Gefördert durch:

Bundesministerium für Wirtschaft und Klimaschutz

aufgrund eines Beschlusses des Deutschen Bundestages

SCALE-UP E-DRIVE

Consortium Study “Innovative Materials in Electric Motors”

Manufacturing a Stator Prototype Using Innovative Materials and Processes

PEM RWTH AACHEN UNIVERSITY GH induction SWD TRUMPF RÖSCHER GmbH ELISENTAL LCD LaserCut AG dap Digital Additive Production RWTH AACHEN UNIVERSITY WAFIOS WAELZHOLZ 3M Wickeder Westfalenstahl QUICKFairs® Coiltech

bayern innovativ DLR e-mobil BW RWTH AACHEN UNIVERSITY TUM

Consortium Study – “Innovative Materials in Electric Motors”

Manufacturing a Stator Prototype Using Innovative Materials and Processes

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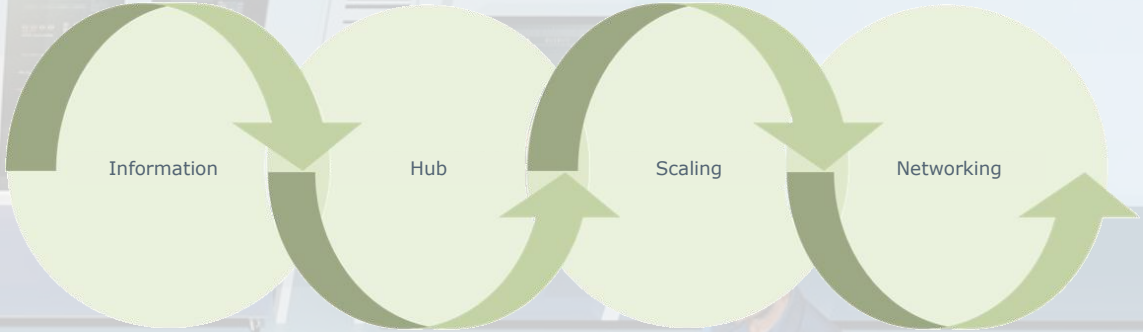
Manufacturing a Stator Prototype Using Innovative Materials and Processes

“Scale-up E-Drive” Research Project

Transformation Hub for Electric Drives

Challenge

- By 2030, up to **200,000 jobs will be lost** in the automotive industry due to the **shift away from internal combustion engines** to electric drives.
- Small and medium-sized enterprises (SMEs) with a high level of technological expertise in special applications of internal combustion engines are at **risk of missing the boat in the ongoing transformation**.
- The hub’s activities will provide SMEs with **targeted support** for the transformation.



Approach & Goals

- The **overarching goal** of the Scale-up E-Drive transformation hub is to **process current trends** and industry information and **make it accessible** to the players in the value chain of electric drives in Germany **on a non-discriminatory basis**.
- **PEM’s task** is to **prepare essential findings** from industry and research **for a broad audience** and to convey fundamental knowledge on electric drives in an interactive and practice-oriented manner.
- In addition, **new and existing players** in the value chain are **networked in innovative formats**, to jointly address central issues.

Project Partners

SCALE-UP E-DRIVE

Grantor	BMWK	**Duration**	January 1st 2023 to Dec. 31st 2025
Project Sponsor	VDI | VDE | IT	**Funding Code**	16THB0006E

Consortium Study – “Innovative Materials in Electric Motors”

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“Scale-Up E-Drive” Transformation Hub

Motivation for the Study – “Innovative Materials in Electric Motors” Technology Demonstrator

Demand

„The transformation of the automotive industry is creating a **high demand for product innovations**.“

Supply

„Technology companies develop and offer **innovative solutions** for future electric motor technologies.“

Successful use of new product technologies is prevented by the current **lack of market access**.

Approach

The development and manufacturing of holistic technology demonstrators offer innovation driving companies a platform for the targeted presentation of their solutions.

“Scale-Up E-Drive” Transformation Hub

“Innovative Materials in Electric Motors” Technology Demonstrator

What is shown?

Innovations for **individual components of electric motors** for traction applications

What is done?

Manufacturing of demonstrators based on a **neutral reference design**, including process documentation and preparation of the results

Who is the consortium?

Companies with a **product innovation with a physical proof-of-concept** and **valid property right**

Where is it presented?

Key events 2025:

- Coiltech Augsburg
- Coiltech USA

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Consortium Study – “Innovative Materials in Electric Motors”

PEM | RWTH AACHEN UNIVERSITY

SCALE-UP E-DRIVE

Objective and consortium

RÖSCHER GmbH

TRUMPF

PEM | RWTH AACHEN UNIVERSITY

SWD

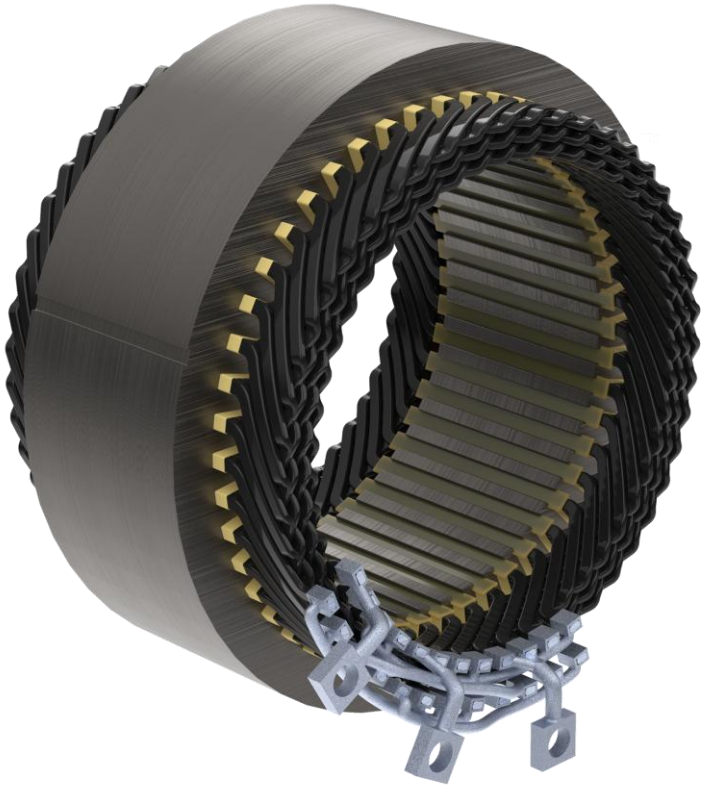
LCD LaserCut AG

3M

ELISENTAL

WAFIOS

WAELZHOLZ



Wickeder Westfalenstahl Wickeder Group

GH GROUP induction

dap Digital Additive Production | RWTH AACHEN UNIVERSITY

QUICKFairs®

Coiltech International Coil&Winding Exhibition

Objective

Design of a **stator technology demonstrator** using **innovative materials** and **processes in a specialized consortium,** enabling **accelerated prototyping.**

Consortium Study – “Innovative Materials in Electric Motors”

SCALE-UP E-DRIVE

Overview of the consortium’s contributions

PEM of RWTH Aachen University
Assembly and project organization

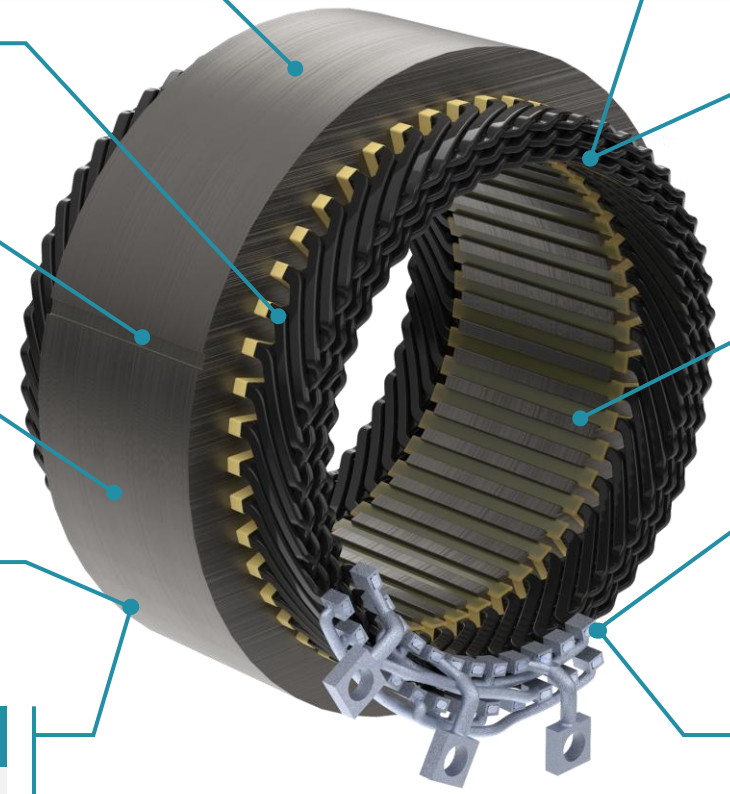
3M Germany GmbH
Provision of expandable slot liner

Wickeder Westfalenstahl GmbH
Lamination process for electrical steel

SWD AG & LCD LaserCut AG
Lamination stack design and manufacturing

C.D. Wälzholz GmbH
Raw material electrical steel

Elisental GmbH
Raw material aluminum wire



Wafios AG
2D-Winding mat bending

Röscher GmbH
3D-Stamping of the winding mat

GH Induction GmbH
Expandable slot liner activation

TRUMPF Laser and System Technology
Additive manufacturing of the busbar assembly and laser welding

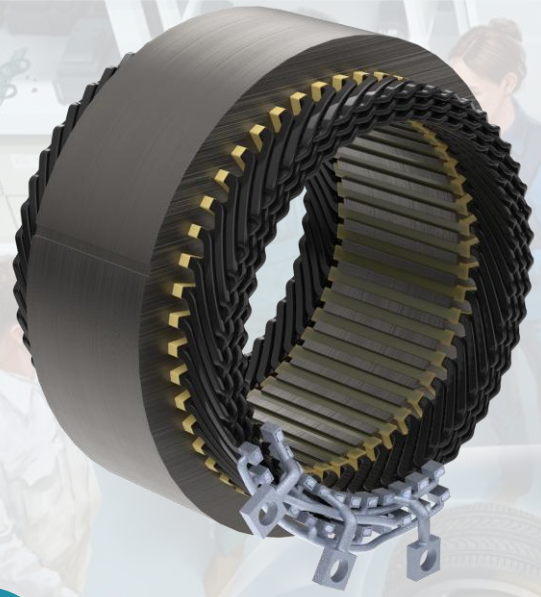
dap of RWTH Aachen
Automated generation of the busbar assembly

Consortium Study – “Innovative Materials in Electric Motors”

Manufacturing a Stator Prototype Using Innovative Materials and Processes

“Innovative Materials in Electric Motors”

Geometrical data of the Stator Prototype



Key-data of the technology demonstrator

Active length:	70 mm
Outer diameter stator:	215 mm
Outer diameter rotor:	150 mm
Winding topology:	Continuous Hairpin Winding
Conductor material:	Aluminum
Conductor dimensions:	4mm x 2mm

Objective

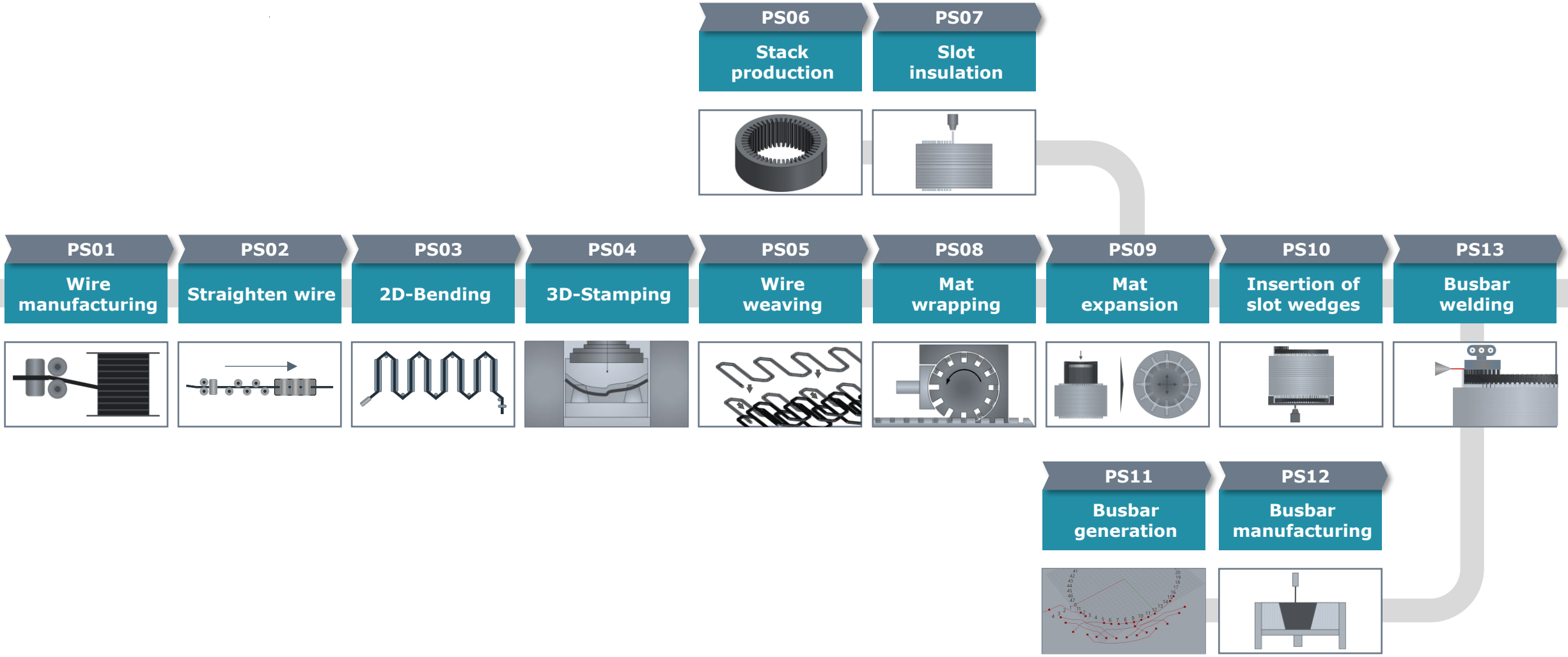
The aim of the second iteration of the “Innovative materials in electric motors” technology demonstrator project is to **set up a technology demonstrator** for the rotor and stator and to **exhibit it again at the key trade fair Coiltech**.

Consortium Study – “Innovative Materials in Electric Motors”

Manufacturing a Stator Prototype Using Innovative Materials and Processes

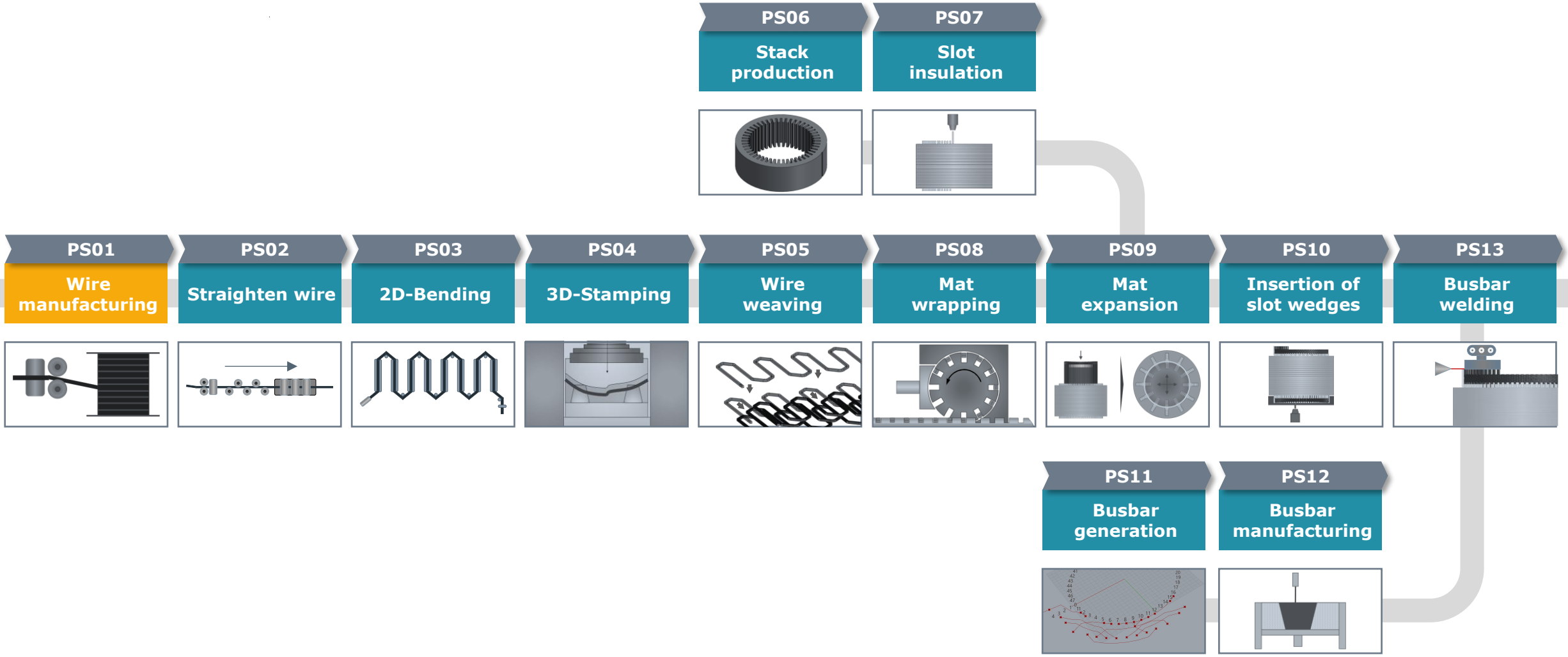
Materials and Production Processes

Process Chain for Stator-Demonstrator Manufacturing



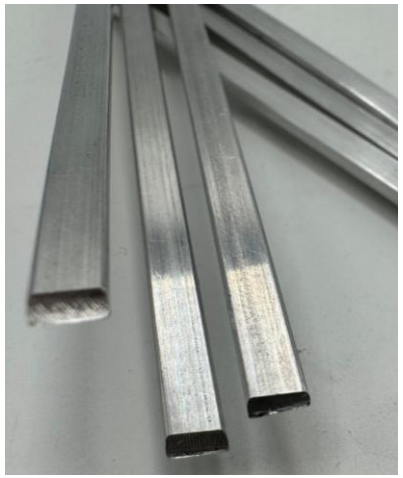
Materials and Production Processes

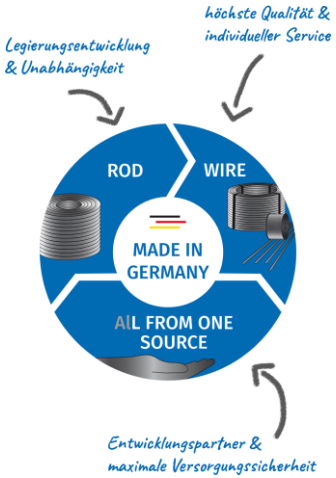
Process Chain for Stator-Demonstrator Manufacturing

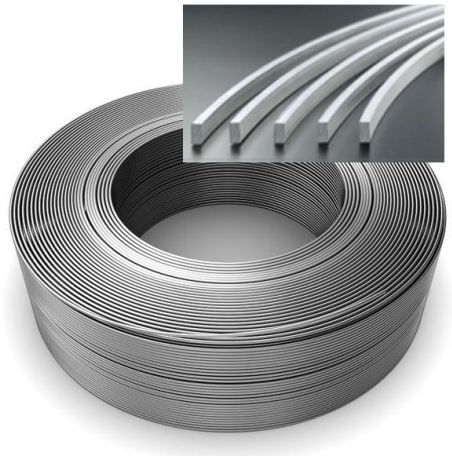


Wire manufacturing

Drahtwerk Elisental W. Erdmann GmbH







Contribution information:

- Drahtwerk Elisental W. Erdmann GmbH is a family-owned company and one of the leading European manufactures of aluminum wire
- Elisental has a broad portfolio of aluminum wires for various areas such as cold heading wires, wires for joining technology, wires for bending and forming technology and wires for the packaging industry
- In the context of the consortium study “Innovative Materials in Electric Motors”, Elisental provided the raw aluminum wire in a 4x2 mm dimension

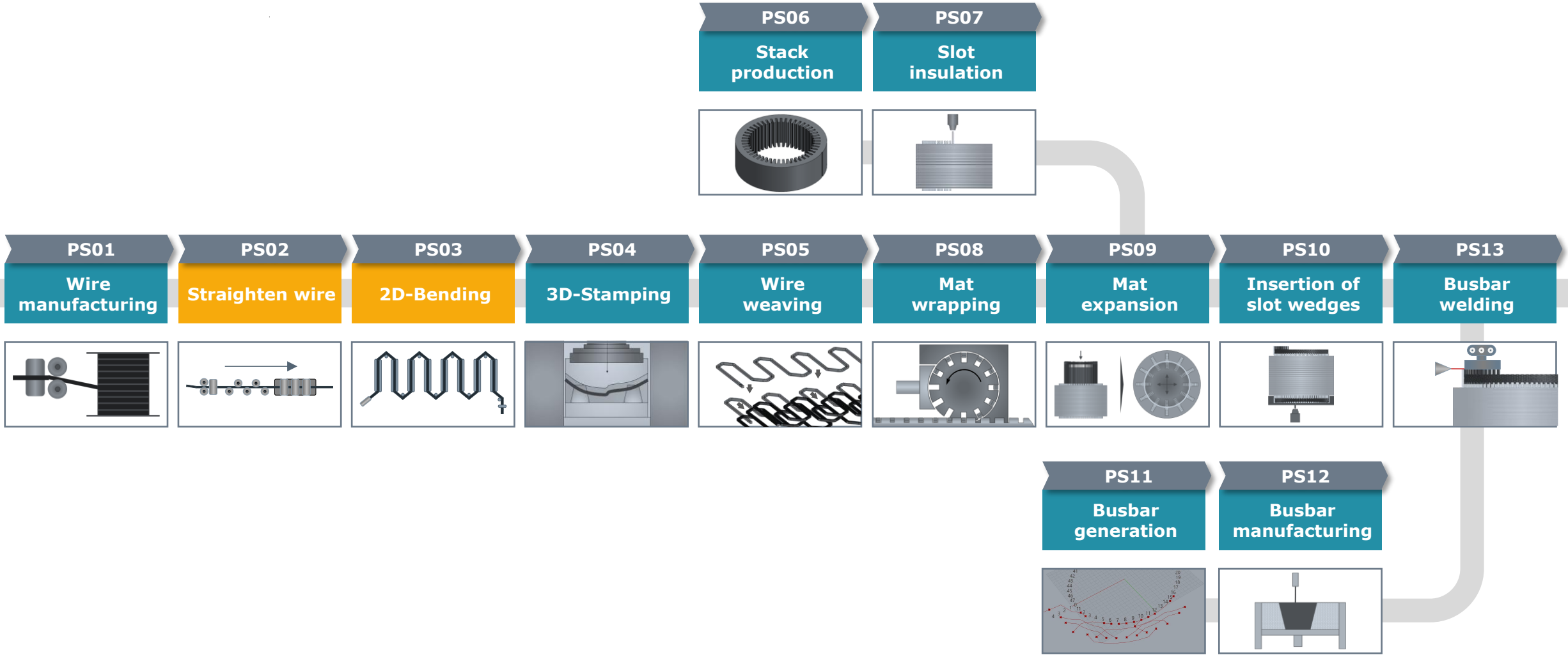
Torsten Schneider

Sales & Business Development Director
Drahtwerk Elisental W. Erdmann GmbH

Phone +49 (0) 2392 697-40
E-Mail schneider@elisental.de

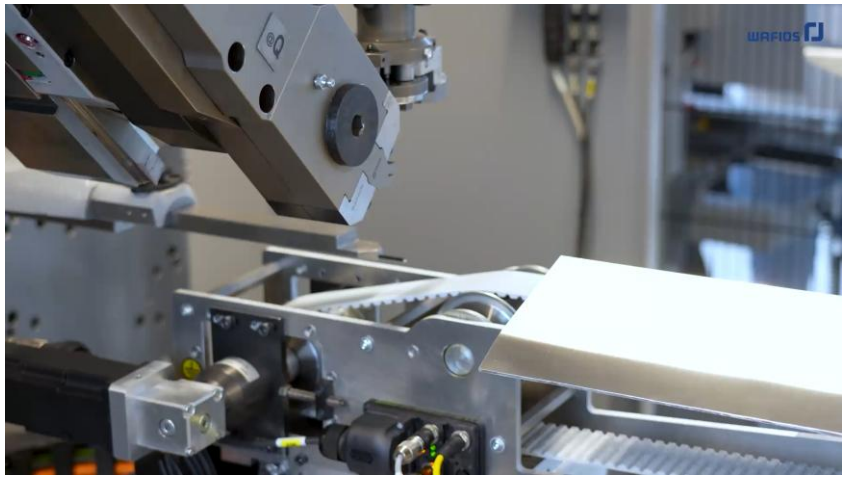
Materials and Production Processes

Process Chain for Stator-Demonstrator Manufacturing



Winding mat manufacturing – Straightening & 2D-Bending

WAFIOS AG



Contribution information:

- Wafios is specialized in CNC-bending of flat-wires using the highly flexible FMU40 E bending machine
- Utilizing a new development by Wafios, the HQ-Bening (High-Quality Bending), enables the machine to produce the 2D-geometry of continuous winding mats used for continuous hairpin stator applications
- Possibility to process a wide variety of hairpin materials with the same tool, e.g.:
  - Wire geometry
  - Wire material (e.g. copper, aluminum)
  - Wire insulation (e.g. PAI, PEEK, PI, Kapton, etc.)

Martin Bauer

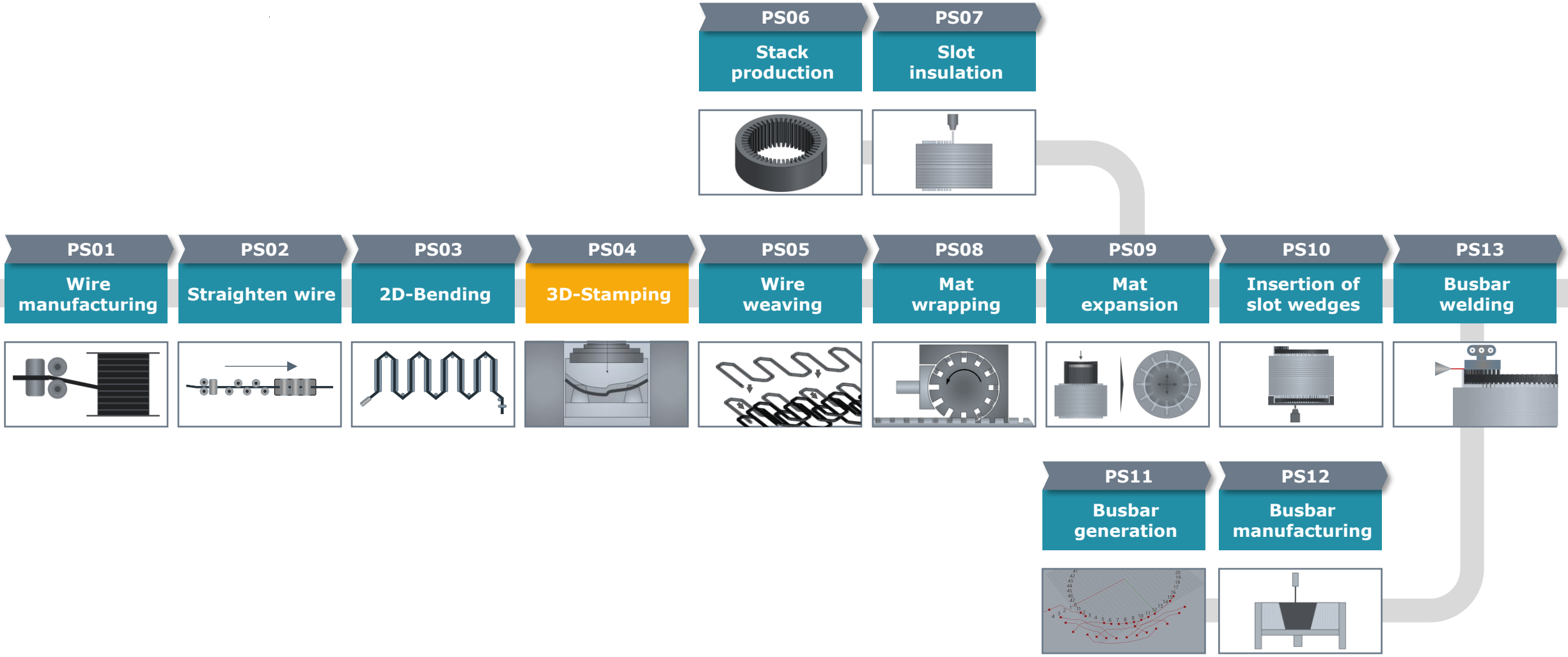
Industry Manager, E-Mobility
WAFIOS AG

Phone +49 (0) 171 1847438
E-Mail Ma.Bauer@wafios.de

WAFIOS electrifies...

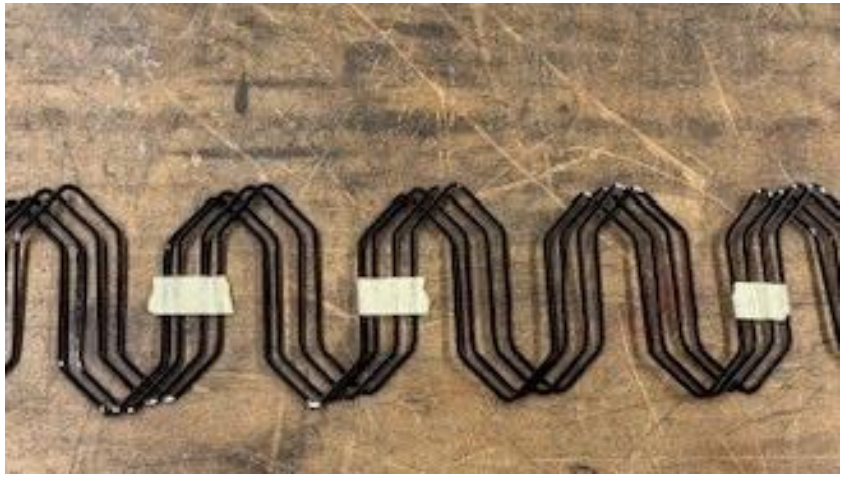
Materials and Production Processes

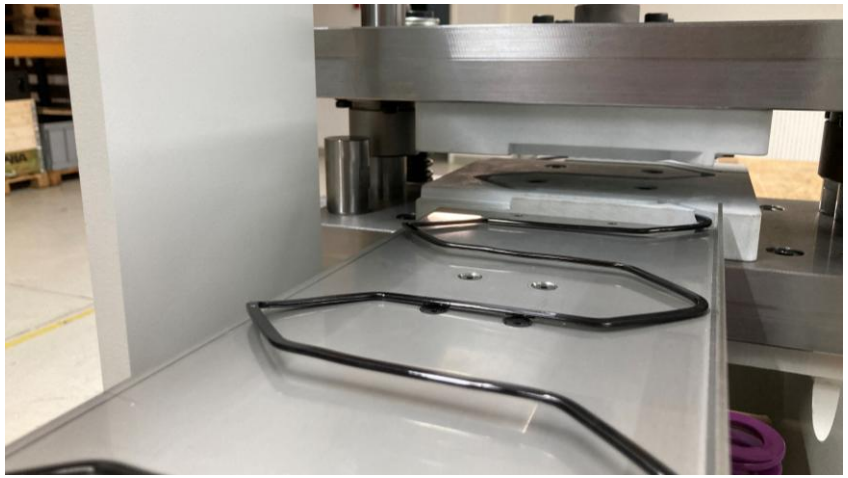
Process Chain for Stator-Demonstrator Manufacturing



Winding mat manufacturing – 3D-Stamping

Röscher GmbH Automatisierungstechnik und Konstruktion





Contribution information:

- Röscher GmbH is an engineering service provider and specialized machine manufacturer located in Berlin
- Regarding E-Mobility Röscher offers customized solutions for prototyping and small series of stators for traction drive applications like stator design, 3D-stamping, slut insulation, wire separation and twisting
- In the consortium study Röscher transferred their know-how from 3D-stamping of hairpins to continuous winding mats and provided the necessary engineering and prototype machinery

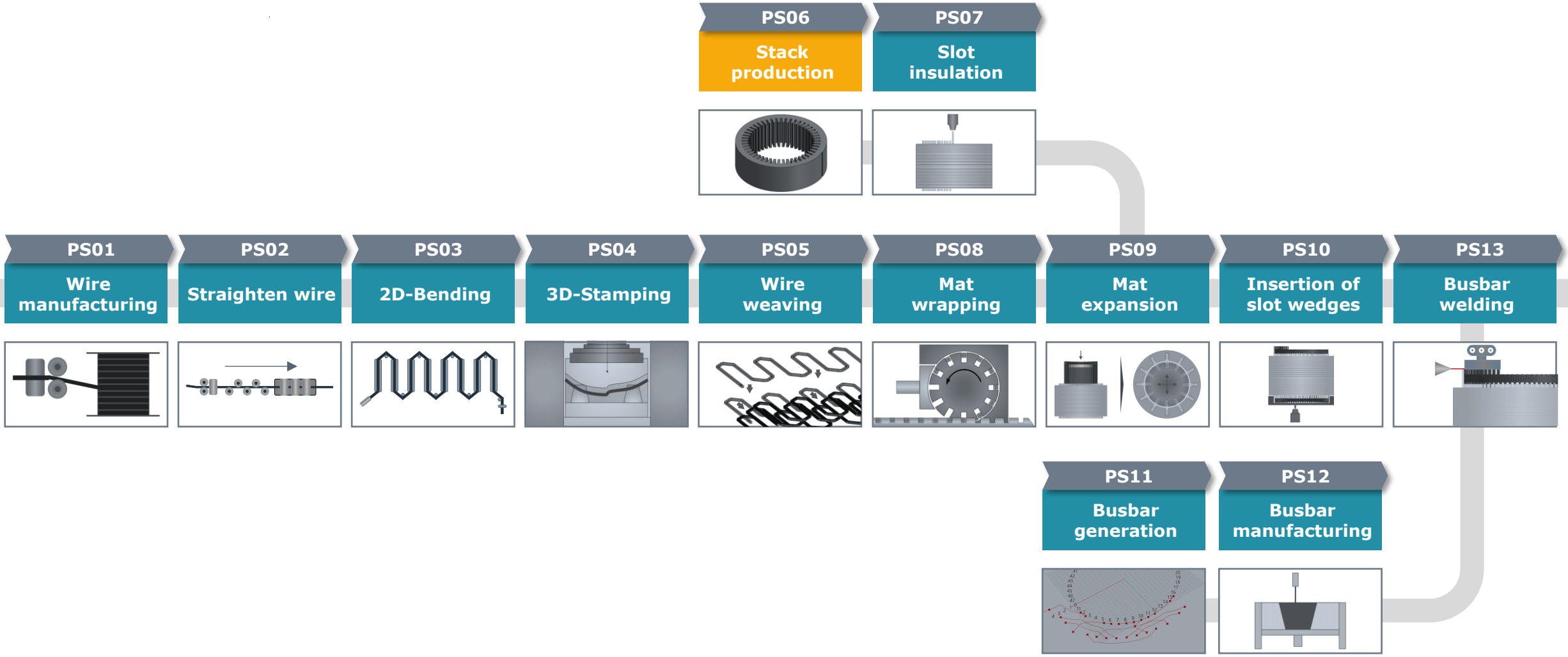
Dr. Gero Heusler

CEO
Röscher GmbH

Phone +49 (0) 1575 34 21 453
E-Mail g.heusler@roescher-gmbh.de

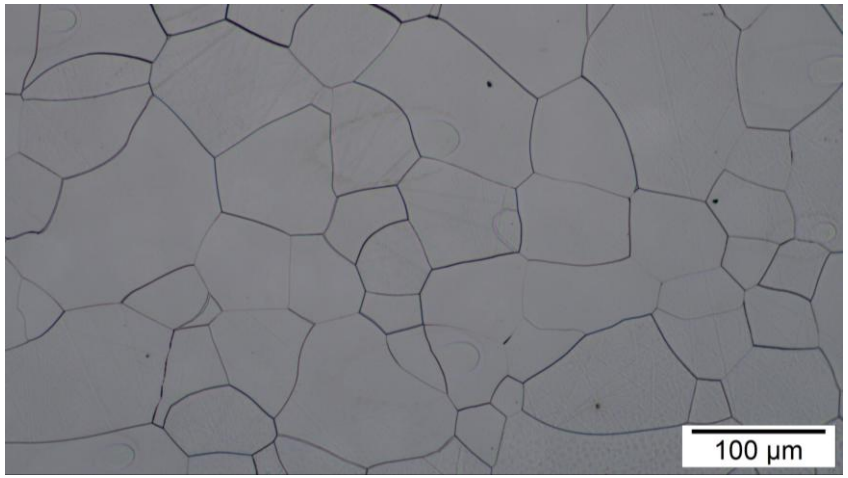
Materials and Production Processes

Process Chain for Stator-Demonstrator Manufacturing



Stack production – Electrical steel production

C.D. Wälzholz GmbH & Co. KG



Contribution information:

- C.D. Wälzholz GmbH & Co. KG is one of the technology leaders for electrical steel with a global presence
- Wälzhols offers norm materials as well as customized material solutions tailored to specific characteristics
- Regarding the consortium study Wälzholz provided the raw material, the electrical steel, for the subsequent stack production, covering the following process steps:
  - Cold rolling of the hot band to 1 mm thickness
  - Final annealing to reach the desired magnetic and mechanical properties
  - Average grain size in the horizontal line cutting method of approx. 52 µm by C.D. Wälzholz GmbH & Co. KG

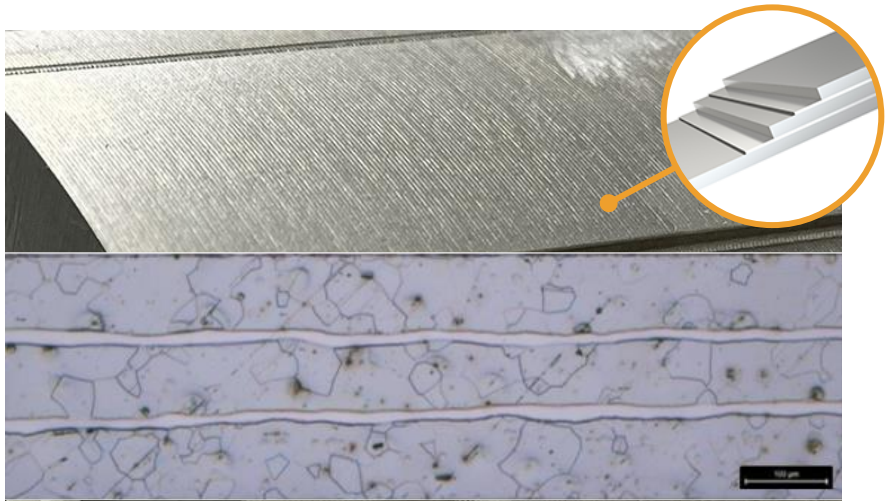
Dr.-Ing. Christoph Dahlmann

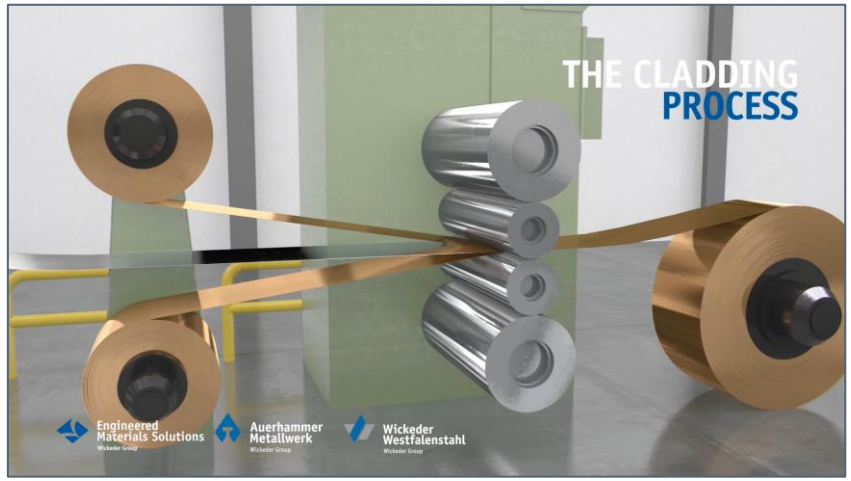
Werkstofftechnik Elektroband
C.D. Wälzholz GmbH & Co. KG

Phone +49 (0) 2331 964-2395
E-Mail Christoph.Dahlmann@waelzholz.de

Stack production – Electrical sheet production

Wickeder Westfalenstahl GmbH





Contribution information:

- DEBAND® developed by Wickeder Westfalenstahl GmbH, which is a composite material consisting of alternating ferromagnetic and non-ferromagnetic layers forming a sheet stack already layered in itself
- DEBAND® realizes thinnest electrical steel/functional layers in an optimally processable product (punching, punching and stacking, laser welding possible)
- The material used in this study comprises 3 quasi NO10 strips with a total thickness of 0.3mm
- Studies show increased efficiency in the higher frequency range (>400 Hz) compared to reference material
- Total losses reduced by up to 30% compared to the same quality as a single sheet

Carina Franken
Director Business Development
Wickeder Westfalenstahl GmbH
Phone +49 (0) 2377 917-361
E-Mail Carina.Franken@wickeder.de

Dr. Dominique Korbmacher
Business Development
Wickeder Westfalenstahl GmbH
Phone +49 (0) 2377 917-417
E-Mail Dominique.Korbmacher@wickeder.de

Stack production – Design, Cutting, Stacking & bonding

LCD LaserCut AG | SWD AG

Contribution information:

- Engineering of a suitable segmentation geometry
  - Up to 55% material savings over conventional lamella production (Here: 12,25 kg)
  - Maximum material flexibility for the electrical machine design
  - Full industrialization and best overall part tolerances reduction
- Manufacturing of the stator lamellas using laser cutting
- Backlack bonding of the stator segments
- Assembly of the stator segments
- Quality control (Geometry, Magnetic properties, Mechanical properties)

Thomas Stäuble
CEO
SWD AG

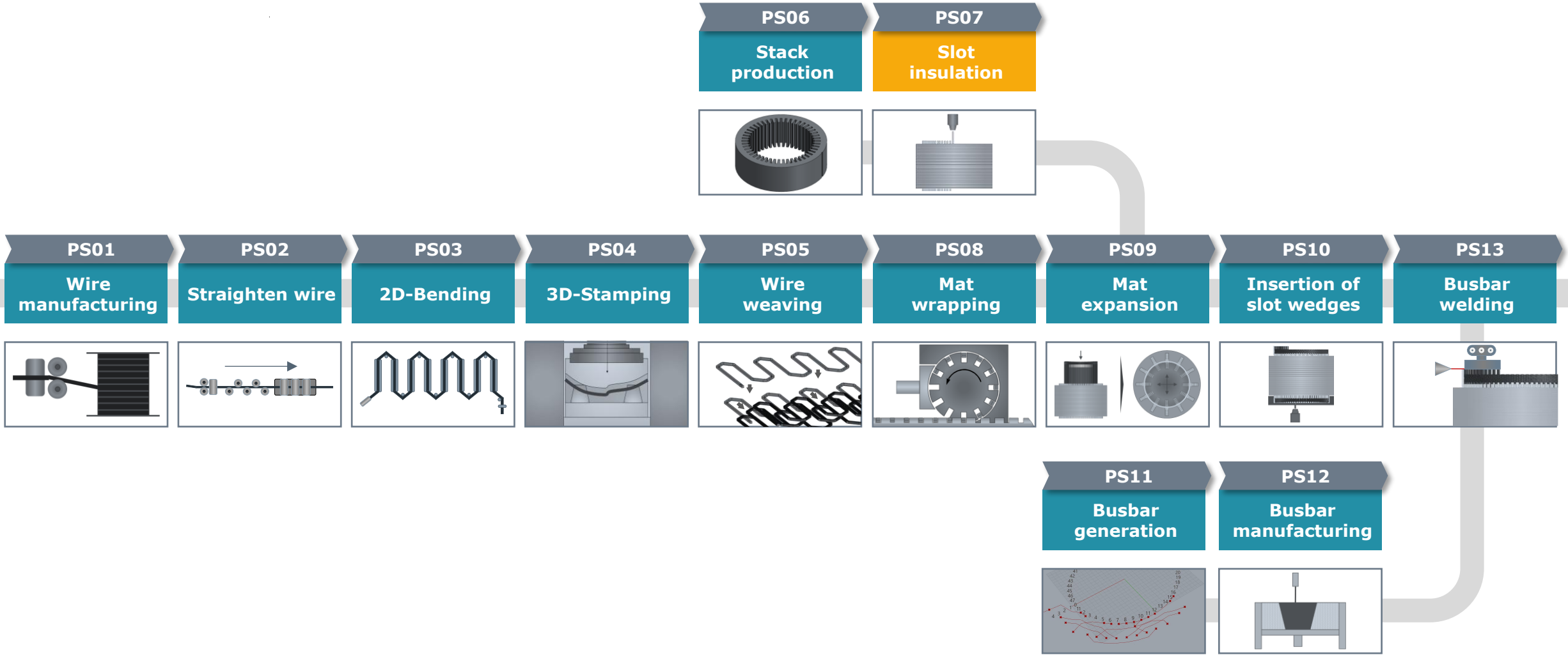
Phone +41 62 867 92 01
E-Mail t.staeuble@swdag.ch

Giuseppe Pasquarella
CEO
LCD LaserCut AG

Phone +41 62 867 92 22
E-Mail g.pasquarella@lcd-lasercut.ch

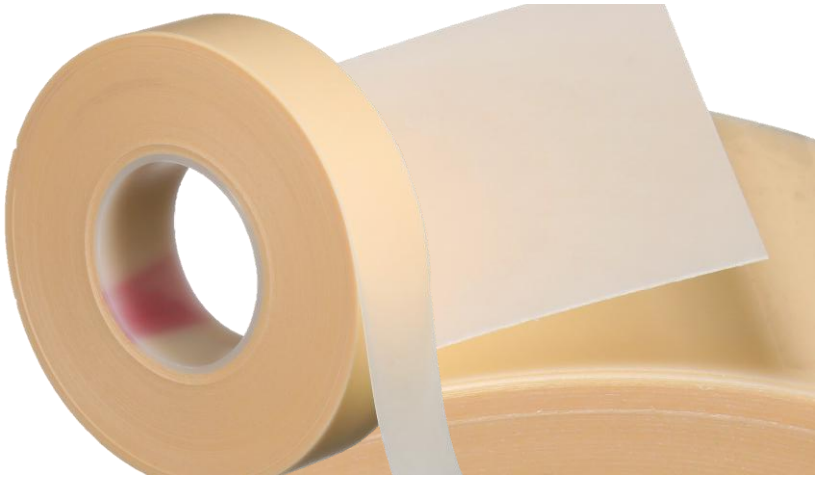
Materials and Production Processes

Process Chain for Stator-Demonstrator Manufacturing



Slot insulation – Expandable slot liner

3M Deutschland GmbH



Contribution information:

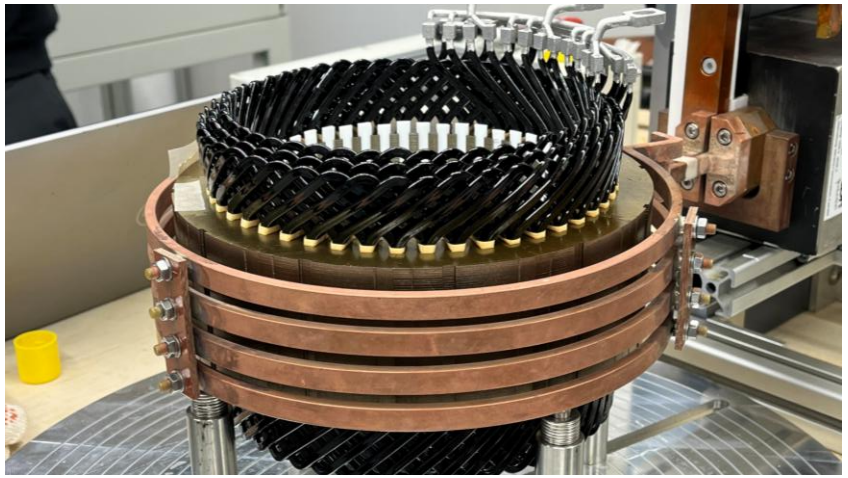
- 3M™ Expandable Slot Liner ESL-FC190
- Eliminates need for impregnation with varnish application in slots
- Smooth surface suitable for automatic insertion equipment
- Electrically insulating, mechanically protecting and securely holding the coils
- Process steps for application:
  - Expandable slot liner (ESL) inserted into slots
  - Coil winding inserted into the insulated slots
  - Heating for expansion of ESL (room temp. to 180°C, approx. 3 minutes)
  - Hold temperature for curing (180°C, approx. 10 minutes, curing time may be adjusted depending on temperature)

Jürgen Schnusenberg
Application Engineer
3M Deutschland GmbH

Phone +49 (0) 2131 145914
E-Mail jschnusenberg@mmm.com

Slot insulation – ESL activation

GH-Induction Deutschland GmbH



Contribution information:

- Controlled uniform heating of the stator lamination stack to activate and expand the ESL and provide the electrical insulation and thermal transfer layer as well as the mechanical fixation of the wires in the slot
- Heating up of the lamination stack form 20°C to 180°C with 60 – 70°C inline per minute using an inductive heating ring
- Heating process:
  - Step 1: Heating from 20°C to 60°C, 3M ESL is soft
  - Step 2: Heating from 60°C to 120°C, 3M ESL expand
  - Step 3: Heating from 120°C to 180°C, 3M ESL hardens
  - Step 4: Keep temperature at 180°C, 3M ESL is cured

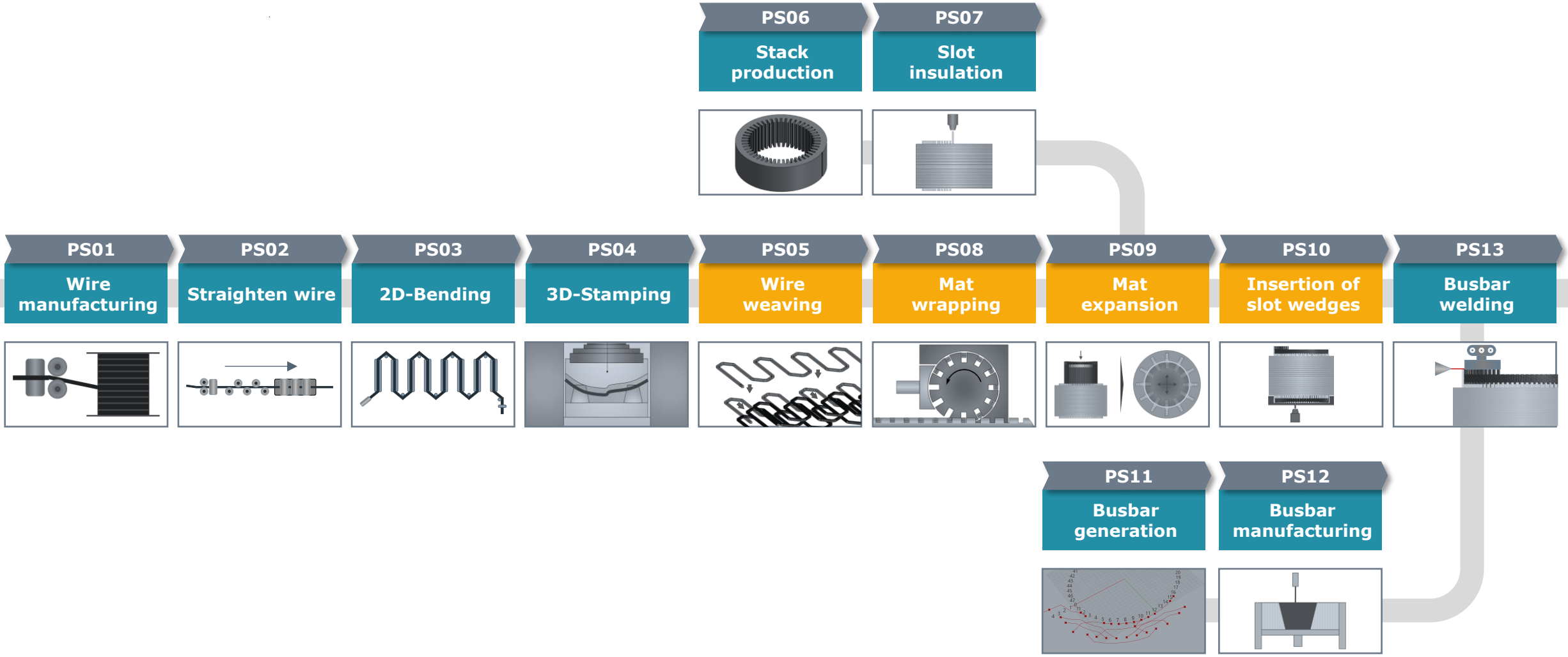
Thorben Jungblut, B. Eng./MBA

Sales Management
GH-Induction Deutschland GmbH

Phone +49 (0) 151 40730361
E-Mail M.Krupa@sh-wire.de

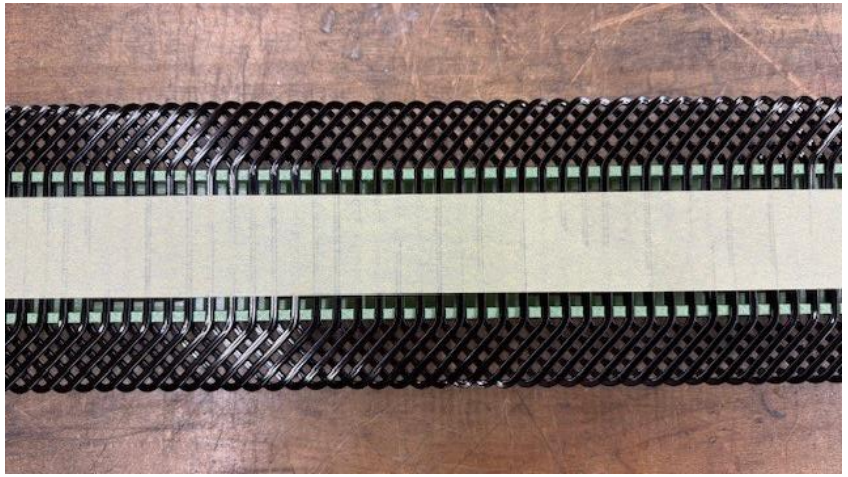
Materials and Production Processes

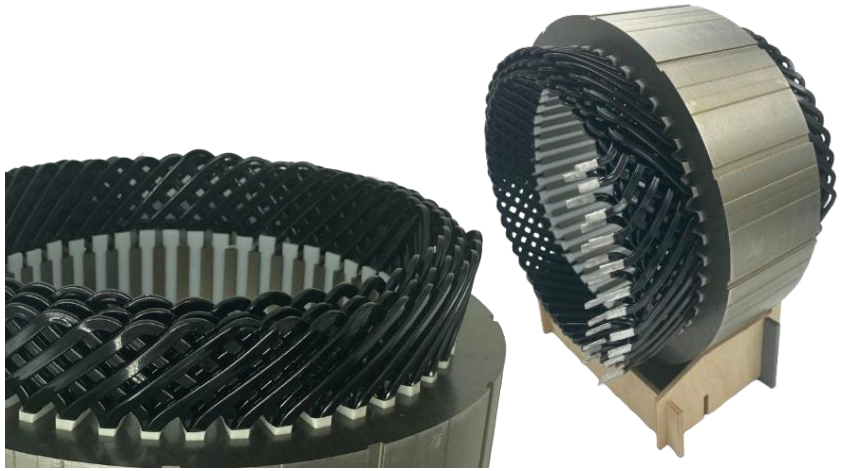
Process Chain for Stator-Demonstrator Manufacturing



Bending mat assembly – Weaving, wrapping & expansion

Chair of Production Engineering of E-Mobility Components (PEM) of RWTH Aachen





Contribution information:

- PEM of RWTH is a research institute specialized in production engineering for the electric drivetrain components like the electric traction motor
- In the consortium study PEM used prototypical process setups to perform the mat weaving and wrapping as well as the expansion into the stator lamination stack
- For the slots covers a special, heat-resistant material was used to withstand the subsequent baking of the stator assembly to activate the ESL material
- The processing approach used by PEM for the prototype build-up can be flexibly adapted to different continuous stator designs as well as other overall stator topologies as well

David Drexler

Research Assistant
PEM of RWTH Aachen

Phone +49 (0) 152 21 730752
E-Mail d.drexler@pem.rwth-aachen.de

Materials and Production Processes

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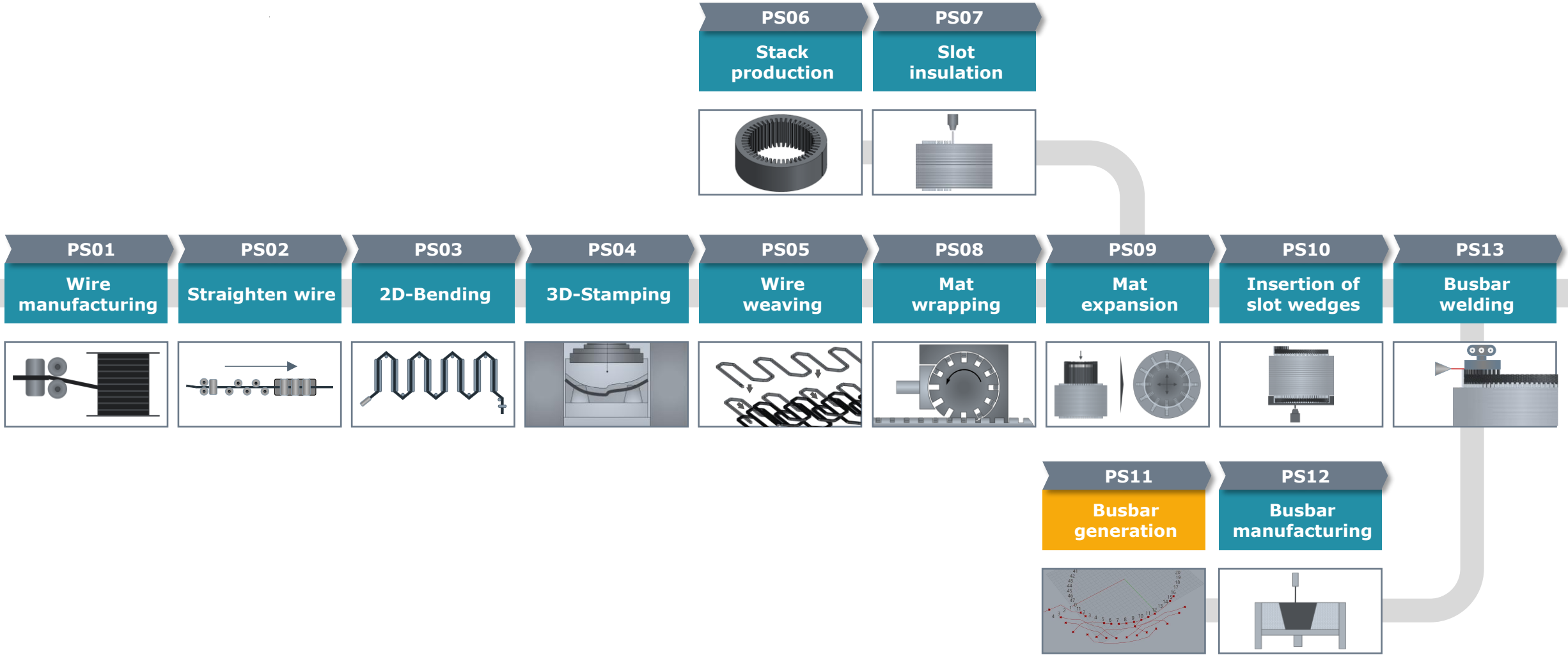
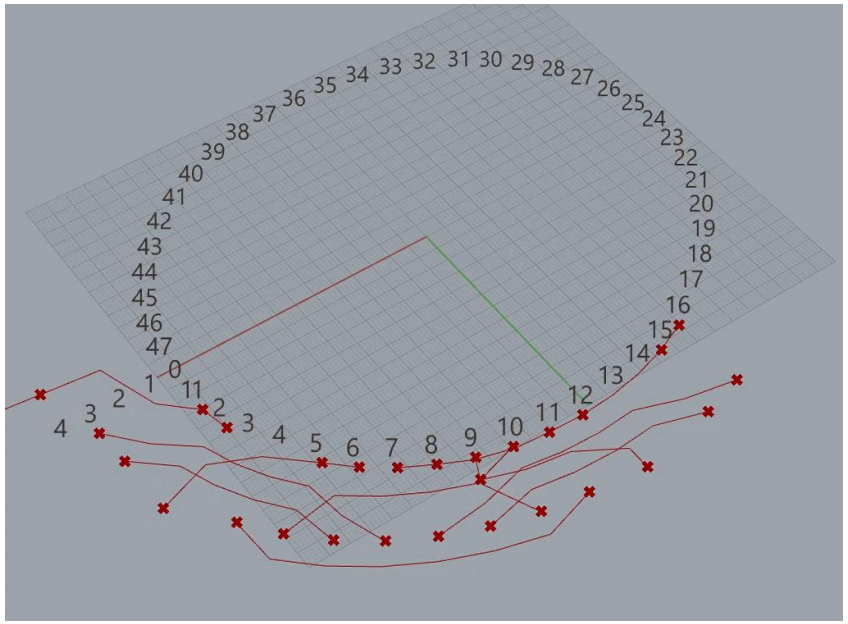


Busbar – Busbar generation

Digital Additive Production (dap) at RWTH Aachen University



Contribution information:

- Transfer of winding complexity of hairpin stators into the busbar assembly
- Automated design generation of busbar assemblies based on data-driven design modeling, considering electrical and production boundary conditions
- Optimized design space using numerical optimization algorithms
  - Shortest path algorithm
  - All connections areas to the hairpin winding in the same layer for welding
- Input: Winding scheme/busbar connection points and general stator and wire parameter
- Utilization of production potential offered by additive manufacturing

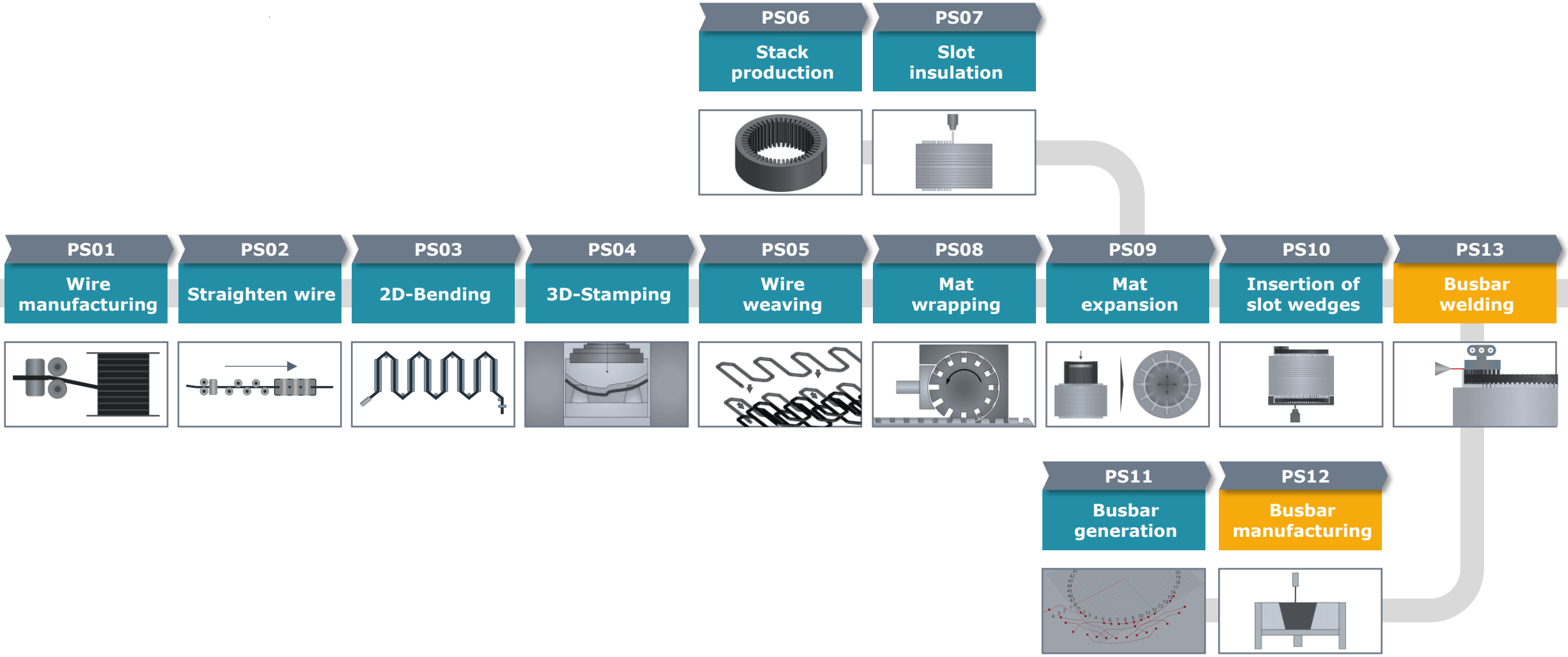
Carsten Putz

Group Lead “Data Driven Design”
dap at RWTH Aachen University

Phone +49 152 592 832 56
E-Mail carsten.putz@dap.rwth-aachen.de

Materials and Production Processes

Process Chain for Stator-Demonstrator Manufacturing



Busbar – Busbar manufacturing & Busbar welding

TRUMPF Laser- und Systemtechnik GmbH

Contribution information:

- Additive manufacturing of the generated busbar assembly using aluminum powder in a SLS-process (Selective-Laser-Sintering)
- Contacting of the aluminum wire ends and the busbar assembly using 3,5 – 7,0 kW, depending on the feed rate (overall energy input approx. half of copper contacting)
- TRUMPF Disk Laser with high beam quality 2mm x mrad, Fiberdiameter 50/200µm (2-in-1 Fiber), BrightLine Weld waveguide
- Scanning optics PFO33-3, new-generation 2D scanner
- No shielding gas necessary
- Laser stripping possible with TruMicro ns-pulsed lasers (2 kW average power, 100 mJ pulse energy), typical processing time (10 mm stripping length) <0.5 s

Matthias Beranek IWE

Industry Manager E-Mobility
TRUMPF Laser- und Systemtechnik GmbH

Phone +49 (0) 171 9916288
E-Mail Matthias.Beranek@trumpf.com

Consortium Study – “Innovative Materials in Electric Motors”

Manufacturing a Stator Prototype Using Innovative Materials and Processes

For further information do not hesitate to contact us!

David Drexler, M. Sc., M. Sc.
d.drexler@pem.rwth-aachen.de
+49 (0) 152 21 730752
Bohr 12, 52072 Aachen

Michael Nankemann, M. Sc.
m.nankemann@pem.rwth-aachen.de
+49 (0) 151 165136 76
Bohr 12, 52072 Aachen

SCALE-UP
E-DRIVE

Responsibility for content

PEM of RWTH Aachen University
Bohr 12
52072 Aachen
E-mail: info@pem.rwth-aachen.de
Phone: +49 241 8027 427

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