21ST INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

AN EMPIRICAL SURVEY ON EFFICIENCY IMPROVEMENT FOR THE COLLABORATION BETWEEN DESIGN AND SIMULATION DEPARTMENTS

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Abstract

Efficient collaboration between design and simulation departments is a challenge in many industries. Under the cost and time pressure of product development, CAD/CAE integration has become increasingly important. This paper presents the results of an online survey and expert interviews within the German industry to analyse the collaboration of design and simulation departments. Four aspects of CAD/CAE integration were considered in the research project: people/communication, process, data, and tools. A similar questionnaire survey, which was conducted in 2006, is the base for this research. Through the analysis of the results and a comparison with the survey from 2006, weak points of the current collaboration were discovered. Thereby, a need for further research in this area is proven. In interviews, the survey results were discussed with experts to find solutions for the discovered issues. This paper provides an overview of the current collaboration of these two departments and also its challenges. The insights provided by the survey show directions for further research on the collaboration between design and simulation departments and where the greatest impact can be achieved.

Keywords: Simulation, Collaborative design, Communication, CAD/CAE integration, Online survey

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Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21st International Conference on Engineering Design (ICED17), Vol. 2: Design Processes | Design Organisation and Management, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

An important requirement to win market shares is a successful product (Ponn and Lindemann, 2008). The industry is forced to introduce new products faster and cheaper into the market in order to keep its competitiveness. For example, in automotive industry the development time has reduced dramatically in the last ten years, by about 1/3 on average, and the development costs, measured at the requirements, have rather decreased (Lepper, 2004). In order to fulfil these requirements, companies have gradually abandoned the expensive production and testing of prototypes in the product development process (PDP) by widely using computer aided design and simulation (CAx-) tools (Stangl et al., 2014). Simulation is not only pure end-calculations of designs, it also participates in the whole design process (Großmann, 1998). Although simulations are increasingly applied in product development processes, they are yet far from being used optimally along the entire process (Pavasson et al., 2014; Novak et al., 2012).
The collaboration between design and simulation departments plays an important role in this context of cost-down and speed-up of the PDP. A more efficient collaboration between design and simulation departments is therefore desired.
In 2006, dozens of practitioners from the German automotive industry were interviewed. The complex connections among product, process, IT system, data, and engineers were analyzed in the project (Kreimeyer et al., 2006). This paper describes the results of a similar survey and compares them to the survey from 2006. It thereby provides insights on the current state of collaboration between design and simulation departments and reveals leverage points for improvement possibilities and further research.
The goal of this paper is therefore at first to generate a current view on the collaboration and to analyze its development in the last 10 years and then to find out the optimization possibilities to improve the efficiency of the collaboration through comparison and analysis of the survey results.

2 STATE OF THE ART AND RESEARCH

In the survey from 2006, the efficiency of the collaboration between the two departments was analyzed in detail (Kreimeyer et al., 2006). Figure 1 shows a result of the survey: about 70% of the design engineers consider the collaboration to be efficient. However, almost 40% of the simulation engineers believe that further improvements of the collaboration are needed.

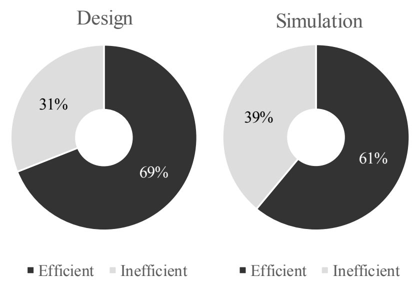

Figure 1. Perceived efficiency of the collaboration between design and simulation departments (Kreimeyer et al., 2006)

There are four core dimensions for a comprehensive and holistic integration of design and simulation departments: product, people, data, and tools (Deubzer et al., 2005). The latter three together build the fifth dimension: process, which is considered as a stand-alone dimension as many authors regard it separately from the other four dimensions (Kreimeyer et al., 2005). The product dimension usually depends on the company, so that a general useful suggestion for improvement possibilities in that area is almost impossible to be generated from questionnaire projects. For this reason, only the other four dimensions are used to guide the survey of this paper. As found by Eriksson et al. (2014), simulation is often used early during the product development process, which is sometimes neglected in engineering design textbooks. Companies are confident in the potential of simulations, as they often use simulations as part of validation instead of physical prototypes. Such an integration of simulations in the PDP brings improvements of the efficiency. As the models for simulation are generated with certain simplifications, however, Albers and Nowicki (2003) emphasize at the same time that there are also risks of reliability. Because of simplifications, a final simulation may provide a false result, hence physical tests cannot be fully replaced by virtual simulations.

In order to improve the communication and understanding between design and simulation departments, Petersson et al. (2013) suggest design engineers to take over parts of the simulation activities. A simulation template and a KBE system (Knowledge Based Engineering system) were developed to monitor the simulations. This system ensures to keep the simulation process straight-forward, thus the risk of mistakes and misunderstandings of the actual simulation procedure can be reduced.
Despite these approaches and the wide-spread application of simulations in product development, there is still room for improvement as the results of this paper will show.

3 METHODOLOGY

For this survey, a six-page questionnaire based on the questionnaire from 2006 was created. It consisted of five parts with a total of 31 questions. The parts were *Process* (nine questions), *Design* (seven questions), *Simulation* (four questions), *Improvement opportuniti*es (eight questions), and *General information* (three questions). Most of the questions were single choice with some multiple choice and open questions as well. In order to achieve a high return rate, this survey project was conducted through an online survey. In the survey from 2006, on the contrary, the spreading of questionnaires and the collection of answers was done via e-mail. In this project, the whole questionnaire was designed to take less than 15 minutes to answer. The invitation to the online questionnaire was spread through a mass e-mail tool to a total number of 215 potential participants. All invitees were selected so that they had work experience in mechanical engineering. The questionnaire project lasted for a total of 50 days before the summer holidays. During this period, the participants were reminded twice via e-mail to participate in the questionnaire. The time interval between the two reminders was about two weeks and they brought a significant increase in participation each time. At the end, the results were analyzed in detail via comparison to 2006 and expert interviews. To do that, participants of the current survey that came from the automotive industry were filtered and analyzed separately as all the participants of the survey from 2006 came from that industry field, while the current survey was spread over multiple industries. For the interviews, some experts, which had volunteered at the end of the online questionnaire, were invited to discuss the results more thoroughly. Three interviews were conducted with expert from heavy machinery (three managers), servo gearheads (one engineer), and the automotive industry (one manager). Each interview lasted around sixty minutes and all interviews were based on separately prepared question guides. At the beginning of the interviews, selected results of the online questionnaire were presented. Using this as a base, the interview was built according to the categories of the online questionnaire. Where there was a high divergence between answers to specific questions from different participants of the survey or the results of the online survey did not match hypotheses from literature, they were presented to the experts for discussion. Twelve to fourteen questions were formulated this way in each interview, completed by some follow-up questions.
The results of the survey and the suggestions collected from the interviews are shown in the following section.

4 RESULTS

The results are presented in the three dimensions: people/communication, process, and data and tools according to Kreimeyer et al. (2005) with the adaption that in this project the concept "people" was specified as "people/communication". Concluding from that, some recommendations are given.

4.1 Participants of the survey

83 records were collected in total from the online survey. Ten of them could not be used because of incompleteness. Therefore, 73 records were included in the analysis. 31 participants (42 %) were design engineers; 13 participants (18 %) were from the simulation department. The remaining 29 participants (40 %) had work experience in both departments. According to their working area, the participants are divided in three categories: “Design”, “Simulation”, and “D&S” (Design and Simulation). Almost half of the participants came from mechanical engineering companies. 40 % worked in the automotive industry, while the rest of the participants worked in other areas, for example rail vehicle construction and antennas. The number of participants per question is stated in the figures. They vary due to the different target groups (design, simulation, or both).

4.2 Overview of the current collaboration

As shown in the Figure 2, almost 90 % of the respondents state that the current collaboration between design and simulation is efficient. However, almost 50 % hold the opinion that the collaboration can be further improved. The original question was: "Do simulation and design work together efficiently in the current product development process in your opinion?" (All questions are translated from German by the authors.)

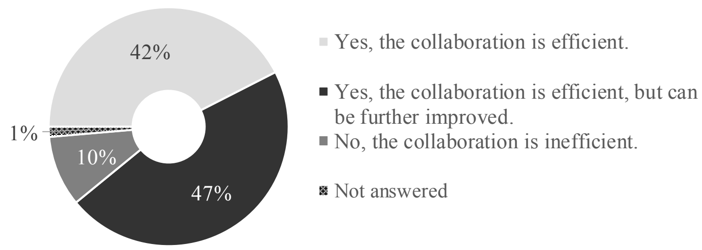

Figure 2. Overview of the efficiency in the current collaboration

The comparison of the efficiency between 2006 and 2016 is shown in Figure 3. The category D&S was not listed in the old survey, so the data of this category is not comparable. It can be seen from the diagram that the efficiency of the collaboration has increased within the last ten years. The percentage of design engineers that think the collaboration is efficient reaches even 100 %. As in 2006 all participants came from the automotive industry, the participants in 2016 were filtered accordingly for comparison.

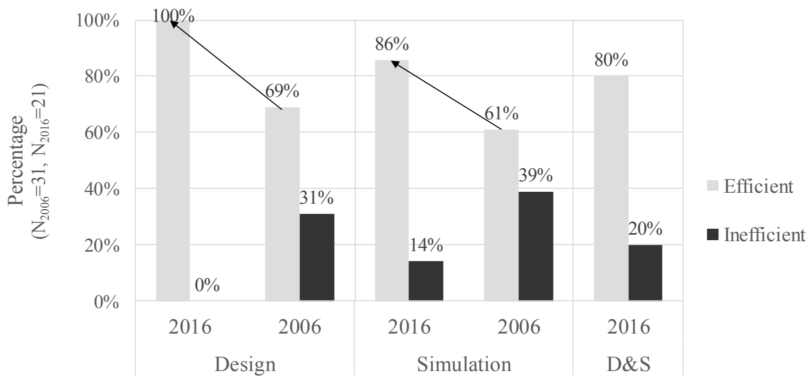

Figure 3. Comparison of the efficiency between 2006 and 2016 (automotive industry)

As shown in Figure 4 (Q: "What is the key to a successful collaboration between design and simulation in your opinion?"), the respondents chose “People/Communication” as the most important key to improvements. After that there are "Process", "Tools", and "Data". Thus, the aspect “People and Communication” can be considered an important leverage for successful collaboration.

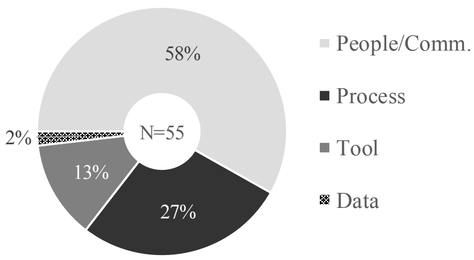

Figure 4. Keys for successful collaboration

4.3 People/Communication

The communication between design and simulation departments has two directions. The geometries or simulation requirements are sent from design to simulation. Often improper simulations can be caused due to a lack of explicit simulation requirements supplied by design engineers. An earlier paper suggests a requirements oriented simulation concept to clarify the communication in the direction from design to simulation (Schweigert et al., 2015).

Simulation results flow from the simulation department to the design department. According to Kreimeyer et al. (2006), the simulation results are usually transferred to the design department through "presentation", "report", or "face to face communication". A similar result was also found in this survey. In the questionnaire, the simulation engineers were specifically asked, "In which form do simulation engineers provide the results to design engineers?" As shown in Figure 5, over 80 % of the simulation engineers create a report to transmit the analysis results. About 70 % of the simulation engineers prefer direct communication to hand over the results. It is relatively uncommon to send the data sheet directly.

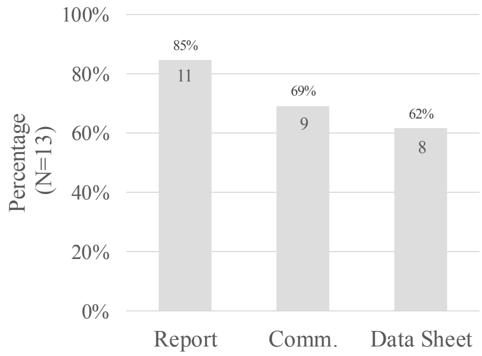

Figure 5. Forms to transmit simulation results (multiple choices possible)

As shown in Figure 6 (Q: "Are the design and simulation departments in your company located closely to each other or even in the same office?"), only half of the respondents state that in their companies the two departments are located closely to each other. Nearly 40 % think that their collaboration would be more efficient if the two departments were not separated. In large companies, however, which have a high number of development engineers, it may be impossible to place all engineers in the same office, for instance due to the resulting office size. Besides, when there are too many employees in the same office, this may also cause disturbances, which in turn influences the total efficiency.

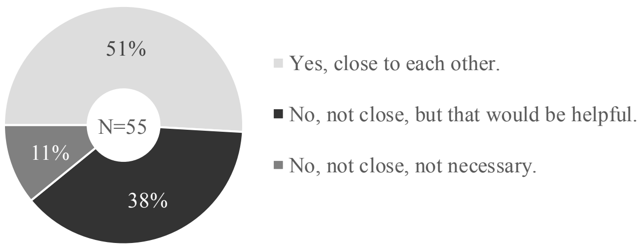

Figure 6. Location of design and simulation departments

After talking about the objective factors, the subjective factors should also be taken into account. In the survey (cf. Figure 7, Q: "Will you accept additional tasks to improve the efficiency of the total development process?"), over 50 % of the respondents showed no resistance to do additional tasks if the total efficiency can be increased. The proportion will go up to over 80 % if there are certain incentives. Only less than 15 % of the respondents state clearly that they will not accept additional tasks. However, the experts from heavy machinery explain that there is no need and it is also not possible to push each engineer to do additional tasks from another department. The engineers often do not want to take additional tasks, since they themselves are already fully occupied, or they just do not know how.

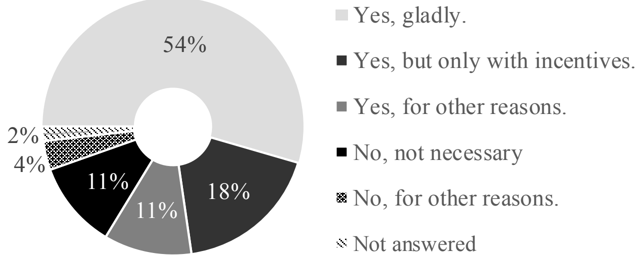

Figure 7. Acceptance of additional tasks

Another possibility to improve the efficiency is to encourage engineers to bring in their own ideas. Most engineers have an equal or better understanding about their tasks as their managers. This bottom-up approach can open a new door for efficiency improvement. The expert from servo gearheads recommends a CIP system (short for Continuous Improvement Process) for that. In the servo gearheads company, there is a CIP template. All employees can fill in their own ideas about the improvement suggestions. The suggestions will be evaluated regularly through a standard process. The most valuable ideas are filtered out and implemented.

4.4 Process

After "People/Communication", the "Process" domain is regarded as the second important key to improve the efficiency of collaboration between design and simulation departments. Usually, the long simulation process is regarded as a reason for slowing down the whole PDP. However, the results from this survey give a different answer. As shown in Figure 8 (Q: "Does a typical simulation process last too long, so that it is the bottle neck of the PDP?"), over 70 % of the respondents think that the simulation process is not the bottle neck of the PDP. However, the experts from heavy machinery regard this result doubtfully, because for different products there are different simulation requirements. They think, it depends on the industry field whether the duration of the simulation process influences the PDP negatively or not. For example, at the heavy machinery company, the long simulation process is the bottle neck of their PDP.

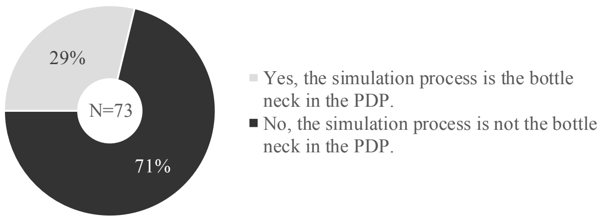

Figure 8. Simulation process as a bottle neck in the PDP

Furthermore, in this survey over 70 % of the design engineers say that the simulation results always prove their own hypothesis about the geometry. The expert from servo gearheads thinks that this high proportion is the base to possibly abandon the strict distinction between design and simulation departments in small- and medium-sized companies (cf. Section 4.6). Such a structure is already in use in a company of the experts from the German industry. The expert from servo gearheads said that in his company, there is only one development office, which is built up of twelve development engineers and thirteen so called series engineers. In both groups simple CAD-integrated simulations are performed. This structure is very efficient in his opinion. Because of the simple structure, the responsibilities of each engineer are clearly defined and there are rarely communication or organizational problems. The expert emphasized at the same time that the advantages of this structure only exist, when the amount of new developments stays on a low level. With the increase in complexity and new developments, a separate simulation department may be necessary, which is also true for companies with a high number of employees due to organizational issues.

For companies with a large proportion of new developments and a high number of employees, as the expert from the automotive company suggested, the first problem to be solved is to unify the goals of both departments. Simulation engineers have the goal of realizing functional requirements of the product. Design engineers, however, are driven by various properties of the product like size, weight, and most importantly costs. These target conflicts aggravate collaboration issues. As a possibility in order to conquer the conflict, "Quality Gates" as of Pfeifer and Schmitt (2014), are widely used in German companies according to the expert.

Another problem of collaboration is often the lack of a standardized product development process, which can lead to a failure of keeping all departments updated on the current status of the development process (Schweigert et al., 2015). This problem was also corroborated by the results of this survey. Different opinions were collected by one question. As shown in Figure 9 (Q: "Which department starts the PDP in your company?"), almost 90 % of the design engineers from the automotive industry think that they start the development process, which in the opinion of simulation engineers just counts for less than 30 %. Due to the lack of a clear definition of the PDP, design engineers consider themselves as the initiators of the development, while simulation engineers have the same opinion about themselves.

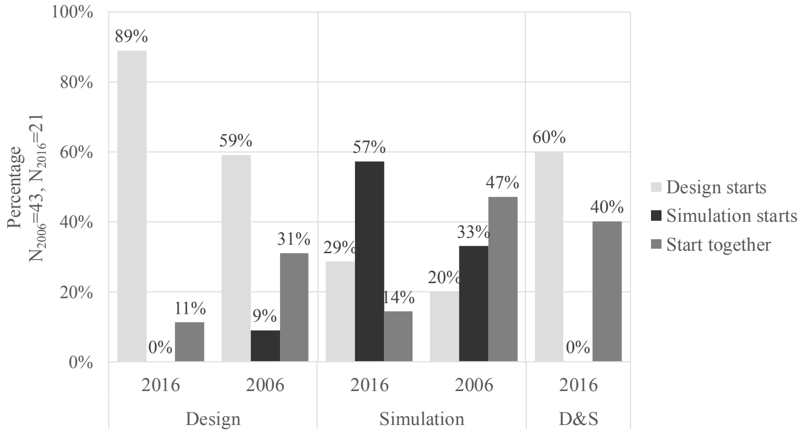

Figure 9. Initiation of the product development process

Pahl and Beitz (2013) advice to transfer the geometry in early phases of the PDP to the simulation department to insure a participation of simulation engineers. In the survey, about 60 % of the participants hand over the geometry to simulation colleagues at early phases. Less than 20 % of the respondents do not do that and also consider it as not useful. The experts give a precondition for this early cooperation, namely, the two departments must run parallel. If the design engineers have already updated the geometry before the simulation analysis is finished, it is unnecessary to do the simulation. In comparison with 2006, the parallelism of collaboration has almost not changed (Figure 10, Q: "How high do you estimate the level of parallelism of design and simulation in your area of responsibility?"). So the precondition may be hardly achievable. The experts in the interviews prefer a process of collaboration, in which engineers are encouraged to perform design-accompanying simulations with FEM tools in CAD software. The simulation department then calculates critical issues at the end of the process with the purpose of verification.

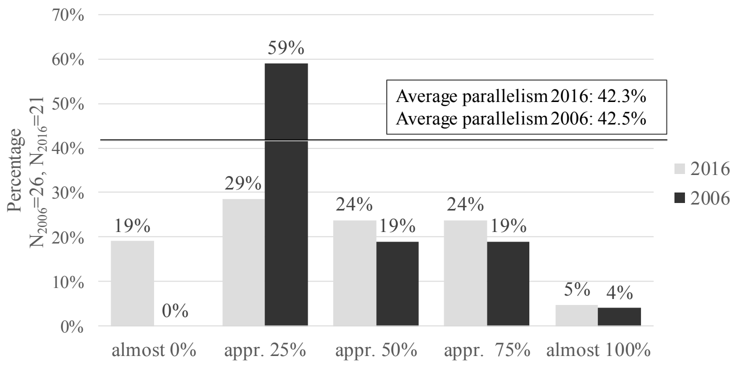

Figure 10. Parallelism of design and simulation departments

4.5 Data and Tools

Data and tools are discussed together in this chapter, because these two dimensions have close connections and are in many areas standardized. In this survey, less than 30 % of the design engineers use the simulation results directly. Over 70 % redesign the components according to the simulation results. This potentially redundant redesign of a component can cause waste in the product development process. A direct connection between simulation software and design software is desired to avoid these wastes (cf. Section 4.6).

The management of data is another aspect to be discussed. An issue of data management is the absence of a central documentation system (Schweigert et al., 2015). As shown in Figure 11, almost half of the respondents have no common PDM/PLM (Product Data Management/Product Lifecycle Management) system in their companies. This can lead to a poor exchange of latest information. This condition of the usage of PDM/PLM systems has increased by about ten percent as could be expected due to the emergence of according IT solutions. The reason for the still comparably low percentage of these systems may lie in the high costs or a low complexity of the products, which does not justify the effort to introduce a new software, according to the experts.

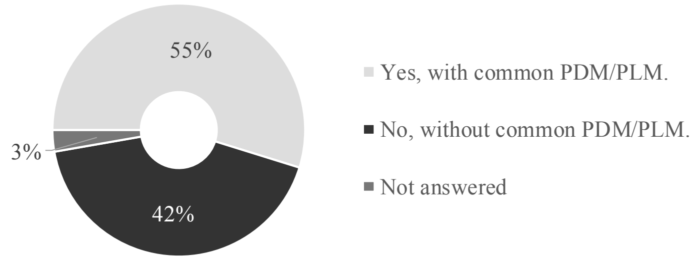

Figure 11. Common PDM/PLM system for design and simulation departments

4.6 Recommendations

From the findings of the survey, several conclusions can be drawn that lead to some basic recommendations. The following section summarizes the recommendations from the survey, which in many cases are supported by the expert interviews.

In general, all the discussions in the dimension "People/Communication" could be categorized in three communication possibilities: communication between design and simulation departments, communication from managers to design and simulation, and communication from engineer to management level. The improvement of these three communication channels will arguably also lead to the increase of the total efficiency of the collaboration between design and simulation departments.

The survey from 2006 found that simulation departments prefer to transmit simulation results in written form (Kreimeyer et al., 2006). As shown in this survey and the expert interviews in 2016, to create a report is still widely used to send results from simulation to design departments. To create a report is the "traditional" as well as the most common way for communication as also stated by the experts from heavy machinery in the interview. However, to create a report is often time-consuming and inefficient due to the additional documentation effort, but until today official reports are still not replaceable as shown in the survey. This is also because without a simulation data management (SDM) system, reports are highly important for traceability although the usage of a common PDM system between the two departments has increased from 46% in 2006 (Kreimeyer et al., 2006) to 52% (cf. Figure 11) in the automotive industry. Therefore, the importance of the official report should not be underestimated. One possible way to speed up the creation of a report, though, is the digitization and automation of the creating process. Such a report software can be integrated in the PDM/PLM system to create a central data base with a single source of truth, which is important as stated by the experts from heavy machinery.

After creating reports, engineers prefer to transmit results through face to face communication (cf. Figure 5), which is arguably the easiest way. While the same result was also found in the survey from 2006, in the old survey there was also an equal proportion for data sheets and direct communication, which changed in favour of direct communication in 2016. This is interesting as one might suspect that with emerging technology the proportion of directly transmitted results increases. On the contrary, in order to improve the efficiency of the communication, as the experts stated, companies should encourage direct and face-to-face communication between the two departments, while still considering traceability and knowledge management aspects. In some companies, there are regular meetings, so that design and simulation engineers can sit together in person to discuss current geometries and other open questions. This is considered a useful solution to increase communication. However, it depends on the employees and how much time they are able and willing to invest in it. In order to deal with this, design and simulation engineers could be placed in the same office or at least near to each other, whereby the design and simulation engineers could communicate more frequently and also much easier.

To avoid large and inefficient offices, Warnecke (1992) suggests a management concept called "Factory in the Factory" to tackle this situation. A company can be divided in several single small companies, so-called "Centers". Each center is self-organized, while the targets of each center should be free of conflicts and must serve the achievement of the overall company goals, which corresponds to the opinion of the expert from the automotive industry. Hence, the design and simulation department or parts of them could build up a development center. Each project can rent the necessary engineers from theses centers. Meanwhile, the design and simulation engineers could sit together in the project office to accomplish the project efficiently. Another approach is to use virtual reality (VR) to support the collaboration of two departments. Kan et al., (2001) have introduced an internet virtual reality collaboration for effective product design, which is also useful to approach the problems of product development with international cooperation. The support of VR brings more flexibility in the

collaboration of two departments. However, to the current date this is not state of the art in the collaboration of design and simulation departments.
As found in the survey, over 50% of the participants have no resistance to accept additional tasks. In order to take full advantage of the willingness of employees to integrate further tasks into their work to improve the total efficiency, the experts suggest to encourage design-accompanying simulations. These simulations can bring "Job Enrichment" as of Schlick et al. (2010) for the design engineers with a potential of higher satisfaction. Furthermore, design engineers could get a quicker valuation of their designs before they continue their work. At the same time, the simulation engineers could fully focus on complex simulation tasks. The experts in the interviews emphasize that a detailed instruction should be offered by the simulation department. It is also recommended to set a contact person for the design department to support the design-accompanying simulations.
Concerning the process domain, in order to design an efficient PDP, companies can be divided into two categories. The first category are companies that have only a few product development engineers and a low percentage of new developments. The second category are large companies with many new development tasks or a high number of employees. For companies in the first category, like the expert from servo gearheads suggested, it could be more efficient to abandon the clear boundary between design and simulation departments. As the experts suggested, design engineers could estimate a large part of the load cases with their experience, or calculate a rough result quickly with FEM tools in CAD software. With a strong integration of the two departments, the management and collaboration can be simplified. For companies in the second category, as the experts from the heavy machinery emphasized, a clear defined PDP is needed to eliminate the redundant works. Besides, the targets of both departments should also be unified regularly.
The sometimes unnecessary redesigns of parts after the simulation process have great influence on the efficiency of the collaboration of design and simulation departments. The data show even an increase in this field (used in 33 % of cases to integrate simulation results into designs in 2016 compared to 25 % in 2006 in the automotive industry). Misunderstandings, which can occur with data exchange, might cause further waste of resources. It is recommended to improve the direct usage of simulation results. For instance, Hessel (2003) and Burblies et al. (2003) suggest that geometries, which are optimized through simulation, should be evened, so that they can be used directly in the CAD software.

5 CONCLUSION AND OUTLOOK

Despite the high efficiency improvement since 2006 in the collaboration between design and simulation departments, there is still potential for further improvements. The improvements can be conducted in five dimensions: product, people/communication, process, tools, and data. People/Communication is hitherto not often regarded in research, although it offers many opportunities for further improvements. For companies with a small and medium scale of new developments, it is suggested to combine the design and simulation departments as development centers, so that collaboration and management are easier and clearer. For companies with a large scale of new developments, the company should clearly define the PDP and unify the targets of the two departments regularly.
Tools and data are the aspects, which are explored furthest, both in research projects and in business. The most significant issue found in this survey is the double processing of geometries. In order to avoid this waste, the direct use of geometries from simulations should be improved. Another problem is the lack of a central documentation system. A PDM/PLM system or a central repository could help to manage the documentations.
Generally, this paper shows directions for further improvements of collaboration between design and simulation departments with a high potential for quick achievements. A detailed and deep investigation of improvement possibilities and their connections will be completed by further research. In collaboration, “people” play an important role. Research in cooperation with social sciences may bring in some new approaches to improve the efficiency of the collaboration.
There are also some limitations of the results presented herein. All participants were engineers or managers that have connections with the institute conducting this research, which may result in a certain bias. Furthermore, almost all the participants come from big companies. (According to the Recommendation of the EU 2003/361/EG, companies with more than 250 employees are so called big companies.) Therefore, the results may not reflect the whole German industry correctly. In order to investigate that, a further survey that aims at small- and medium-sized companies may be needed.

Besides, only three expert interviews were conducted in this project, so that the diversity of the collected expertise is limited. A further comparison and combination of the expertise might be fruitful. Currently, further expert interviews are conducted to deepen the understanding of the situation, in which the relationship between the occurred changes and the company fields will be analyzed. Furthermore, statistical methods are used to identify crosslinks between the questions and answers of this survey. Thereby, clusters may be identified and further improvement possibilities found. For instance, a comparison of the link between the efficiency and aspects like processes and location of offices may be very insightful.

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