Optimization of Main Relay for Hybrid Car and Robust Design Optimization of Automotive Micro Relay

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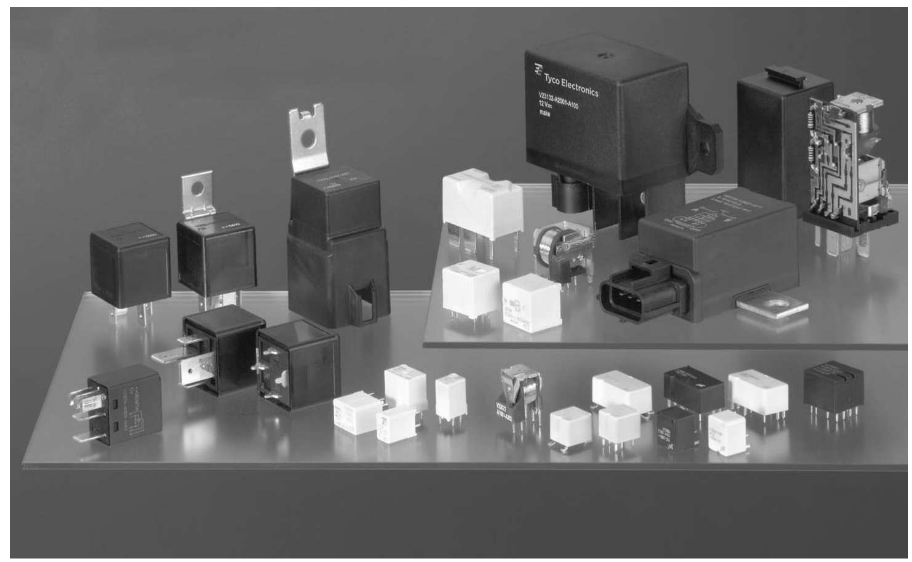
Tyco Electronics

Relay Products Group – Automotive Product Range & Applications

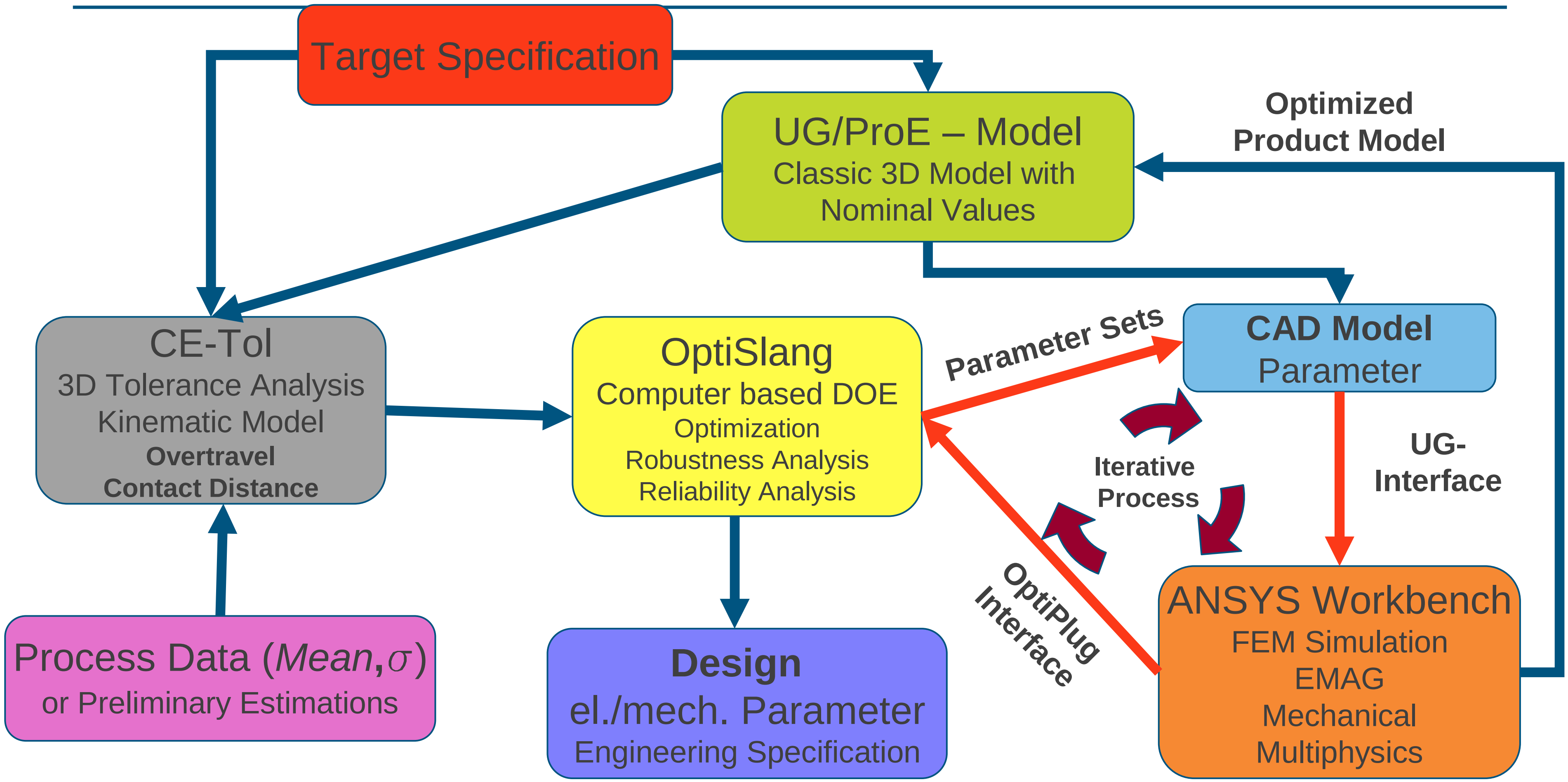
Our product range of Plug-In, PCB and High Current Relays as well as customized solutions covers virtually all applications:

- Flasher, electric windows, door locks and sunroofs
- Air conditioning, lamps, seats
- Wiper controls, fan motors, fuel pumps
- Heaters (seat, front/rear windows)
- Motor management
- Electric power assisted steering (EPAS)
- Latching (bistable), 42 Volt
- THT, THR and SMD relays
- High power applications (battery protection, hybrid and fuel cell power net)



Relay Products Group

Workflow Robust Design Optimization



→ **Introduction OptiSlang Jan. 2009**

Optimization of Main Relay for Hybrid Car

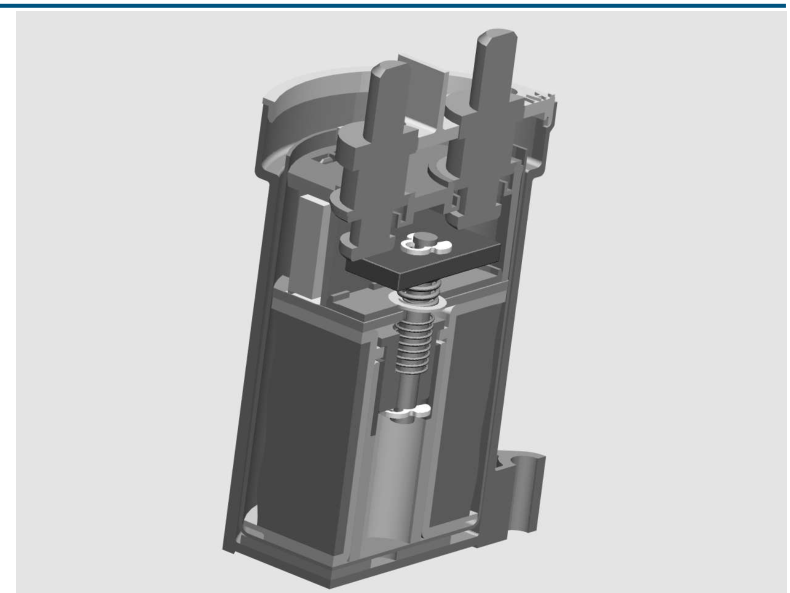
Levitation

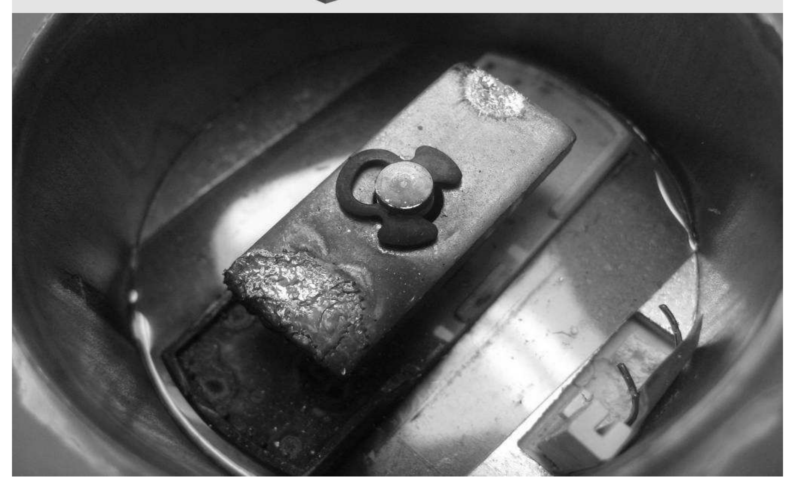
- LEV200 main relay for hybrid truck application
- Short circuit current 4000A
- Switching capability 850V / 1200A

→ Relay damaged due to levitation

- Increased pressure inside relay cause of explosion

Relais12.wmv





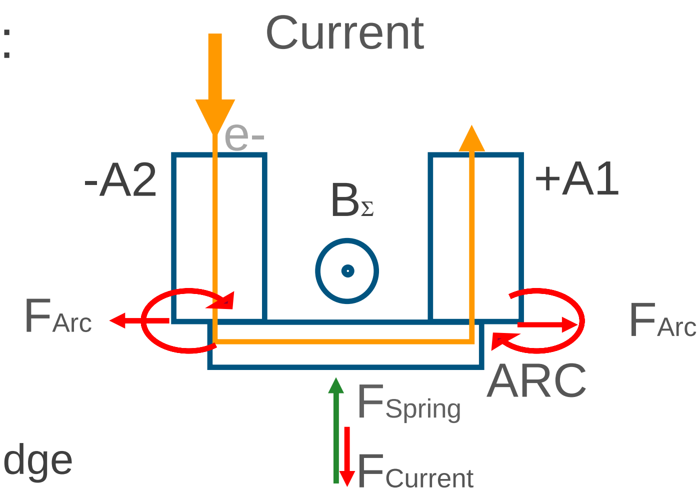
Optimization of Main Relay for Hybrid Car

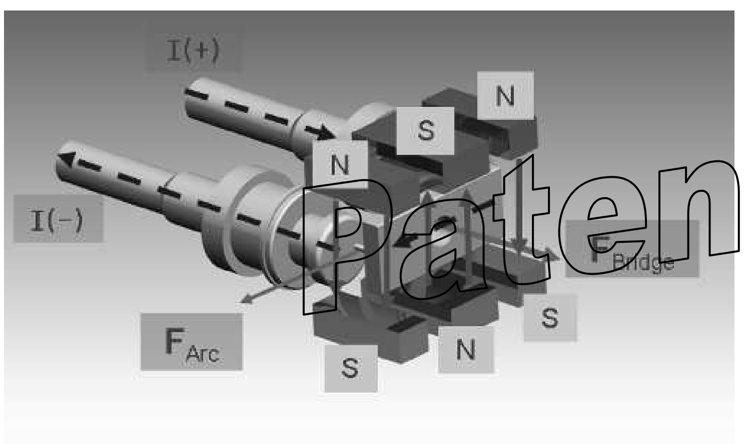
Problem Description

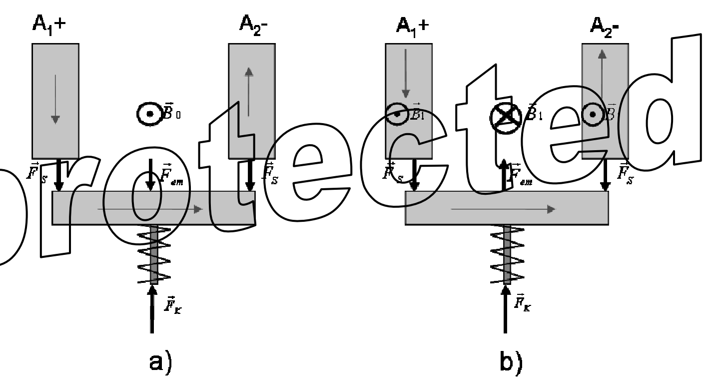
- Levitation Effect on Contact Bridge:
  → Spring force reduced by force caused by short circuit
- Arc will blow out to outer side
- Best interrupt capability

Basic Idea: 3 Magnet Pairs

- Center: 1 pair for compensation force on bridge
- Outer side: 2 pairs for arc suppression







Old design

New design

Optimization of Main Relay for Hybrid Car

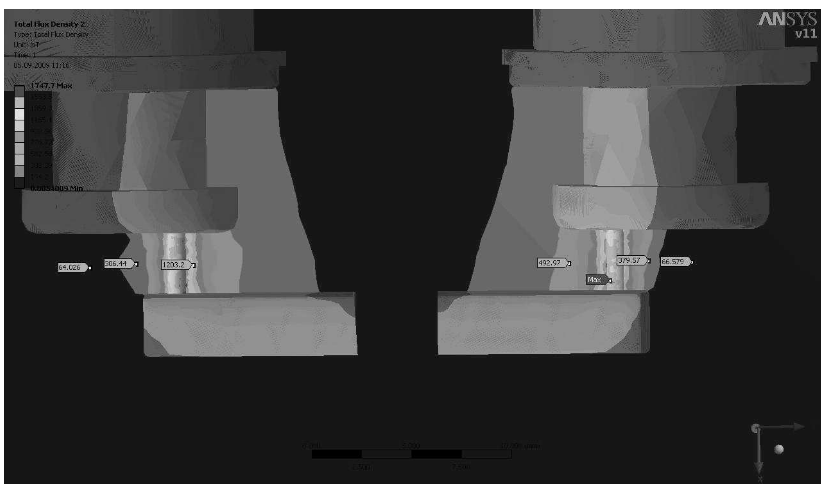
Problem Description

- FEM Model of Contact Unit with Arc Lorentz Force Query

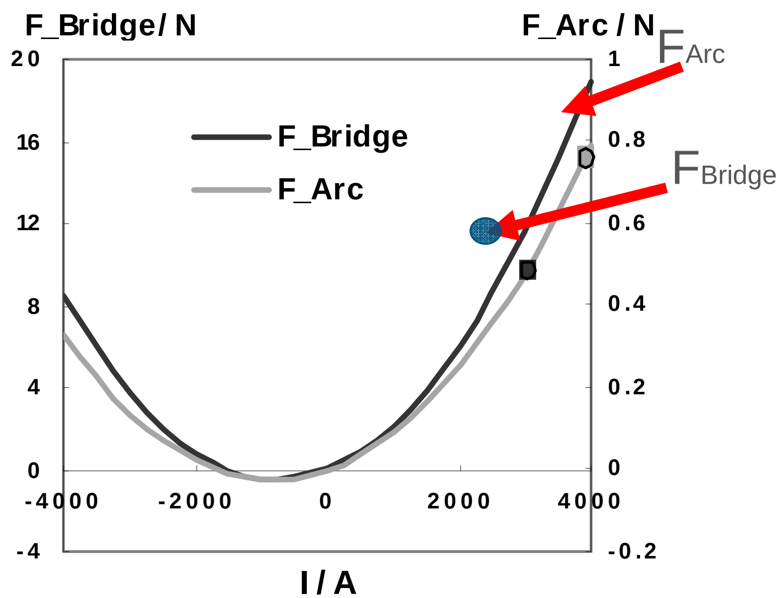
General equation: $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B}),$

→ E= 0: $\mathbf{F}_{mag} = q(\mathbf{v} \times \mathbf{B})$

B-field on bridge and arc:



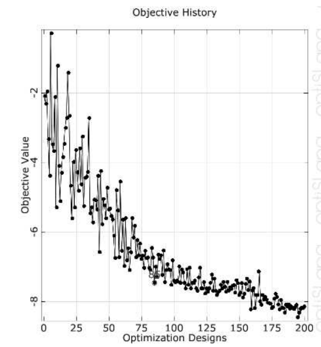
→ Force = target values for optimization

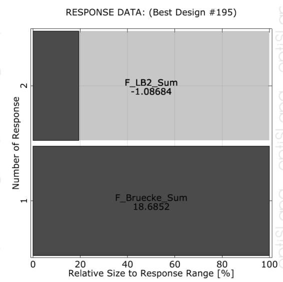


Optimization of Main Relay for Hybrid Car

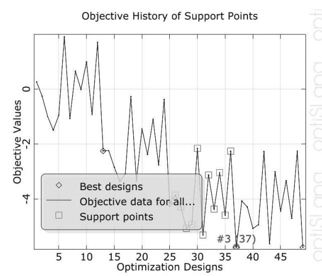
Optimization Steps

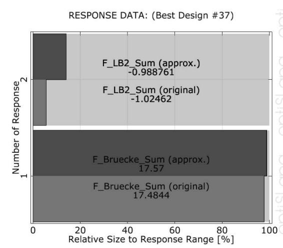
- Evolutionary Algorithm



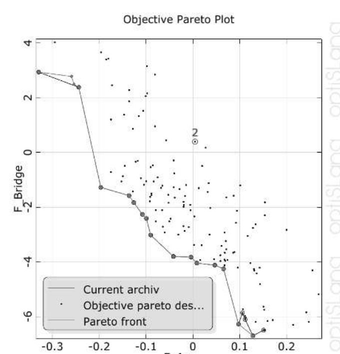


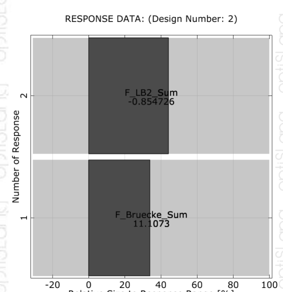
- ARSM Method





- Pareto Optimization





Results of converged optimization:

F_{Arc} → + 25%

F_{Bridge} → + 62%

F_{Arc} → + 16%

F_{Bridge} → + 52%

Design 2: F Arc → + 0.5%
F Bridge → - 3.5%

Design 8: F Arc → + 3.2%
F Bridge → -1.5%

Optimization of Main Relay for Hybrid Car

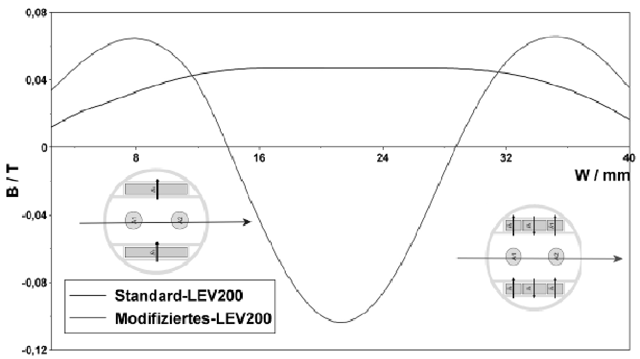
Results of Design Optimization

- Optimized magnet design with sufficient save of material

Results Pareto Optimization

	Design 2	Design 8
F Arc	0.854	0.877
% Diff Target	100%	103%
F_ Bridge	11.1	11.33
% Diff Target	97%	99%
Vol Mag 2	863.4	563
Vol Mag	2105.3	1410.8
Sum Vol Mag	2968.7	1974.1
Vol Mag old Design	4200	4200
% rel. To old Design	71%	47%

- Measured flux density in comparison with old design

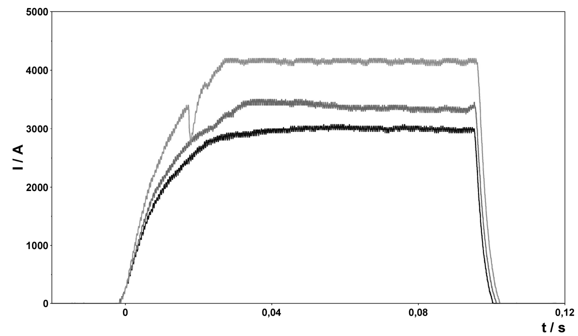


Optimization of Main Relay for Hybrid Car

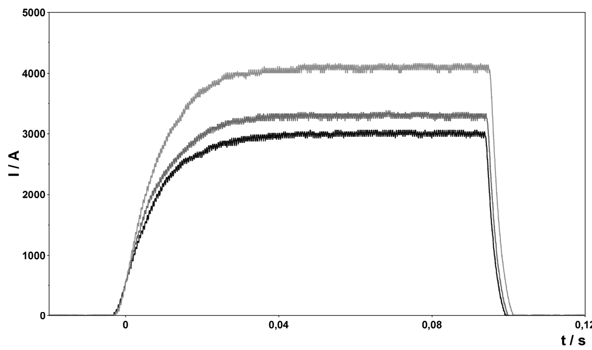
Test Results

- Current I = I(t)

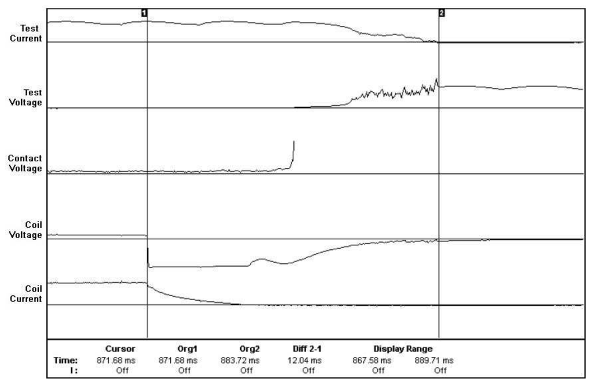
Old design

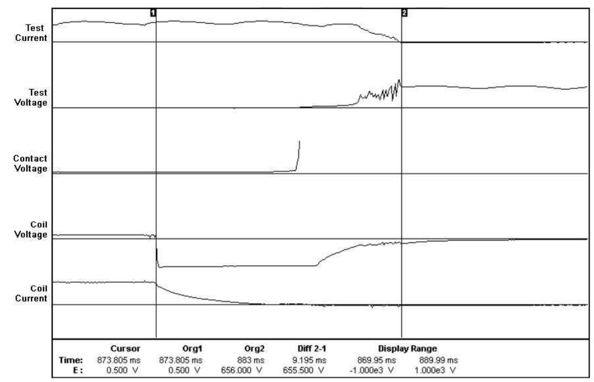


Modified design



- Interrupt 1200A @ 850V





Improvement of Micro Automotive Relay
Challenge

- Arguments for introduction of stochastic optimization methods

→ Design Optimization to save of costs in short term

→ improved process capability to reduce cost

→ improved reliability to reduce quality costs

→ practical also in currently manufactured products

Improvement of Micro Automotive Relay

Challenge

- Force displacement and spring curves line „normal“ production

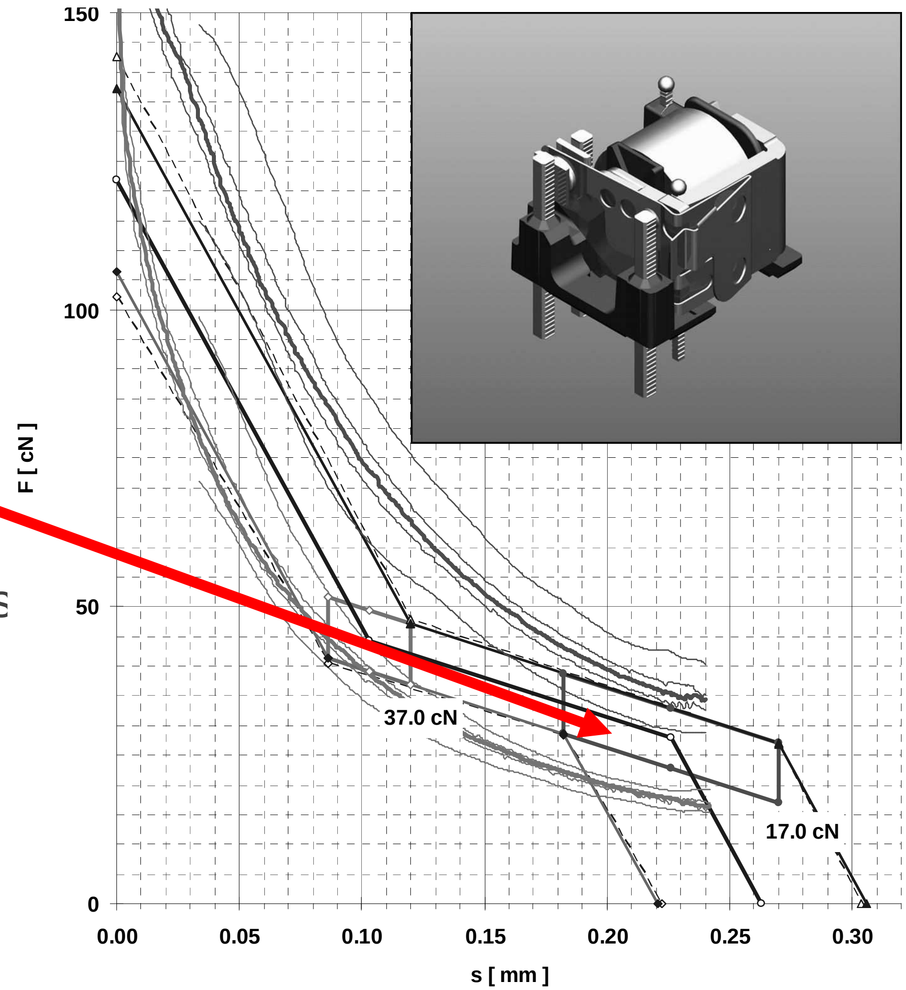
→ Problem:

scrap if F_{spring}>45cN

→ Goal:

* Find most important contributions

* Improvements to reduce spread of motor force



Improvement of Micro Automotive Relay

Robust Design Optimization

Target:

Improvement of product and process capability (without major changes!!)

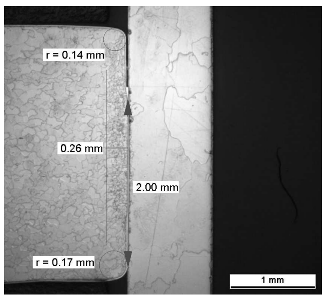
Steps:

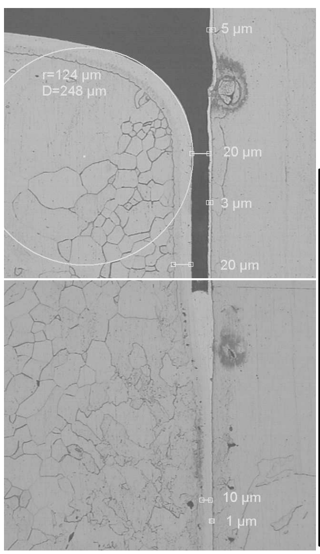
- Design / process parameter definition
- Determination of real geometrical tolerances
- Robustness Analysis to find out most important contributions
- Improvement and validation

Improvement of Micro Automotive Relay

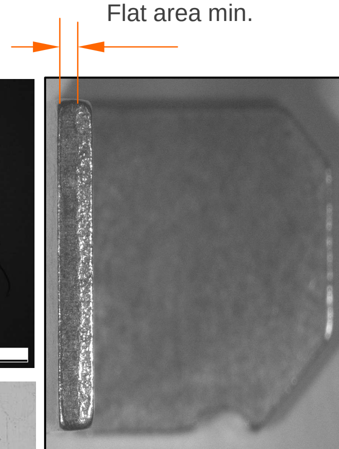
Analysis of Geometrical Dimension

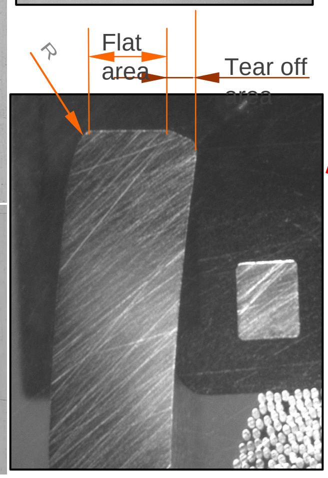
Core-Frame-Weld



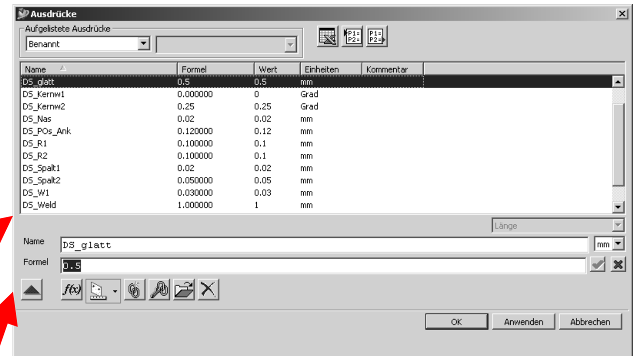


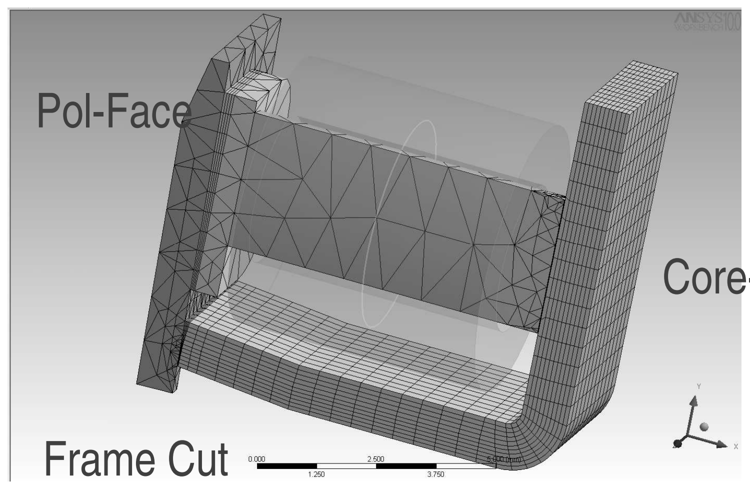
Frame Cut





10 CAD Parameter





Core-Frame-Weld

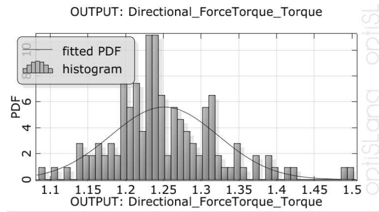
Improvement of Micro Automotive Relay

Robustness Analysis – Sensitivity Analysis

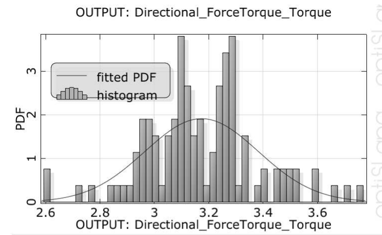
Torque

Pull In

Pull Through

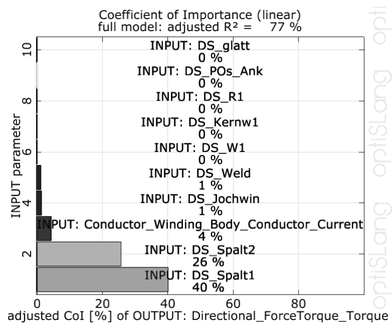


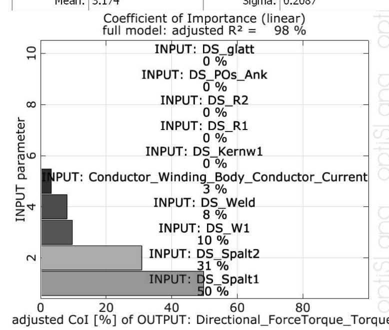
Statistic data			
Min:	1.085	Max:	1.502
Mean:	1.251	Sigma:	0.07127
CV:	0.05695		
Skewness:	0.7568	Kurtosis:	4.256
Fitted PDF: Normal			
Mean:	1.251	Sigma:	0.07127



Statistic data			
Min:	2.593	Max:	3.768
Mean:	3.174	Sigma:	0.2087
CV:	0.06575		
Skewness:	0.131	Kurtosis:	3.75
Fitted PDF: Normal			
Mean:	3.174	Sigma:	0.2087

Importance





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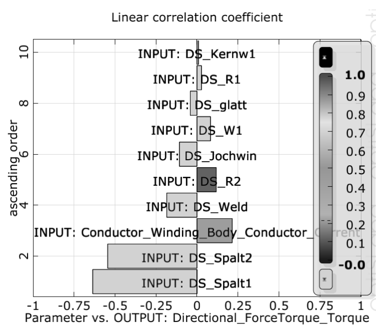
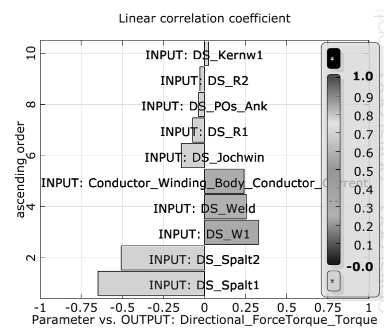


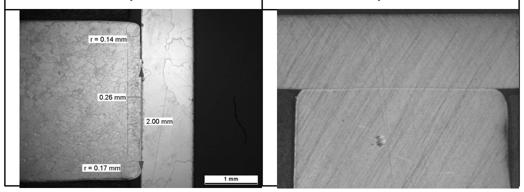


Improvement of Micro Automotive Relay

Design improvement and results

Core-Frame-Welding

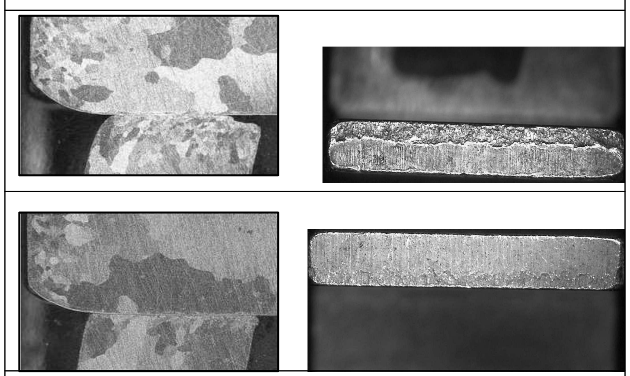
Before improvement	After improvement



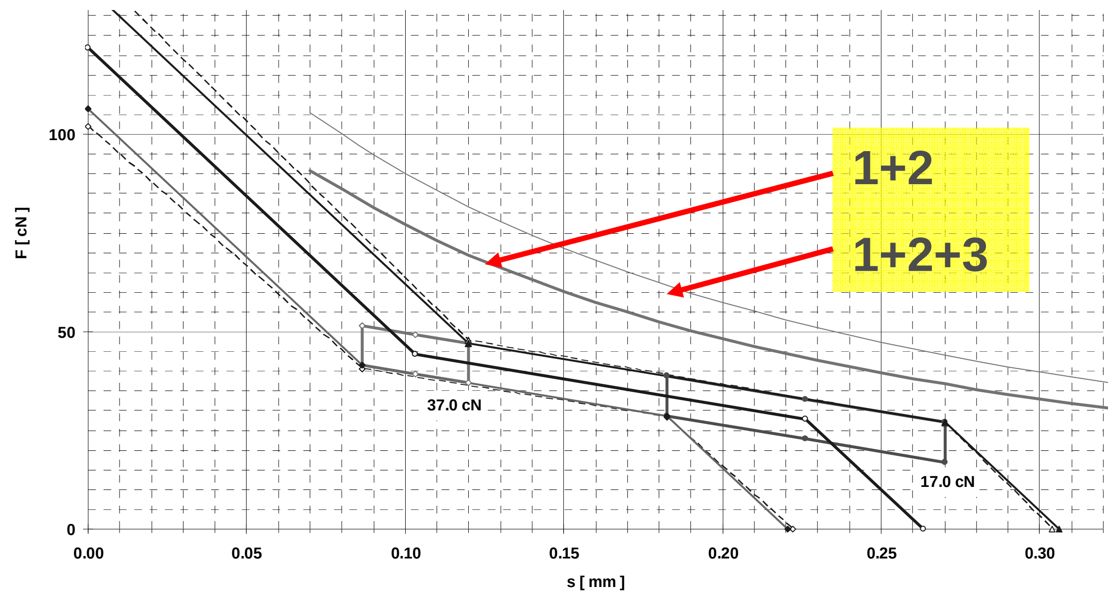
1. Welding region improved by new welding process
2. Cutting tool with minimized tear off
3. Coil winding improvement (new wire type) → new coil (more) AT

Frame

Before improvement



After improvement



Improvement of Micro Automotive Relay

Results

- Design becomes robust design without major design changes
- Robustness optimization procedure was done without error loops
- No unexpected results over time
- Optimized effort (invest) for best results
- Introduced in manufacturing