Systematic Management of Knowledge as an Integral Part of the Infrastructure of Tool and Die Making Companies

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Abstract--**Due to its key role in the value chain between the product development and the mass production the tool and die industry is one of the most important industries in the manufacturing sector. In an increasingly global production environment the tool and die industry in high wage countries like Germany or Japan stands in an aggressive competition with suppliers from Eastern Europe or China. Additionally there are the three major trends in production engineering that have a direct impact on the tool and die industry: low factor costs in Eastern Europe and Asia, an increasing product derivation as well as a demographic change in society. To cope with those trends and to stay competitive the tool and die industry has to manage both organizational and technological challenges. One of those challenges is the systematic management of the organizational and personal knowledge. Especially in technological focused industry sectors like the tool and die industry the establishment of knowledge management methods has been neglected. However knowledge management is an integral part of the infrastructure in manufacturing. This paper therefore defines the key methods for an effective knowledge management in the tool and die industry.**

I. INTRODUCTION

The tool and die industry is one of the most important industries in the manufacturing sector due to its key role in the value chain between the product development and the mass production [1]. Through this link, the tool and die industry enables the product development to realize new products as well as the mass production to produce those products at a high quantity and economical prices. Efficient and highly productive tools are the bases for a high-performance manufacturing sector. The tool and die industry therefore largely contributes to the economic performance of major economies [2, 3, 4, 5]. However due to an increasingly global production environment the tool and die industry in high wage countries like Germany or Japan stands in an aggressive competition with suppliers from Eastern Europe or China [6, 7]. Facing this situation, the industry has to develop business differentiators to preserve international competitiveness. One of the most important differentiators is the existing knowledge advantage.

To retain the knowledge advantage there has to be a systematic management of both the organizational and personal knowledge. Unfortunately the tool and die industry in Germany has consequently neglected the establishment of knowledge management as part of the existing infrastructure in manufacturing. However the Aachener Tooling Academy (WBA Aachener Werkzeugbau Akadmie) together with its partners Daimler, PWO and ZF have set up a research project to identify the key methods of knowledge management for the tool and die industry. Over a period of 2 years the project team has evaluated over 50 methods and created a catalog of requirements to find the most effective methods for the transfer and the use of knowledge in tooling.

After giving a short overview over the German tool and die industry this paper shows how knowledge management can be integrated into the value chain of the tool and die industry as part of the infrastructure. Part of the knowledge management are methods to transfer and use organizational and personal knowledge. The identified key methods for a successful transfer and use of knowledge are presented in chapter 5. The paper closes with a conclusion and a short outlook.

II. THE GERMAN TOOL AND DIE INDUSTRY

The German tool and die industry has about 54.000 employees [8]. 80% of the produced tools are either injection and compression molding or forming tools. After the global crisis in 2009 and 2010, the industry has recovered very quickly and is almost back at pre-crisis sales. Most of the 4.800 German toolmakers are medium-sized companies with less than 20 employees [9]. The market access of toolmakers can either be external or internal. An external tool shop offers customers tools as its final product. Internal tool shops, on the other hand, build tools for their companies' own production. They are therefore a supporting unit within a producing company.

However German toolmakers are still facing margin losses even after the crisis and consistently increasing sales. The reason for this development is the upcoming competition especially from Eastern Europe and Asia. The quality of their tools has increased enormously but their prices are still low. Thus the German tool and die industry tries to stay competitive by focusing on the five fields of action costs, time-to-market, quality, innovation and productivity [6]:

Costs: Depending on the sector, tools account for up to 30% of the total production costs [5]. Due to the use of the tool, planned maintenance and unplanned repairs, additional costs which are directly connected to the tool accrue over the lifetime. Experts assume that 60% of the total production costs are determined by the production tool [11, 12]. Innovative tool concepts enable the customers to realize significant cost-saving potentials over the life-cycle of the product because of the tools high productivity.

Time-to-Market: Product life-cycles shorten continuously in most industries. In times of high global competitive pressure, the success or failure of a product is often decided by the passed time to the market launch. Referring to the

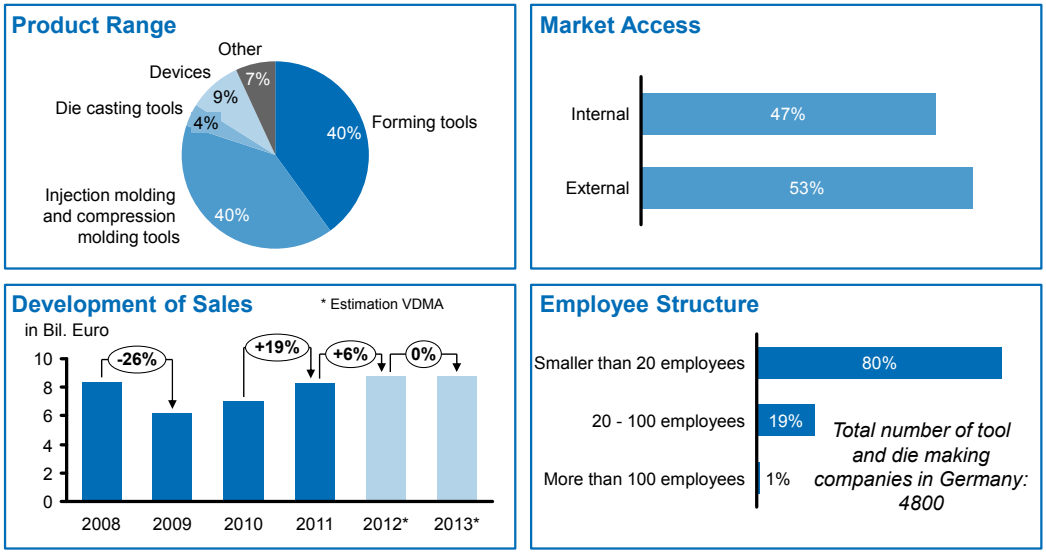

Figure 1: Facts and Figures of the German Tool and Die Industry [10]

realization of a new product, the production of the tool is on the critical path between product development and mass production. It is often one of the last remaining factors for a significant lead time shortening. Therefore the speed of order processing in tool making and the lead time in tool manufacturing has direct impact on the product success.

Quality: Beside the tool by itself and the interaction between the tool and the machine, the production processes of goods and services are essential to the products quality. These factors determine the customers' perceived quality and thus its satisfaction. In addition to technological developments, various organizational measures, caused by the high complexity of the tool manufacturing, are necessary to achieve high customer satisfaction through quality.

Innovation: The production of a tool provides its services in both directions of the value chain. New types of processes and tool concepts enable a more economical production. Because of its expertise the toolmaker can actively participate in the customers' product development.

Productivity: The productivity of a tool in use significantly determines its life cycle costs. Therefore a high level of tool availability is a crucial factor in the tool's overall cost calculation, which affects the production of the tool. Thus the importance of the tool's purchase price often retreats into the background when focusing on the entire life cycle.

III. TRENDS IN THE MANUFACTURING SECTOR AND THE CHALLENGE FOR THE TOOL AND DIE INDUSTRY

The demand for tools has increased continuously in the past years. Due to a high product variety, caused by an increasing **product derivatization,** more tools with differing designs are being ordered [13]. Because of small lot sizes for individual derivatives the costs for tools related to the total costs of a product rise [14]. Thus the available budget for a tool shrinks which forces the tool shop to reduce its price. Therefore the tool shop has to offer a better price-performance ratio to keep on coping with the customers' demands of restricted budgets as well as high quality standards.

The **globalization** has lead to new markets and new market actors with significantly lower factor costs [15, 16]. In the past years the German tool and die industry was able to differentiate by the quality of their products. However the global competition has caught up both technological and quality wise. Thus, a differentiation by quality is no longer promising but the differentiation through a more efficient value creation process [6]. Additionally the rootage in the new markets gains more importance which is only possible by opening up local tool shops. To ensure an efficient value creation process as well as the rootage in the new markets the tool and die industry needs efficient value creation structures.

Currently the German industry is in the comfortable situation that the number of employed people is at an all-time high with about 45 million employees. But the producing industry will be confronted with a fundamental change of the labour market, because the workforce is expected to decrease to 32 million employees in 2050. This development results from the upcoming retirement of the baby boomer generation as well as recessive birth-rates in the past decade. Another factor is the immigration of workers from other countries, which is not high enough to balance the decrease of the German work force in the next decades. This problem is not a worldwide problem, because the workforce development faces very different circumstances in different countries. China and the USA for example will see a similar growth of their workforce until 2020, but then they will follow different paths. While the USA can keep up a steady growth rate,

China will face demographic problems and see a decline of their work force especially due to their one child policy [17]. The **demographic change** increases the need for an effective knowledge management for companies, because they will face a lack of qualified employees. Employees will need a fast way to access the stored knowledge, so they can be more productive. Additionally, the medium age of employees will increase and the systems used for knowledge management should incorporate their requirements.

All three shown trends have a direct impact on the tool and die industry. However the most threatening trend for the tool and die industry is the demographic change because it is not directly influenceable. Nevertheless it is possible to cope with this trend by implementing an effective knowledge management anchored in the companies' infrastructure.

IV. KNOWLEDGE MANAGEMENT AS PART OF THE INFRASTRUCTURE

The role of knowledge in the manufacturing industry gets more important due to the changes from an agricultural to an industrial society. Competing companies try to improve their products and processes in order to reduce costs and to offer customers more attractive products. This development redefines knowledge as an important resource of companies besides the traditional resources labor, land and capital [18]. Especially complex tasks, which have to be handled by multiple specialized departments and persons, call for a quick and easy exchange of knowledge within a company or a network with the same interests. Otherwise mistakes can be repeated or too much time is used to find a solution, because existing knowledge was not accessible in a certain situation.

Knowledge is defined as cross-linked information from which further knowledge can be derived. Information consists of data. The meaning of the data can be interpreted by using a semantic and by seeing the data in a specific context. Data itself consists of single characters, like letters or numbers, which positions are defined by syntax [9]. Existing knowledge also builds a basis to evaluate and learn new knowledge. Knowledge on the one hand is generated and used by persons and therefore underlies the unpredictable human nature. On the other hand knowledge exists in organizations within documents, databases or working routines [20]. Because of this uncertain situation regarding the accessibility of knowledge there is a need of knowledge management in organizations which sees knowledge as an important resource. Another reason to implement a system for knowledge management is the difference between explicit and tacit knowledge. POLANYI defined explicit knowledge as knowledge which can be articulated by the knowledge owner and can be documented [21]. The knowledge owner therefore has to be aware of the knowledge and be able to transfer it to another person or a kind of documentation [22]. Tacit knowledge on the other hand is defined as knowledge, which is used to solve problems, but the knowledge owner is guided by an anticipation he has built from former experiences. Persons without the experiences and tacit knowledge would not be able to solve a problem in this manner based on the given information. Tacit knowledge influences the decisions of the knowledge owner, but the knowledge owner does not have to be aware of all of his tacit knowledge and therefore mostly is not able to explain his tacit knowledge to other people [21, 22].

The goal of knowledge management is to identify and transfer existing knowledge and to generate new knowledge for organizations and people. PAWLOWSKY states that a successful knowledge management leads to improved work routines and increases an organization's ability to learn [23]. A well-known concept by NONAKA and TAKEUCHI describes four different strategies to transfer knowledge between persons. The transfer of tacit knowledge to another person is possible by socialization. In this case the tacit knowledge is not transformed to explicit knowledge. The other person learns through imitating the knowledge owner. In this case, the tacit knowledge does not have to be articulated, for example by a language. If the knowledge owner is not able to spend time with other persons in order to socialize his knowledge he has to transform it to explicit knowledge. This is defined as externalization. The implicit knowledge gets documented for example by writing it down and other people can read the documented knowledge. The transfer of explicit knowledge to tacit knowledge is achieved through internalization. This process happens when explicit knowledge is repeated and used multiple times. The last form of knowledge transformation is called combination. By combining existing explicit knowledge, new knowledge can be generated [24].

A model how organizations can use the resource knowledge was created by PROBST. The knowledge management model consists of six functions, which are arranged in a loop. The loop starts with knowledge identification and knowledge acquisition. The next two functions are knowledge development and knowledge transfer. The last two functions in PROBST knowledge management model are knowledge application and knowledge preservation. The path along the loop of knowledge management functions shows the typical process to use knowledge as a resource and improve continuously. To increase the acceptance and success of knowledge management in an organization, the two strategic functions knowledge management objectives and the evaluation of results have been added to the loop. These strategic knowledge management functions aim for a better integration and improvement of a knowledge management system and reduce barriers to embed the system in the daily routines of the employees [25]. The knowledge management model by PROBST shows that knowledge management is an integral part of the infrastructure of producing companies.

A general challenge for knowledge management is how companies can benefit from knowledge management and how to structure their knowledge management system. Although 91% of companies asked in a study conducted by the

Fraunhofer Institute that say that knowledge is an important resource, only 25% state that they use this resource in an efficient way [26, 27]

V. KEY METHODS FOR THE TOOL AND DIE INDUSTRY

The research project "Development of a Knowledge Management Method Set" conducted by the WBA and its partners Daimler, PWO and ZF lasted over 2 years. Figure 2 shows the general approach of the research project. Step one was a collection of methods. Every partner had to share its methods with the others. Additionally the WBA conducted an extensive search for new methods which were unknown to the participating companies. Step two contained the evaluation of the methods according to the special requirements of the tool and die industry. In step three, based on the evaluation, it was possible to deduce a method set for the knowledge transfer and knowledge use within the tool and die industry.

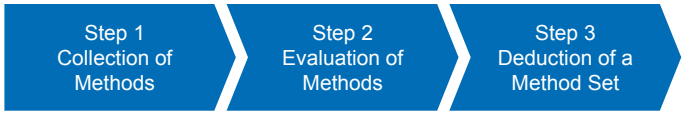

Figure 2: Approach of the Research Project

During step one, more than 50 knowledge management methods were collected, both from the companies and the extensive research from the WBA. The collection contained a detailed questionnaire that was filled out by the participating companies as well as an extensive literature and internet study conducted by the WBA. Additionally interviews with managers from other tooling companies supplemented the list of 50 knowledge management methods. Before evaluating those methods, the project team saw the need of reducing the focus of the research project to a more manageable size. Therefore, following the knowledge management approach by PROBST, the project team defined two out of six major knowledge management functions to focus on; knowledge transfer and knowledge use. The focus was needed to address the broad topic of knowledge management in a more specific way. For the project team the knowledge transfer and the knowledge use seemed to be the most urgent fields of knowledge management in the tooling industry. Additionally to this curtail the broad term of knowledge was defined in a more specific way. For the tool and die industry the term knowledge can be split up into four knowledge categories: process-oriented basic knowledge, function-oriented basic knowledge, detailed knowledge and special knowledge. Figure 3 shows the exact definitions of those knowledge categories. Only by this categorization a distinct classification of knowledge management is later on possible.

To finally evaluate the collected methods, special requirements from the tool and die industry had to be derived. As stated above, the tool and die industry consists of mainly small and medium enterprises, which do not have a great financial power. Furthermore the industry has to cope with rising competition due to an increasing internationalization as well as the proceeding demographic change in Germany. Based on this situation, 7 requirements for the use of knowledge management methods in the tool and die industry were derived by the project team.

Benefits/Costs of implementation: How high are the benefits of the knowledge management method in proportion to the costs of implementation?

Benefits/costs of maintenance: How high are the benefits of the knowledge management method in proportion to the costs of maintenance?

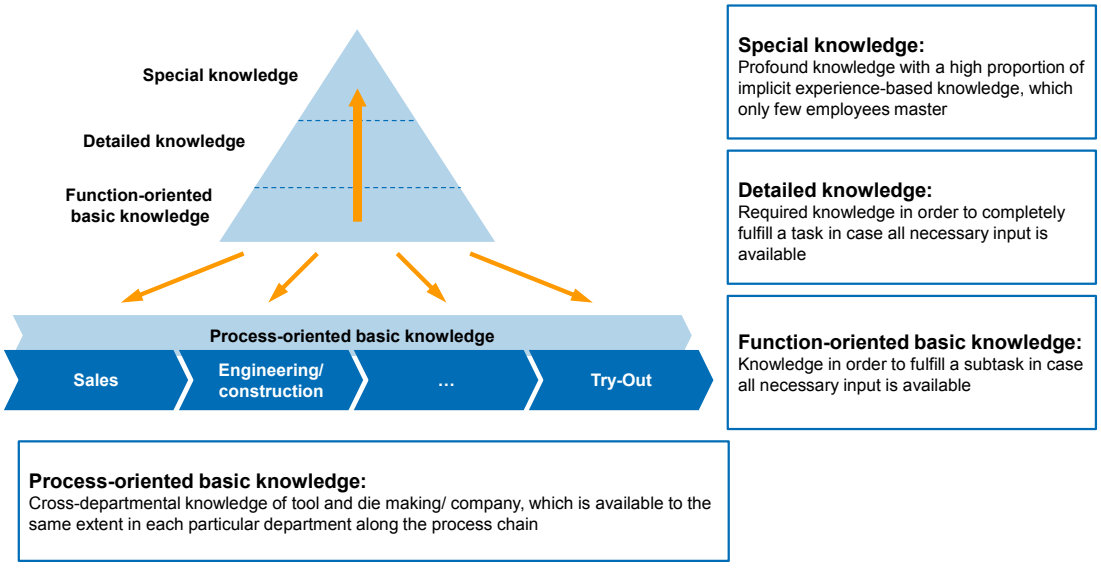

Figure 3: Knowledge categories

Sustainability: In what way is it possible to efficiently utilize the method for a longer period of time (short-term vs. long-term)? How sustainable is the method itself?

Ease of use: How easy to use is the knowledge management method? How easily can the method be applied? How high is the actual benefit?

Accessibility: Is the knowledge management method specifically designed for a range of activities and structures knowledge suitable for application? In what way do certain prerequisites exist (e.g. access to PC)?

Scope of application: In what way can the knowledge management method be carried over to other departments (design, production, assembly)? In what way can the knowledge management method be used in solving other problems?

Acceptance: How high is the acceptance of the knowledge management method among employees?

Figure 4 shows the general approach to the evaluation of knowledge management methods. For each method the degree of fulfilling the requirements was evaluated by using Harvey Balls. A full Harvey Ball stood for a complete fulfillment of the requirement whereas an empty Harvey Ball showed that the requirements were not met at all. To quantify the evaluation each Harvey Ball was given a score from 0 to 4 (0 = no fulfillment; 4 = complete fulfillment).

The evaluation of the method was conducted by the project team consisting out auf Audi, Daimler, PWO, ZF and the WBA as well as 12 further tooling companies from the WBA network. In total 25 different experts from the German tooling industry evaluated the methods. After conducting the evaluation the ones that had in average a higher score than 3 were considered to fulfill the requirements of the tool and die industry. Those methods were arranged in a matrix which consisted of the two knowledge management functions knowledge use and knowledge transfer on the x-axis and the four knowledge categories on the y-axis. As shown in Figure 5 it was possible to include 13 methods in the method set. Since certain methods could address more than one knowledge category as well as more than one knowledge function they were arranged accordingly.

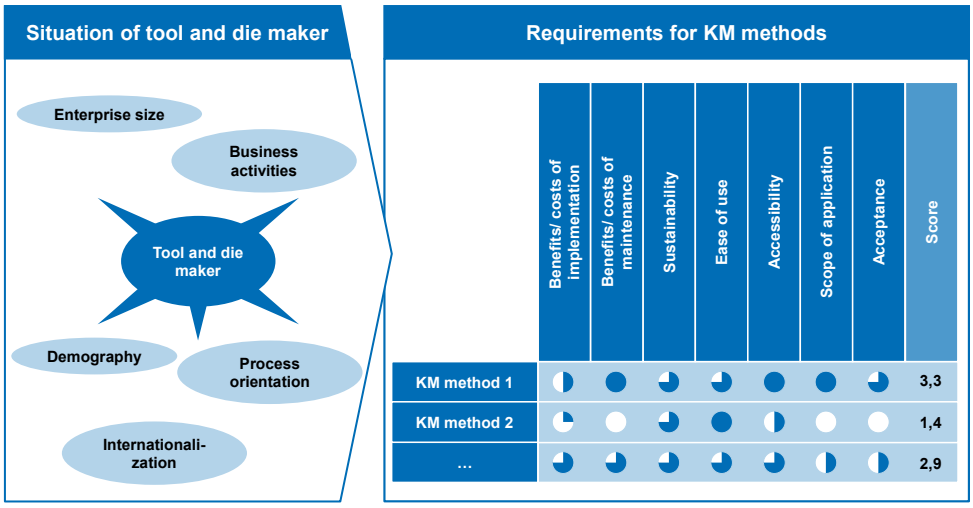

Figure 4: Evaluation of Knowledge Management Methods

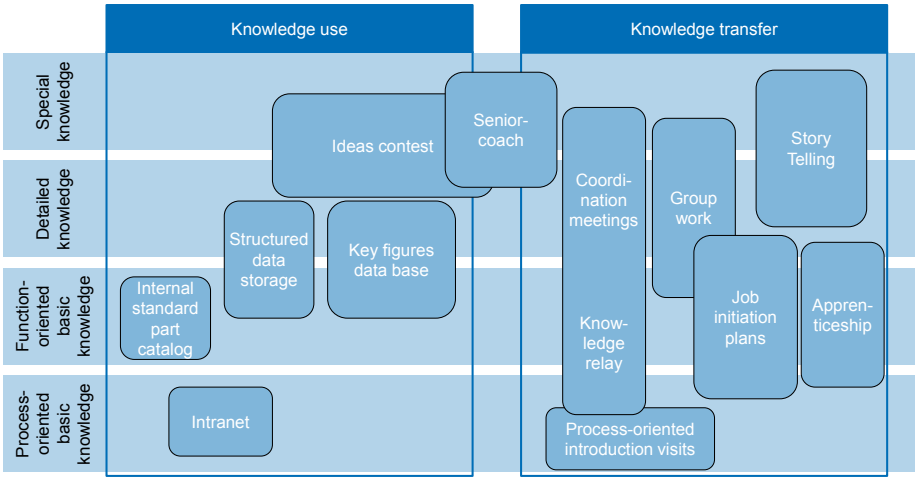

Figure 5: Knowledge Management Method Set

Figure 5 shows the 13 knowledge management methods for the tool and die industry to effectively use and transfer knowledge.

- **Intranet:** Information portal for the employees
- **Internal standard part catalog:** Specifications for the design of tools
- **Structured data storage:** Company wide standard storage of product specific data
- **Key figures data base:** Key Performance indicator analysis
- **Ideas contest:** Generation of ideas through a contest
- **Senior-coach:** Experienced employees act as senior-coaches for young tool makers
- **Coordination meetings:** Regularly team meetings with a standard agenda
- **Knowledge relay:** Standardized and moderated process during a job handover
- **Process-oriented introduction visits:** Organized run through the tool shop following the process chain
- **Group work:** Group discussions and plans of action
- **Job initiation plans:** Presentation of company structures and processes
- **Story telling:** Written report of major company events
- **Apprenticeship:** 3-year apprenticeship of new tool makers

The deducted method set gives the tool and die industry a good overview over the main methods for specific knowledge categories as well as knowledge functions. Within the conducted research project all participants were convinced that the 13 shown methods should be an integral part of the supporting infrastructure of tool and die making companies.

VI. CONCLUSION

The tool and die industry is one of the most important industries in the manufacturing sector due to its key role in the value chain between the product development and the mass production. Especially high wage countries like Germany or Japan have to cope with rising international competition. Therefore the industry has to develop business differentiators to preserve international competitiveness. One of the most important differentiators is the existing knowledge advantage. To retain the knowledge advantage there has to be a systematic management of both the organizational and personal knowledge which is deeply integrated into supporting infrastructure of manufacturing companies.

This paper showed results from the research project "Development of a Knowledge Management Method Set" conducted by the WBA and its partners Daimler, PWO and ZF. From a starting set of over 50 knowledge management methods a method set including 13 relevant methods was deducted in a structured evaluation process. This method set for the knowledge use and knowledge transfer gives the tool and die industry a perfect overview over the most effective methods when starting to implement a knowledge management system as integral part of the supporting infrastructure in manufacturing companies.

Future research should focus on the implementation of the knowledge management method set and the individual development of each method especially for the tool and die industry. Thereby a sustained integration into the supporting infrastructure can be assured.

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