MANAGING ENGINEERING KNOWLEDGE IN SPECIAL MACHINE DESIGN COMPANIES

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Abstract: This paper deals with Knowledge Management (KM) in the specific industrial context of special machine design. Our purpose is to study how relevant a KM approach in such an environment is. The theoretical background highlights the concept of crucial knowledge and the codification and personalisation strategies. From a field study, we show the existence of recurrences and experts in special machine engineering design, justifying a KM approach. We also put forward a condition to make this approach effective: the existence of a device enabling experts to work collaboratively.

1 INTRODUCTION

This paper is in line with the manufactured industrial product design field. Manufactured products are obtained by transforming raw material using industrial techniques and processes. Designing such products is nowadays a collaborative activity; this involves all the life cycle stakeholders who have to work together in order to define a product taking all their constraints into account.

The design activity is composed of many elementary activities whose goals are to propose artefacts that model the product from different points of view: functional, conceptual, structural…

In order to make these activities successful, designers can rely on their own knowledge coming from their expertise and previous projects. But they also need information -technical, scientific, organisational, working process…- they can find in digital or paper resources. During design activities designers also generate information and knowledge which help them to solve problems they are confronted with. It is this kind of knowledge and information which supports designers during design activities that we are interested in.

Studies whose objective is to manage information and knowledge supporting elementary design activities already exist in design literature (Matta, 2008). Our work focuses on a special machine context. A special machine is built to meet the particular needs and constraints of a specific client and only one device is usually produced. Therefore, the questions that have to be addressed are whether it makes sense to think about a knowledge and information management approach in such a context and subsequently how to make this approach relevant.

The paper is organised as follows; we first give some theoretical background and go in more details on our research question. Then, we present a field study within a company that produces special machines, and we describe some specific observations. Finally, we give some results of our analysis; we show that a knowledge management approach is relevant in the context of special machines and we highlight founding elements to its structuring and conditions of implementation.

2 THEORETICAL BACKGROUND

Many research works deal with knowledge management within companies. However, different points of view are encountered about this object that they call knowledge (Ahmed et al, 1999). Wilson, who underlines a common confusion between information and knowledge (Wilson, 2002), defines knowledge as what we know: "*knowledge involves the mental processes of comprehension, understanding and learning that go on in the mind and only in the mind, however much they involve interaction with the world outside the mind, and*

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interaction with others". This point of view, that we adopt here, leads us to call into question the meaning of knowledge management.

Knowledge management is claimed to be a way of improving the efficiency of engineering design activities by fostering knowledge formalization and sharing (Gardoni & Dudezert, 2005). In the SECI model, Nonaka and Takeuchi (Nonaka & Takeuchi, 1995) argue that in engineering, knowledge is built during projects through social interactions between the two dimensions of knowledge: tacit (knowledge that is linked to people or organization) and explicit (knowledge that has been identified and formalized). It is to be noticed that the latter is rather what we call here "information" according to Wilson's point of view. The resulting dynamic relies on four modes of knowledge conversion: socialisation, externalisation, combination and internalisation.

Hansen et al. (Hansen et al, 1999) define codification and personalisation approaches as the two main knowledge management strategies. On the one hand, the codification strategy is based on knowledge formalisation and relies on information repositories which enable users to access "codified knowledge". The codification strategy mainly addresses the externalisation, combination and internalisation modes of Nonaka's knowledge conversion model. On the other hand, the personalisation strategy enhances knowledge sharing through a socialisation process and is based on knowledge networks. The underlying knowledge conversion mode is mainly the socialisation.

Some research works try to combine both the personalisation and the codification strategies in associating information repositories and knowledge networks (Mentzas et al, 2001). With the aim of reducing the codification effort, Beylier also proposes an approach integrating both strategies (Beylier et al, 2008). The principle is to distribute codification effort while fostering collaboration between several experts. This approach proved to be efficient, but the results have shown that a continuous coordination effort is necessary to ensure a satisfactory codification process. Our strategy fits into this scheme of associating an information repository, a knowledge network and a collaborative workplace.

In addition, engineers involved in a design process may be considered as knowledge workers (Petroni et al., 2008) and a large amount of knowledge is used and created during their daily work. Therefore, intending to account for the whole of this knowledge would not be sensible. Grundstein introduces the notion of "crucial knowledge" to point at knowledge that is essential for decision-making process and for the progress of the value-adding processes (Grundstein, 2008). Locating this crucial knowledge then becomes a key element in the knowledge management approach.

Following this brief literature review, the issue of how relevant a knowledge management approach in the context of special machine design is, leads us to locate the crucial knowledge, to identify among this knowledge relevant candidates for a codification strategy, and to characterize the knowledge network that should complete the proposal.

3 FIELD STUDY

3.1 Industrial Context

The study was carried out within a company which designs, manufactures and sets up special handling machines. These handling machines are designed to be used in a nuclear environment. They thus meet specific standards and are subjected to particular constraints in terms of reliability and safety (personnel protection, mainly from radioactivity). The handling machines are overhead cranes for heavy loads (from 30 tons up to 500 tons).

All the designed and produced machines are single. They are prototypes and thus there are no mass production effects. The company answers a specific invitation to tender where the entire infrastructure around the overhead crane is to be designed. In this context, the company is usually associated with a consortium of companies. The design and manufacture of such a unit extend over several months, even over several years.

3.2 Our Investigation Process

The investigation work proceeded within the design department of the company. We stood as external observers. Two main sources of information and knowledge came out from this phase of investigation:

- technical documents, *i.e.* documentary resources;
- discussions with the people handling the technical study of the machine, *i.e.* human resources.

Figure 1 gives a schematic representation of the activities undertaken by the observer in relation to these two information sources. These activities are described thereafter.

3.2.1 Documentary Resources

In order to better understand the specificity of the industrial context, we get back to the technical documents used by the designers for the design phase of a new project.

A first category relates to the documents attached to previous and in progress projects. Each project involves one or more requirement lists, setting up plans, overall plans, costing, detail designs, dimensioning, calculation and testing reports. All these documents relate to each study of overhead crane. Each project represents many files to be studied. We analyzed a total of 13 projects.

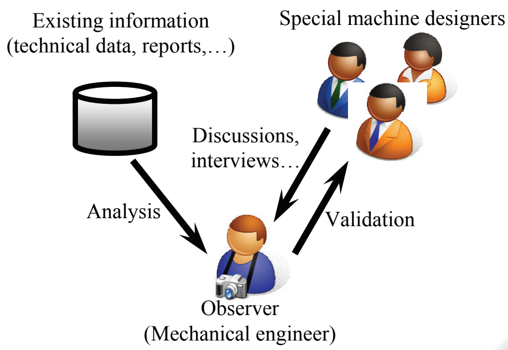

Figure 1: The observation system.

A second category of documents is often used by the designers to support their activities. They are documents transverse to the various projects, related with the competences of overhead cranes designers. These documents are for example standards, calculation codes, etc.

3.2.2 Human Resources

In parallel with the analysis of technical documentation, we worked with several actors who are involved in these projects. Three of them will be shown to have a special role in the design:

- a manager of the design department who validates and directs the various proposals of the design department,
- a person in charge of welding, metallurgy and materials,
- an engineering analyst.

3.2.3 The Observer's Approach

The work we have achieved led us to stand as observers in relation with the above mentionned documentary resources as well as the staff involved in the technical process.

At an early stage of our investigations, we shot a series of interviews with the Design Office Manager - amounting to a total of 10 hours. Our goal was to build an overall vision of how the Design Office Manager addresses the study of a new handling machine. More specifically, we aimed to identify the various stages the Manager considered as key issues in processing a project study as well as the main features to take into account when starting to design a crane. At that stage, using the video enabled us to keep record of all the critical information we might have missed otherwise, and to go back with further discussions when needed.

In a second stage, we worked with both the documentary and human resources described earlier. We tried to account for every piece of information - be it documentary-based or interview-based - by addressing issues such as "*Why does this piece of information need to be used*?" "*Why does this action need to be taken*?" This enables the observer to first get acquainted with the *information* and then to build his own *knowledge* before redefining it in order to convey it and make it as communicable as possible for the designer. This stage is known as the codification stage. At that point, in-depth discussions with the designer are necessary in order to enrich the codification of the information.

Finally, the validation stage enables the observer to ensure that the information is fully understood and properly rewritten.

The discussions with the designers took place at four specific levels:

- first, the industrial field level – which involved introducing the industry and the technical dimension;
- second, the project level – issues regarding people involved in the project and how it is carried out were addressed;
- third, the module level - which is used in overhead cranes;
- and finally, the component level (the components are parts of the modules).

The content of the interviews with the designers became more and more accurate as the technical documents were analysed and as explanations about the information analysed were made necessary.

3.3 Observations

In this paper, we will not go in great details on all the observations we have made for two years but rather focus on a particular issue which illustrates the results we present in section 4.

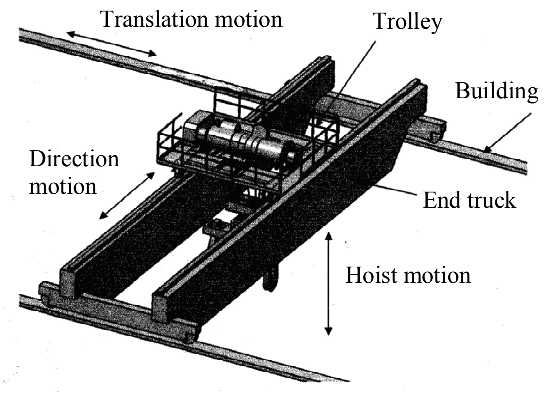

Figure 2: A typical overhead crane.

Figure 2 shows an overhead crane that is under study in the company. The crane is composed of:

- a structure - usually known as the frame - composed of an end truck and a trolley designed with steel giders that are mechanically welded;
- a translation motion system that allows the motion between the end truck and the building;
- a direction motion system that allows the motion between the trolley and the end truck;
- the hoist system.

The hoist system consists in rolling a wire rope on a rope drum. As this system proved quickly a key module in handling nuclear loads and as it is the “know-how” of the company, we decided to put the emphasis on this module. Besides analysing the design of the “hoist system”, we also analysed the design of a number of its components.

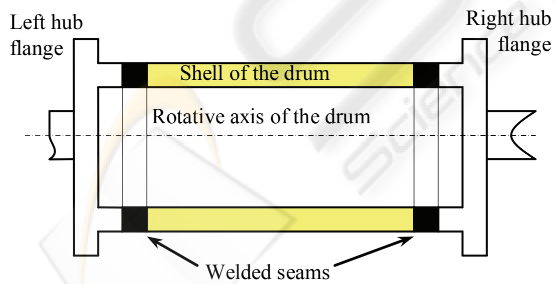

Figure 3: Schematic design of the drum.

We only focus now on a key design rule for the welded rope drum. This drum is made up of a cylindrical hollowed shell and two cylindrical hub flanges jointed to the shell as shown by figure 3. The hub flanges are fit into the drum shaft.

Each of the two welded seams shown in figure 3 plays a major role for the drum design. All the mechanical power developed by the drum shaft is transmitted to the handled load through these joints.

Two categories of welded seam designs are achieved: the welded butt seam and the welded T-joint, as shown by figure 4. Both categories of welded seams are not similar. As for the mechanical strength is concerned, the welded butt joint is much stronger than the T-joint. However, the welded butt joint is much more difficult to achieve. As the shell of the drum and the hub flange have to be processed, as they also require more specific machining before welding and need to be precisely positioned, the welded butt joint proved more costly than the welded T-joint.

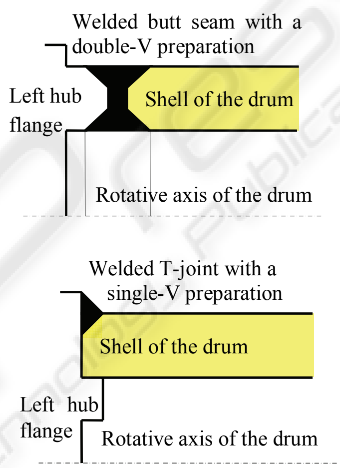

Figure 4: Two categories of welded seams.

After having described the field study, we will now present the results achieved so far regarding the “Knowledge Management” in our industrial context.

4 RESULTS

Our field observations make it possible to highlight some results of interest. These are structured around three key issues: the identification of recurrences, the role of technical experts, and the importance of rules at the interface of expertise.

4.1 Many Recurrences

We first notice that in spite of the unique nature of each project, the special machine design process shows many recurrences:

- at the customer level and the associated requirements. The response to an invitation to tender and the proposed technical solutions are widely linked with the customer under consideration. It is known for example that for the customer X a Y-type drum is required;

- at the level of the approach to be used in carrying out a new design study. In view of the wealth of information, the uncertainties of a project, the standards to be met, the designer has the ability to develop an approach which, on the whole, will be repeated over the following projects, or whose specificities can be spotted;
- at the level of the architecture and of the different modules of the system. For example, all the handling equipments that we analysed involve the same technology: a wire rope is used to hang the load. The design of the hoist module is repeated over the projects;
- at the component level. For example, it was observed that the hoist module always includes a rope drum, a geared motor, a braking device, a wire rope and a tackle block.

While these recurrences are more particularly observed between the different design projects, some others also exist at the inside of the projects. The welded seam shown in the previous section is an example of such recurrence. Defining a welded seam is a common situation within a handling equipment design. Welded seams are even a crucial issue in the special machine domain which widely involves this assembling technology.

In a special machine context, the existence of these numerous and multi-level recurrences was far than obvious. It is to be noticed that the designers themselves were unaware of that at the beginning of our study. This result is of great importance to legitimise and to adjust the codification part of our knowledge management strategy.

4.2 The Key Role of Technical Experts

During the observations, it also rapidly became apparent that some of the participants in the handling equipment design have a special role in the process. Regarding the design of the drum for example, three people were involved in the main technical decisions: the experienced designer, the engineering analyst, and the metallurgist. All are known by their colleagues to be particularly skilled in their domain. They are considered as experts and take part in the design process in different ways:

- they carry out their own design tasks, as the other stakeholders of the design do;
- they define the design approach which fits at best with the requirements of the current project. They put the project on the right track;
- they provide the design teams with technical advice when needed.

In order to achieve that, they mobilize different kinds of knowledge, and more particularly:

- knowledge in relation with regulation (standards in force and, above all, action rules that they built to use these standards);
- technical knowledge (principles of solutions, design rules, limitations…). An example is the design rules they use to define the welded seams for the drum;
- knowledge in relation with the customers and their expectations;
- knowledge of the previous projects. This includes the lessons learnt.

As for the recurrences previously pointed out, the existence of these experts and the role they play are of major interest for defining the knowledge management approach. This participates in locating the crucial engineering knowledge. This also gives some elements for defining the required knowledge networks (personalisation strategy).

4.3 Needs for a Collaborative Device

Considering the different kinds of welded seams described in section 3.3, each of the three experts we previously pointed out uses the same explicit rule: the welded seam between the shell of the drum and the hub flange must be a welded butt seam. But it came out from the discussions that their related knowledge was not the same:

- from the design office expert point of view, compared with a welded T-joint, a welded butt seam improves the joint mechanical strength. This gets rid of stress concentration areas which could lead to a material breaking point;
- from the engineering analyst point of view, the strength of a welded butt seam is calculable because of the material continuity between the drum and the hub flange. As there is no continuity with a welded T-joint it is impossible to have a reliable modelling for strength calculation;
- from the metallurgist point of view, welding crack initiation occurs when hydrogen atoms are included in the welding. Welding techniques exist to avoid embedding such particles. But ultrasound or X-ray checking is necessary after welding operations for certification. Only a welded butt seam can be checked by ultrasound or X-ray checking.

Therefore, while the action rule seems to be the same, its justification by each expert is different. As we attended to this work, a common and shared welding design rule emerged from our instigation: "*A welded butt seam will be used when this welded seam has to be checked. Such choice will make it possible to validate the calculation hypothesis of material continuity*".

An important corollary appeared immediately: "*If the specifications list or the calculation code do not require checking the welded seam, then a less expensive welded T-joint has to be chosen*".

This example shows that our presence as observer (and knowledge management actor) gave the experts the opportunity to share and define a design rule at the interface of the three expertises. An autonomous collaborative building of such a rule requires a device (including areas, tools, methods…) enabling experts to share their points of view. The role of such a device is to help experts in personalisation and codification strategies. We could make the hypothesis of the relevance of the rule justification as a means to support these strategies.

While the welding issue was the example we use in this paper to put forward the necessity of a device to allow codification and personalisation strategies, we met other design situations (crane structure, hoist system) where it could also be relevant.

5 CONCLUSIONS

In this paper, the analysis of a company producing special machines has been conducted in order to envisage how feasible knowledge management in such context is. After discussing briefly the concepts of information and knowledge and analysing the present strategies relevant to implement a crucial knowledge management approach, the context and the investigations carried out have been described. The observation analysis led us to some results showing that a knowledge management approach is relevant in the context of special machines.

First, in spite of the unique nature of each project, the existence of numerous and multi-level recurrences has been observed. This result is of great importance to legitimise and to adjust the knowledge management strategy.

Second, the recognized existence of experts and the role they play are of major interest for defining the knowledge management approach. This participates in locating the crucial engineering knowledge and gives some elements for defining the required knowledge networks.

Third, we showed the necessity of a collaborative device to allow codification and personalisation strategies because it has been proved that different experts in the same company should explicit differently the same design rule.

To sum up, for knowledge management in a context of special machine design, it is necessary to identify expert people and crucial engineering knowledge, to point out the recurrences and their level, and to give means at disposal for confrontation between experts. With this aim in view, works are in progress to develop such an adapted collaborative device.

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