Karlsruhe Institute of Technology

EVS35 OSL2022

wbk Institute of Production Science

Product-Production-Co-Design for Agile Production of Electric Traction Motors

International Electric Vehicle Symposium 35 – June 14, 2022

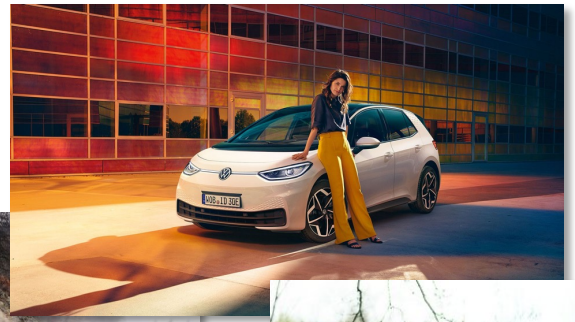
Source: KIT/Breig

Motivation

Economic Challenges of Modern E-Motor Production

Customer Demand

?



[2]

[1]

[3]

High uncertainty of sales forecasts as a result of significant changes in usage behavior – mainly driven by digitalization and sustainable mobility concepts.

Supply Chains

[4]

High risk of breakdowns due to economical and technical need for complex global supply chains.

References: [1] Mercedes Benz, [2] Volkswagen, [3] Bosch, [4] Picture Alliance

Motivation

Economic Challenges of Modern E-Motor Production

Economic Frame Conditions

[1]

High volatility of economic frame conditions as a result of international trade conflicts and resulting restrictions.

Legal Frame Conditions

[2]

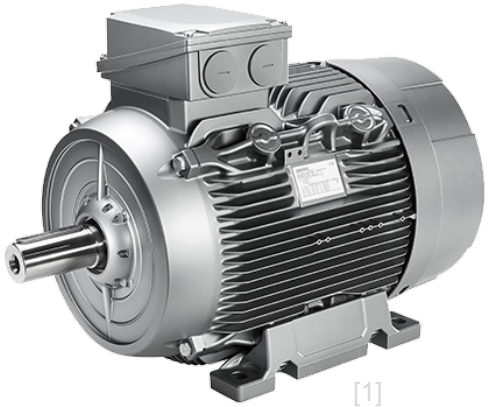
[3]

High dependence of customer demand and market development from legal restrictions – especially against climate change.

References: [1] Global Risk Institute, [2] European Commission, [3] Tagesschau

Motivation

Technical Challenges of Modern E-Motor Production



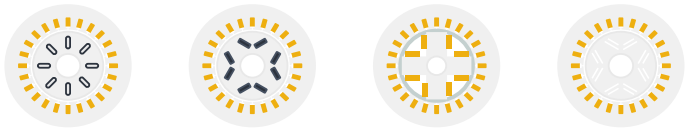
[1]

Industrial Motor

- Moderate requirements for installation space and power density
- Cost-optimised production with low process variance
- High variance of motor topology
- Constant operating conditions

Motor topology?

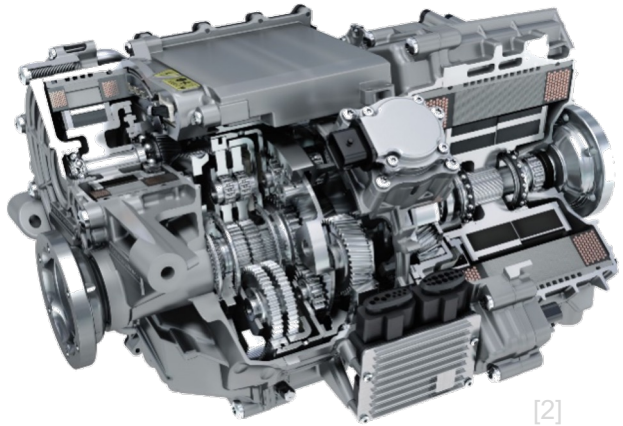
ASM | PSM | SSM | RM



Production technology?

Linear Winding | Needle Winding | Flyer Winding

Hairpin-Technology | Continuous Hairpin



[2]

Traction Motor

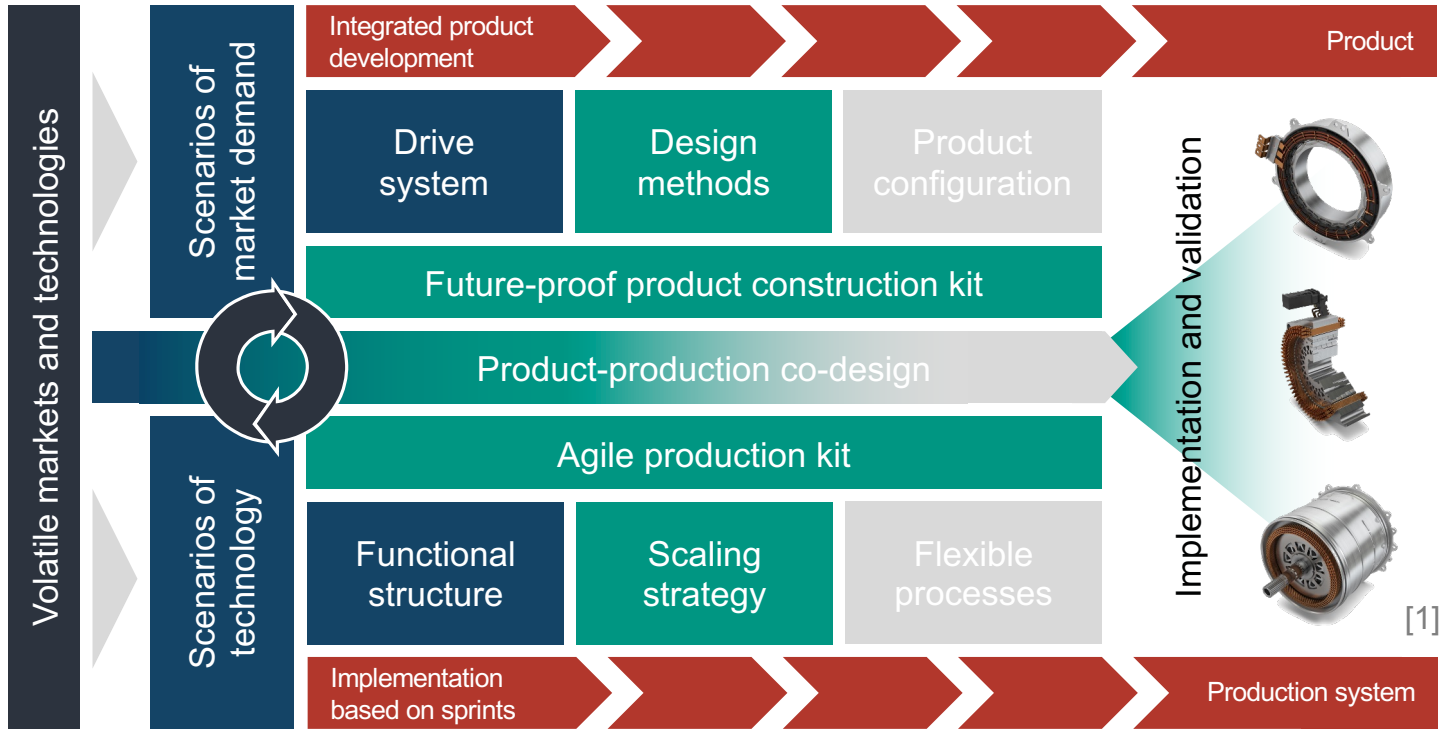
- Highest requirements for installation space and power density
- Cost-optimised production with volatile quantities
- Product-driven technologies
  - Motor topology
  - Production technology

Sources: [1] Siemens, [2] Schaeffler

Background

Projects AgiloDrive1 and AgiloDrive2

Approach



Partners

- **Leading partner: Schaeffler**
- **KIT: wbk, IPEK & ETI**
- **13 industrial partners**
- **3 associated partners**

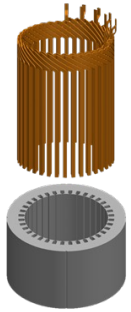
Sources: [1] Schaeffler

Basics of Electric Motor Production

Simplified Process Chain of Hairpin Stator Production

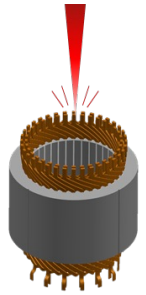
Forming

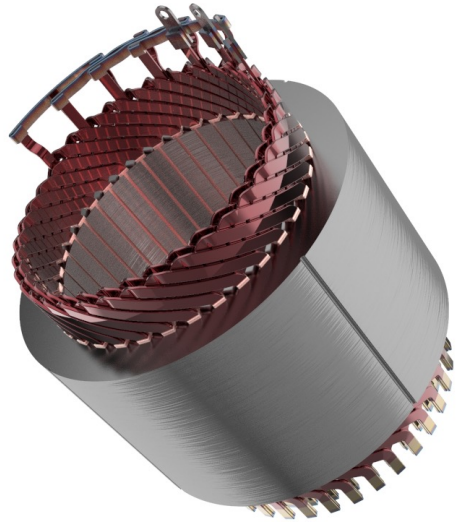
Assembly



Twisting

Joining





Forming
- Hairpin coils
- Busbar elements

Assembly
- Composing of coils
- Insertion of arrangements

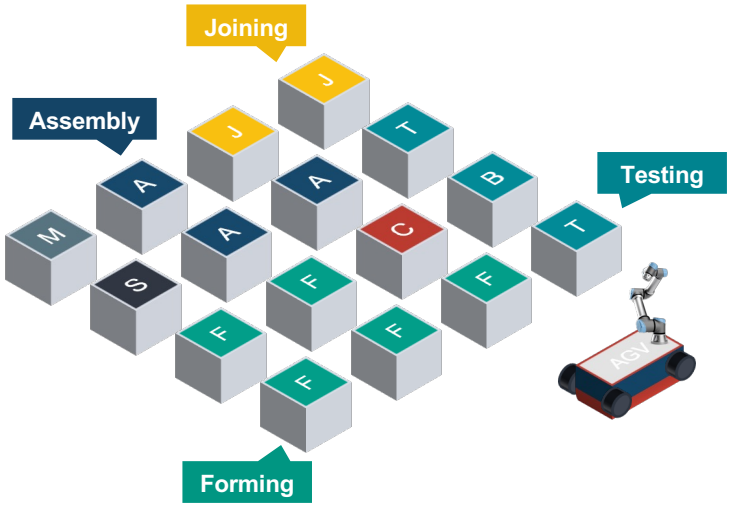
Twisting
- Widening of Hairpin-Ends
- Twisting of every Layer

Joining
- Laser welding of coils
- Soldering of busbars

Sources: wbk/KIT

Building Blocks of an Agile Production System

Nomenclature of Agile Production Using the Example of Balancing the Rotor



Agile Production System

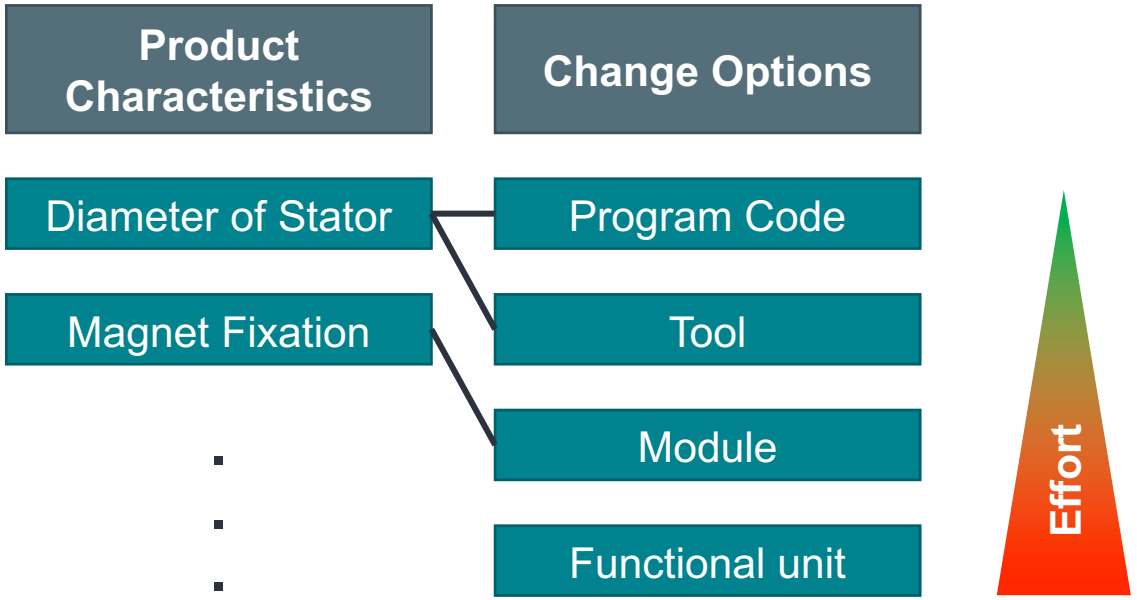
Balancing

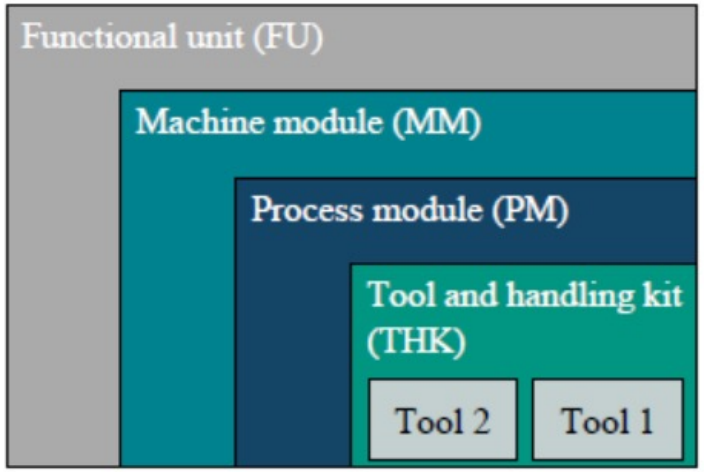
Functional Unit (FU)	Balancing		
Machine Module (MM)	Spinning	Measurement	Compensation
Process Module (PM)	Clamping	Drilling	Handling Module
Tool and Handling Kits (THK)	Drill A	Drill B	Drill C

Sources: KIT/wbk

Methodology

Change Options of Functional Units and Their Components



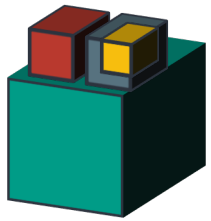


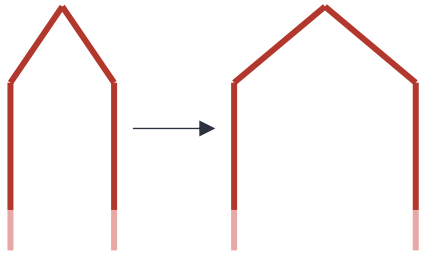
How does a change of the product characteristics affect the production system?

Product-Process-Interrelationship

Interrelationship Using the Example of a Hairpin-Stator

Change of Program Code



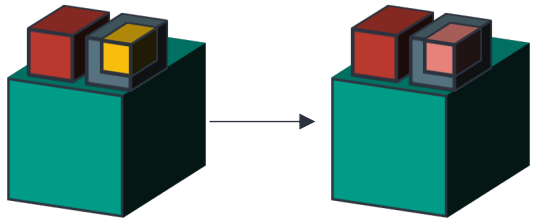


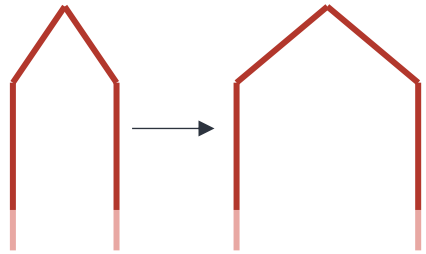
```
1 Start
2 Param_1 := {120.0, 24.9}
3 Param_2 := {60.5, 4.8}
4 End;
```

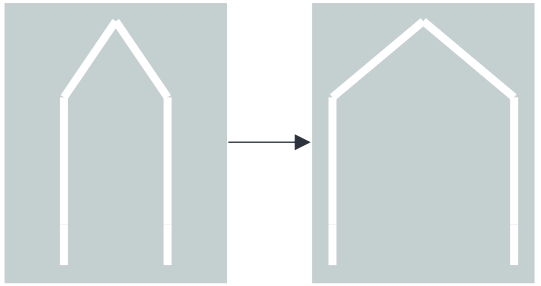
```
1 Start
2 Param_1 := {140.0, 24.9}
3 Param_2 := {80.5, 14.8}
4 End;
```

Kinematic Bending

Change of Tools



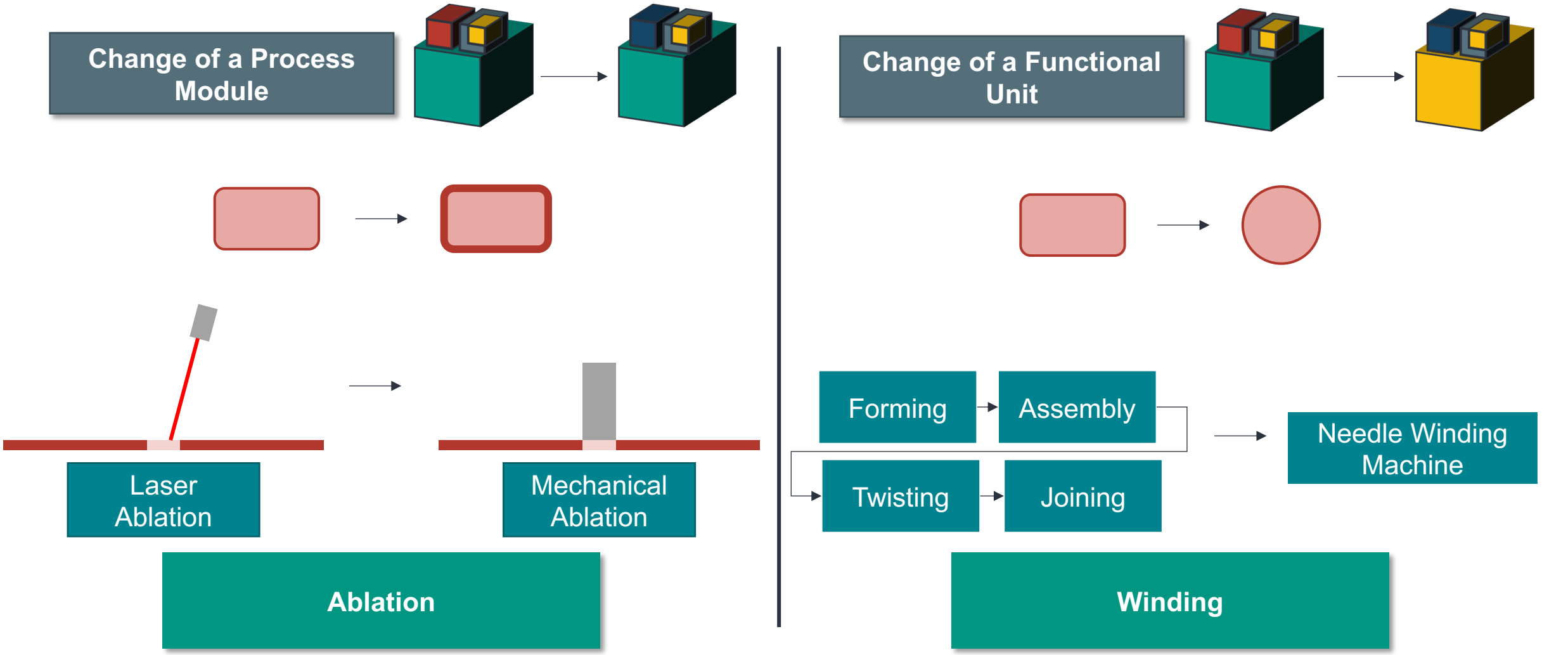




Tool-bound Bending

Product-Process-Interrelationship

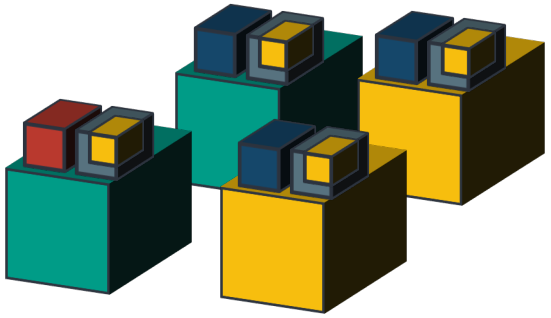
Interrelationship Using the Example of a Hairpin-Stator



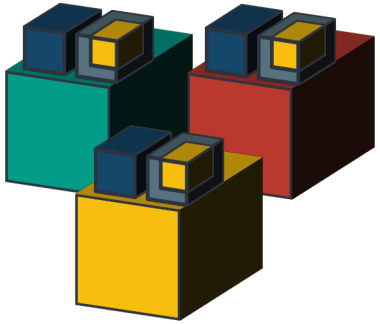
Influence of a Product Change on the Production System

Possible Changes in the Production System

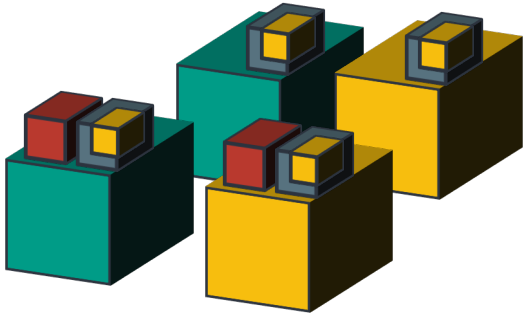
Product A → **Product B**



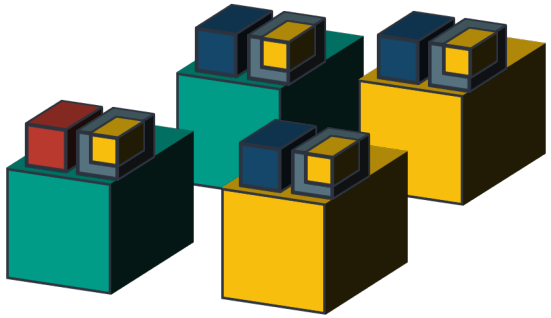
“Original” Production System



Change of Functional Unit



Change of Modules

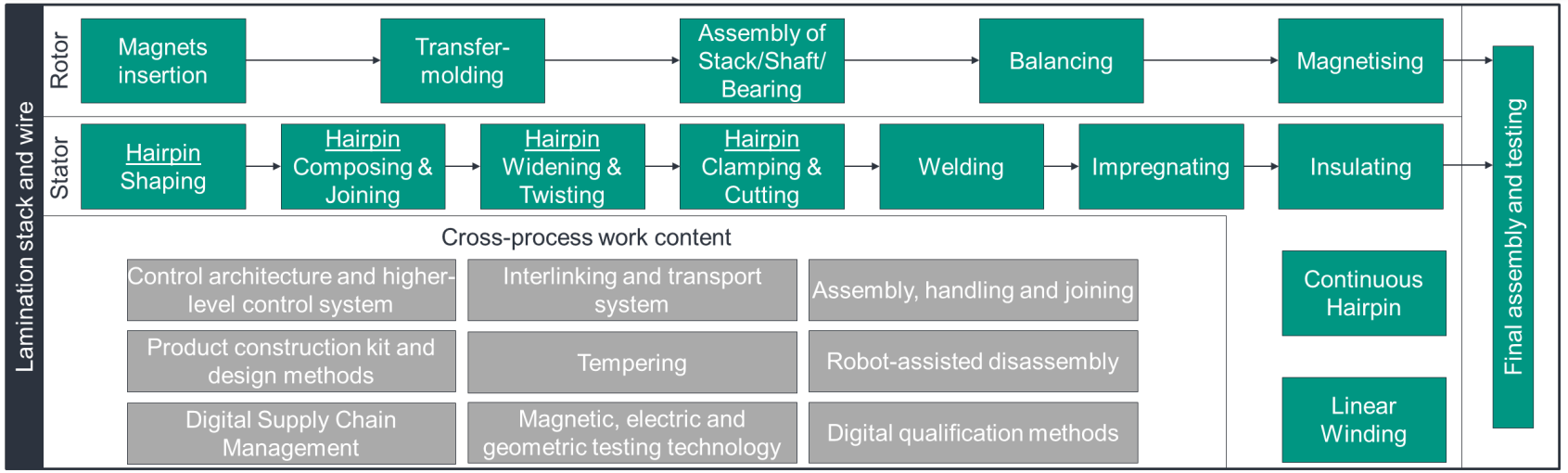


Change of Program Code

Outlook

Further Investigations in AgiloDrive2

2020/21	2021/22	2022/23	2023/24
AgiloDrive1	AgiloDrive2		
Concepts and Analyses	Implementation and Validation of the Agile Production System		



In the project AgiloDrive2 the approach can be applied to all processes and machines that need to be developed.

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Baden-Württemberg
MINISTERIUM FÜR WIRTSCHAFT, ARBEIT UND WOHNUNGSBAU

AGiL drive

Thank you very much for your attention!

Make sure to visit us at the German Pavilion in C02-08a!

e-mobil BW
Landesagentur für neue Mobilitätslösungen und Automotive Baden-Württemberg

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