Design Margins

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The Problem

• Design optimisation aim to meet but not exceed multiple requirement to make product cheaper or lighter
• Margins are “surpluses” above the parameter requirements
• Margins provide a room for manoeuvrer
• If a margin is used up, change will propagate across other parts
• Understanding and planning margins is critical for companies
• Margins have many names: room for growths, tolerance, buffer
• We need to capture and model margins systematically to manage design processes effectively
Overview

• Starting point
  – Product planning
  – Engineering change
  – Freeze
• Types of Margins
• Model of Margins
• Outlook
• Conclusions
Background
Erosion of margins in design

Margin get smaller over Time

Last change pushed design over the edge
Change Propagation

Classification of component behaviour

Classification of process behaviour

Margins

Degree of absorption

Degree of propagation

Absorber

Buffers

Carriers

Multipliers

Constant

Number of changes

Time

Avalanche

Blossom

Ripple

Margins
Component Connectivity

Legend:  
- Change relevant parameter
- Change irrelevant parameter
Component Freeze

**Conceptual freeze**
- Customer requirements

**External freeze**
- Detailed specifications, lead times, pre-defined parts

**Internal freeze** (by design team)
- Conceptual decisions by design team
- Part dependencies, defined interfaces, parameter decisions

**Margins**
Empirical Study
The Interviews

• Eight interviews in October 2013
  – Platform
  – Brand
  – Design engineers
  – Analysis engineers
  – Feature experts
  – Simulation engineers.

• Chassis team in Volvo trucks

• Analytical focus on margins and concepts of margins
  – Summary of interviews
  – Identification of key quotes
  – Abstraction and falsification of theoretical concepts
Margins in design process

Margins are discussed in different ways

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Overdesign

• In product planning for core components
  – Future generations
  – Different brands
• New applications in the future
• Avoiding unnecessary changes during design process
• Different use conditions
• Customer misuse
Safety margins and requirements

- Safety margins are planned into the product requirements,
- Safety margins are add explicitly to the component
- Depend on the use case including extreme scenarios
- Safety margins are hidden
Tolerances

- Exist for manufacturing and assembly
- Can test all the combination
- Careful tolerances for engine and gear shift, but for other components
Clearances

• Clearances are very important in
  – Engineering change
  – Integration of features
  – Optimising a product

• Thinking about clearances
  – Margins (of what?)
  – Requirements (of what?)
  – Constraints (on what?)

• Competition between teams
Different Concepts of Margins

- **Customers**
  - Needs
  - Safety margin

- **Product definition**
  - Requirements

- **Design**
  - Capability/Performance
  - Design margin
  - Tolerance

- **Manufacturing**
  - Robust production

Requirement margins

Product margins

Not to scale
Margins and requirements

- Safety margin
- Design margin
- Tolerance

Perspectives
- New generation
  Margins cater for uncertainty
- Engineering change
  Margins allow change

needs
requirements
capability
robust
Overdesign: Room for growth

Current needs

Future needs

Requirements

Safety margin

Design margin

Tolerance

Perspectives
- Product planning
- Design might not be aware of these margins

Capability

Robust
Overdesign: avoiding change

Safety margin
Current needs
Requirements
Future needs
Capability
Robust

Design margin
Tolerance
Perspectives
- Product development
Designed in flexibility

• Products can create margins through being tunable, i.e. drill holes specifically rather than predrilling them.

So if I give you another example, we have... a shock absorber here installed on a bracket, it is on the frame rail, something like this… That bracket is positioned attached with only one hole... in that position you will see it sitting like this, and then sitting like that in another position. That height I think... have a valuation of... well I calculate lowers that… 32 different positions.

In height and in length wise as well. One bracket.

• Margins in systems by adapting those components that “can do up”

• Creation of system margins by replacing components

There could be margins in the feature that you were certain, rubber stiffness, the vibrations get too much and then you can create some margin by introducing a softer rubber and you can do for all or for a few or part.

• Margins are traded off against each other
Margins as mitigation across different perspectives

Margins

Brand identity ↔ Communality
Features ↔ Features
Product optimisation ↔ Platform optimisation
Product cost ↔ Process cost
Product cost ↔ Use contexts
Knowing margins

- Designers don’t know about the margins built into the requirements
- Margins on features usually not known
- Designers have a sense of margins of their own components against their requirements
- This understanding is quite localised
- Margins are not explicitly communicated
Margins testing

• Physical testing to see the product meets the requirements
• Simulation is life testing, i.e. until it breaks

*It’s a bit different here. When we analyse we calculate what will the life be, so we analyse really until the end, until it breaks. Of course it doesn’t matter for us, it takes just as long time*

• Simulation finds margins
• Feedback only on whether the targets are met or not
• They could track changes in margins through project, but don’t do so
Margins testing

• No warning for small margins of safety in the moment
  sometimes they know that and sometimes it’s sort of an unknown because we pass the test but we don’t know by how much we passed it. That’s a problem I think that it’s not always testing to failure. I always say that a successful component test always ends in complete failure. (FO)

• Margins could be identified in a few hours on request

• Supplier also only test to requirement and not to failure so margins are not known

I'm fed up with this, yeah we fulfil the requirement, we don't have a problem and then...but then you don't know where the borderline is ...But test to fail then ... know you really don't if you have one percent margin or if you have 150% margin.(SS)
Optimisation and margin

- Trade-off between optimal solution and communality across the platform
Definition of Margin

With requirements

\[ M(P) = \text{Cap}(P) - R(P). \]
Definition of Margin

With constraints

\[ M(P) = \text{Cap}(P) - \text{Const}(P) \]
Definition of Margin

With requirements and constraints

\[ M(P) = \text{Cap}(P) - R(P). \]
Definition of Margin

With ranges of requirements

Margins can vary for the same component
Margins and Uncertainties

\[ M(P) = B(p) + E(p) \]
Margins and Uncertainty

- Buffers
  - Safety margins
  - Tolerances
- Excess
  - Overdesign
  - Room for growth
- Excess provides designers with space to manoeuvre
- Designers must reduce uncertainty to increase excess
  - Better requirement analysis
  - Better testing
  - Platform architecture
Sharing margins

- Customers are unclear about requirements
- Supplier are unsure about what they can offer, in terms of margins on existing solutions
- Companies are reluctant to disclose uncertain information
- Explicit modelling and communication of margins can reduce iteration
Change Management

• When making changes designers looks for where they can make changes and try to minimise changes
• Margins allow them to make changes that do not propagate or don’t become multiplier
• No explicit support for modelling margins
  – Flagging up critical components
  – Prediction change propagation better
Further work

• Case study of change processes in Volvo cooling system to analyses how exactly margins affect change behaviour

• Modelling margins
  – Margin index for components
  – Aggregation of margins
  – Margins in relationship

• Change predication with accurate margins
Product Planning

- Products evolve over generations
- Controlled innovation through technology infusion at particular points
- Unplanned changes increase cost and risk
- Design for flexibility
- Most companies need to consider a product platform
Conclusions

• Understanding margins allows change prediction
• Companies should communicate margins