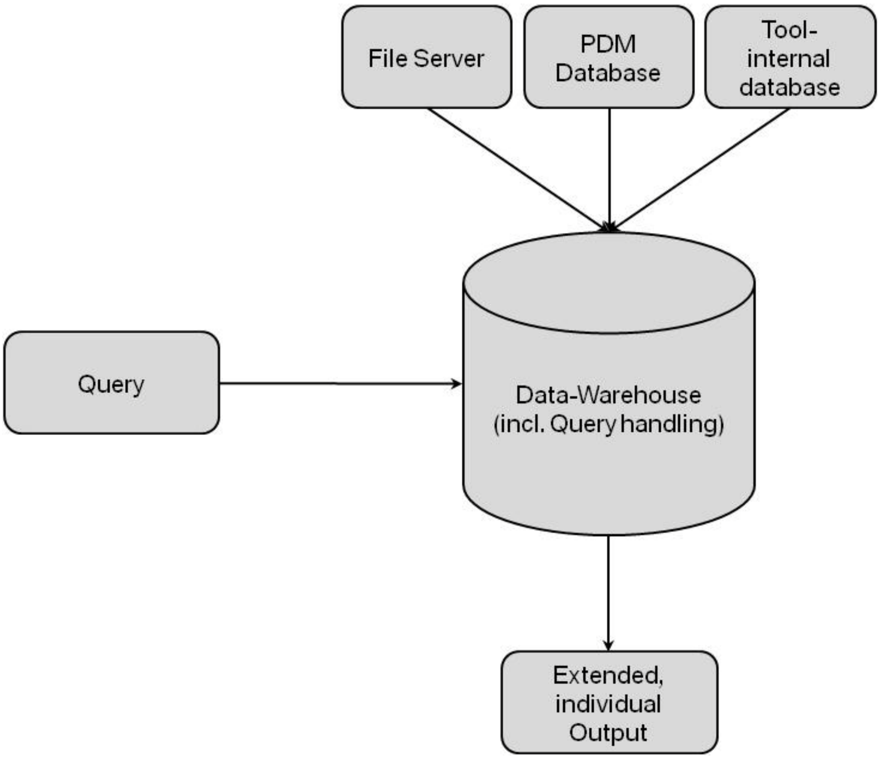

Figure 2: Possible structure of a data warehouse solution

The underlying structure of the data warehouse solution is shown in figure 2. Three of the mentioned information sources (see chapter 3.1.) can be implemented in the data warehouse easily. Local hard drives and internet sources are problematic to implement in a data warehouse structure for different reasons: The internet is for example subject to constant changes and has no strict structures like databases what makes it difficult to get the important information using a static script. The local hard drives shouldn’t be scanned for important information during the working hours, because that would cause a dramatic performance problem on the client computers. Running the scan over night would not be useful, because the client computer won’t be running or connected to the company network.
The disadvantages of the data warehouse solution are not immediately apparent. But depending on the main targets to be covered, there are some points that have to be thought of. Problems are especially posed through having to copy the data to build up a data warehouse:

1. A significant amount of additional data is generated. Thinking of the costs generated by the needed storage and software it can be questioned, if the additional value is higher than the additional costs. The main cost factors are the storage itself (hardware) and the software on top (database, etc.).
2. The process of copying the data itself generates a huge amount of traffic in the company network. Therefore the time frame for the update process has to be considerably great. It is not practicable to launch such a process several times a day. This means you don’t access the current knowledge but always a slightly older data status. Thinking of big companies, such as BMW, there are a lot of changes in the data every day. Constantly working with data that is not updated is crucially impacting the development process and is therefore not a feasible solution for these kind of processes.

3. It should be mentioned that integrating new data sources is quite complex. The mapping between the new data source and the structure of the data warehouse can be problematic, if the information structure of the new source is significantly different to the previous ones.
4. Because the data warehouse is a database, it makes all of the administrative work necessary, in addition to the existing administration for the existing systems.

5.2. Search Engine

The second alternative is to create a central tool that is capable of getting real time information from the different sources (systems, databases and file servers). This central tool can be a search engine that is connected to the different sources. Because of the direct connection to the different sources, there is no need to copy the data, which at the same time reduces the necessary administration significantly. The second significant advantage is the possibility to work always in real time on the sources. All this significantly reduces the possible costs to run such a system.

Because one key request to the system is the capability to deal with the different semantics, a standard search engine by itself will not be sufficient. Therefore the search engines need to be combined with some sort of "translator"-tool that is able to translate between the different semantics.

The idea is, that the user that is searching a certain material gets all the information, also for all possible synonyms for the given name of the material (see figure 2). So the favored solution is a hybrid between a classical search engine and data processing to overcome the semantic issue.

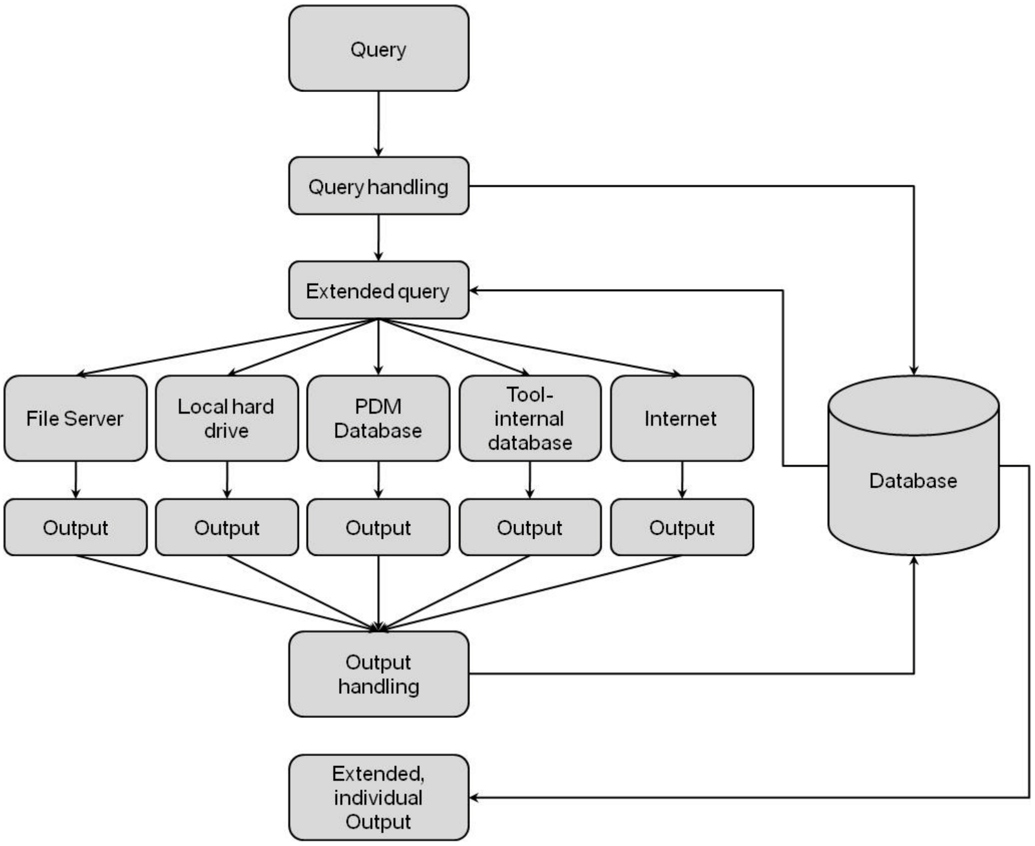

Figure 3: Possible general structure for the future tool

As shown in figure 3, the query given by the user will be extended, e.g. with all the known synonyms. Also the consolidated output is handled by the background database. This possibly enables the system to filter the results and to normalize all the results to one semantic (regarding the material name). Also the search results can be filtered in respect to the user's rights for the implemented systems. That is essential to fit the requirements regarding the information security.

The challenge that is posed to this solution is to overcome the different used semantics. As argued before, there is no general solution for overcoming the semantic problems until now. So the future work in this project will focus on possible ways to overcome the semantic differences regarding the different naming for materials.

6. RECOMMENDATION: SEARCH ENGINE

After comparing the two possible solutions, the search engine appears to be the more sufficient approach.

Especially the high flexibility in combination with the comparatively low administrative effort needed led to the recommendation. The integration of new sources can be done independently from the already integrated sources. This flexibility is very useful if internet and unstructured sources are supposed to be integrated as well. Both of these sources are dynamic and not as static as data bases or information systems.

Another important advantage of the search engine is the ability to find and handle information more effectively using all the functions a search engine provides. This is based on the matter of fact that the search engine is searching in the actual systems and sources and not a summarized copy of the data.

7. ONE POSSIBLE WAY TO OVERCOME THE SEMANTIC DIFFERENCES FOR MATERIAL NAMINGS

A first prototype of an approach to overcome the semantic differences in the field of material naming has been realized. This prototype focuses on the semantic differences in one system to isolate this problem from the multi-source-problem. The MDS (as described in chapter 3) was chosen to be the example database because of the big semantic differences caused by the number of data suppliers. In the MDS the main focus of the contained data is the composition of the assembled parts used in the current portfolio. The information covers the chemical composition of the used materials [6].

The developed way to overcome the semantic differences is based on a comparison between a master table of reviewed materials (name and chemical composition). So the basic principle is a comparison between a material of the master table and the actual material to be tested. The principle is shown in figure 4.

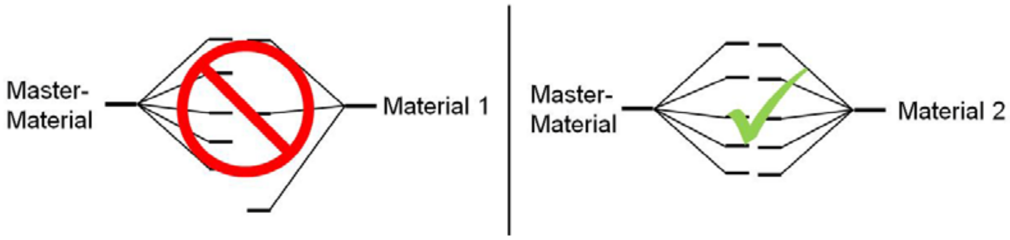

Figure 4: Basic principle of the comparison between a master material and the materials to be tested

The comparison refers on the saved properties in the database. The basic approach is to cluster the materials by their properties and put one master material for each cluster in the master table. In that way, the master table can be updated easily with new materials and by adjusting the clustering (changing the degree of similarity needed to form a cluster) the degree of precision in the master table can be fitted to the individual needs.

At this moment overcoming the semantic differences in the above shown way illuminates two points that need further consideration:

- First of all, the significant amount of manual work has to be reduced. In the diploma thesis every single material had to be verified manually, the prototype system only suggested possible fitting master materials.
- The second point is that until now the materials in the master table don't have the same degree of detail then in the original database. For example are the different additives in polymers summarized and not described in detail.

That fact seems to be a huge disadvantage but by thinking of the main reasons to get rid of the semantic differences, this disadvantage is not as significant as expected.

The big advantage of standardizing the labeling of materials is the ability to compare the material data of different systems or different list of parts or assembly groups within one system with no homogenous semantic. To compare the data it does not matter if there are details of information that had to be cut down to be able to compare. At the moment you need the very detailed information for one specific material you can easily navigate from the master material to the original one in the certain spot you are looking for it.

For example asking for a certain material let's say Polyamid 66 (without filler), with the developed algorithm you can identify where this material is used. As a next step you could look up all the different kinds of this material used (different suppliers, different additives, different colors, etc.).
It has been proven, that it is possible, to overcome the semantic differences for material naming by comparing the chemical fingerprint of the materials.

8. CONCLUSION AND NEXT STEPS

The challenge of combining the material information of different sources in different departments in a company is complex and because of the mentioned effects (e.g. information not integrated between systems) and needs (e.g. legislative requirements) quite important to master.
Thereby there are two problems arising to master that challenge: First is the connection of the systems and sources itself and publish the information via one defined way. The second problem is the occurrence of the semantic differences in the material information between the different sources which makes an automatic combining of the sources impossible.
Of the two approaches to overcome the first problem the search engine is recommended. The main advantages over the data warehouse are the higher flexibility, the possibility to implement unstructured information sources like file servers or internet sources as well. By combining the search engine with a data base, functions like filtering the search results to the individual rights of the current user are possible. Using this approach it is possible to get material information from different sources with one central tool. The remaining challenge is overcoming the different semantics.
One possibility to deal with the different semantics is clustering the materials by their chemical fingerprint. In a prototype that approach was tested successfully within a system storing the IMDS data of an automobile manufacturer. In the IMDS the problem of the different semantics occurs because of the big number of suppliers publishing their material data.
Future work should concentrate on two main topics: In order to be able to overcome the semantic differences in more than one system, the approach of using the chemical fingerprint has to be extended to physical and mechanical information. The second topic is the data security. When also sources are connected, that contain confidential data, the security of this information has to be assured, ideally without restricting the benefits of the system.

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