CWIEME BERLIN | 3-5 JUNE 2025 MESSE BERLIN

The CFW Continuous Flow Winding: a new paradigm in e-mobility motor manufacturing process

IMA EV-TECH
Technologies for E-Mobility

MAVEL

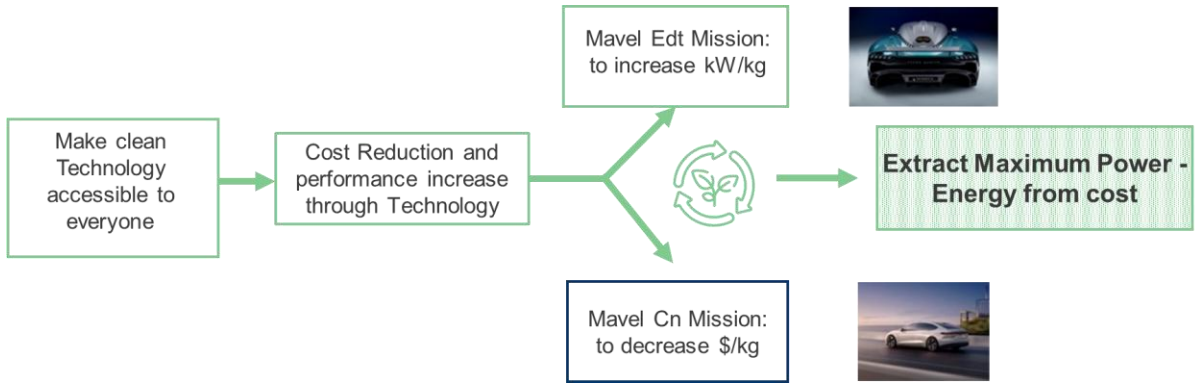
POWERED BY IMA AUTOMATION

IMA

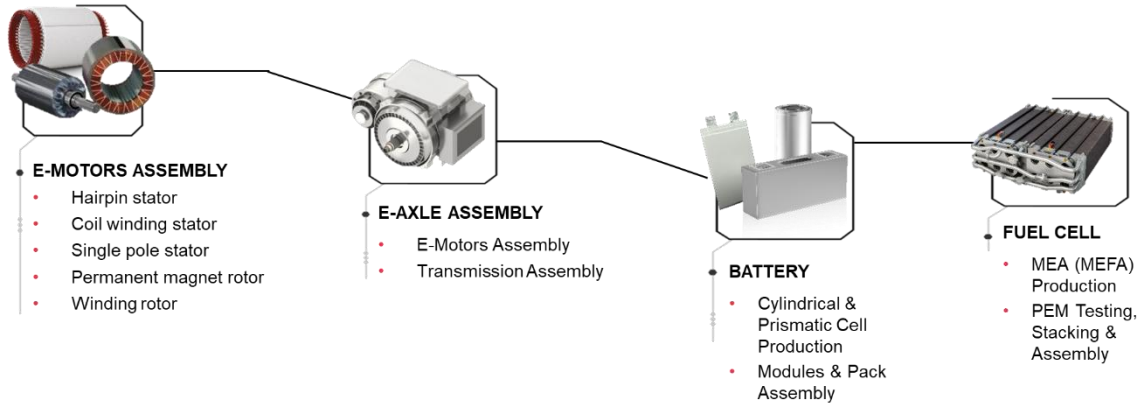
Companies presentations

Transform KNOW WHY in KNOW HOW for SAFE and ADVANCED POWERTRAIN : MAKE E-PWT TECHNOLOGY ACCESSIBLE TO EVERYONE

Two BUSINESS area : D&D and testing , Production area



IMA EV-TECH is the business unit of IMA AUTOMATION, entirely committed to electric vehicle (EV) assembly technologies.
This unit specializes in the development of complete lines and assembly technologies for EV solutions such as battery cells (cylindrical and prismatic), fuel cells, e-axles, e-motors, stators and rotors.



Mavel Motor technology

MOTOR CHARACTERISTICS (case study P4 oil cooled)

Axial dimension		
	CFW	Hairpin/ Wave winding
BB SIDE	29mm	34mm
NON-BB side	22mm	29mm

Peak current density

65 A/mm² (*)

Continuous current density

40 A/mm²

POWER DENSITY kW/Kg 160kW in 9,5 kg (16.8)

TORQUE DENSITY Nm/Kg 150 Nm in 9,5Kg (15.8)

COPPER DENSITY kW/Kg 160kW in 1.6 kg copper (100)

MAGNET DENSITY kW/kg 160kW in 0,7 kg Magnet (228)

AC losses mitigation

Advanced direct cooling

Compatible with every rotor technology

Production-ready design

(*) *per 10 sec*

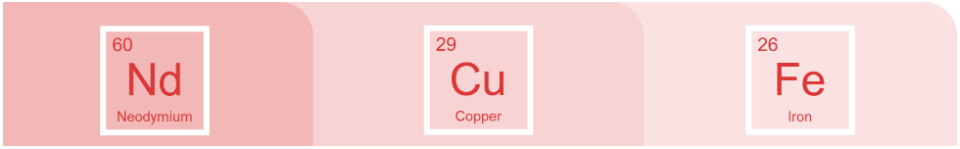
Mavel Motor technology

Specification Overview

Parameter	Values	Unit
AP Diameter x length	160 x 62	mm
AP weight	9.5	kg
Rotor max speed	24’000	rpm
Voltage range	400/800	V_{DC}
Peak power (10s)	160	kW
Peak torque (10s)	150	Nm
Continuous power	100	kW
Continuous torque	95	Nm

Main Features & KPIs

- Asymmetric rotor pole layout (AI improved design)
- OCFW winding technology (limited soldering)
- Direct oil cooling of stator winding and rotor shaft
- KPI’s
  - Power densities
    - **Up to 17 kW/kg (active parts)**
    - **Up to 40A/mm² continuous CD**
    - **Up to 60A/mm² 10” Current Density**
    - **Up to 100 kW/kg (Copper)**
    - **Up to 228kW/Kg (Magnet)**

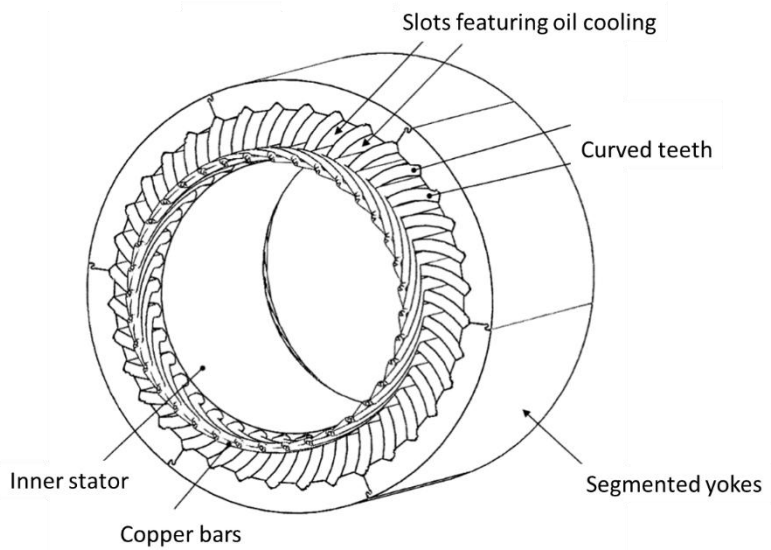


0,7 kg (Magnet) **1,6 kg (copper)** **13kg (block base)**

Mavel Motor technology

Shaped Closed Slot Design improve the performance and enable the effective copper insertion

- **AC losses mitigation** slot enclosure consistently reduces AC losses at high speeds while exploiting high copper fill factor for enhanced efficiency
- **Compatible with all rotor topologies** slot enclosure enables airgap harmonics reduction minimizing rotor losses and improve magnet utilization for superior performance
- **Advanced cooling capability** direct slot oil cooling engineered for in-deep heat extraction. The design ensured effective stator-to-rotor fluid separation with robust sealing capabilities
- **Production-ready design** Slot curvature allows axially compact end winding, preventing plastic deformation during insertion. Continuous winding pattern minimizes welding points, streamlining production and increasing manufacturing efficiency



Compatible with all rotor topologies

Stator technology

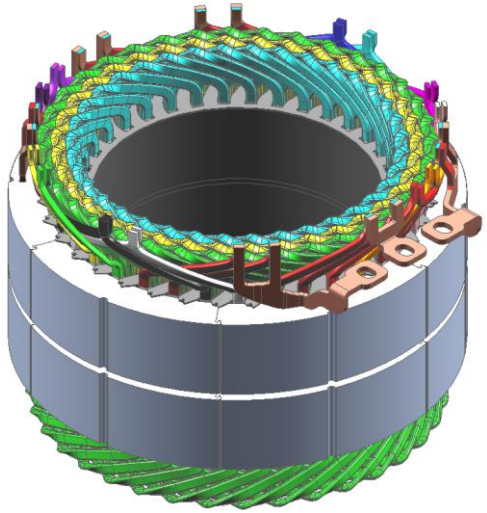
Oil Continuous Formed Windings

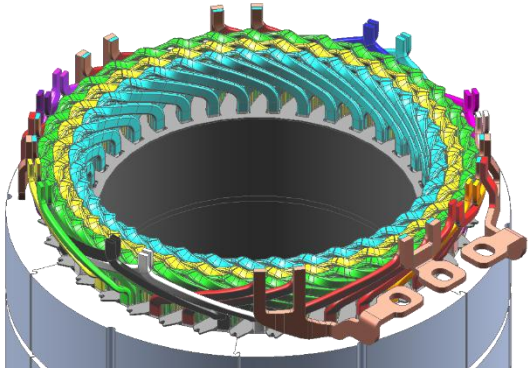
Design Goals and Objectives		
To maximize the efficiency and the density of the motor	• **Maximize the Torque/ kg (copper) ratio** • Enable the direct oil cooling of the conductors • Minimize the skin effect and the proximity effect on the conductors	**Closed slot to reduce the harmonics**
To enable high speed / high efficiency of the motor	• **Maximize the Torque/ kg (magnet) ratio** • Protect the magnet against the Harmonics through the closed slot geometry	**Less slot to increase the copper density**
To optimize the production process IMA AUTOMATION	• **Avoid plastic deformation during the insertion process, preventing wire damage** • Maximize production efficiency and output • Minimize scraps and reduce costs	**Directly Channelled Oil on the Slot to reduce temperature and improve eff.**

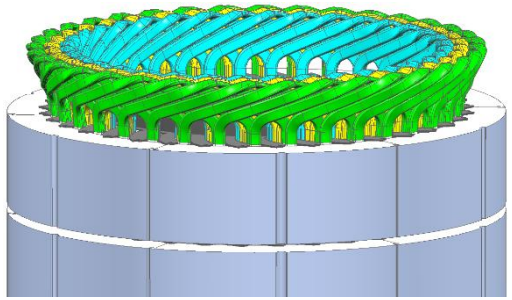
Stator technology

The production process designed by IMA AUTOMATION allows the following results to be achieved on the product:

- The forming process allows for a strong reduction in the crown height compared to other processes:
  - Minimum total length of the motor
  - Maximization of copper use efficiency







Axial dimension // Busbar side

	CFW	Hairpin/ Wave winding
Crown	22mm	29mm
Welding point	29mm	34mm

Axial dimension // Non-Busbar side

	CFW	Hairpin/ Wave winding
Crown	22mm	29mm

Mavel Rotor technology: Permanent magnets

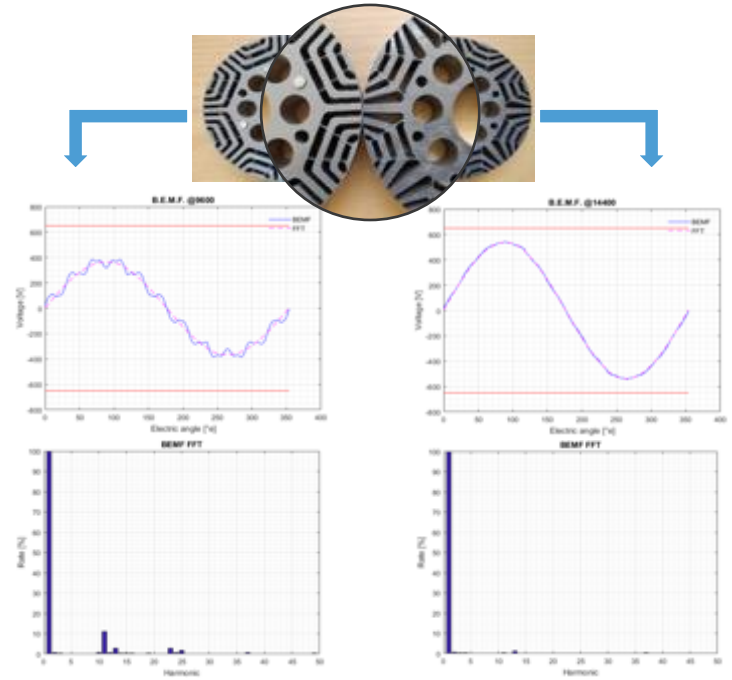
Asymmetrical design improves NVH and doesn’t require skew

Key Innovation:

- ASY Asymmetric rotor flux barrier
- Optimization of NVH
- Skew-free
- Carbon fiber sleeve for high-speed premium application

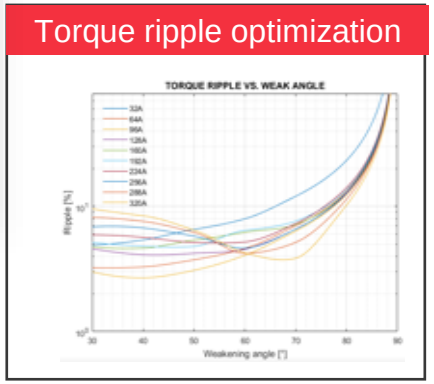
Key Benefits

- Minimizes ”torque ripple” (and associated NVH) up to 20% – throughout the whole operating range vs a symmetrical design
- Avoids the need for “skewed” configuration: to achieve the same “torque ripple”
- Reduces the bearing stress
- Improves the motor NVH
- Allows the high speed for the motor
- Reduces the steel stress

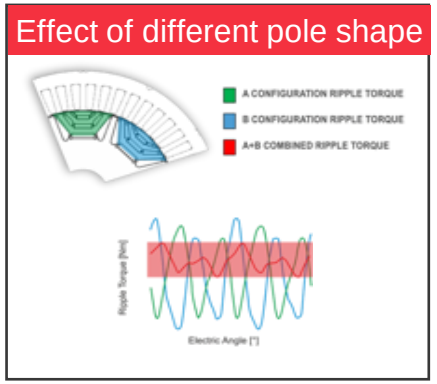


Key Features:

Torque ripple optimization



Effect of different pole shape

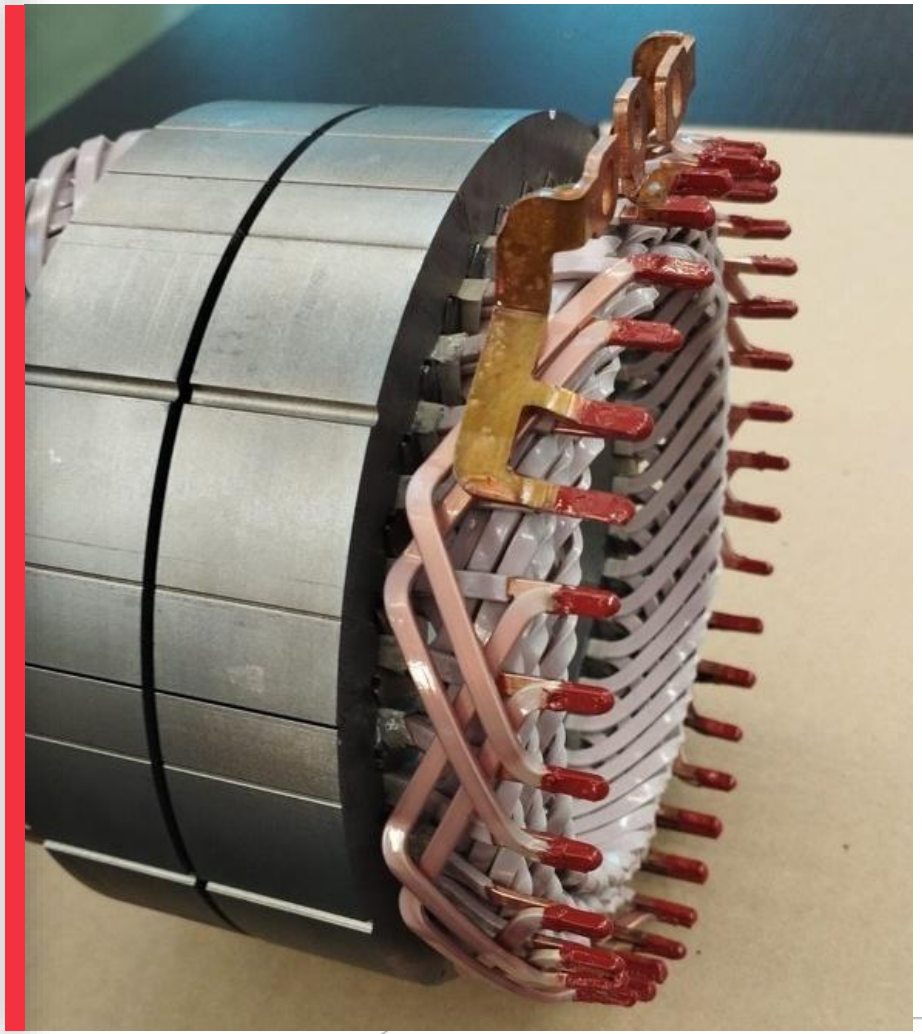


Manufacturing: Product advantages

From the mass-production processes point of view, the CFW motor combines the advantages of the hairpin motor, where the dimensions of the crowns are controlled by specific forming processes, with the advantages of the inserted motors, where there is a drastic reduction in welding points.

In detail, with IMA AUTOMATION processes the following product advantages can be highlighted:

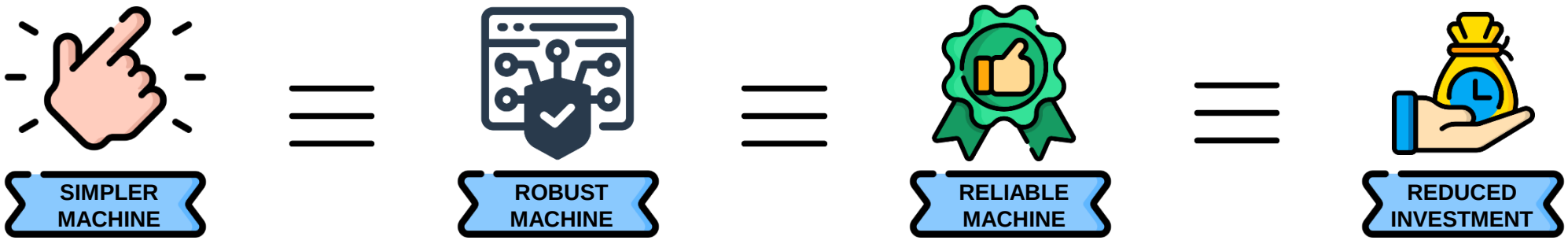
- ✓ Minimum total length of the motor.
- ✓ Maximization of copper use efficiency.
- ✓ CFW 3D modeling before insertion into the stator stack to ensure:
  - Perfect coupling with adjacent waves.
  - Avoid plastic deformations after the wave has been formed.
- ✓ More efficient slot liner insulation scheme.



Manufacturing: Product advantages

Consequently, it follows:

- **Full control** of the stator production achieved by means of processes divided in several steps. This leads to have simpler machines with a reduced investment.



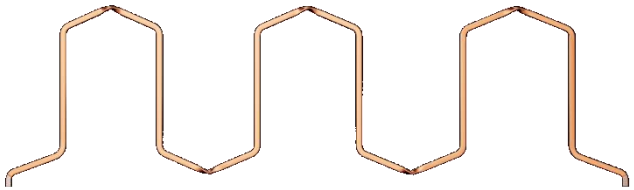
- **Modular lines:** the machines allow rump-ups. In addition, also the economic investment is modulated.

The following advantages will be explained in detail in the next chapter.

Manufacturing: Product advantages

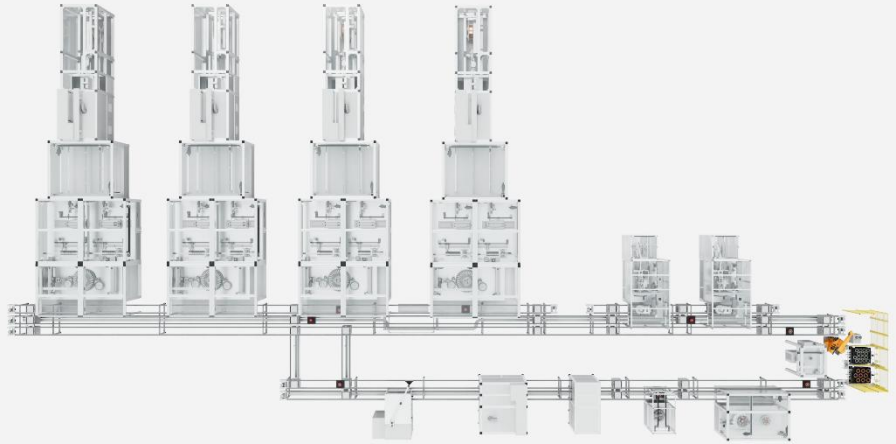
The production process designed by IMA AUTOMATION allows to reach the following manufacturing advantages:

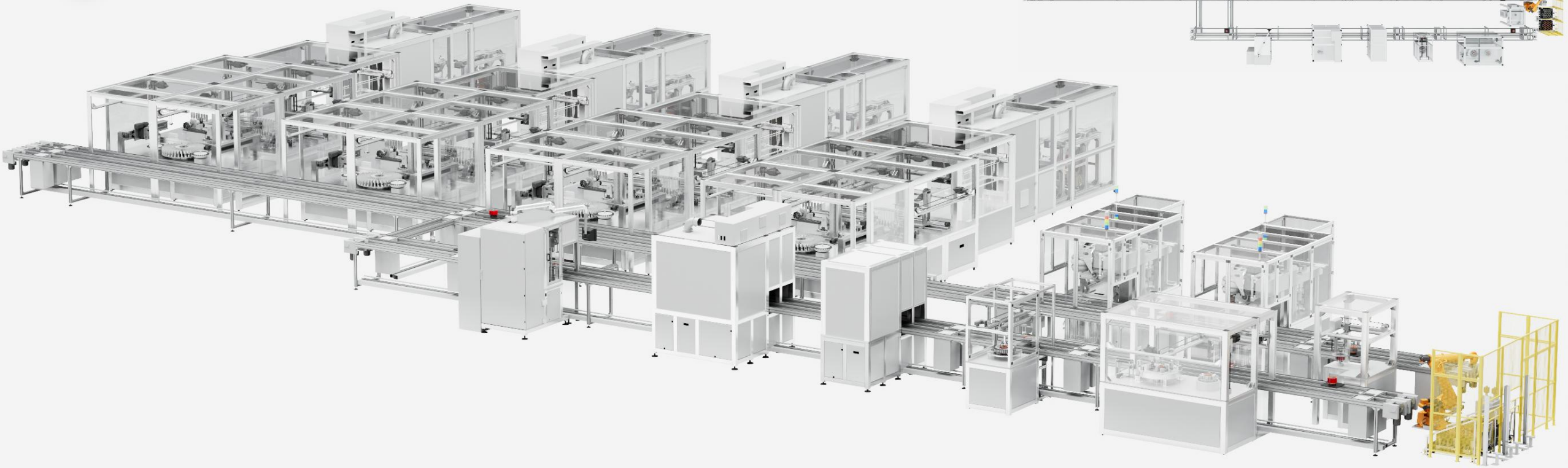
- **Reduced number of processes**, as the following machines are avoided:
  - Wedge assembly machine
  - Insertion/forming press
- **Compact Wave Winding** and therefore are easily manipulated and formed with small machines
- **Fewer number of welding machines** (compared to hairpin lines)
- **Reduced economic investment**
- **Fully automatic process**



Manufacturing: High productivity

- Footprint **18x35 m**
- Cycle time **83 sec** *per stator*
- **250 dd/Y, 21 h/d, 3 shifts**
- Productivity **193K Pcs/y**
- OEE **85%**





Manufacturing: Key features

-10% OPEX for lower consumption and floor space occupation.

Less maintenance thanks to reduced number of station.

-10% CAPEX for lower machine.

Less operator in line (due to lower process).

Intellectual property of the product.

Production technology strictly linked to product design: these processes cannot be used with other types of wave windings but concern the specific CFW design.

Easy to implement scalable E-Motors design.

Thank you
for your attention

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