

Manufacturing of Coil Formers by integral Open-die Forging and CNC Ring Rolling Process

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Solutions in Metal

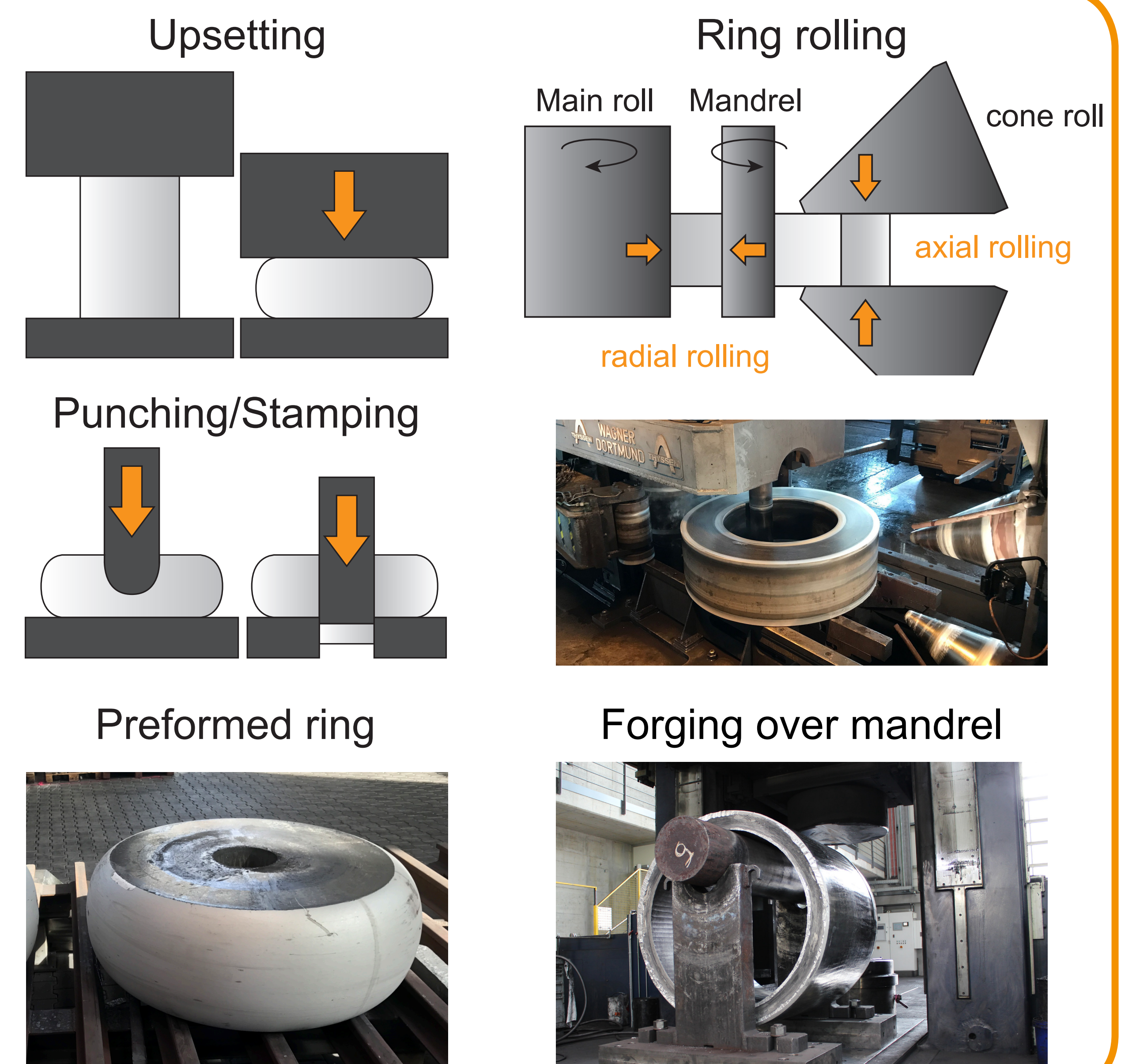


Motivation

Materials used for normal- or superconducting magnets have to fulfill a set of high requirements. To withstand high magnetic fields and to not disturb the accuracy of the magnetic detectors, material classes are preferred which have a low magnetic permeability e.g. aluminium alloys. Also strength and toughness have to be high enough to withstand the stresses in high vacuum or cryogenic conditions. Further, the single components define the final shape of e.g. spooled coil formers and consequently the magnetic field geometry. In order to avoid any distortions of the magnetic field, very narrow tolerances have to be achieved for the machined parts. The following sections show the exemplary manufacturing of such a coil former with the main steps of forging and machining.

Forging and Ring Rolling

- Using aluminium base material for manufacturing of coil formers
- Forging blanks are manufactured by open die forging using a hydraulic press with 3000 t press force (30 MN) and a CNC ring rolling mill
- Casted base material preheated to forging temperature (400 - 500°C)
- Rings made in three steps:
 1. Upsetting of base material
 2. Punching with a mandrel and piercing/stamping of a hole into the workpiece
 3. Ring rolling with control of axial and radial reduction
- Defined circumferential growth by reducing thickness of preformed ring
- Rings up to 600 mm in height fabricated by radial/axial ring rolling mill
- Rings or bushings above 600 mm in height fabricated fully by open die forging over the mandrel
- CNC assisted ring rolling allows a constant reproducibility and usage of less additional material
- One coil former consists of 4 supporting disks, 7 intertwining rings with different heights and 4 intertwining bushings



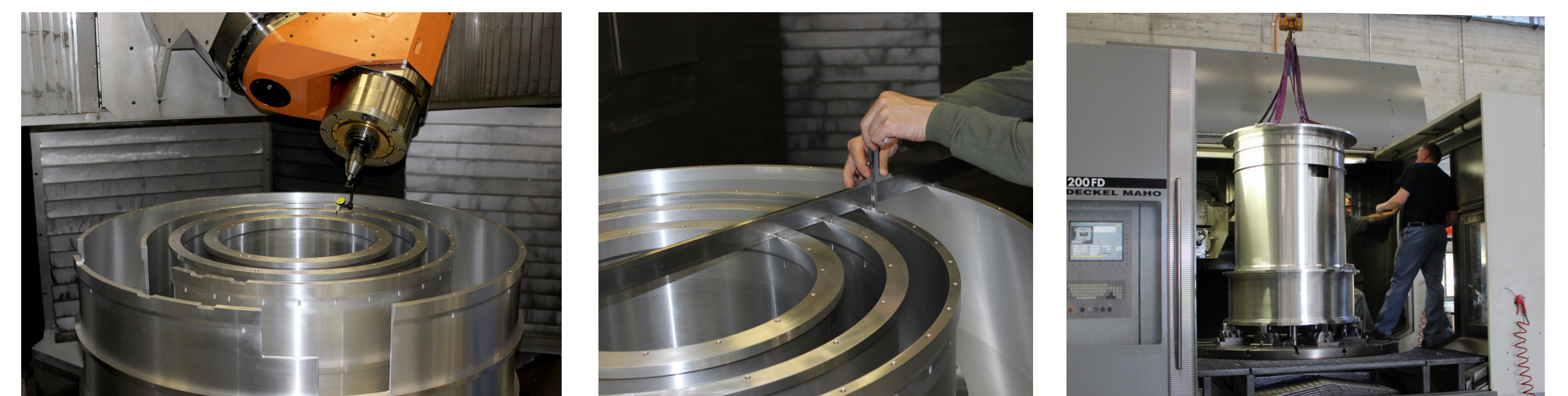
Machining and Assembling

- Machining in several steps to minimize residual stresses (intermediate loosing and reclamping)
- First operation on CNC turning machines
- Intermediate stress relief annealing
- Final machining on CNC milling and turning machine
- Complete dimensional control on 3D coordinate measuring machine
- Assembling of machined parts directly on milling machine
- Further machining of assembled parts to ensure all dimensions and tolerances on the final component
- Final control and check of the complete assembly

Machining on CNC turning machines



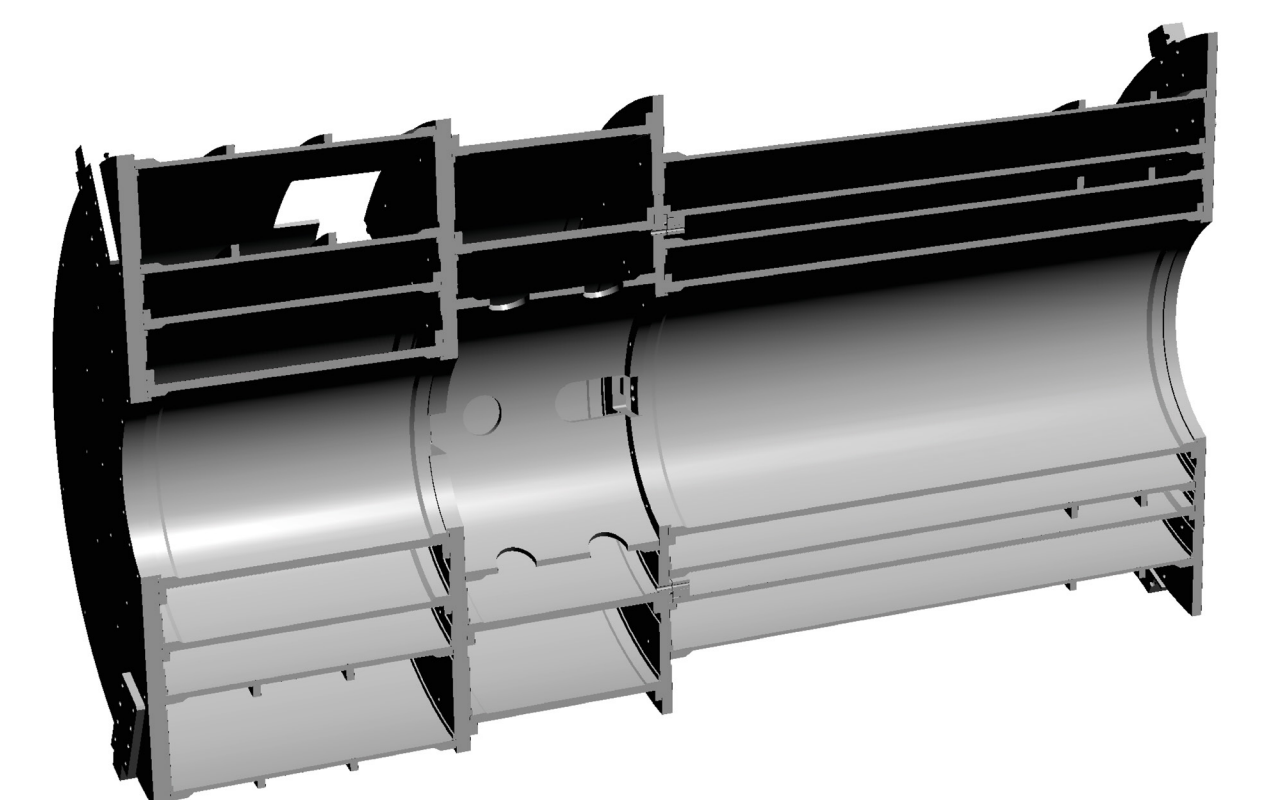
Assembling of all components on CNC milling and turning machine



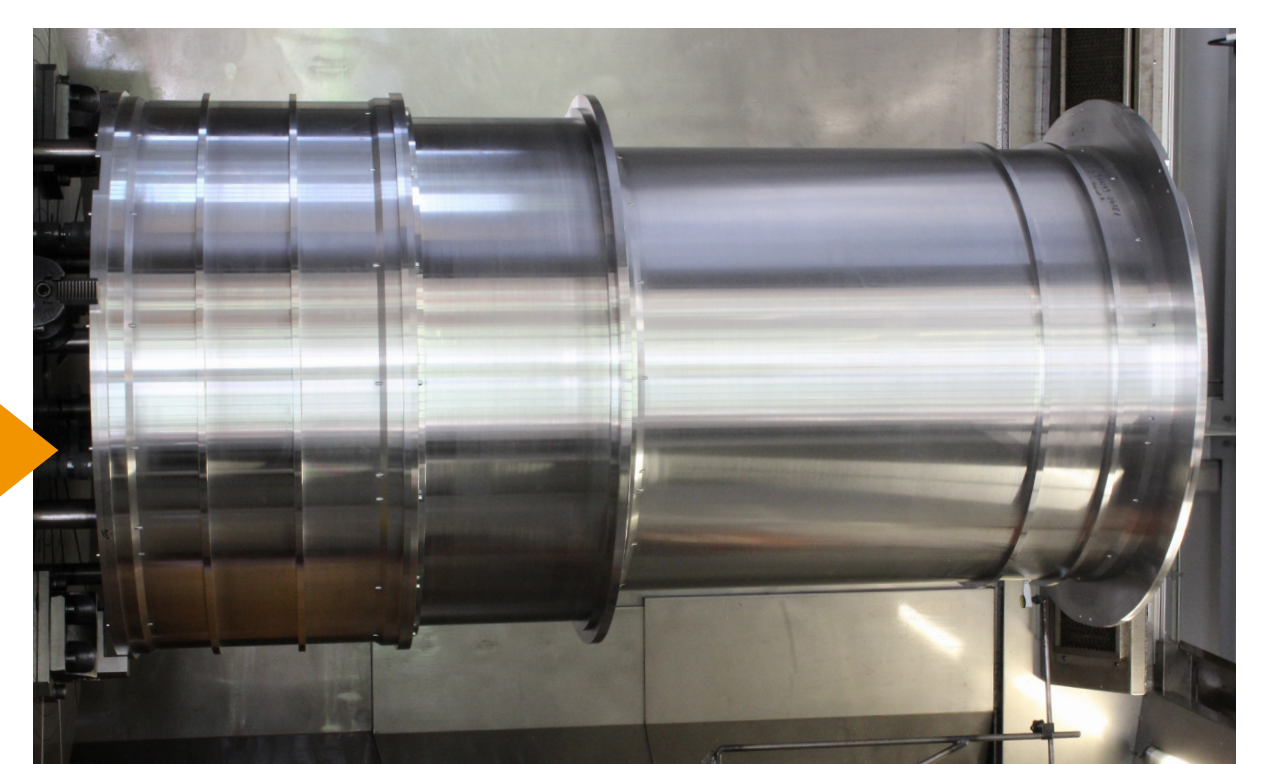
Conclusion and Outlook

- Complete coaxial coil formers with high complexity were fabricated made of forged aluminium (AlMg4.5Mn) with a low magnetic permeability
- Weld joints and hence weak points are completely avoided by integral forging and CNC rolling of circular parts with less additional material
- Circular and precise ring rolled parts show less warping during the machining compared to bended and welded rings made of plates which allows to achieve narrower tolerances up to ± 0.025 mm e.g. at diameter 800 mm
- Forgings offer higher strength and toughness due to the dense structure and process inherent resulting grain flow oriented along the stress lines
- Forged components are also possible with other high strength aluminium alloys e.g. AW-7175 (AlZn5.5MgCu) or AW-6082 (AlSi1MgMn) as well as titanium, nickel-base and stainless steel alloys
- Cost-effective manufacturing is possible due to less warping during the machining and subsequently less reworking

Forged blanks



Machined parts



Assembled Coil Former