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“JOINING THREE HEADS” – EXPERIENCES FROM MECHATRONIC PROJECTS

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Abstract

Denmark is one of the leading countries of mechatronic oriented product development. Mechatronic solutions lead to elegant, multi-functional and easy-to-use products, with increased quality and performance.

There is a challenge for mechatronics in helping to create complex and highly functional products, in an environment of ever-increasing demands upon attention to cost, efficiency, flexibility, reliability, etc. during the product’s development phases.

Mechatronics is not simply a working method, nor is it simply the result of a combination of three (or more) subject disciplines; it is also a mindset. This paper reports on a research investigation where the profiles and mindsets of engineers from three subject disciplines – mechanical, electronic and software engineering – were explored.

1 Introduction

A large proportion of Danish industry focuses on niche markets, or the high-end of well populated markets, in order to do business. Elegance, multi-functionality and ease of use are three of the qualities that are striven for in these markets, as these compensate for the somewhat higher prices that a Scandinavian product has to demand. Mechatronics is seen in Denmark as an enabler for such products, which helps to ensure that these qualities are reached, and at the same time that costs are saved, product assortment is maximised and multi-product development is made easier.

There is a general shift of focus and understanding from *the product as an artefact* to *the product as a utility/carrier of value*, which gives an additional challenge for us to consider mechatronics as carrier of many different solution alternatives and configurations of products.

In short, Danish industry has the following reasons to focus closely on mechatronics:

- Danish industry must continue to be a leader in mechatronics, if it is to survive on the global marketplace
- as products become easier for the end-user to use (through a well designed man-machine interface), their internal architecture becomes more and more complex
- demands on products’ size, price, environmental performance, efficiency, flexibility (upgradeability), reliability, etc. point towards more integrated and therefore complex products

- industry's need to renew its knowledge and competencies in mechatronics leads to the need for descriptive models in this area
- the product manager's need to be able to understand how to build an optimal mechatronic project team leads to a need for models and experiences
- the product development team's need to be able to work together as a multi-functional team, in order to gain the most effective results possible (i.e. innovative products), leads to a need for deeper understanding of the working methods, patterns and mindsets of the various subject engineers.

The above reasons drove the empirical investigation described in this paper, as part of the P* Programme[1] at DTU.

2 Research Method – An Empirical Study within Danish Industry

In an attempt to explore the experiences of Danish companies in carrying out mechatronic product development projects, an empirical survey was carried out, where the five Danish P* companies – Bang & Olufsen, Danfoss, Foss Electric, Nokia and Oticon – gave access to one product development team each. Within each company, project team members were invited to a semi-structured interview to tell of their experiences in developing mechatronic products.

The nature of the semi-structured interview technique was chosen for two reasons in this case:

- semi-structured interviews allow the interviewee to lead the interview if they wish, telling about their experiences and opinions
- there is a substantial safety net in this situation, provided by the interviewer, who should steer the interview to cover the whole expanse of the exploration's enquiry, especially if the interviewee runs out of things to talk about.

It was ensured that project team members from both the mechanical, electronics and software disciplines were represented, as well as project leadership and/or product development planning representatives. It is recognised that each of the project teams studied had strong representation from other equally important subject areas, such as optics, acoustics, chemistry, bio-technology, etc. However, for the purposes of this investigation (and thus this paper), focus was set on the three common denominators of mechanical, electronics and software engineering.

Interviews lasted approximately 1½ hours per person, were tape recorded and transcribed. In total 25 people were interviewed.

Each company received a company-specific report, telling of the findings from their individual project team interview, and in addition, a main report was compiled [1], reporting the overall experiences gained from the investigation. Furthermore a workshop was held, based upon the findings from this investigation, where a further nine Danish companies were represented.

[1] P* - a wholly industry funded programme of research into product development practices and needs, running from Dec. 1998 – Dec. 2000.

This paper is based upon some selected aspects from the main report, describing mindset and working methods. Of course, the paper Is supported by the body of theory, models and approaches built up over the past decade, through PhD projects [2], visiting researchers [3] and various research events.

3 A Brief Look at Three Types of Engineer

In the following, we will take a brief look at the characteristics of the three types of engineer, before sharing our conclusions from the research, which is where the real insight for further work emerges.

Software
Software engineers are a relatively new (and rapidly increasing) breed in many companies. Many of them have had many jobs before, and they are the most difficult group of professional employees for industrial companies to keep hold of, due to the continual growth of the market (and thus job opportunities).

Software follows an extremely systematic course in its development and there exist many models to keep and guide software development. Software is often developed on a “platform” basis and a large proportion of software content can be used again in many product generations.

It is explained that when first one had identified the manner in which software shall be structured, it is reasonably easy to continue to structure and build algorithms in. However it was a general experience that there was no systematic manner of cataloguing and reusing algorithms from previous software versions – a clear area for improvement.

Software engineers are used to waiting. It is usually way into the project before the software man becomes fully involved in the project – and it is usually software that is the last to finish. Whilst this was generally accepted by most software engineers, there was an expressed wish to receive earlier mock-ups of hardware to give an opportunity of how to go about structuring the task. It would not be so bad having to be last in the project each time, if only the other colleagues appreciated that this was the way of the world. It was revealed that if time became tight in the project, the software department would often get the job to complete, normally from the electronics colleagues. This was not felt to be a optimal way of developing mechatronic products.

Electronics
Electronics engineers seemed in the study to have a place in between the mechanical and software engineers, as communicators in the tri-functional collaboration. This was often due to the electronics engineer’s education and interest in the interfaces between his own competence area and those which his work is influencing.

Electronics design is often focused on connecting the physical and the user-interface together. The task of the electronics engineer is to conform to the physical frameworks laid out by the mechanical design of a product/component, whilst also supplying a processing power tailored to the software that will be utilised by the product.

Electronics engineers are typically involved fro the very early stages of the project, and find no problem n starting their design, by the use of mock-up models, that can replicate the final specified electronics capabilities without having to apply to the physical constraints of the final design.

There is often a very close cooperation with software people, due to the close relationship between software and electronics. However, they find it difficult to foresee how they could help software people earlier, by providing early mock-ups to work on, as these mock-ups are not reliable enough to be given away.

Electronics engineers were seen to work relatively systematically, but are heavily dependent on an iterative approach to their work, especially as there are a multitude of possible solutions to each task; some solutions are more elegant and efficient than others.

Electronics engineers agree that software colleagues should be involved earlier in the project, if only to listen and gain an overview of the project's layout.

Mechanical

Mechanical engineers represent the most long-standing and traditional of the disciplines in this tri-functional team. They are used to working to iterative engineering design models and to following a specification for a product's development and realisation. Mechanical engineers often account for the majority of the grey hairs in the product development team, and often perceive themselves further away from their software colleagues than the software colleagues do from them.

This said, mechanical engineers see great challenges in developing products with ever increasing complexity. It was explained that the smaller that products become, the more need there is for mechanical engineers' expertise, in ensuring even more precision and faster delivery of results.

There was recognised to be a necessary change in the way in which projects are organised, towards more multi-disciplinary working methods, and it was admitted that the perfect working methods are still to be found, to facilitate such multi-functional teams.

Mechanical engineers see too their software colleagues' problem in getting hold of information earlier. But they too say that this information is difficult to share, as the very early phases of the project are very uncertain, with many concepts being attempted, which may not come to fruition.

4 Conclusions – Joining Three Heads

The findings from this investigation lead us to a series of conclusions about the execution of mechatronic product development and the working methods, patterns and mindsets of such practitioners. We shall devote a paragraph to each conclusion.

There was no doubt that in each case, successful mechatronic products were being developed by well functioning teams of experts from various disciplines. But in each case, it was expressed that continued success in mechatronic product development relies on well-considered working processes and techniques, which currently do not exist to a satisfactory level. Project reviews currently have no explicit demand on the project team to show that they have carried out mechatronic-focused considerations in their product development. Setting high demands to teams, to show a level of attention to the integration of technologies will drive the need for closer working techniques.

In the early phases a product development project, there exist no satisfactory means of neutrally considering the solution possibilities for the means in which the product's many functions should be solved. A new approach is necessary to help "cut the cake" in the project's early phases, so that the mechatronic nature of the product becomes designed-in, rather than coincidentally derived.

Any new approach to considering mechatronic product development in an integrated fashion should respect the need for a high level of quality in each discrete subject area. One of the main reservations found in the investigation to an integrated and common approach to mechatronic product definition and development, was that the individual competence areas could risk suffering from having to make too many compromises, resulting in a less-than optimal final solution, where the excellence of each discreet competence should be manifest.

Creativity should be encouraged and supported in projects. One of the current barriers to "equal opportunities" in projects, (i.e. the equal chance for both mechanical, electronic and software engineers to have a say in which slice of the cake should be solved in their own competence area), could partly be solved by taking a common approach to the project from another starting point, guided and steered by creativity techniques. Further into the project, an appreciation of the advantages of solving problems across competence boundaries should be fostered.

Clear demarcation of tasks and sub-projects, not based upon disciplines, but upon product functionalities, will help both to create a shared leadership of the project's sub-tasks, and also a ensure readiness to give tasks to external parties (consultants, contractors, suppliers, etc.). This thinking is in line with the theories related to modularisation and platform engineering [4], where an understanding of both the discrete components/modules and the interfaces among these leads to a new and innovative way of understanding and utilising the product and its many modules.

A new way of viewing the product is necessary, in order to be able to find solutions that lie across many disciplinary boundaries. One of the companies investigated told that the "magic" in their products lies in the close interaction between mechanical, electronics and software engineering, and not alone in the discreet disciplines. An extended function-means approach [5] could be one such way of ensuring a new viewpoint from which to perceive the product.

Project managers should posses both organisational and technical competences in the three disciplinary areas. There is much discussion about the types of qualifications expected of mechatronics engineers and of the people who should lead and guide these engineers. It was experienced from this survey that technically specialised leaders were rather scarce in the projects. One approach to this problematic was seen in a specific company, who employed two team leaders for each project, one who had the responsibility of taking care of the technical development of the project, and the other who focused on the organisation of the project and the people.

Project coordination (and timing) is extremely important, in particular where the coordination of information flow to the software developers is concerned. One of the roles of the project manager should be to ensure that the correct people are occupied with the correct tasks at the correct time. In this survey we saw that there were both (formal) methods, (informal) approaches and (organisational) routines for doing this. But an need was expressed for a more integrated approach to coordinating competencies in the project.

5 Discussion

Our goal with this research is to identify new working methods that allow for the design and development of mechatronic products. We feel that an important step forward with this goal could be achieved by focusing on the following areas:

- New procedures for product development, such as: procedures, elements, product-life thinking, product modelling, design preparation, aspects, and improvement in integrated product development.
- Product synthesis (managing “the magic”), in particular looking at: a holistic approach to product design [5], [6], the domain theory [7], and building a synthesis model for mechatronics.
- Synthesis of mechatronics, including important issues such as: cutting the cake, functional thinking, MES bridging models, and common areas/methods.

Through this focus on these areas, we believe that we will be able to identify and develop new procedure for mechatronic product development, consisting of explanations in the following areas:

- procedure’s context
- threads in the procedure
- descriptive dimension
- holistic model.

6 References

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