

## Motivation

In fast changing environments flexibility is often mentioned as a basic necessity. This flexibility incorporates strategic and management flexibility, flexible development processes, flexibility in production like flexible manufacturing systems (FMS) as well as flexible products, which can easily be adapted to changed conditions during the product life.

Even though flexibility in the product context is often mentioned and products are labeled flexible, only little scientific research can be found on this topic. Especially the link between uncertain and changing requirements and the flexible design of the physical product is still to be analyzed.

## Aim

The aim of this research is to gain a better understanding of flexible products, their development, their properties, their advantages and trade-offs and if product flexibility is a useful way to handle uncertain, vague and fast changing requirements. Therefore following topics have to be clarified:

- What is product flexibility?
- What are flexible products? What are their properties?
- How are flexible products developed?
- How the development process be improved?
- Is product flexibility useful to handle uncertain requirements?
- Is product flexibility useful to handle changing requirements – already during the development process?

## Approach

This research projects is based on the Design Research Methodology (DRM) proposed by Prof. Blessing:

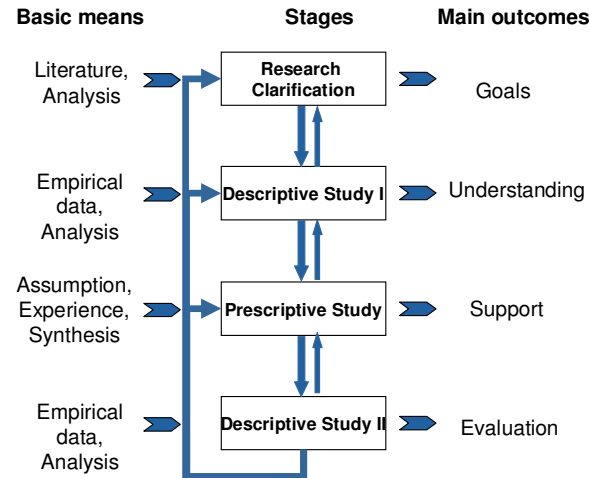


Fig. 1: Design Research Methodology

Within the first stage – Research Clarification – the goals of the research were defined with help of literature studies.

The Descriptive Study I was carried out as more comprehensive literature study on the one hand side and as a practical project on the other hand side: a bioreactor for cell cultivation was developed with very vague requirements. It was designed flexible when possible and had to be changed and adapted to new appearing requirements.

In order to ease the future development of flexible products a new supportive tool is developed in the Prescriptive Study.

Evaluation of the new support will be carried out in the Descriptive Study II. And is partly part of the same practical project as well.

## Present results

The results of the research were presented on different international scientific conferences. Here a brief overview is given.

### Flexibility in Product Development (PD)

Flexibility in PD “denotes a willingness and an ability to accommodate requirement changes during the design process (i.e. before the system is fielded)“.

### Product Flexibility

In correlation with the definition given above flexible products can be understood as products which can be adapted to changed needs and requirements with little amount of time and costs within the development phase as well as during the rest of the product life cycle.

### Flexibility and Robustness

According to the definition given above, the most flexible products are the ones that do not have to be changed and/or reconfigured when requirements change. Even though these products are often considered flexible here the term ‘robust’ is proposed for these products, which are insensitive to external changes.

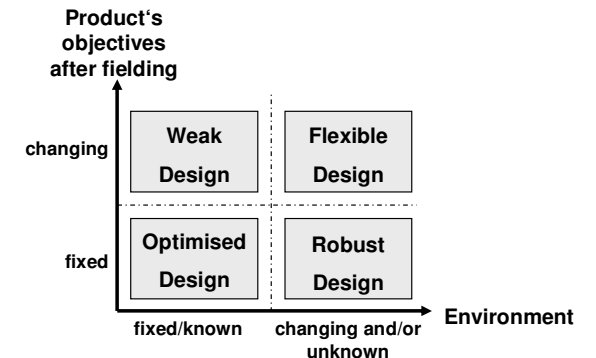


Fig. 2: Flexibility and Robustness as a function of the products' objectives and environment.

### Model of product flexibility

In order to create a better common understanding a new model for product flexibility was developed (cf. Fig 3).

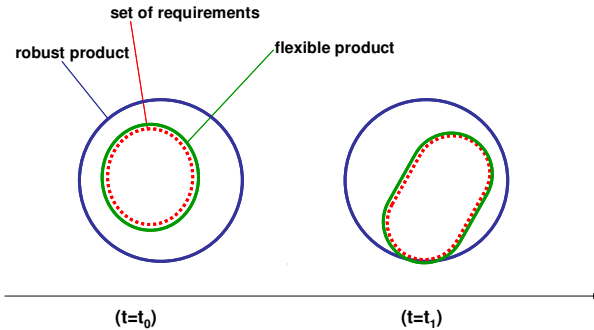


Fig. 3: flexible and robust product's ability to adapt to changed requirements over time

Robust products (blue) cover all (most of the) requirements (red). Also flexible products (green) cover all requirements. When the requirements change over time the flexible products can (easily) be adapted to the new situation. According to the definition this is already possible during the development phase. Robust products do not change over time, but due to their robustness they (hopefully) still cover all requirements in future situations.

### Guidelines for the development of flexible products

As a supportive tool for the development of flexible products (including robust products) 38 guidelines for the development were collected, clustered in six groups and compiled to a comprehensive set. The six clusters are:

- Decoupling and modularisation
- Inherent flexibility
- Easy (dis-)mounting
- Standardisation
- Extended Use
- Overengineering

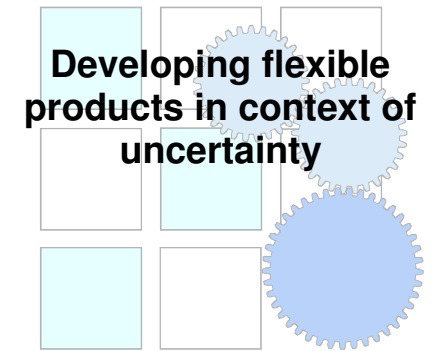
An example for the guidelines is given in Fig. 4. All of the guidelines are illustrated graphically in order to ease the understanding. The layout is based on traditional and well known collections of guideline with other focus in engineering design.

#	Guideline	unflexible	flexible
21	Plan redundancies		

Fig. 4: Extract of the newly compiled guidelines

### Future work

Even though the all guidelines for the support are taken form scientific literature and/or derived form practical projects their application still has to be evaluated. With help of a laboratory study we want to analyse the applicability of the guidelines and investigate, if a flexible product design is a useful approach to handle uncertain, vague and changing requirements.



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