INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
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RESPECT DESIGN OR EXPECT DISASTER!

Crispin Hales

Keywords: Design failures, root cause analysis, design process analysis, case studies.

For over half a century design researchers and practitioners have been studying and analysing the engineering design process, with the aim of developing theories, methods and tools to improve design effectiveness at varying levels of technical complexity. An enormous range of documented output has been generated, from which has come a detailed understanding of how to produce successful designs in a systematic, competent and professional manner. There has been a growing attempt to pass on this knowledge, experience and methodology in a practical way, but the reception is usually more sceptical than enthusiastic. Often the focus in industry is on immediate issues of production and cost savings, while in university engineering departments it is biased towards engineering analysis to maximise research revenue.

It is clear from the investigation of numerous engineering failures and disasters that the simplest and most fundamental **design** methods, guidelines, rules and recommendations are still not understood, accepted, or used by many who claim to be competent engineers and project managers. In fact it often becomes evident during an accident reconstruction or failure analysis that the **design expertise** of the team members working on the project was so abysmal that they produced a defective design unknowingly, despite their undoubted competence in engineering analysis and testing.

The time has come for the engineering design community to become more forthright and insistent that leaders in industry, academic institutions and regulatory bodies give serious attention to matters of **engineering design,** as distinct from matters of **engineering analysis**. With the wealth of knowledge, experience, methods, guidelines and tools now available to support the engineering design process, there is no excuse for poor design management or for defective designs. It is unacceptable for qualifying engineers to be deficient in design competence. It is unacceptable for engineering regulations, codes and standards to be set in place without appropriate review of the engineering design issues. The International Conference on Engineering Design provides an excellent forum for the presentation and discussion of such issues and from now on participants will have the opportunity to make their voices heard with more unity through its formal sponsoring body, the Design Society.

Three selected examples of failures in design will be presented, each one illustrating a different type of deficiency in the engineering design process. The largest industrial loss in U.S. history, the massive recall of a redesigned product and a gruesome accident with a large machine serve as stark warnings for those unwilling to respect the decades of work by design researchers, practitioners and educators in trying to improve the way we do design.

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ENGINEERING DESIGN – THEORY AND PRACTICE

Billy Fredriksson

Modern high-technology products are characterized by an ever-increasing number of functions, built-in knowledge and heightened performance, brought about by the close integration of mechanics, electronics, computers and software. This places new demands (both technological and managerial) on the product development or systems engineering. The development and manufacture of advanced products require very heavy investments. A large portion of the total life cycle cost and value is already defined and committed in the design process.

The engineering design part of product realization is fundamental and a very important capability for industry and its competitiveness. The paper discusses engineering design both from a scientific and a practical perspective. It is divided into three parts.

Firstly, the importance of building scientifically based theories, methods and tools for engineering design is discussed. It is discussed in comparision to natural sciences (like physics and mechanics) and to art (like music and painting). The question is asked-What is engineering design?

Secondly the application of different engineering design and product development methods and tools are exemplified. Cases are from aircraft engineering design and management including systems integration and involving subsystem suppliers in the virtual enterprise.

The industrial base and its global competitiveness is of course a strategic asset and very important for the welfare and growth in any country. Thirdly, therefore the importance of developing and maintaining a sustainable leading competence and capacity for engineering design is discussed.

Six years ago the Swedish Foundation for Strategic Research, SSF took the initiative to start the graduate research school ENDREA (Engineering Design Research and Education Agenda). One year later the graduate research school in manufacturing, PROPER, was started. These two initiatives have now developed national networks in engineering design and manufacturing and a relatively large number of Phds have been examined and research in many areas have been performed. Now, as the next step, the SSF has decided to invest into the ProViking program of research in product realization (including product development and manufacturing). The ProViking program includes also a national graduate research school making it possible to maintain and further develop the national networks of cooperation in education and research. With these programs as a background the paper discusses different aspects and mechanisms for developing efficient cooperation between academy and industry. How to build-in the right driving forces and incentives for both industry and academy is also discussed. The importance of developing a good cooperative environment between academy and industry for education, research and industrial applications in engineering design is exemplified.

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WHAT IS THIS THING CALLED DESIGN RESEARCH?

Lucienne Blessing

The importance of engineering design as an industrial activity and the increasingly complex and dynamic context in which it takes place, has led to the wish to improve engineering design. Although people have designed for centuries – and no doubt attempted to improve the process -, it did not become a research topic until well into the second half of the 20th century. Still, despite 30 years of design research, the field is not always considered to be a scientific discipline. A lack of clarity exists about what constitutes design research and how to go about it. The aim of the presentation is to shed some light onto "this thing called design research", to draw boundaries and encourage discussion.

1 Design research

Design is a complex activity, involving artefacts, people, tools, processes, organisations and the micro- and macro-economic environment (market, legislation, society) in which it takes place. Design research aims at increasing our understanding of the phenomena of design in all its complexity and at the development and validation of knowledge, methods and tools to improve the observed situation in design. It is this integration of "generating knowledge about design and for design", that is "instrumental to the development of engineering design".[1]

Engineering design research has experienced an exponential growth. The downside is that:

- Many strands of research have emerged, that are neither established nor clearly defined;
- It is no longer possible to obtain an overview of the results;
- Referencing islands are common: groups of researchers refer to each other's work, only by coincidence becoming aware of the work on other islands.
- No agreed terminology exists: even for basic terms such as 'function' and 'design';
- Little verification and validation of findings takes place;
- All address something different: few attempts exist to bring results together;
- All do something different: no established research methods and methodology exist.

2 Main issues

Three related issues need addressing:

- The lack of overview of past and present research activities,
- The lack of use of results in practice,
- The lack of scientific rigour.

Design research shows a large diversity of research topics and methods. Although “variety has the potential of delivering value […] there is a risk that research may end up in a set of unconnected streams and in a sort of methodological anarchy where anyone can come along and claim the scientific validity of his work” [2]. This is what happened in design research. To develop comprehensive models and theories, the results have to be brought together.

If the aim of design research is to improve design, and if this research is to be successful, research should have some effect in practice. Important issues are: the development of guidelines, methods and tools on a solid understanding of designing; a proper validation of the developed support; and addressing the implementation of this support.

A lack of scientific rigour can be observed. Design research must be scientific in order for the results to have validity in some generic, practical sense. For this, design research has to develop and validate knowledge systematically. This requires a research methodology.

Design research, as defined here, not only involves the formulation and validation of theories about the phenomenon of design. It also aims at improving the observed phenomenon. That is, design research involves design, namely the creation and evaluation of a desired situation and of the means to realise this, which cannot be derived directly from an understanding of the present situation. These activities should be made explicit in a research methodology [3].

3 Conclusions

Design research has passed through three overlapping phases: Experiential, Intellectual, and Experimental [4], but a theoretical framework has been largely missing. Together with a fast growing number of researchers, this has led to increasing concerns about the efficiency and effectiveness of design research. In the near future we have to focus on the improvement of our research: an established methodology is one of the main requirements. A methodology that covers both the study of the phenomenon of design as well as the development of design support. Only then, we might enter the next phase in design research: the theoretical phase.

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DRIVE-BY-WIRE BY SKF

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Keywords: Drive-by-Wire, FILO

This paper describes in short the development of drive-by-wire technology by SKF for automotive applications, which include steer-by-wire, brake-by-wire and clutch- and gearshift-by-wire. These developments have been used for the Bertone-SKF FILO concept car, showing both the acquired design freedom and technical capabilities offered by drive-by-wire technology.

1 Drive-by-Wire

Mechatronics is a major strategic focus within SKF. For both the automotive and off-road vehicle industries, drive-by-wire is now established as the technology to replace many of the traditional hydraulically and mechanically operated systems and will increasingly be introduced in the coming years.

By-wire systems are moving at an increasing pace from the development and engineering labs into mainstream production. SKF's technology and its manufacturing skills in high-precision, high-volume engineered units gives an ideal base from which to address the drive-by-wire technological developments.

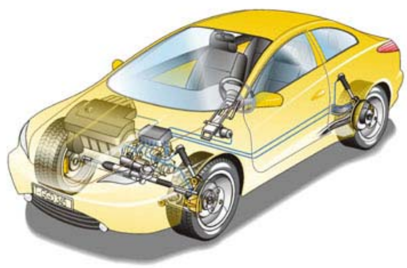

Figure 1. An example of a drive-by-wire car.

The aerospace industry has employed fly-by-wire concepts successful for many years and the drive-by-wire system follows these principles closely. Essentially in by-wire systems an electronic system replaces the direct mechanical control of a machine. This means, for example, that the movements made by the driver with the steering wheel are not transmitted mechanically via the steering column, via the steering rack, to the front wheel as in conventional control. Instead, the driver's physical movement on the steering wheel is sensed and converted into a digital electronic signal that is transmitted to a Smart Electro-Mechanical Actuation Unit (SEMAU) that controls the steering angle of the wheels. The same principle can be applied to the braking and gearbox systems. By removing the direct mechanical link between the driver and the steer, brake and gearbox, the feedback to the driver is removed as well, e.g., the feedback from the tire/road friction. It is essential that the drive-by-wire systems provide the driver with the proper feedback for safe car handling.

2 The Bertone-SKF FILO concept car

The development work has been presented to the public with the unveiling of the Bertone-SKF FILO concept car at the 2001 Geneva Auto Show.

Mechatronics, the combination of mechanical devices under intelligent, electronic control, is at the heart of the FILO. It is these techniques that allow much of the interior redefinition, allowing for a reassessment of how a driver interacts with the vehicle and environment in which it is being driven.

Stile Bertone used the opportunity of the drive by wire technology offered to re-design the interior architecture of the automobile and to create a living space devoid of the traditional constraints imposed on position and freedom of movement.

The abolition of mechanical links for all these functions in favour of by-wire systems have created new space that allows for the complete re-design of the interior, fully exploiting the broad freedom that such systems can offer.

Figure 2. The FILO drive-by-wire concept car.

3 Conclusion

The developments on drive-by-wire technology are still ongoing. In 2002 the next concept car has been developed, the Bertone-SKF NOVANTA, making use of the third generation drive-by-wire technology.

Another development by GM has been presented on the Paris Auto show; the GM AUTOnomy HyWire concept car. In short, this concept car is powered by a fuel cell, using hydrogen as fuel, producing electricity and water only. Traction is delivered by a central electric motor driving the front wheels. Braking and steering is performed by SKF drive-by-wire systems.

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DEMANDS FOR SUSTAINABLE DEVELOPMENT

Tim McAloone

Introduction

Sustainable development is a term, which has existed for some years now and in its definition it describes the need for society in general and industry in particular to positively consider people, planet and profit (known as the *3P's* or the *triple bottom line*) together, in order to achieve a balanced economy and ecology [1]. However, it is not apparent that the demands for sustainable development have successfully been understood or implemented in industry, despite the increasing calls for sustainability considerations to be made, either through consumer and general societal demands (e.g. legislation, standards, purchasing power, lobbying), or through pressure from the growing number of sustainability indexes on the open stock exchange.

Since 1999, for example, a number of sustainability indexes have been operated by Dow Jones, who state corporate sustainability as being:

"…a business approach that creates long-term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments. Corporate sustainability leaders achieve long-term shareholder value by gearing their strategies and management to harness the market's potential for sustainability products and services while at the same time successfully reducing and avoiding sustainability costs and risks." [2]

A number of indices are thus developing in a new global standard for *responsible investors*, with which to measure a company's performance when considering and incorporating the principles of sustainability.

There is no doubt that this emergence and growth of responsible corporate investment is a positive reflection of the desire of society to become more responsible about environmental and social well being, whilst also ensuring the rewards of an economical success as a result. Yet it is still unclear as to how one can ensure an approach that will harness the market's potential for sustainability products and services, when discussing at the company board meeting, planning in the project room, or sitting at the drawing board.

State-of-the-art with respect to product development

The main demands of sustainable development can be broken down into many operational aspects and furthermore to professional approaches for industry. The past fifteen years have seen many attempts at operationalising the sustainability demands related to environmental considerations into mindsets, methodologies and tools – an approach commonly known as ecodesign. Ecodesign is, thus far, probably the most operational attempt at achieving sustainability for a product developer to consider, due to its concrete nature, considering physical changes to a physical product. There are now a number of centres of excellence in ecodesign practice, both in industry and academia, where tools and methods have crystallised into positive changes to the environmental performance of the product under development. However, there are even more instances where the tools and methods developed fail to be integrated into real life product development, due to shortcomings of either academia or industry whilst developing the tools, or when attempting their integration. This paper will both demonstrate the successful examples of ecodesign development and integration, and investigate the shortcomings when integration in industry fails.

After more than a decade of research and development of ecodesign approaches we can see a steady progression from the single-case, artefact-based approaches to ecodesign, to more holistic, multi-product and even product-service related considerations. Ecodesign *leaders* are thinking in these terms, whilst many companies still lag behind with respect to the most elementary of ecodesign activities. A roadmap of sustainability needs to be drawn for industry, in order to make clear for all, where the known sustainability goals lie, where the leaders currently are and which paths the followers should choose.

The challenge of sustainability: hope for the future

It is certain that for sustainability to become an operational consideration for companies and their product developers, efforts must be made to interpret and communicate the demands in a language that fits into the other daily considerations of the organisation (about cost, quality, time, shareholder value, etc.).

On the other hand, we can see that if we are to achieve quantum leaps in the improvement of the products and services developed by industry, (with, for example a factor 4, 10 or 20 environmental improvement [3]) then we must begin to employ radically different ways of considering the product, the product development process, and the whole need for the product in the first instance. *Radically different* needn't mean *unrealistically complex*, but should give us a new way of viewing our role as product developers.

We should consider ways in which we can embrace and exploit the benefits of current and emerging technology to aid the process of developing products and services, so that we can begin to create overviews of multiple product life scenarios, product asset planning and the whole issue of material flows when considering the entire lifecycle of the products and services (and the following consequences hereof) that we develop, in order to increase our ability to gain a holistic view of our products and their effect on the environment.

Finally, we need to understand how to equip ourselves with tools, techniques, mindsets and skills to be able to deliver products and services that can contribute to a sustainable environmental, social and economical development.

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