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ACCESSIBILITY TO MATERIAL INFORMATION BY USING STANDARDIZED MATERIAL NOTATIONS

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1. New challenges for material information

Over the last years the automotive industry has faced several challenges regarding material information because of internal and external requirements. On behalf of this paper these requirements arose from:

- New strategic cooperations between OEMs (Original Equipment Manufactorer) or an OEM and a supplier
- Legal enforcements
- Aspects of sustainability and the verification by Life Cycle Assessments (LCA)
- New mobility concepts with an increasing demand for innovative materials (e-mobility)

Strategic cooperations between OEMs affect both: R&D and/or production departments. In particular when both departments are involved in a cooperation, a wide variety of organizational structures, processes, systems and professions (technical, economical, etc.) are affected.
Crucial for a successful cooperation is to agree on the prevailing responsibilities. For the scope of this paper, the responsibilities concerning the used product data management (PDM) and product lifecycle management (PLM) systems to do the documentation in general and the material information in particular are of interest. Material information normally forms an essential part of a company´s PDM system and is frequently requested during the product life cycle of a product. The materials are administrated in accordance to normative regulations such as JIS (Japanese industrial standard) or DIN EN. The exchange of information is not easy to handle due to different data formats and PDM/PLM systems incompatibility.
Legal enforcements have occurred mainly on a European level and, as far as the automotive sector is concerned by the European Directive on End-of-Life [2000/53/EC 2000] and on the type approval [2009/01/EC 2009]. This directive addresses e.g. material restrictions and – as outlined in regularly amended annexes – temporary exemptions. Similar regulations exist for other product groups such as packaging, batteries and electronics. Through the last years the International Material Data System (IMDS) has proved to be a sufficient method for materials communication.
Thinking of the raising awareness of sustainable topics in the automotive industry a variety of new information about materials is needed. Focusing on the information requested by the LCA, new aspects have to be evaluated. Detailed information on the upstream chain and the sourcing location are needed for the calculation of the global warming potential (GWP) of a certain part. This includes the information about the raw material (How is it produced? How is it transported?), the location it is produced (How is energy generated in this area?) and all processing steps up to the final product. Most

of these information is part of the software tool used to generate the LCA. Thereby the difficulty to match the material data in the software tool and those used within the company arises. [DIN 2006]
Regarding the new mobility concepts the two major fields demanding for new material information are the e-mobility and the lightweight construction. Electrical power trains come along with new requirements on the knowledge of electrical and magnetical properties of certain materials is needed. In addition to the electric engine the design of the battery requires information which are new in the automotive industry (e.g. electrochemical). Since nowadays the battery is a unique selling point the development of the energy storage is a core business for the OEM's.
In lightweight construction, which is a well-established field in the automotive industry, introduces new materials in the automotive industry. For these materials new information is required. The usage of carbon-fiber-reinforced plastic (CRP), for example, requires information about the structure of the layers, because it has a large influence on the mechanical properties of the final part.
Taking all these challenges into consideration, two requirements arise:
The need for complete material information over the whole product life cycle and the standardization of the material data sets. Details can be found in earlier papers regarding the accessability of the material data set [Janus et al. 2011]. This paper will focus on the standardization of the material data sets.

2. The necessity of standardization

Meeting the described challenges requires detailed and complete material information. This leads to the necessity of internal and cross-company standardization of materials data. The actual situation is, that information is disspated over a great number of different data sources (structured and unstructured data). The data sources themselves contain information which are partly supplemented from completely different data suppliers.
Thereby it doesn't matter wether one single PDM or PLM system is used or, as in the presented case, numerous systems. Even by using one PLM system the described challenges arise because there will be multiple data suppliers and unstructured data.

2.1 Different data sources

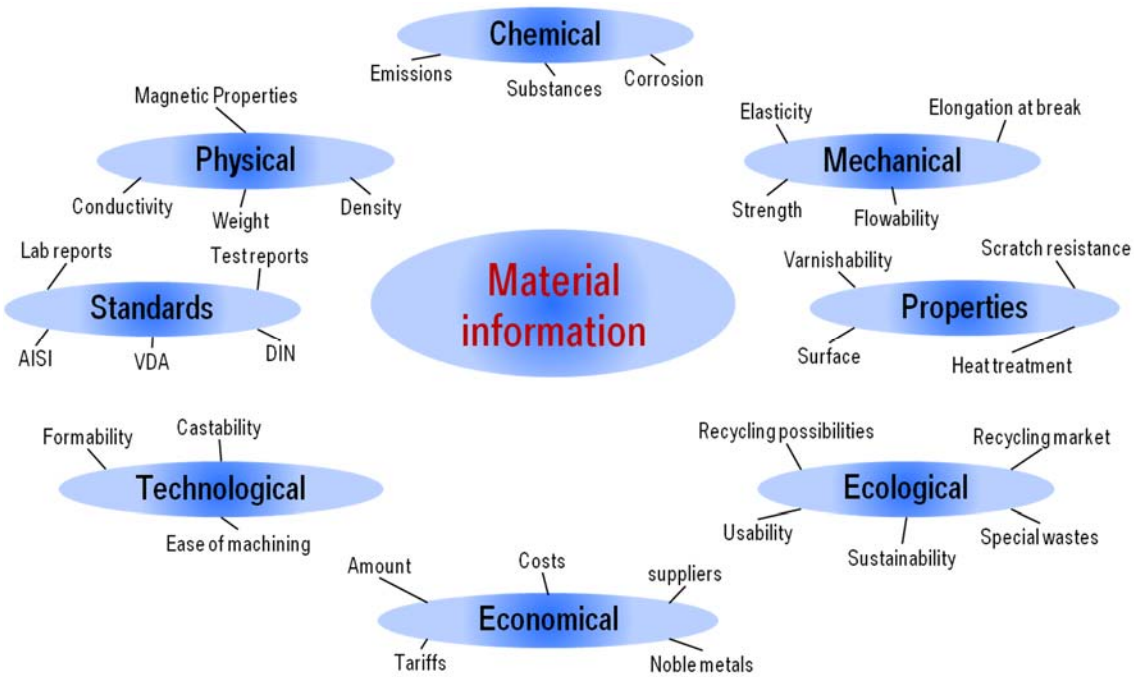

Figure 1. Groups of material information used throughout the company

In networks of large companies material information is located at different locations. In general these sources were especially designed for individual target groups with specific requirements for the information content and system platforms. These data sources are not connected, thus a synchronization of material data was not feasible until now. Similar information is probably stored in different systems and in accordance to the requirements of the individual group of interest. Figure 1 shows the most important identified information fields.
Accordingly, it is not sufficient to use the prevailing information of a company. In a survey that was carried out at BMW in 2010, it became obvious how experts- working with one or more information fields, as shown in figure 1 - are challenged by the described situation (see Figure 2) [BMW 2010].

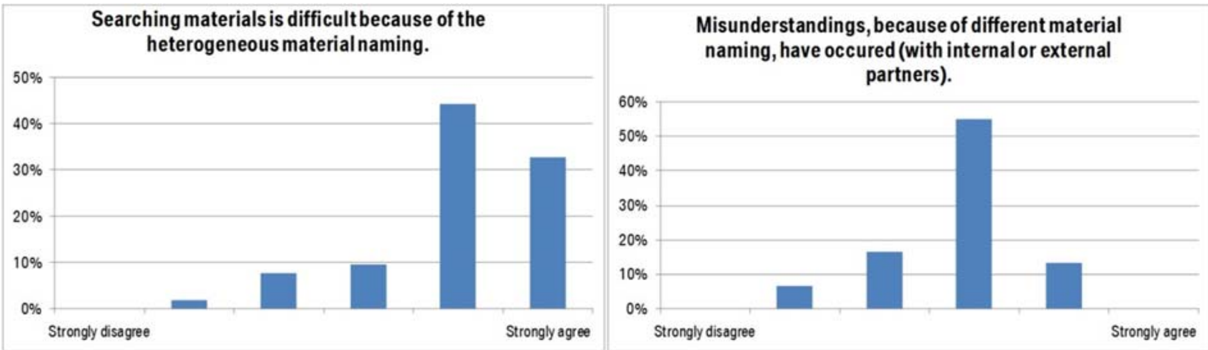

Figure 2. Result of a questionnaire, answers representing in total 170 employees from different departments [BMW 2010]

For most of the participants in the survey the search for material information is difficult because of the heterogeneous material naming (left diagram in Figure 2). Misunderstandings with internal and external partners also occurred in a significant amount of cases (right diagram in Figure 2).
The requirement to easily access various information sources by using one single system is supported (left diagram in Figure 3). The combination of this one single system with a standardized naming was also strongly supported (right diagram in Figure 3).
Consequently, finding the needed information is difficult, time consuming and often leads to misunderstandings.

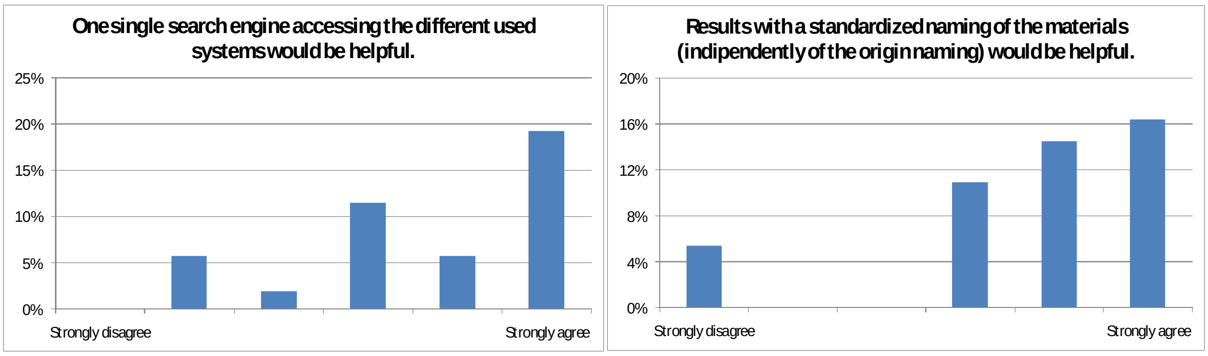

Figure 3. Standardization of the material naming would be helpful [BMW 2010]

Users strongly ask for one single entry to the dissipated material information. Thereby they will likely use more or less unspecific terms and, at the same time, expecting precise result within a standardized framework. So the solution has to capable of satisfying both requirements: Allowing individual systems, but granting accesability by using one entry. The preferred solution to this challenge is the usage of an intelligent search engine. [Janus 2011]

2.2 Different suppliers for the stored material information

Another challenging situation occurs when data from an information source is provided by different data suppliers. This was mainly observed with data sources that retrieve their information from outside of the company. The simulation environment and the IMDS (International Material Data System) are examples of data sources that retrieve their information from external suppliers.

As far as the simulation environment is concerned, the required data is taken either from the standard data sets that come with the simulation tools or are determined by one or several different external laboratories.

Accordingly, materials notations might be completely different. This can lead to misunderstandings (see Figure 2) which can cause rising simulation costs if, for example, a simulation is carried out with the wrong material data set.

In terms of IMDS, the effect of inconsistent material notations is even worse. The IMDS is used to monitor and document compliance with the legal requirements regarding the use of materials. It is used as a web-based platform to exchange the chemical composition of parts and components following the supply chain. Nowadays the IMDS is used worldwide by the major vehicle manufacturers and their suppliers [Hewlett-Packard 2011].

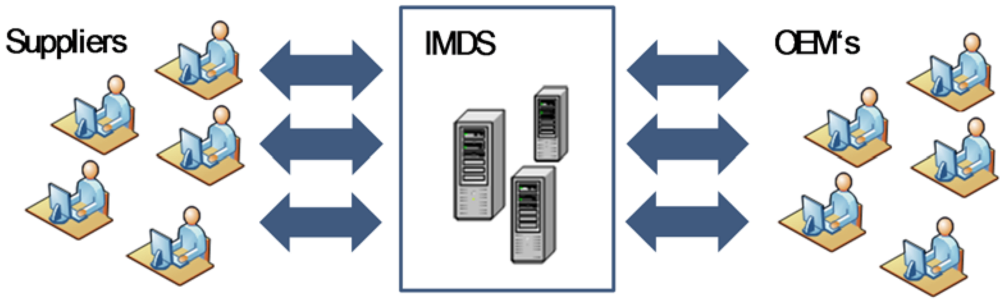

Figure 4. Schema of the interaction between suppliers and OEM's

Taking the upcoming legislative regulations in the EU into consideration, the importance of the IMDS and the data of the IMDS is growing. Especially the REACH legislative, which regulates the use of chemicals [2006/1907/EC 2006], will put pressure on the industry to identify certain substances.

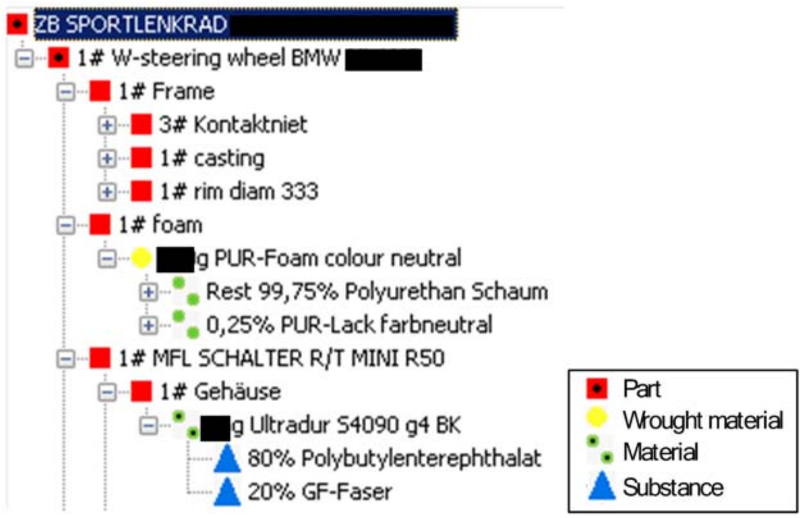

Figure 5. Basic structure of an IMDS data sheet; Screenshot of the in-house IMDS system

For IMDS it is crucial to use consistent substances in combination with the correct part information (like part number, etc.). Whilst the substances are well defined in IMDS, there is no consistent notation for the materials other than a rough grouping in accordance to VDA 231-106 [VDA 1997]. Thus the notation of the materials is left to the author of the data sheet.

This leads to a high redundancy and an inflated number of material data sets in the IMDS. For this reason, the material data sets are hard to evaluate. In order to make the material information available for automated evaluation, a standardization of the material notations is essential. Also the integration in the PDM/PLM system environment is also very challenging.

3. Standardization of material information

In order to solve the mentioned problems, the standardization has to be achieved on two different levels - the data structure of the different data sources and the material notations.

One approach to easily exchange material data sets between different companies (OEM's and/or suppliers) is the specification VDA 231-200 [VDA 2010]. It describes on a detailed level the content and structure of a system purposed for storing material information. At the investigated company the specification is already implemented in the PDM system environment.

Within the company's systems the data should be accessible by one standardized identifier which is available in all of the systems. After analyzing the system environment the material notation was found as the only identifier available in all systems. It is obvious that this systematic access has to comply with the specifications of VDA 231-200. A prototype was programmed in order to find the parameters that are necessary to standardize the material notation.

3.1 Specification VDA 231-200

The main German car manufacturers contributed to the specification VDA 231-200, which describes the key information needed to unambiguously describe a material data set in a system. In addition, the respective data fields are defined so that the data can be exchanged easily.

The main factor for the identification is the describing standard (regulation), which can be an official standard (like ISO, DIN EN, etc.) or company internal one. As shown in Table 1, four of the eight key identifiers are used to describe the used standard.

In addition to the key identifiers the specification also describes 23 more data fields used to store additional information which is not used to identify the material. These fields contain attributes and properties (such as mechanical properties). As this information is not used to uniquely describe a material they are not discussed in detail here.

Table 1. Key identifiers as described in VDA 231-200 [VDA 2010]

No.	Name of data field	Description
1	Material specific identifier	Database key, varies depending on the used system.
2	Regulation type	Abbreviation of the regulation type, e.g. DIN EN, ISO, JIS, ...
3	Regulation number	Number of the used regulation.
4	Legal authority	Originator of the regulation, especially important for company internal regulations.
5	Issue date	Date of the regulation.
6	Brief description (according to regulation)	Brief description / name / short term of the material according to the regulation.
7	Features (according to regulation)	Possibly necessary additional features of the material as described in the used regulation.
8	Additional information	Possibility to describe company specific additional information that is required within the company to identify the material.

In order to implement the data model as described in VDA 231-200, a major restructuring of the existing main material data base was necessary and successfully done. Along with the database, the important PDM systems working with the material data - such as the system assigning the material to parts or the system creating the header of the 2D drawing of the part - were refined. By doing so, the system itself assures that the documentation in the PDM systems and on the 2D drawing is done according to the valid rules and regulations.

After establishing the leading data base ("Material Master"), the next step is to combine the data of the "Material Master" with the remaining data sources. As already mentioned, the notation of the material is the only identifier available in all data sources. Therefore, before the data from the different sources can be combined, the existing data has to be standardized regarding the naming.

3.2 Standardization of heterogeneous notation systems

As already mentioned, the various information sources use different notations for the same materials. Those semantic differences in material naming have to be standardized.

The handling of different semantics within a network is a widely known issue, especially when it comes down to the integration of the embodied information. [Schmidt 2010], [Sanya 2011] Because of the high complexity of the problem, so far no general solution has been found. There have been different attempts to solve the issue of heterogeneous semantics, but all of these either focus on a specific area [Sanya 2011], or are based on requirements that have to be fulfilled by the individual users [Xie 2011]. In addition, the known approaches dealing with semantic differences are not applicable or suitable for the stated problem because in the actual situation different and also autonomous target groups occur. Additionally, the material notation uses a very specific vocabulary and is therefore very hard to standardize using non-specific algorithms. [March 2000]

Focusing on the described situation within the material notations, no directly related research was found. Because of this fact a new approach had to be developed. Based on the described previous research and demands of the empiric requirements analysis, three major goals for the standardization were defined:

- Standardization without changing the original data.
- As much automatisation as possible.
- Flexibility to adjust the standardisation if requirements are changing.

In addition to these goals for the standardization, the solution has to be able to be implemented in a search engine, because this is the framework that will be used to grant overall access to the available material information located in the different sources [Janus 2011].

Because the original data mustn't be changed the standardization has to be achieved by assigning the individual material data set to a standard material with a standard naming. Following this approach, a second advantage can be realised: the different notations in the original data sets can form a list of known synonyms for the assigned standard material. This list can be used by the search engine to improve the search results and to open the material information also by using the synonyms.

The automatisation is necessary in order to get sufficient acceptance by the users. The higher the manual effort for the standardization, the lower is the chance that it will be completed or updated. The only way to realize a high grade of automatization to use the available properties of the material data sets and group them according to the requirements (e.g. grade of standardization). The disadvantage of this approach, however, is the fact that standardization might only be possible for data sources which containing properties that allow a distinct identification of a material data set.

Since the requirements on the standardization are not considered as static, the conditions of the standardization have to be flexible enough to adapt to changing requirements.

3.3 Using chemical composition for standardization

To standardize the data of a specific system some kind of criteria has to be developed. One criteria can be the stored properties of the data sets. In the IMDS, the chemical composition of the materials is stored and therefore can be used as criteria. Another factor which makes the IMDS data a good development environment is the enormous number of redundant data sets, which should be reduced by the standardization.

An algorithm to standardize the materials in the IMDS environment is developed and implemented for testing in a backup copy of the in-house system which stores the IMDS data. This guarantees that the live data is not influenced in any possible way.

The standardization is achieved by defining standard materials with a notation that matches the "Material Master". To ensure this matching, the first set of standard materials was described according to the respective regulations. The following factors lead to the decision of which materials should be in the first set of standard materials:

- Available regulations describing the chemical composition of the material.
- Material which is frequently used in vehicles.
- All relevant material groups of metal and polymer-based materials have to be represented.

Every non-standard material in the database can be compared with the standard materials. Every substance in both materials (standard and the non-standard one) are compared. Because the probability of minor differences in the given chemical compositions is high, the algorithm has to be able to overcome those. A lot of regulations for metal materials, for example, allow certain substances within a given range. Figure 6 shows the general comparison of two material data sets.

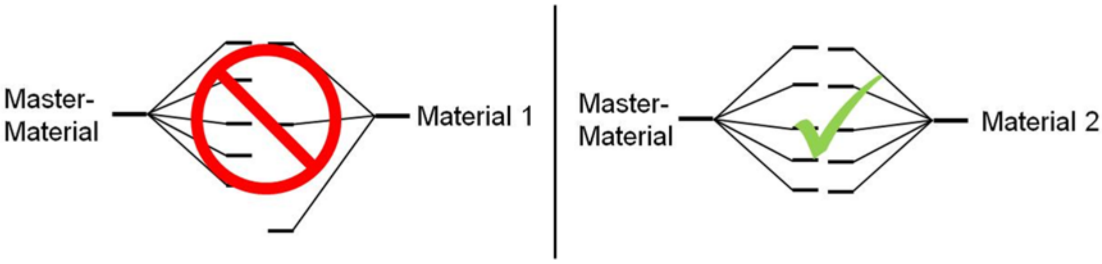

Figure 6. Schema of the comparison between two materials, each small dash represents one substance in the material

Depending on the estimated congruence between Master and Sample material the result can be expected as follows:

- "Total match": This result represents a 100 % match of every substance comparison.
- "Approximity match": The percentage of the successful substance comparisons is smaller than 100 % but still a significant amount of comparisons were successful.
- "No match": The percentage of the successful substance comparisons is so low that we can be sure the materials are different.

The prototype itself is designed for small data sets ("jobs"). For each of these jobs all relevant parameters of the algorithm can be adjusted. By adjusting the characteristics of the algorithm, it is searched for a configuration that will show the most promising results and, most importantly, doesn't produce any incorrect results.

By using an automated comparison of the chemical composition, manual work is significantly reduced. Based on the results and the exact comparison parameters (which are not yet defined), the automatisation might be increased in the future. Regarding flexibility, the standardization using the developed algotrithm allows adjustments to the procedure. On the one hand, the standard materials can be changed. On the other hand the comparison parameters can be altered. If, for example, a regulation changes the notation of a certain material, this can be implemented by simply adjusting the notation of the affected standard material. All regular material data sets associated with this standard material will then be labeled with the updated notation.

4. First findings and discussion of the results

4.1 First findings of the prototype

The first test runs with the prototype were done with changing parameters using a set of material data sets ("test materials") to be compared with a first set of previously defined standard materials. Therfore the expected result was defined by the test materials and standard materials before the job was started. The actual result could be compared with the expected one and thereby the chosen parameters could be rated.

All test runs that have been conducted so far have shown that the amount of "total matches", and to a lesser extent the "approximity matches", was lower than expected. Therefore the number of "no matches" and to a lesser degree "approximity matches" was higher. An example is shown in Figure 7.

After the test runs, each category was analyzed in order to find the reason for the discrepancy. As for the shown example illustrated in Figure 7, the missing matches of the "total match" category were found in the "approximity matches", which is an indicator that the chosen parameters were too limiting for the algorithm to produce the expected results. Taking this into consideration, the result of the "approximity match" category was even worse than expected. Actually, only five of the expected ten matches were found. Through analyzing the "approximity matches" category, the assumption that the algorithm was too strict could be verified.

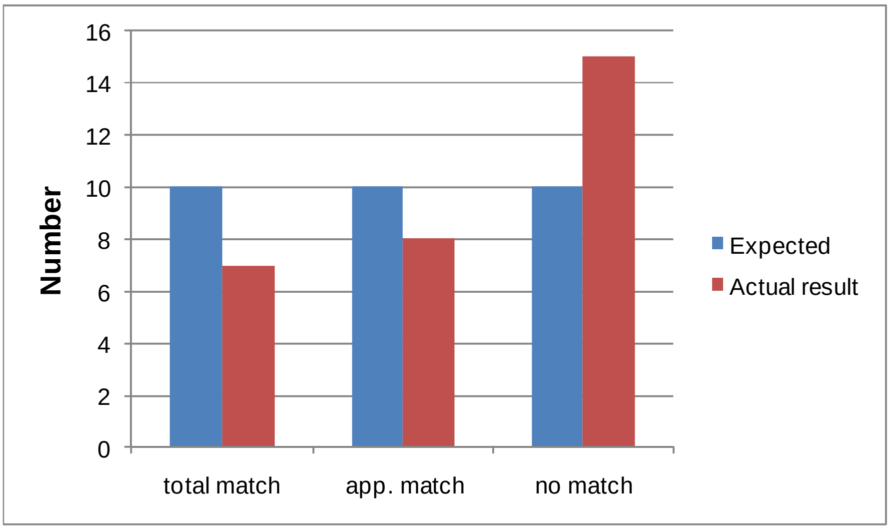

Figure 7. Results of an early test run with a big discrepancy between the expected and the actual results

4.2 Discussion of the results of the first test series

In order to finally verify the parameters, they have to be tested with a larger amount of unknown test materials, which will be done after the currently-running first test phase.

In addition, there are old and new challenges remaining after the first test runs. It was recently discovered that the substances in the data base also have a few redundant entries. This leads to anticipated "approximity matches" resulting in a "no match" classification as the algorithm is not using the substance names but their data base ids for the comparison.

It has been similarily observed that the substances of supposingly identical materials are defined in different ways. On one occasion the substance "aluminium powder" was used rather than the correct substance "aluminium (metal)" to describe an aluminium alloy, which makes a comparison of the materials impossible. However this was rarely observed during the test runs.

Another issue is the way the substance concentration is described in the database. The IMDS allows three different ways:

- Range: Giving a minimum and a maximum value
- Fixed value: one actual value of the substance
- "Rest": One substance in each material can have the value "Rest". This is calculated automatically. For example in a steel data set the substance "Iron" usually has the value "Rest".

If, in two different data sheets of the same material, one uses the "Range" fields and the other one the fixed value field, the comparison will fail because of a high discrepancy in the values. The reason is the way the average value of the "Range" is calculated. It is not the geometrical average but a weighted average which makes sure that the sum of all substances is always 100 %.

A known challenge is the standardization of metal materials with different treatments (like heat treatments), as two different materials with different mechanical properties can have the same chemical composition regarding the concentration of the alloying elements.

All these challenges have to be considered in the next phase where the prototype will be implemented in the actual system and process.

5. Summary and outlook

Driven by the new and/or stricter requirements on the material data the need for standardization is more pressing. This standardization has to be done on two different levels:

- There has to be a standard format for saving material information in data bases so the exchange of information is easier.
- Within the studied company the heterogeneous material notations among the different data sources were identified as problematic. Therefore the material naming in the existing data sources should be standardized.

As for the standard format, the specification VDA 231-200 was introduced and successfully implemented in the company's system environment. In order to do so a “Material Master”, the leading data base for material information, was implemented.

As a next step the remaining data sources should use the same naming system as the “Material Master” so the information can be combined. The IMDS (International Material Data System), which is a data source with a huge amount of data sets and very heterogeneous names, was used as an example to be examined further and used to develop an automated standardization. It is designed to exchange material information (chemical composition) between companies along the supply chain.

As the three major requirements for the standardization the points “no changes on the original data”, “as much automatization as possible” and “flexibility” were identified and set as the basic conditions for the next development steps. In order to match the requirements, a prototype was developed which uses the chemical composition of the materials to standardize the material notation. This is done by allocating the material data sets to standard materials which follow a standardized notation system. In order to do so, the chemical substances are compared with the ones of the standard materials. Depending on the degree of correlation, the result of the comparison can vary from “total match” down to “no match”. The detailed characteristics and parameters of the algorithm have to be defined during the ongoing test phase and are therefore still changed and adjusted.

A small set of standard materials was defined before the first test runs. The main criteria for these standard materials were the correct chemical composition, the coverage of the important metal and polymer-based material groups and a widespread usage. Additional standard materials are defined during the test phase and the following implementation and use phase. The test phase of the prototype is still running. The first results are promising but the final results have to be determined by a test run under real conditions.

The remaining challenges which were discovered by using the prototype have to be solved in order to use the prototype in the regular process. These challenges are mainly based on different ways of describing a material in the data base. In order to overcome those difficulties, new methods and tools like Data Mining will be taken into consideration for the next development phases of the prototype.

After the test phase and the implementation of the tool, the material information of the IMDS has to be combined with the “Material Master” and a similar standardization has to take place in the remaining other sources for material information.

Regarding the rest of the PDM system environment, the standardization of the material notation allows information from the different PDM systems to be combined. Additionally, the complete material information is available during the whole product-life-cycle.

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