Preface

In each phase of the development, production and usage of systems, engineers use *models* for an approximation. Examples for a model would be a rod that is only able to conduct normal forces, an evolution equation for the wear and tear on a machine as well as a usage scenario or a load history. It is generally agreed that a model is the only way to make a system calculable or predictable, even though it is merely a copy of reality and not reality itself. The creation of a model always means to leave out a large portion of reality.

The word a*bstraction* is used to describe this process of consciously ignoring *the part of reality that is irrelevant* to answering the question at hand. However, for cases when the part of reality that is significant to answering the question is ignored in an unconsciously way, the Collaborative Research Centre CRC 805 coined the specific term *unknown uncertainty* or lack of knowledge. Both abstraction and lack of knowledge are always dangerously close to one another. In contrast to empirically based models, abstraction is more absolutely necessary in axiomatically based models. The latter adhere to the law of parsimony (Einstein: "…as simple as possible, but not simpler") and has been a mainstay principle of the natural sciences and engineering since the time of Galileo. The other extreme is the *law against the poverty* or the law against miserliness ("…it is vain to do with fewer what requires more") formulated by Karl Menger. In fact, these two paradigms are not in opposition, but rather complement each other. The simultaneous processing of large amounts of data and nonlinearities which can be modelled adequately by using the law of parsimony represents one research topic. Einstein's and Menger's quotes both reflect the struggle for obtaining valid models on one hand and dealing with lack of knowledge on the other hand.

Lack of knowledge is the most extreme and most significant source of model uncertainty, as its consequences are incalculable and unpredictable. One example is the Challenger accident, when the temperature history was not taken into consideration. Another example is the intercity train accident in Eschede, Germany - here the dynamic material fatigue of elastomers in the railway wheels was unconsciously ignored. An important part of abstraction is to separate the chain of events within a process into individual steps and/or to divide a system into individual components. The abstraction must be carried out at the interfaces. As abstraction and lack of knowledge always go hand in hand, interfaces are a significant source of uncertainty.

Keeping in mind that data are the basis of empirical models, it is assumed below that the creation of status quo models (not future models) has already been accomplished. This implies the existence of either a speculative or a verified and validated functional framework model. In this case, the data are part of the model. We term a model with deterministic parameters and a clear solution *disregarded uncertainty*. *Stochastic uncertainty* takes into account a determinate variability in the form of density functions, in contrast to *unknown uncertainty.*

Uncertainty of a mechanical engineering product as mentioned above, occurs in all phases of the product lifetime – development, production and use. It critically influences process properties and consequently product properties. Incorrect assessment due to uncertainty may have catastrophic consequences in terms of safety, particularly in case of products with load-carrying functions. Thus, it negatively impacts the product's profitability.

In the development process, a finished design is derived from the initial idea. To address uncertainty at this stage, advanced methods of robust design and corresponding mathematical optimisation methods as well as mathematical models for the combination of active and passive load-carrying components within a system network are developed. Furthermore, mathematical algorithms are used to analyse the propagation of uncertainty, and appropriate information models are used to represent and visualise uncertainties. Scaling method-based size range development and dimensional analysis describe the evaluation of uncertainty and modularisation. In addition, new assessment methods and combinations of scaling methods as well as discrete optimization are developed to control uncertainty in the whole system.

In the production process, the physical end product is produced by using raw material. The process chains are optimised with the help of the mathematical methods described above. Metal-forming and metal-cutting methods are rendered in a more flexible way as long as the level of production quality remains consistent. In order to get a complete insight into the individual product lifetime, functional materials for active and sensory components are integrated at an early stage. During the utilization of the load-bearing system, new usage monitoring methods ensure the permanent acquisition of actual loads. At the same time, advanced mechatronic and adaptronic or adaptive technologies stabilise and attenuate the load-carrying structure. Finally, structure or property relationships derived from the utilization process may provide information on the quality and suitability of the product during actual utilization with feedback to the development and production.

From practical experience, causes of uncertainty are usually unclear responsibilities, an increased technical complexity, rising development speed due to increased competition, higher requirements for cross-company quality assurance and an increased cost pressure. In order to address these causes, it is necessary to describe, evaluate and eventually control the uncertainty both in product lifetime and in the whole system by means of appropriate methods. This is also the focus of the research conducted by the Collaborative Research Centre CRC 805, host of the 2nd International Conference on Uncertainty in Mechanical Engineering ICUME 2015 and funded by the Deutsche Forschungsgemeinschaft DFG.

The Organizing Committee of the Second International Conference on Uncertainty in Mechanical Engineering – ICUME is pleased to present several works from an international community and from the CRC 805 giving an academic and industrial perspective to describe, evaluate and control uncertainty in general mechanical engineering and the nine special topics of the mini symposia.

The editors hope to meet the interests of a broad readership with the selection of the following contributions and motivate further investigations.

Peter F. Pelz and Peter Groche

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