

## Development of the NVH measurement stations (EoL)

The effectiveness of application of measurement and simulation methods in development of NVH measurement stations for an industrial production (EoL Testing)

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on 15th of March 2018,  
Academia-Industry Matching Event,  
Stary Smokovec



## Technical Quiz – The Sound Design of Home Appliances?

*Remark: binaural sound recording using an artificial head*



*Remark: all appliances are presented only schematically*

## History of **PED-VAU** department

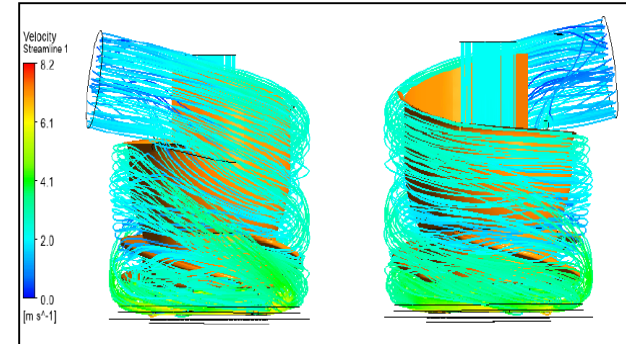
- **2002** – founded in 2002 as predevelopment group for vibration and acoustics at BSH/EDS Regensburg (3 members)
- **2005** – relocation to Košice, Slovak Republic
- **2006** – formal start of cooperation with all BSH product areas as TZSA
- **2011** – formal start of cooperation with Robert Bosch GmbH
- **2018** – 17 members (PED-VAU) (average age 31 years)



**PED-VAU can draw on extensive experience in the field of NVH**

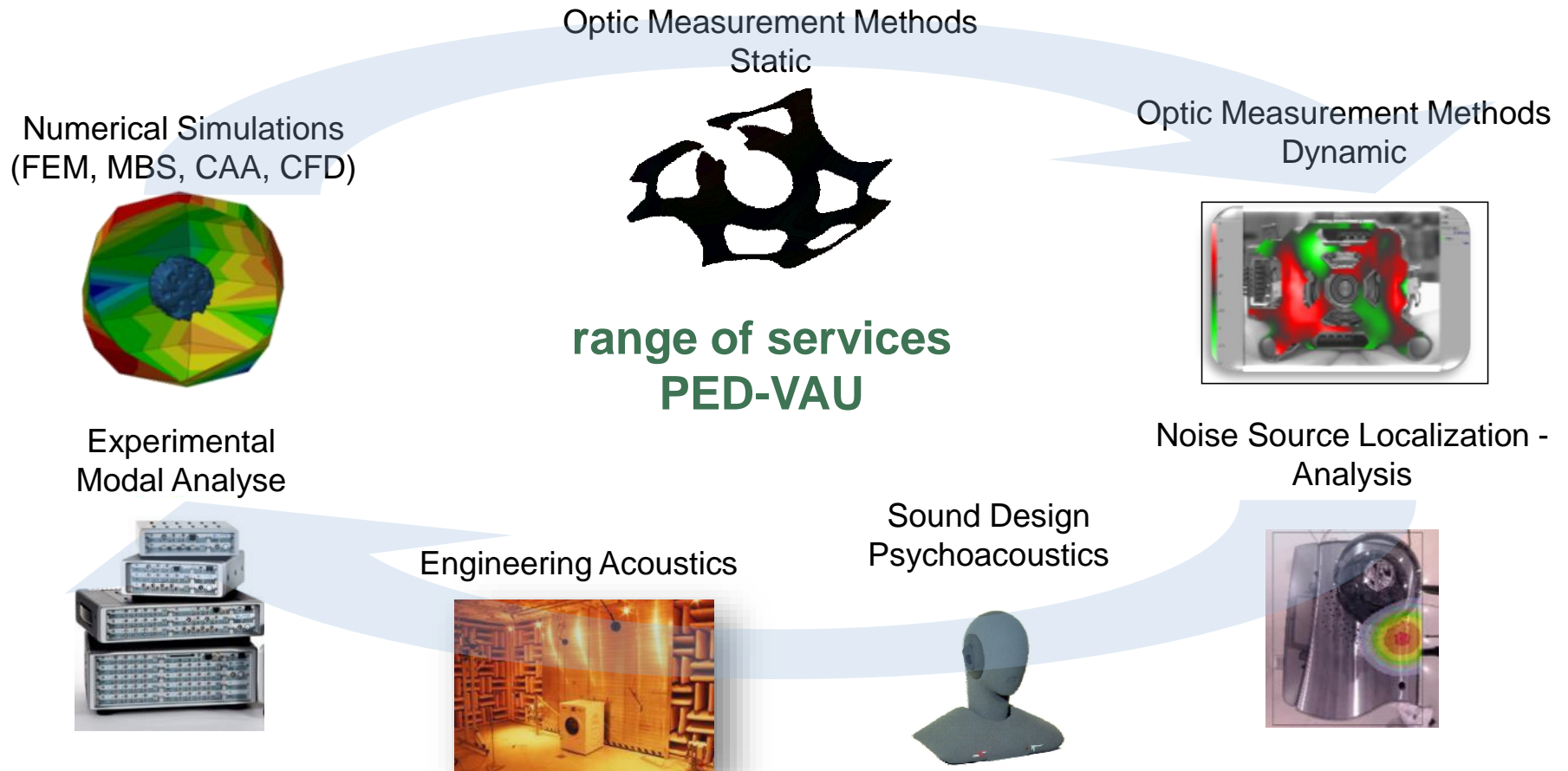
## Mission

- We build competence in field of vibration and acoustics (NVH\*), in order to increase competitiveness of BSH/PED/FEDM especially in parameters such as Time to Market, Performance und Costs.
- We offer innovative, fast, and cost-effective support for Product - / Production process development, concerning sound design and vibration behavior of BSH products as to expand positively differentiating factor in the market.





## Application of interconnected methods

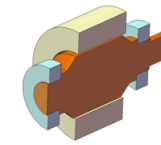
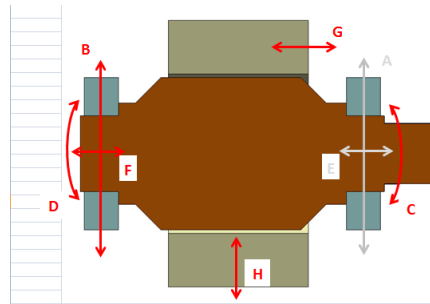


**Linking experimental and numerical methods is the most effective solution**

## Technical specification

Project Title	Test Bench for Hybrid motor	Notes
General overview	This project includes design, construction and production of the test bench for testing hybrid motors under load conditions. It will be designed to be used for below defined types of hybrid motors. The test bench should be used mainly for acoustic testing on the test stage (built-in situation will be defined). The test bench should allow independent setting of bearings' position, settings of rotor position according to "Definition of movements". These movements should be measured with sensors according to "Sensors". The test bench should also allow to measure forces according to "Definition of force measurements".	
Motor types	ASM - (drawing, models will be defined)	
Motor speed range	0-7500rpm	
Max motor power	30kW at 2800rpm	
Max motor torque	100Nm	
Motor cooling	Not required	
Bearings' housing (bushings)	Convertible for different bearings, and also from different materials. They	Max bearing diameter

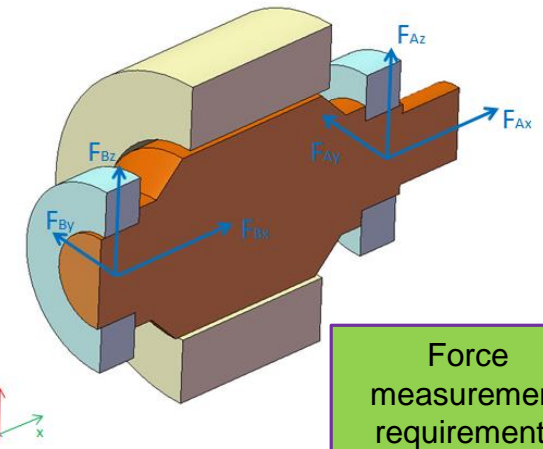
General requirements



Requirements for movements

Movement	Range		Resolution	Measured	Notes	Measuring device	Type
	min	max					
A	-1mm	1mm	0.05mm	with sensor			
B	-1mm	1mm	0.05mm	with sensor	See n		
C	-2°	2°	10'	with sensor			
D	-2°	2°	10'	with sensor			
E	5mm inward	25mm outward	not defined	not measured	movement		
F	5mm inward	20mm outward	not defined	not measured	movement		
G	-10mm	10mm	0.1mm	with sensor			
H	1mm	-1mm	0.05	with sensor			

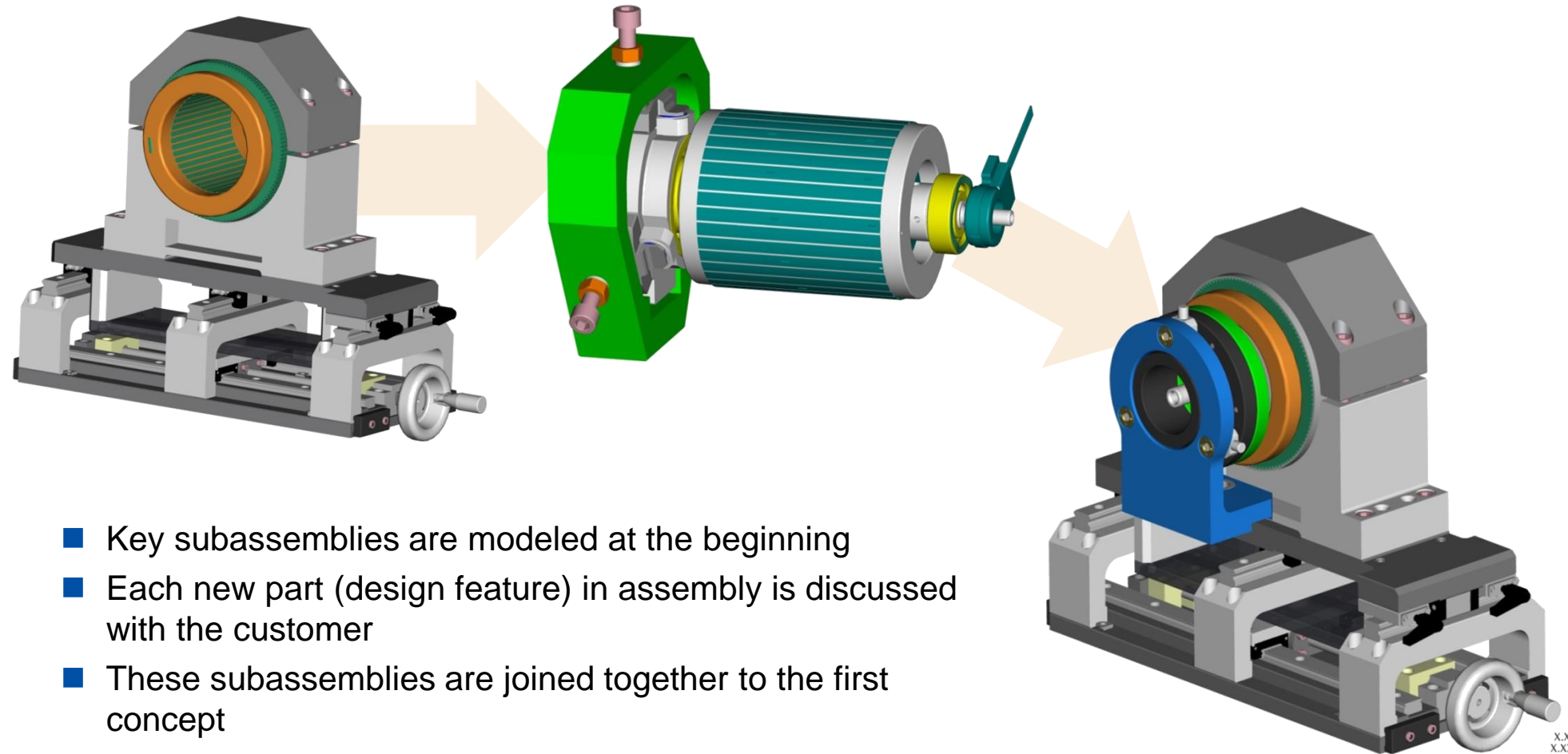
Project part	Name	Part includes	Time (planned)	Notes	Date	Status	
Bearings temperature monitoring	1	Requirements definition	KW49			done	
		Concept proposal (2-3 variants)	Concept1	end of 2013	* first concept introduction - see file 140110_TestBench_01.ppt 140120_TestBench_02.pdf 140127_TestBench_03.ppt 140213_TestBench_04.ppt	10.1.2014 20.1.2014 27.1.2014 13.2.2014	done
			Concept2		140401_TestBench-Concept2_01.ppt 140409_TestBench-Concept2_02.ppt	1.4.2014 9.4.2014	done
							done
Required documentation (for Bosch)	1	Concept description				done	
		Drawings				done	
Testing	2	Function test (break)				done	
		Measurements (required and shown)				done	
Additionally	2	Test bench has				done	
						done	
						done	
						done	
						done	
						done	
Time schedule	3	Production of all parts				done	
		Test of the Test Bench without break				done	
		Teach in (demonstration of the Test Bench)				done	



Force measurement requirements

Force	Range		Notes
	min	max	
FAx	-3kN	3kN	Force ranges are only estimation. also static force has to be measured - range 0-1kN
FAy	10kN	10kN	
FAz	10kN	10kN	
FBx	-3kN	3kN	
FBy	10kN	10kN	
FBz	10kN	10kN	

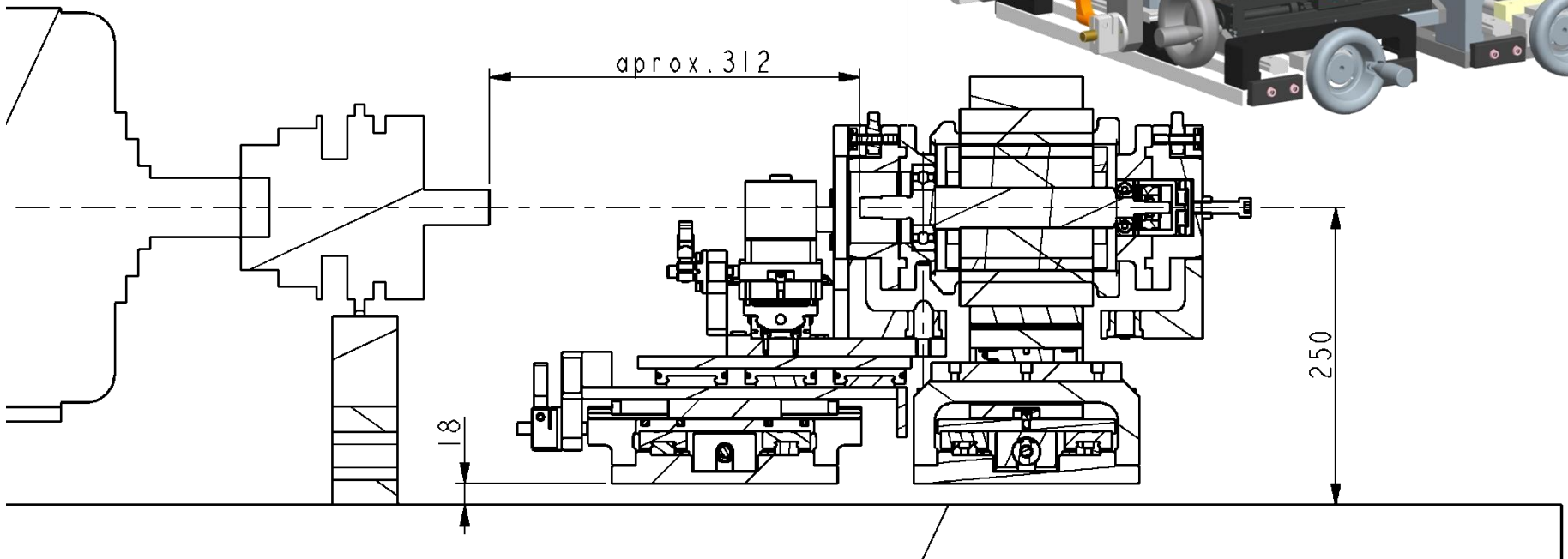
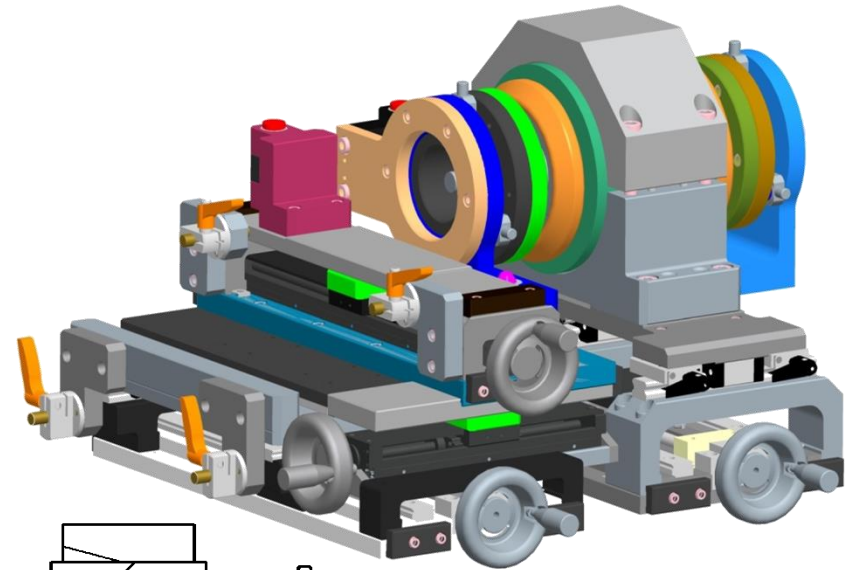
## The design of the first concept



- Key subassemblies are modeled at the beginning
- Each new part (design feature) in assembly is discussed with the customer
- These subassemblies are joined together to the first concept

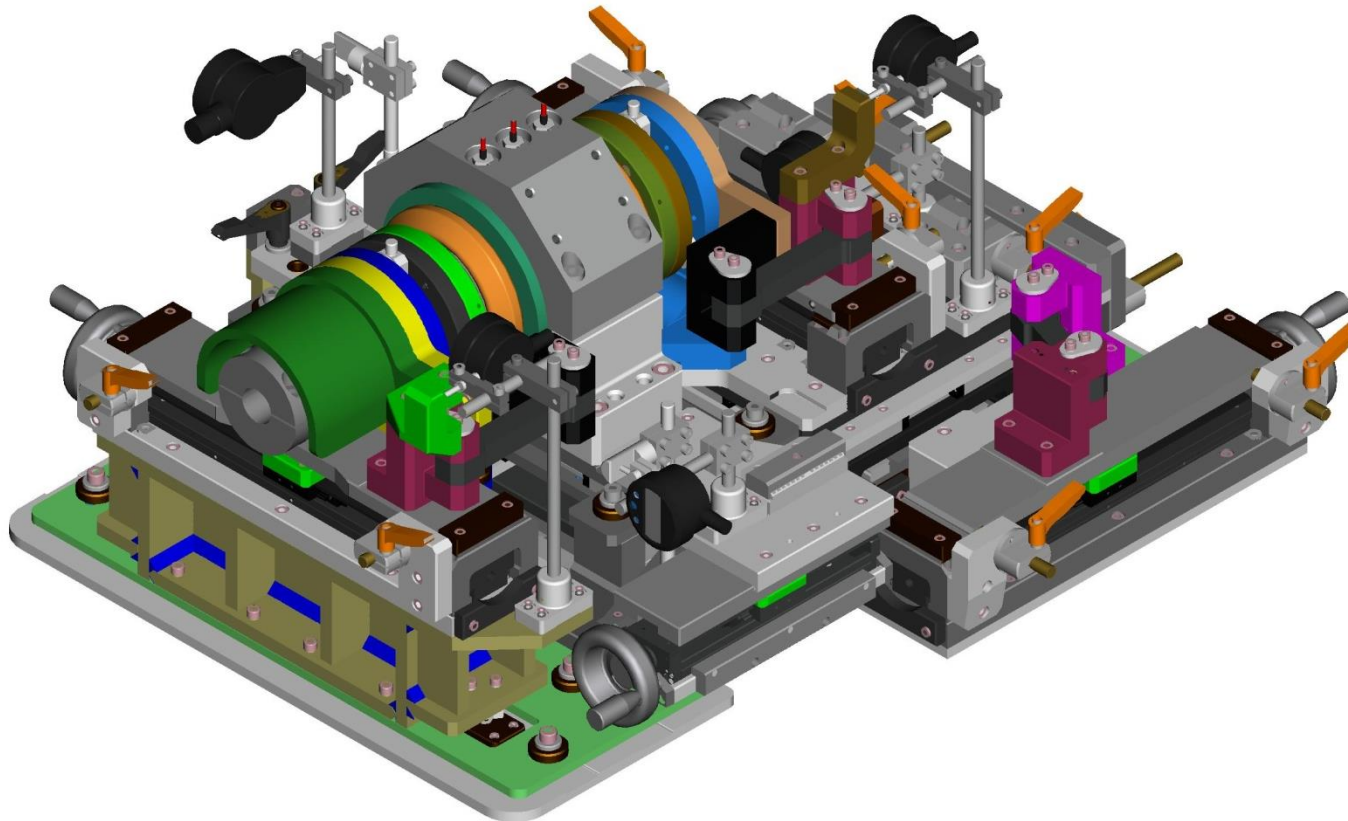
## The first concept

- It contains only design of main movements
- Connection of motor and brake is not defined

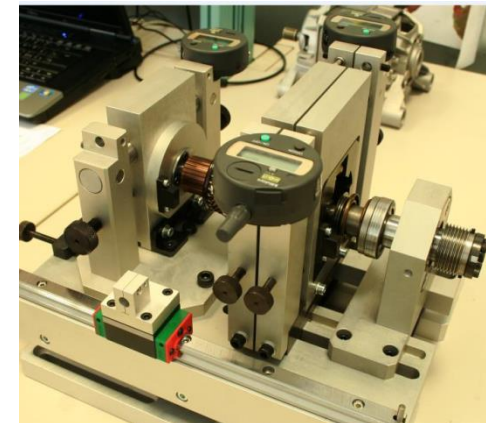




## Final design



Test bench for starter motors

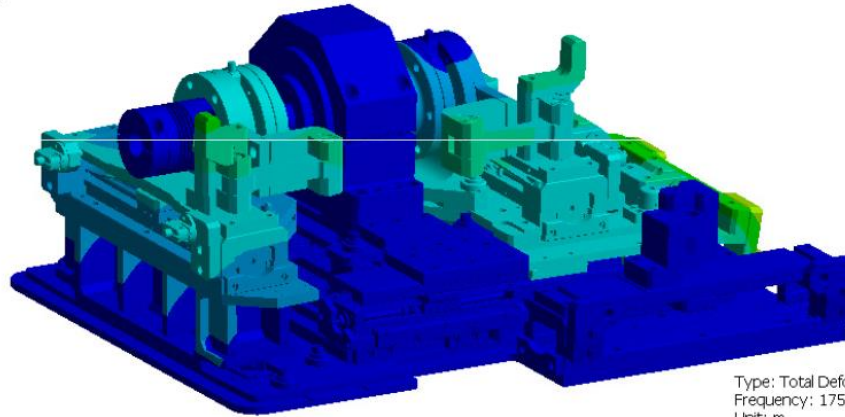


- The whole design was finished in July 2016
- This model was used in numerical modal analysis to check resonances

## Check of resonances – prediction

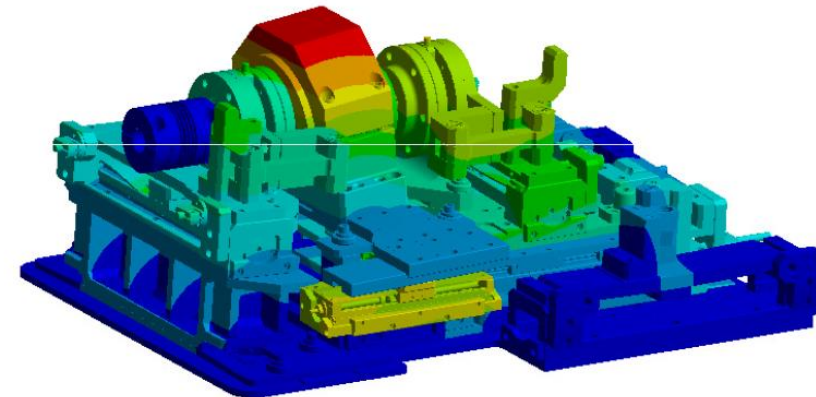
Type: Total Deformation  
Frequency: 161.89 Hz  
Unit: m

0.3703 Max  
0.32916  
0.28801  
0.24687  
0.20572  
0.16458  
0.12343  
0.08229  
0.041145  
0 Min



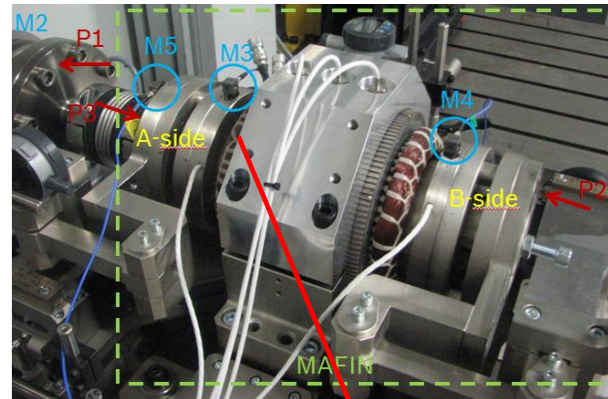
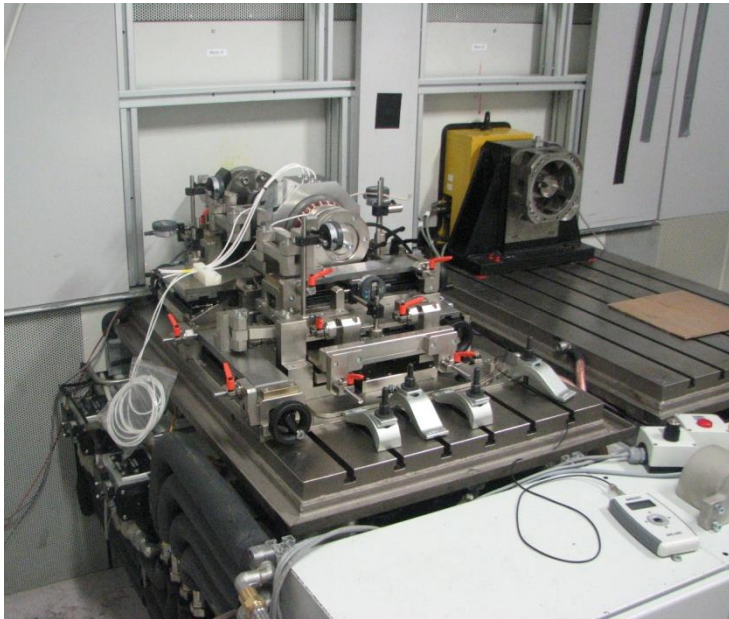
Type: Total Deformation  
Frequency: 175.77 Hz  
Unit: m

0.21963 Max  
0.19523  
0.17082  
0.14642  
0.12202  
0.097614  
0.07321  
0.048807  
0.024403  
0 Min

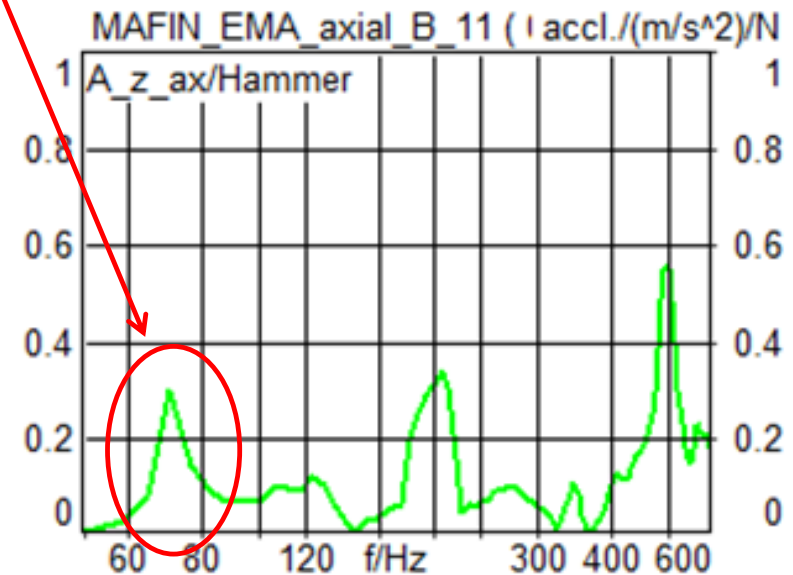


- This numerical prediction was performed only to prove that the first resonance of the test frame is above 125Hz, so the rotor unbalance would not excite any resonance of the frame
- There was not enough time to perform deeper numerical analysis

## The first test at customer

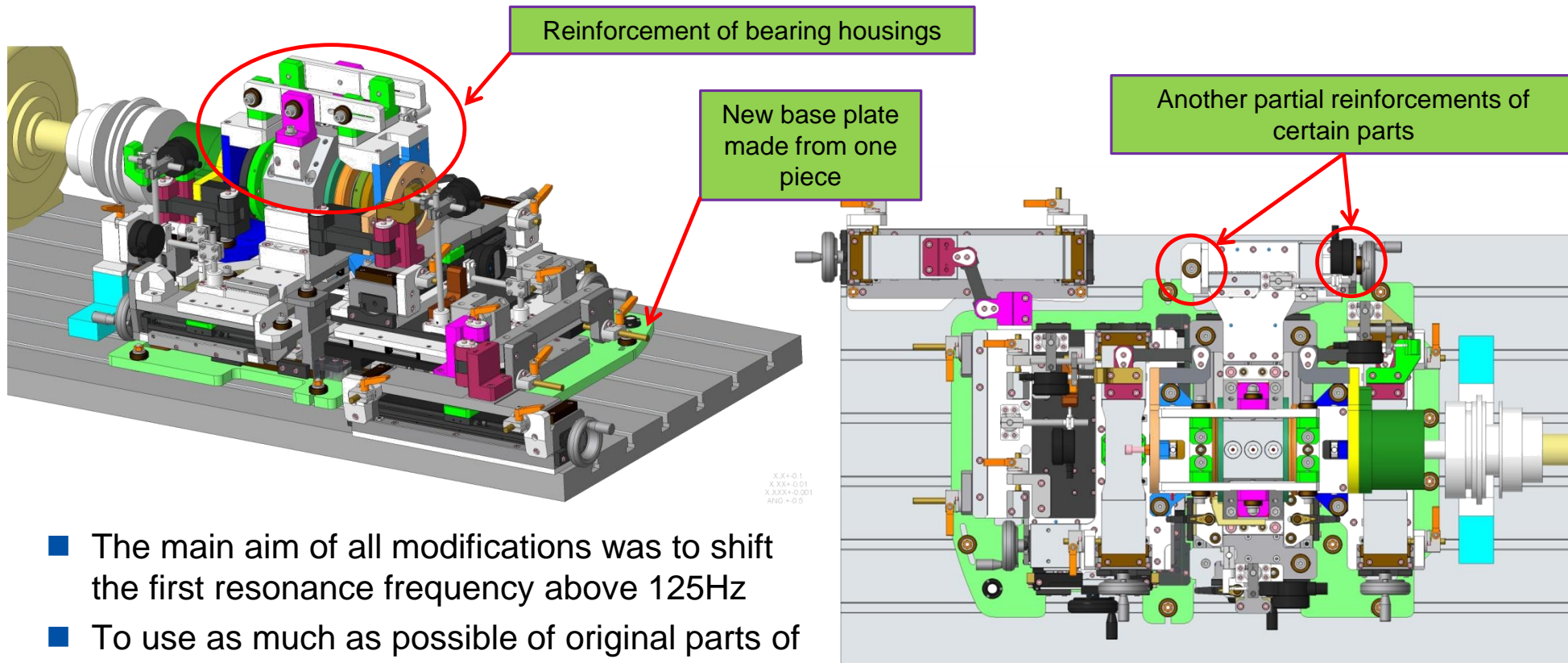


- The first test was done at customer in October 2016
- It was not possible to achieve max. required speed 7500rpm because of resonance at ~70Hz
- The frame did not fulfill requirement of the first resonance and therefore redesign was necessary





## Design modifications – RMK3 design

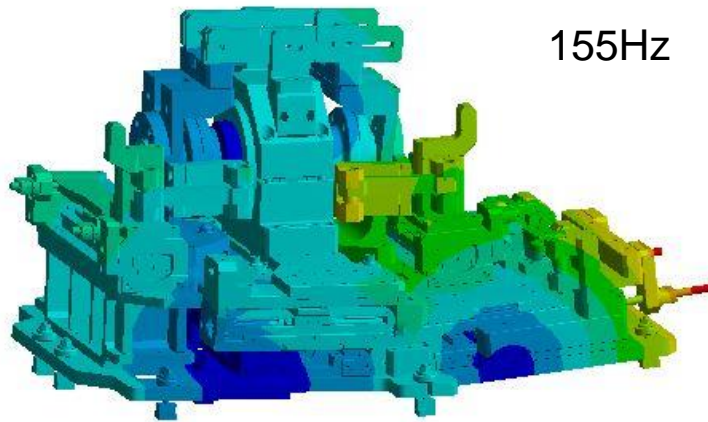
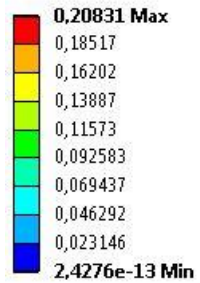


- The main aim of all modifications was to shift the first resonance frequency above 125Hz
- To use as much as possible of original parts of original design
- This time, much more time was spent with numerical predictions and verification

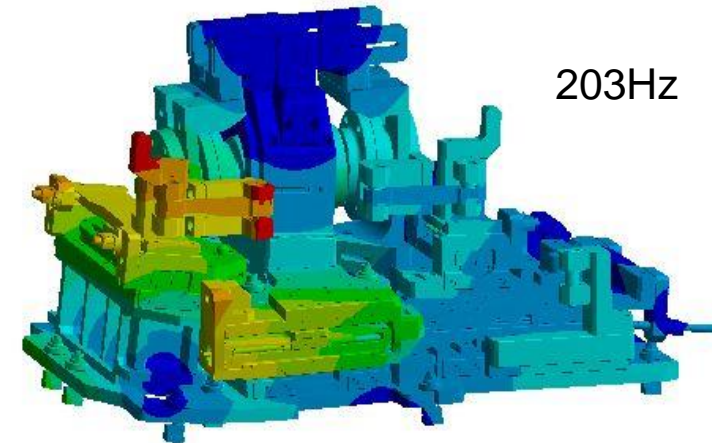
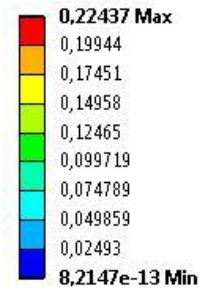


## Prediction of mode shapes after design modifications

Type: Total Deformation  
Frequency: 154,55 Hz  
Unit: m

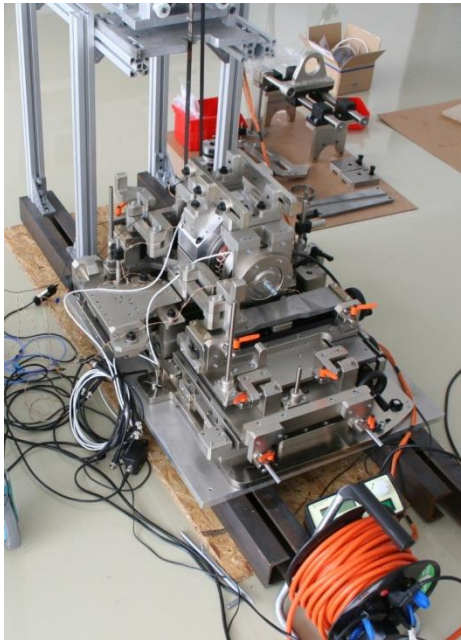


Type: Total Deformation  
Frequency: 203,11 Hz  
Unit: m



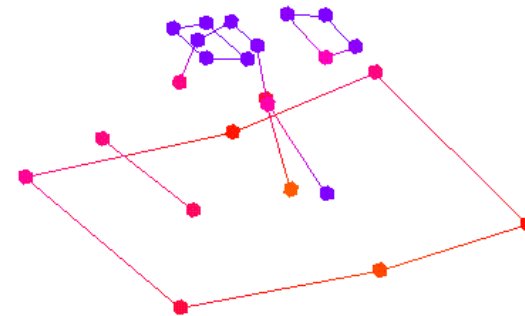
- This time prediction was made also for different boundary conditions
- The process of design modifications took more than 4 months

## The ODS measurement after modification

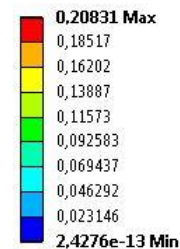


- Predicted value 155Hz was almost achieved – real measured value was 149Hz
- More importantly, well above required value 125Hz

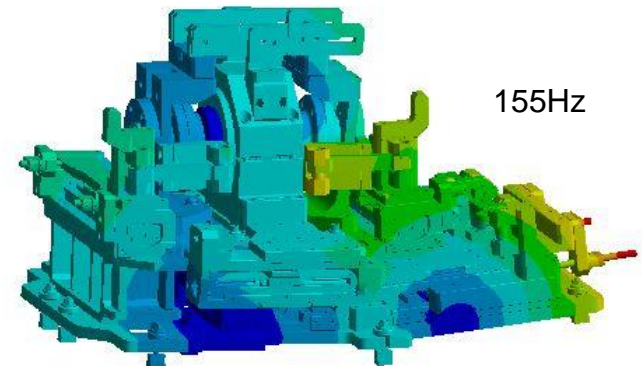
149Hz



Type: Total Deformation  
Frequency: 154,55 Hz  
Unit: m



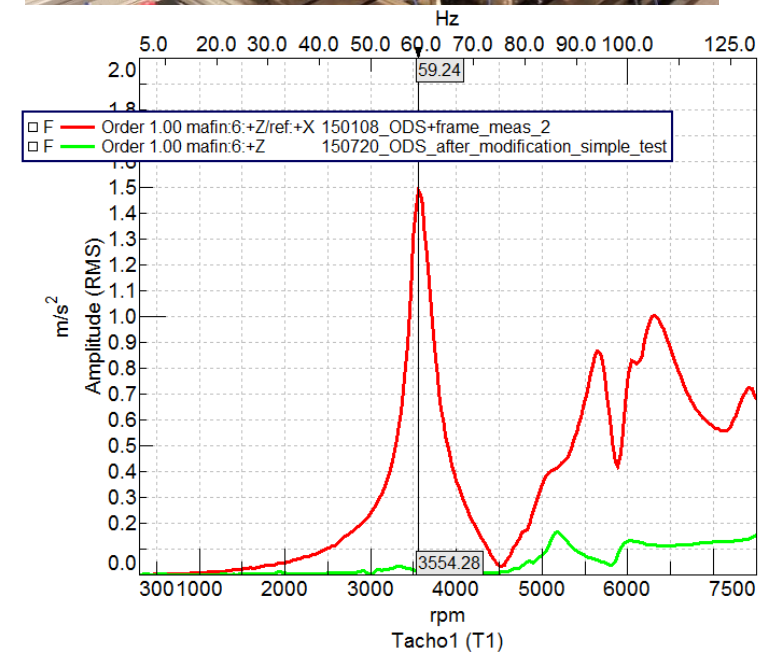
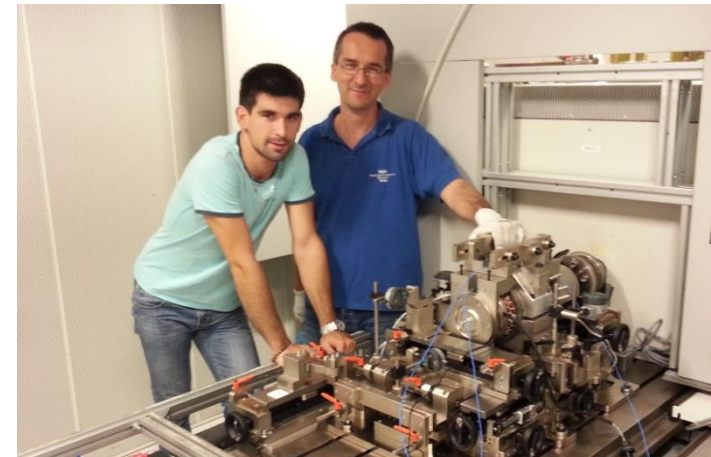
155Hz



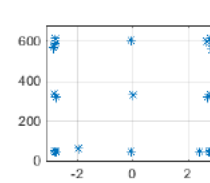
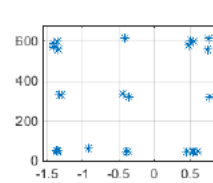
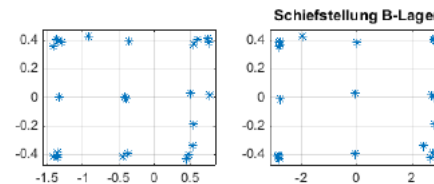
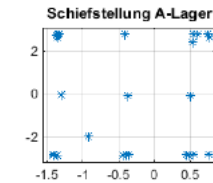
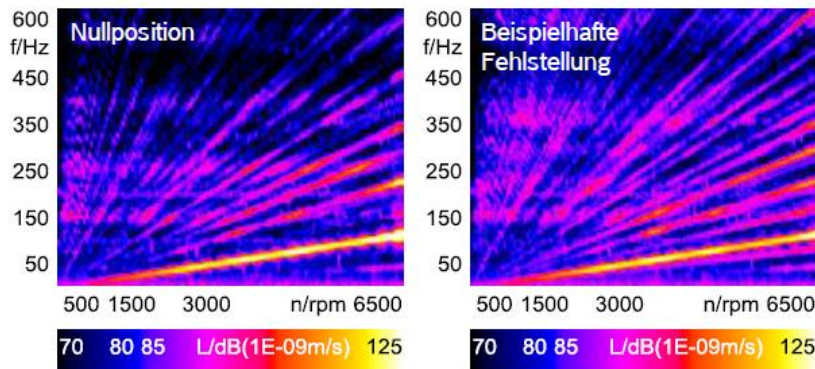
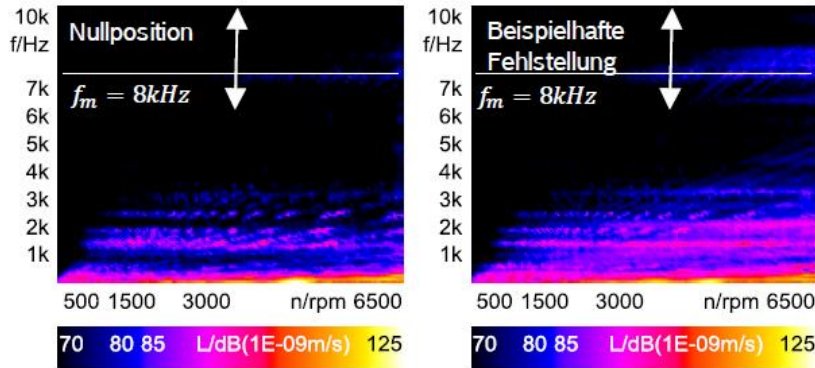
## Final measurement at customer



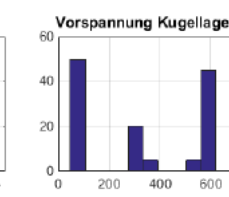
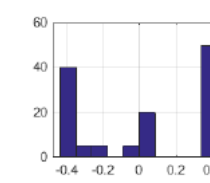
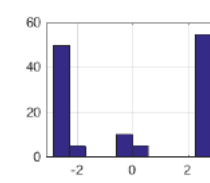
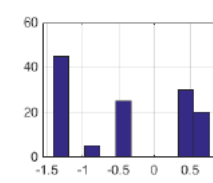
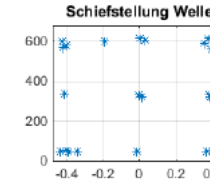
- Measurement at customer (Sep. 2017) proved significant reduction of vibration
- It was possible to run motor to max. required speed 7500rpm



## Results from customer



Matrix-Darstellung

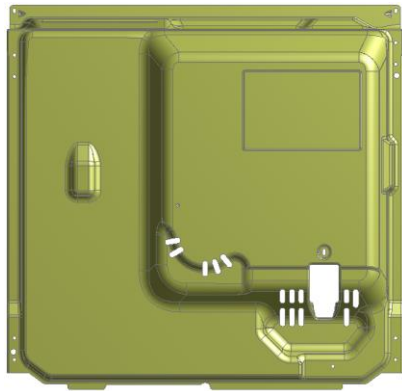


- After few months, first results with different settings of the frame were available
- The first results were obtained without load
- Currently measurements under load are in progress

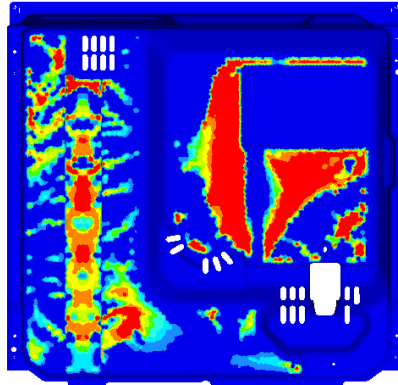


## Built-in oven back panel – workflow of the numerical optimization analysis

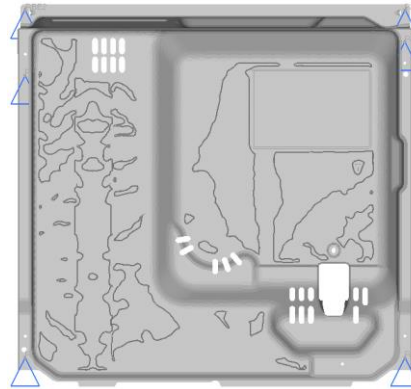
present (flat) design



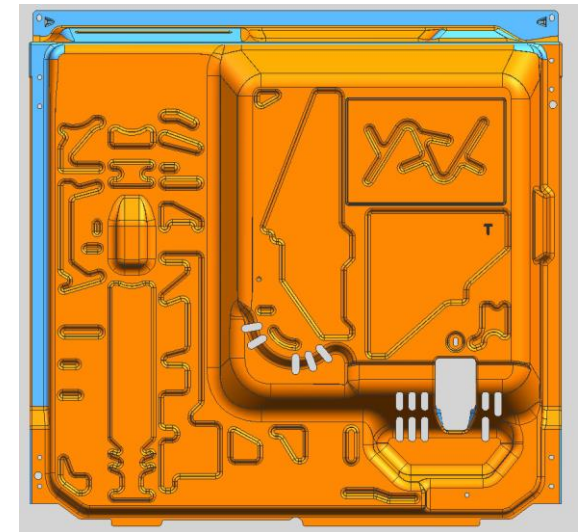
raw optimized model



rough CAD model



final optimized design



preparing CAD model  
and setting  
optimization conditions

export rough  
optimized CAD  
model

simplified CAD  
model ready to  
manufacture

## Results of Sound Optimization I Before vs. After

*Remark: binaural sound recording using an artificial head*

### Washing machine (e. draining): before vs. after



### Cooker hood (at run up): before vs. after



### Automatic coffee machine (pumping): before vs. after



### Hedgecutter: STIHL HSE81 vs. Bosch prototype



*Remark: all appliances are presented only schematically*

# Thank you for your attention

Our contact adress:

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