
9th INTERNATIONAL CONFERENCE ON TUBE HYDROFORMING (TUBEHYDRO 2019)

Tool Aspects for High Temperature Level Gas Forming

Frank Schieck, November 18-21, 2019, Kaohsiung, Taiwan



Tool Aspects for High Temperature Level Gas Forming

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1. Introduction
2. Tools for processes with passive temperature control
3. Tools for processes with active temperature control
4. Tool materials and surface coatings
5. Conclusion and Outlook

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1. Introduction

Importance of forming tools for forming technology

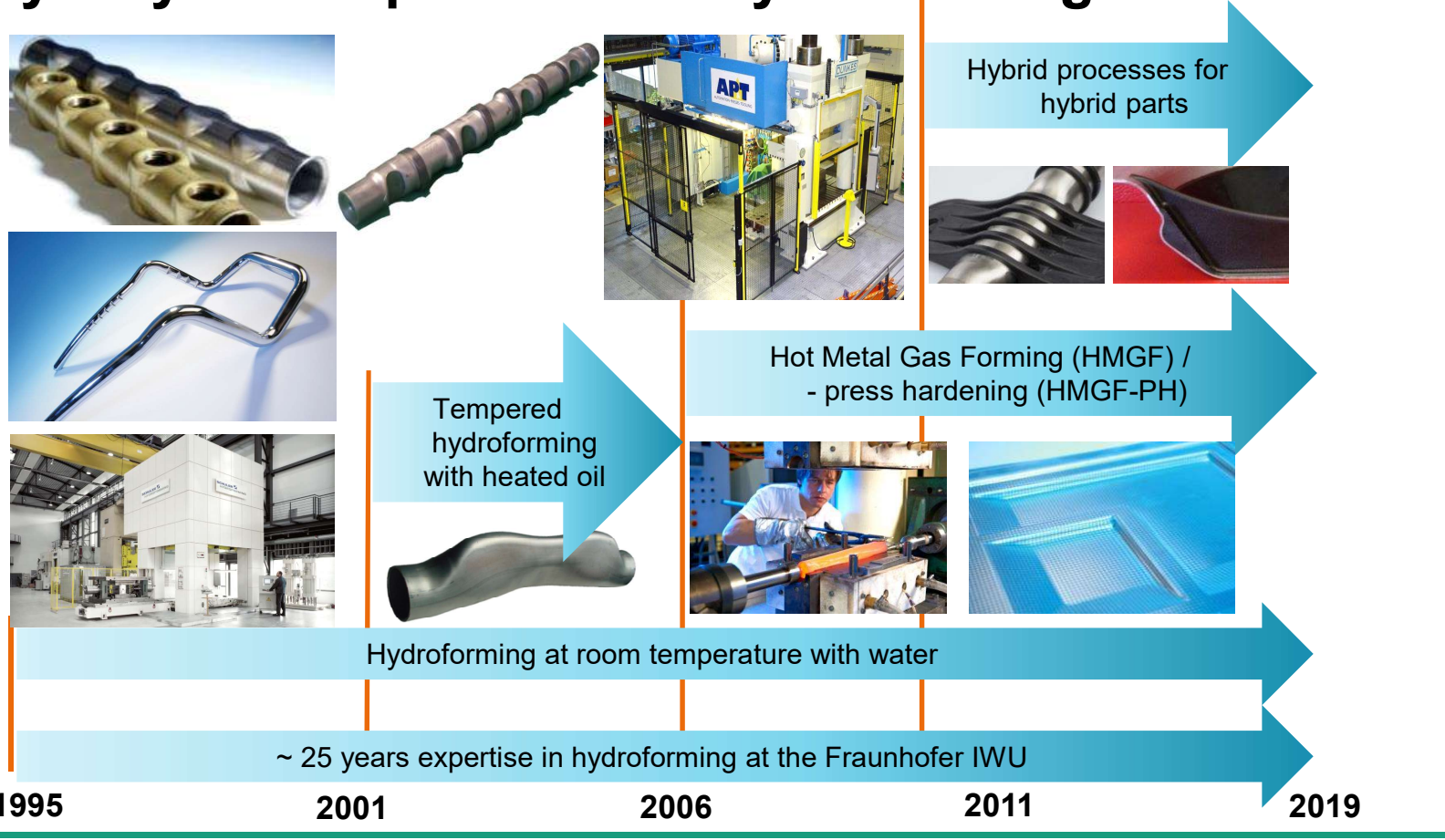
„With the acceptance of the order for the production of a forming tool, the toolmaker (usually) also assumes the responsibility for forming technology, i.e.

he is responsible for the quality-oriented series production of the components.“



1. Introduction

Nearly 25 years experience in Hydroforming at IWU



1. Introduction

Key question: How to bring temperature into process?

Principle strategies

Heat only the workpiece

Passive tool

- simpler tool
- limited process control
- complex handling
- additional periphery
- heating cycle time independent

Example: PHS

Heat workpiece and tool

Active tool

- complex tool and periphery
- process control variable
- tool isolation
- complex handling
- heating devices inside press
- heating cycle time independent

Example: HGMF

Heat only the tool

Active tool

- complex tool
- tool isolation
- process control by tool
- simple handling
- heating devices inside press
- heating influences cycle time

Example: SPF

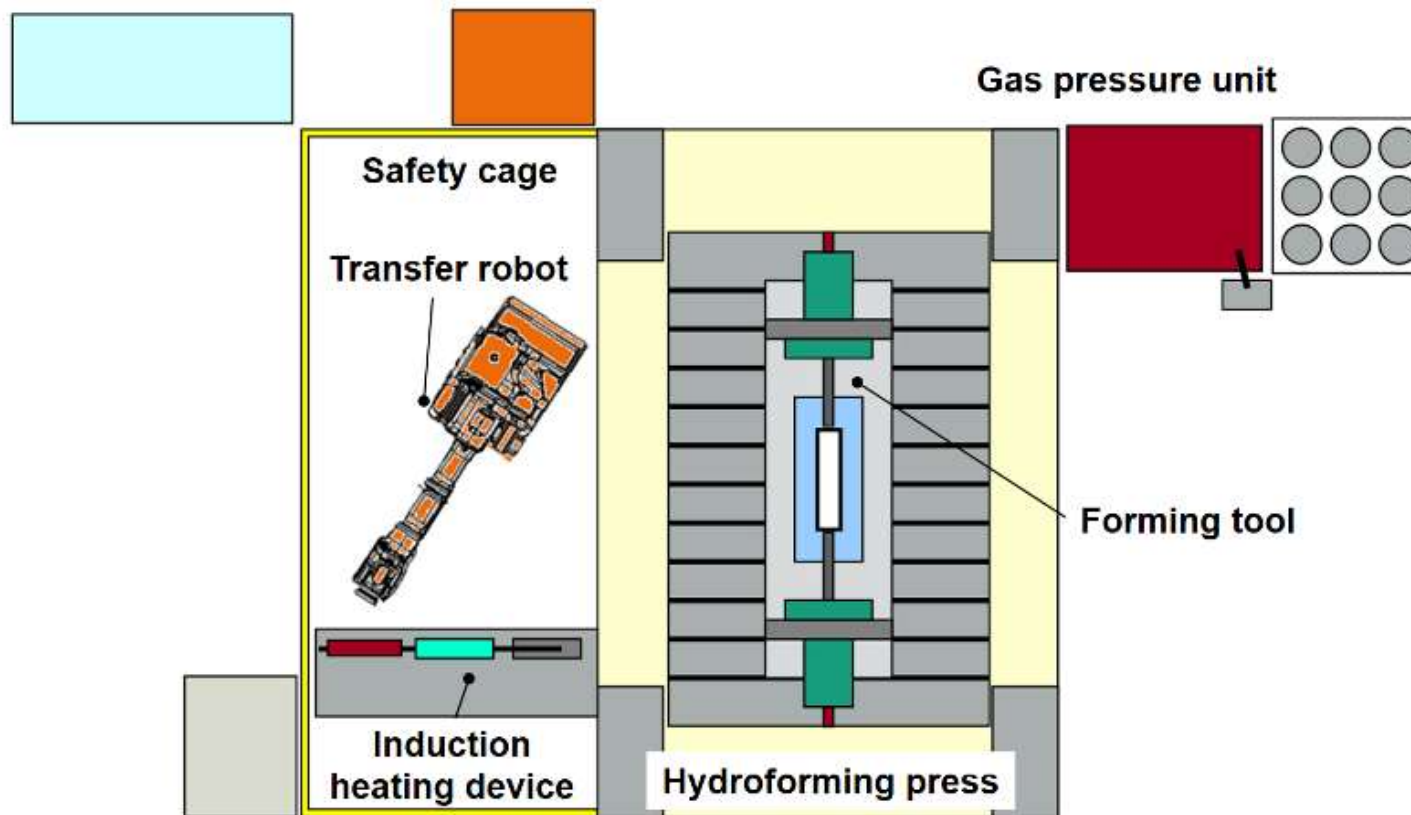
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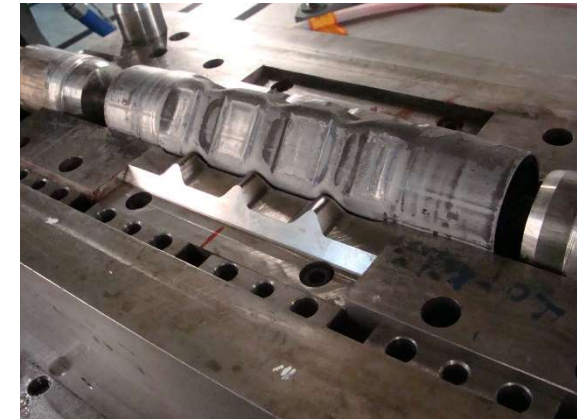
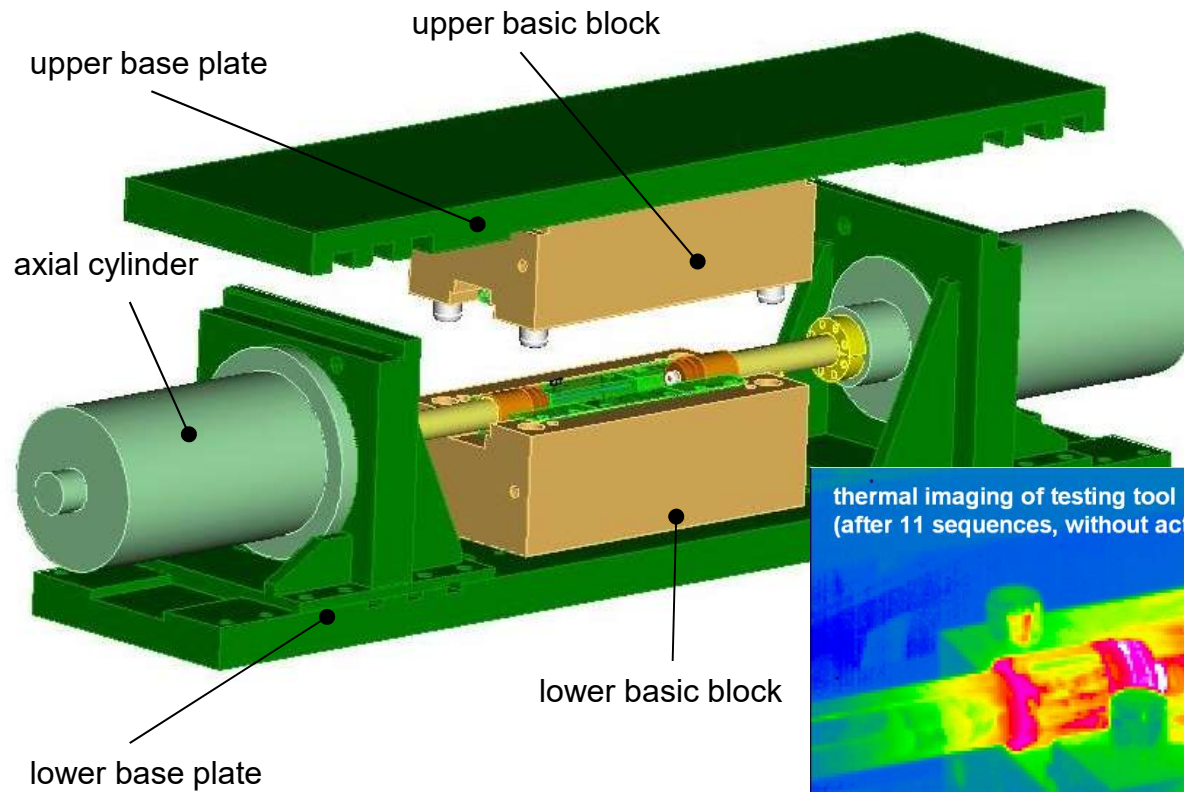
2. Tools for processes with passive temperature control

Plant layout

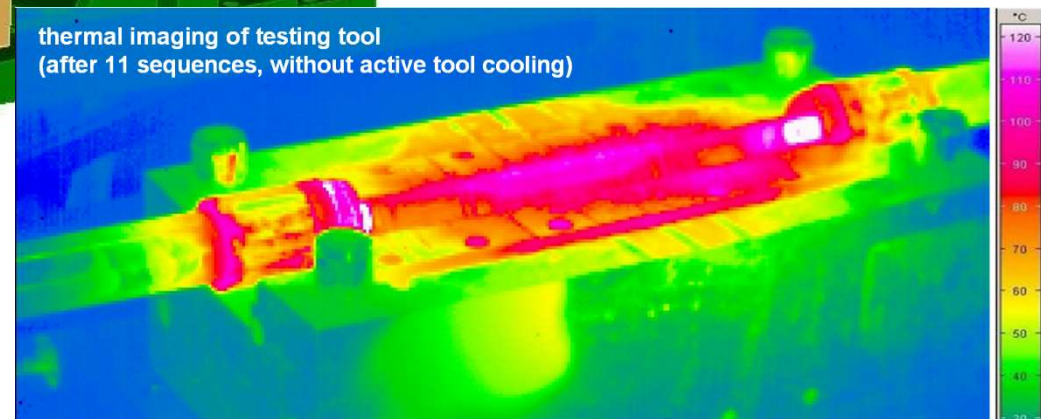


2. Tools for processes with passive temperature control

Principle tool design

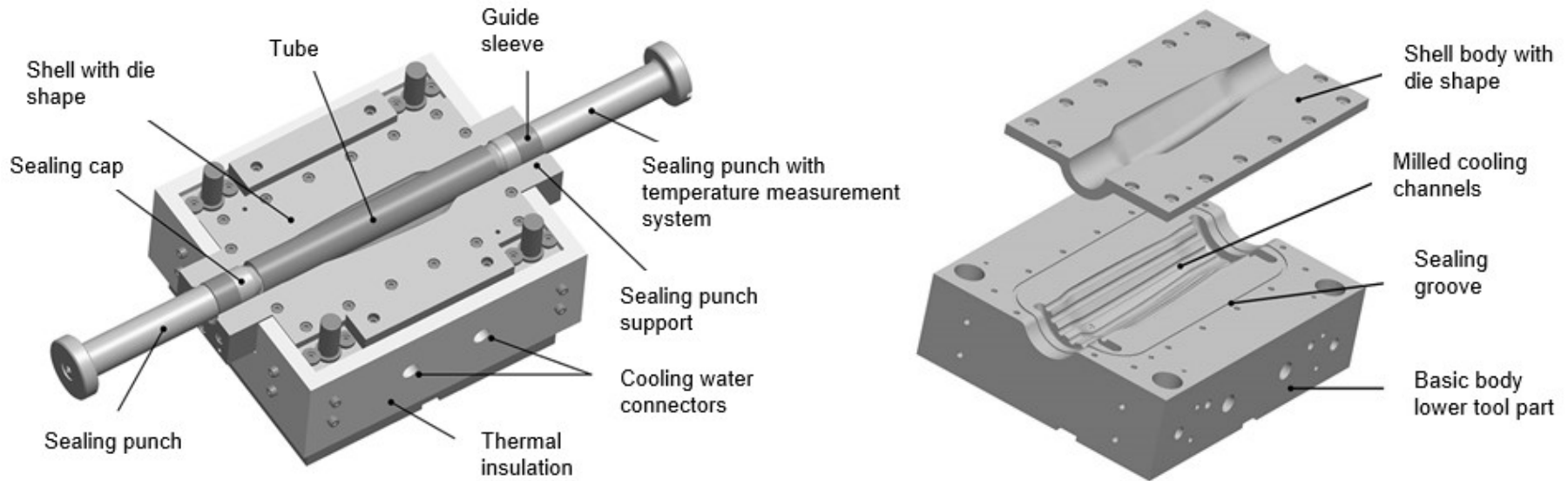


Tool with drilled cooling channels



2. Tools for processes with passive temperature control

Design variant of tool cooling system



Shell with die shape (front side)



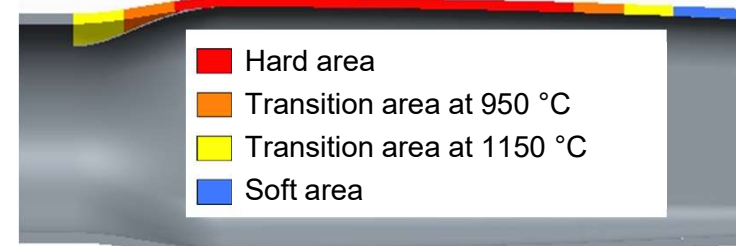
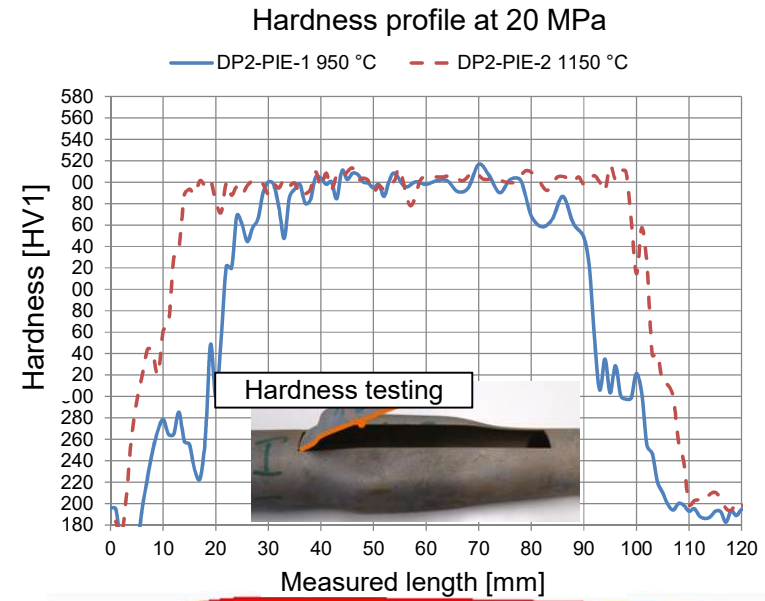
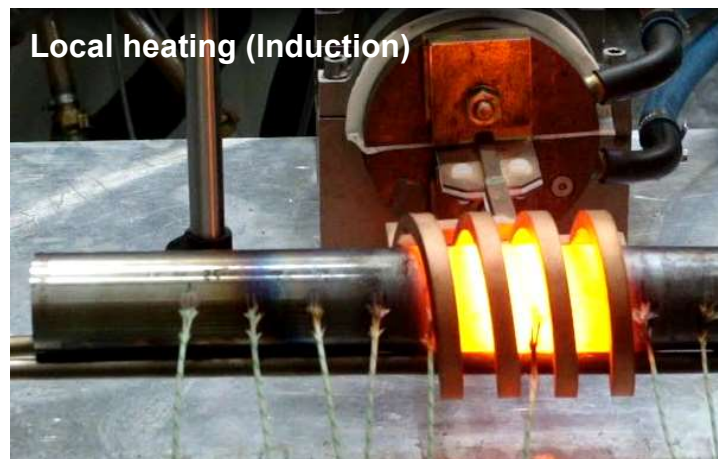
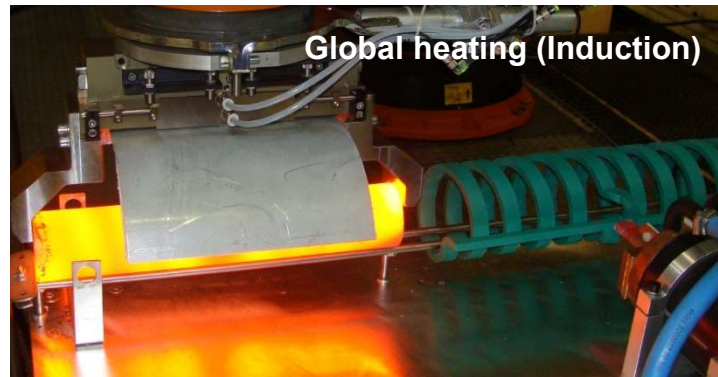
Shell with die shape (backside)



Basic body with cooling channels

2. Tools for processes with passive temperature control

Advantage: Tailored heating



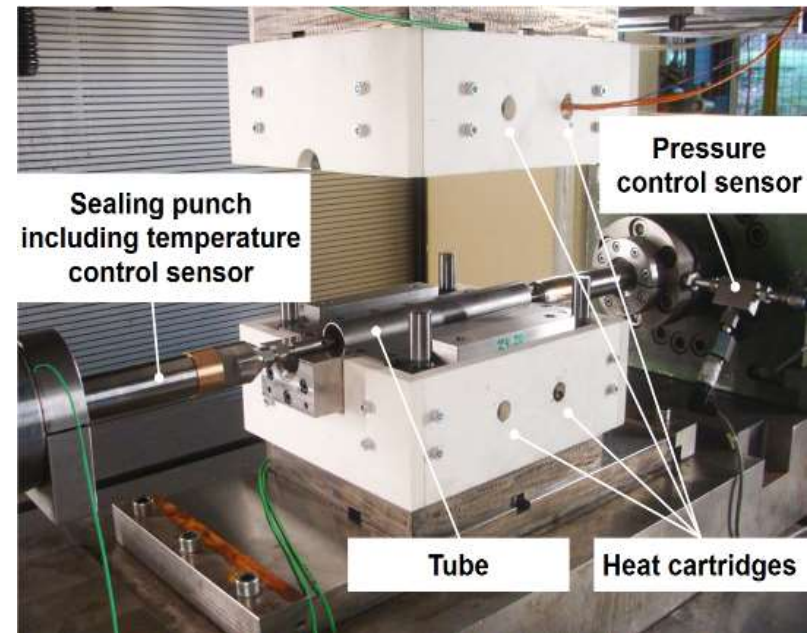
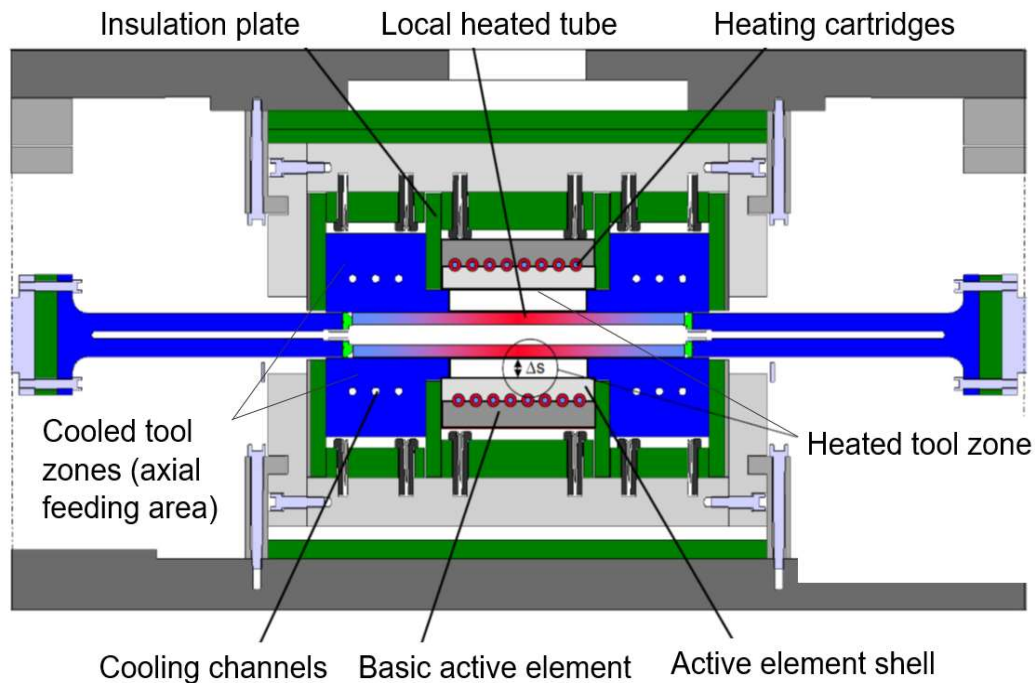
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3. Tools for processes with active temperature control

Principle tool design with internal cavity heating

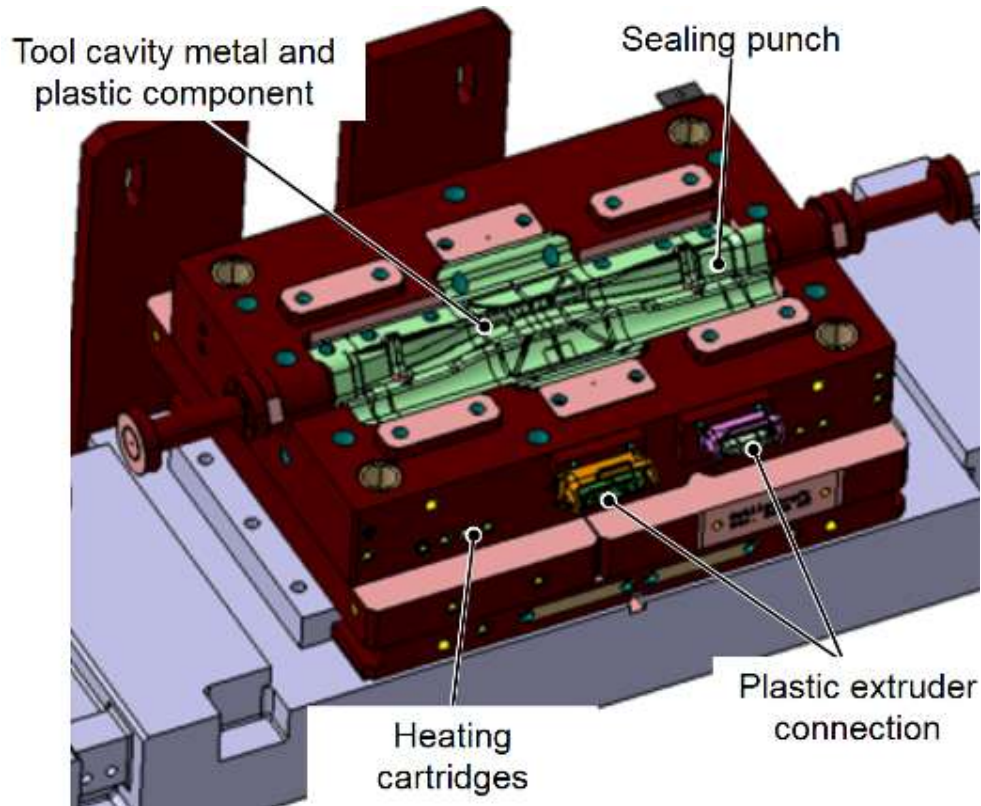


Tool with local temperature distribution by electrical resistance heat cartridges

Advantage: Because of low heat capacity of gaseous forming media has low temperature influence to the process

3. Tools for processes with active temperature control

Application example: Gas Forming & Injection Molding

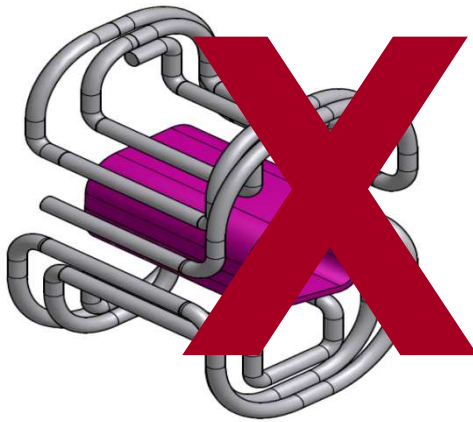


Advantage: In case of a part crack no contamination of cavity by forming media
→ **Avoiding of adhesion problems!**

3. Tools for processes with active temperature control

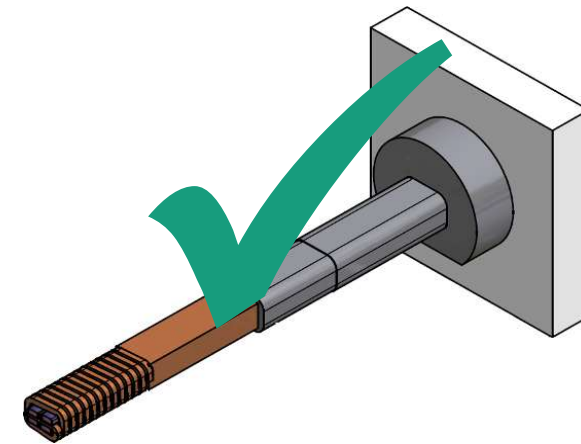
Tools with integrated part heating

Induction heating



induction heating tool insert

- difficult for **integration and isolation**
- complex **tool design**
- less **tool stability** against process forces
- feasible for **pre bended parts**
- implementation of **water cooling easy**



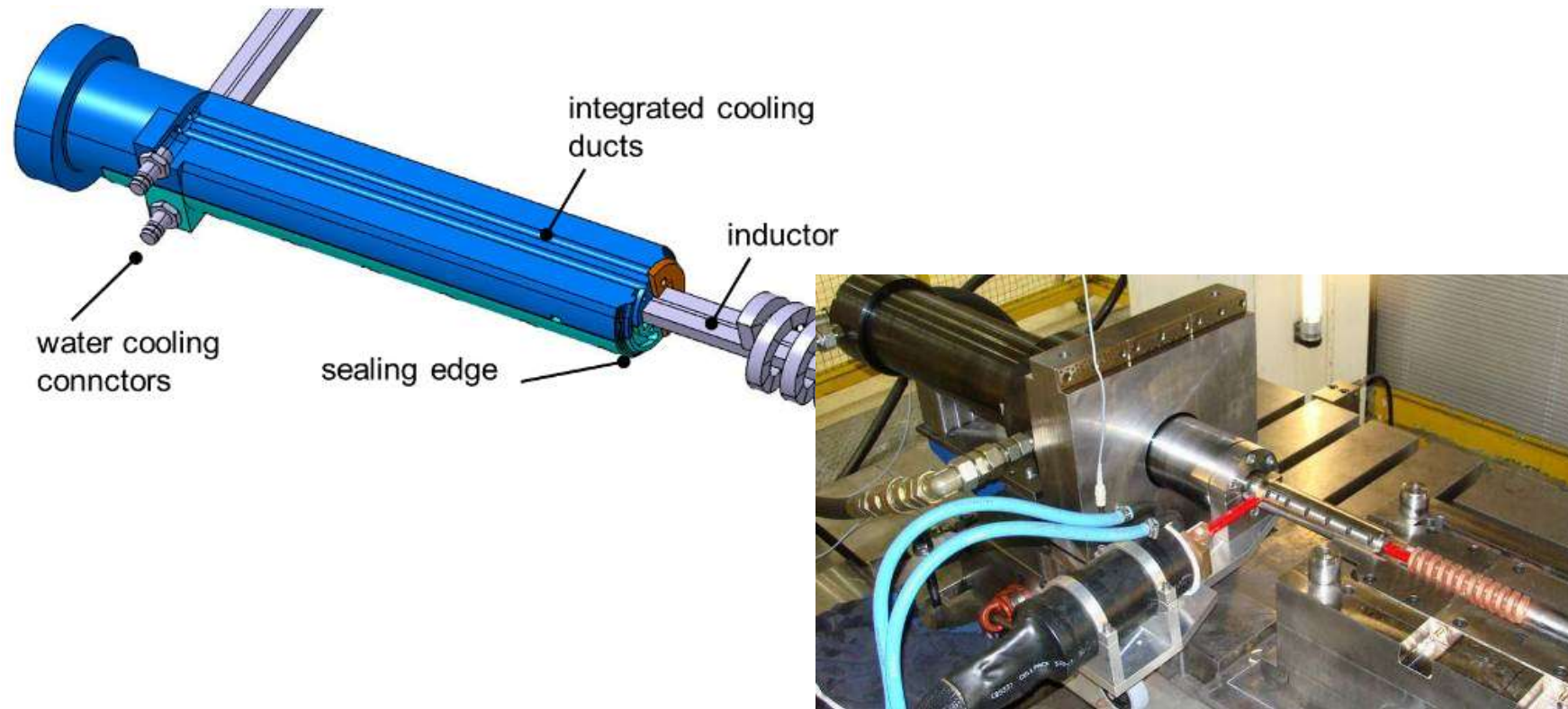
induction heating sealing cap

- difficult for **pressure seal** installation
- not feasible for **pre bended parts**
- long **axial cylinder stroke** requested
- conventionally **tool design** possible
- **retrofit able** for existing tools

3. Tools for processes with active temperature control

Tools with integrated part heating

Induction heating – application example

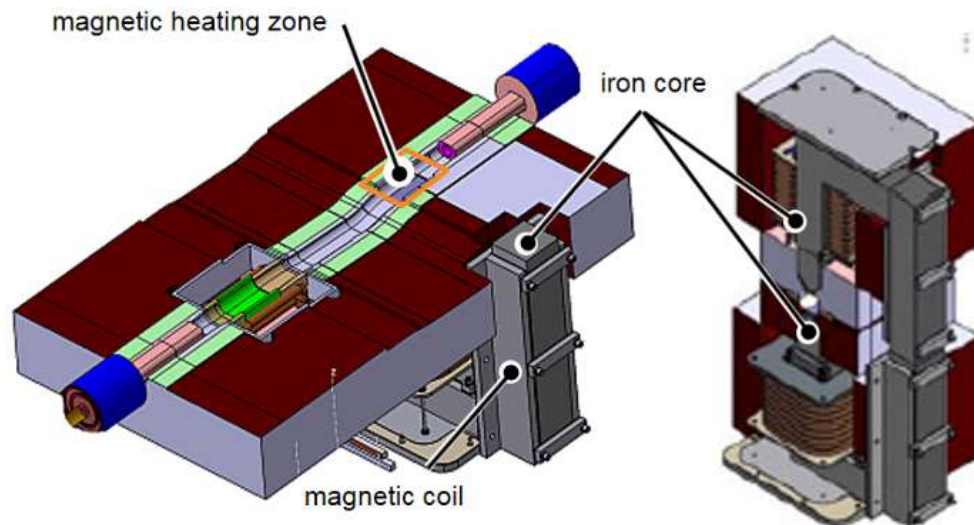


3. Tools for processes with active temperature control

Tools with integrated part heating

Magnetic heating – principle and application example

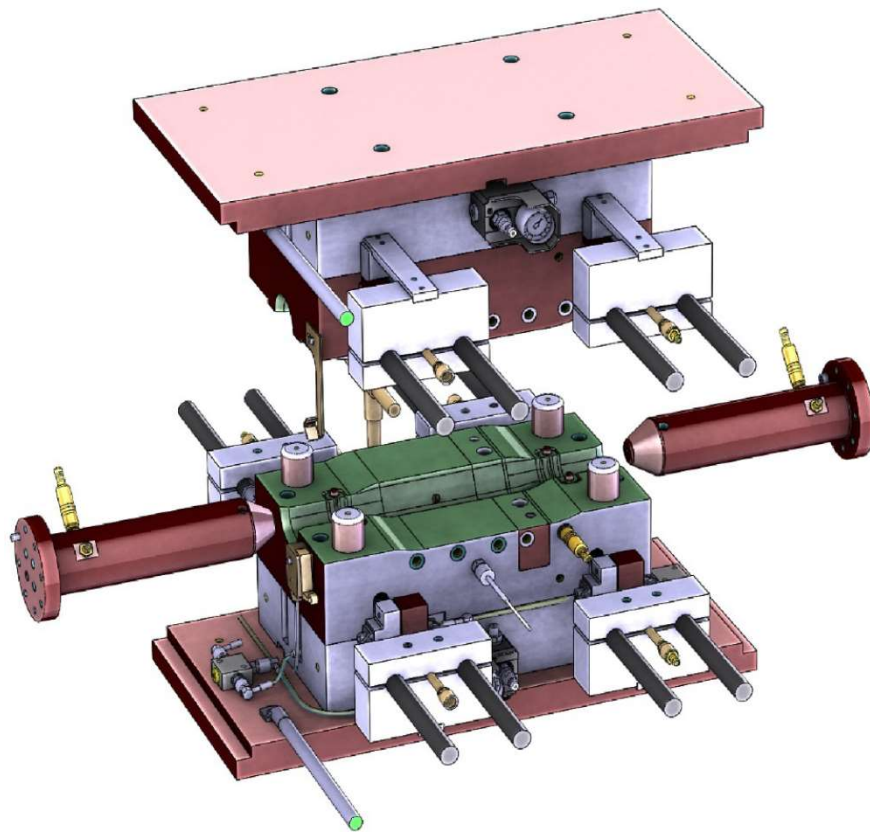
- principle is based on high-frequency magnetic alternating fields
- generated by a magnetic coil with iron core
- tool shielding is relatively uncomplicated
- massive iron core supports the tool very well locally
- voluminous design and lower efficiency leads to a maximal applicable temperature up to 300°C



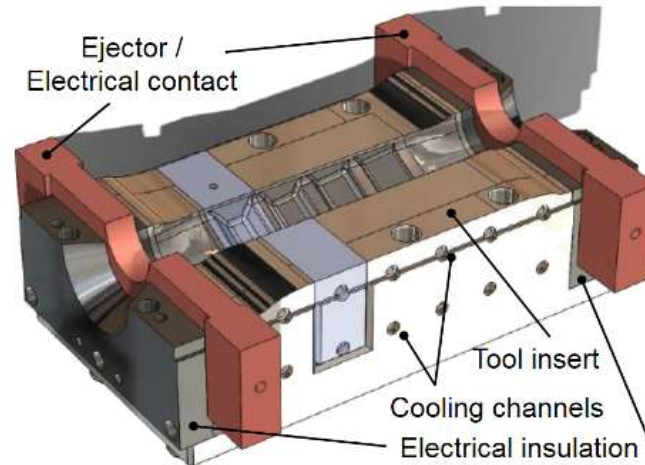
3. Tools for processes with active temperature control

Tools with integrated part heating

Conductive heating – principle



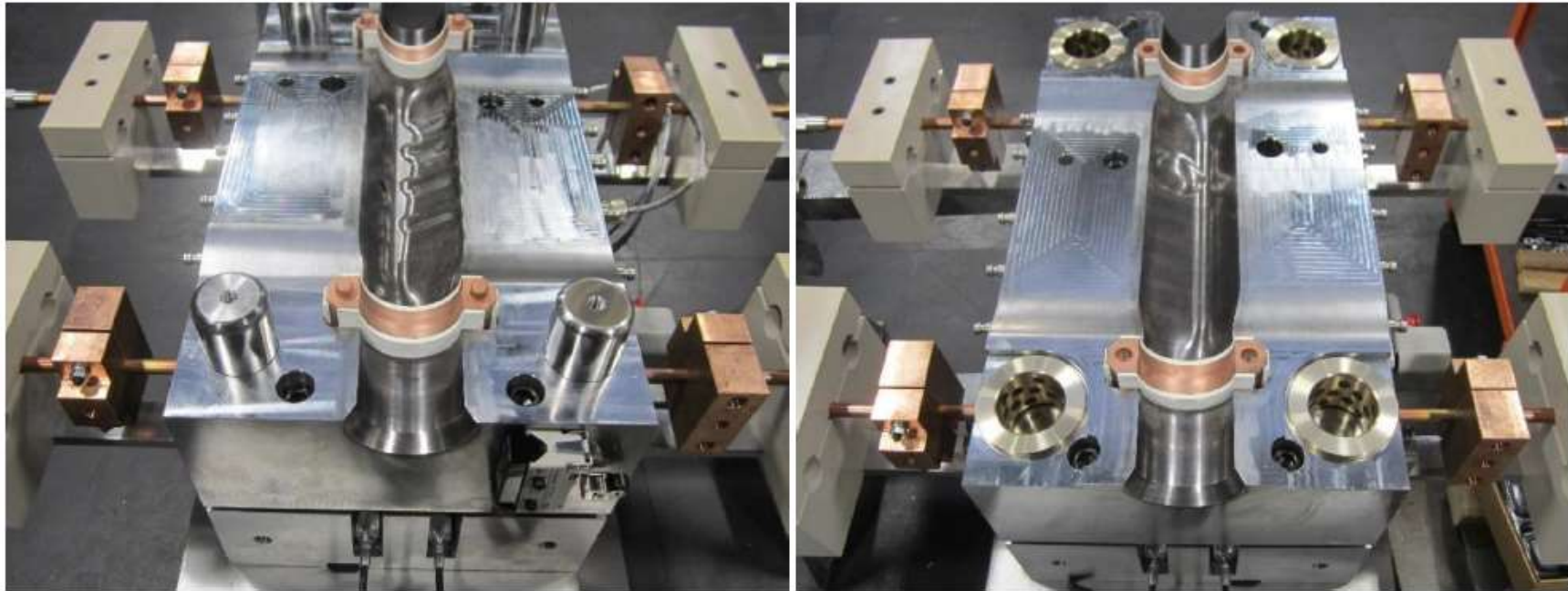
- Direct electrical contacting of the semi-finished product with two electrical conductors
- High efficiency during direct contacting, very short heating times
- Challenge is the electrical insulation of the tool.
- Workpiece must not have any contact with the tool active surface in any area



3. Tools for processes with active temperature control

Tools with integrated part heating

Conductive heating – application example



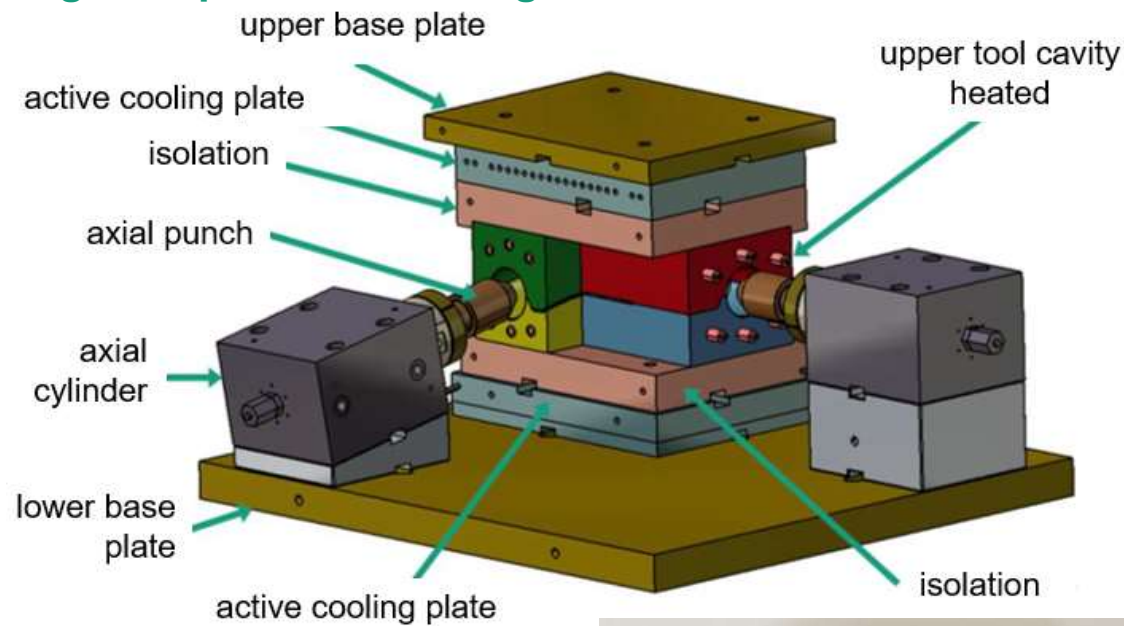
First test geometry, technology & tool development for bended workpieces under progress



3. Tools for processes with active temperature control

Tools with integrated part heating

High temperature forming of Titanium



Titan exhaust manifold
Forming pressure 550 bar
Tool temperature ~ 800°C



Inconel tool active element

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4. Tool materials and surface coatings

Typical tool materials for HGMF

Compromise between strength, wear resistance, temperature resistance, heat transfer coeff., ... costs

Materials in application

- DIN 1.2343 | AISI H11 Tool Steel | X37CrMoV5-1 | SKD6 | BH11 → available & cheap
- DIN 1.2344 | AISI H13 Tool Steel | X40CrMoV5-1 | SKD61 Hot Work Steel → available & cheap
- DIN 1.2367 | --- | X38CrMoV5-3 | --- → available & cheap, lower final hardness
- DIN 1.2709 | --- | X3NiCoMoTi18-9-5 | --- → available & expensive, optimum between hardness and toughness
also in powder for 3-D-printing available
- **Böhler W360** special alloy, optimized hardness & toughness → available & moderate prize, optimum between hardness and toughness
also in powder for 3-D-printing available
- DIN 2.4668 | ASTM B 637 | NiCr19NbMo | UNS N07718 | **Inconel 718** | → available & very expensive, “bad” for machining
especially for Titanium forming tools

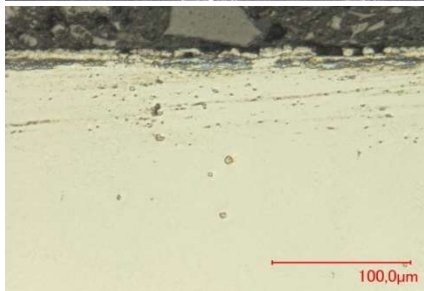
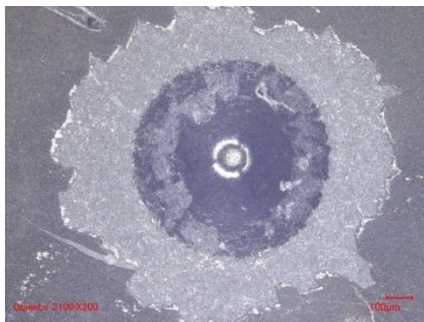
But... at warm conditions the forming pressure is reduced to more or less a third compared to classic hydroforming at room temperature to calibrate same radii!

4. Tool materials and surface coatings

Plasma boring of hot working steels

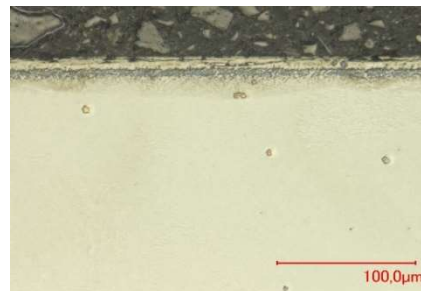
Rockwell intrusion test

600V - 24%BCl₃



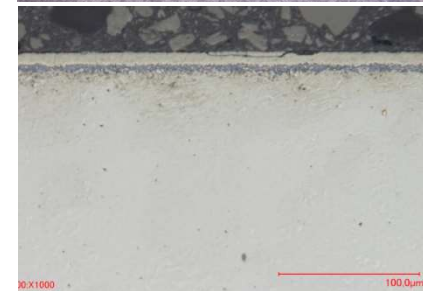
hardness	in layer	basic material
HV	1700	340

0V - 24%BCl₃



hardness	in layer	basic material
HV	2000	370

0V - 14%BCl₃



hardness	in layer	basic material
HV	2170	320

4. Tool materials and surface coatings

Press hardening – tool material and optimized coatings

	W360	CrVN	ZrO ₂ /Y ₂ O (r)	ZrO ₂ /Y ₂ O ₃ (g)	WC-Co 88/12 (r)	WC-Co 88/12 (g)
μ	0.38	0.38	0.41	0.43	0.36	0.39
Tool wear profile height [μm]	10	up to 75	80	7	30	10
Workpiece rough. Ra [μm]	2	1.6	2.6	3.6	5.4	1.8

best overall result

*workpiece roughness of 22MnB5 in as-delivered condition: Ra 1.2 [mm]

- Tool roughness > R_a 3.3 μm / R_z 19.5 μm: **unsatisfactory workpiece surface qualities**
- Large amount of **adhesions** on the rough as sprayed forming edges
- **W360, CrVN and W-g** led to the **best results** overall (friction coeff., profile height, workpiece rough.)

4. Tool materials and surface coatings

Titan forming – optimized tool coatings

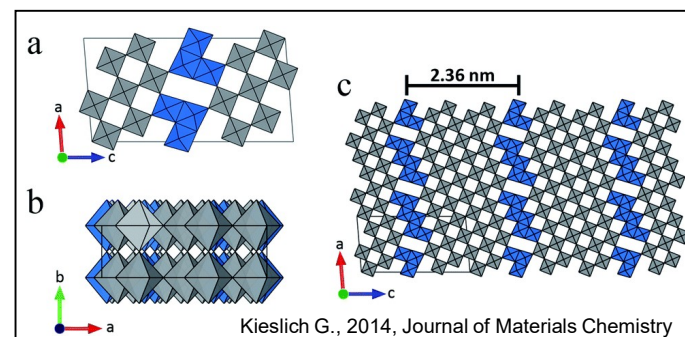
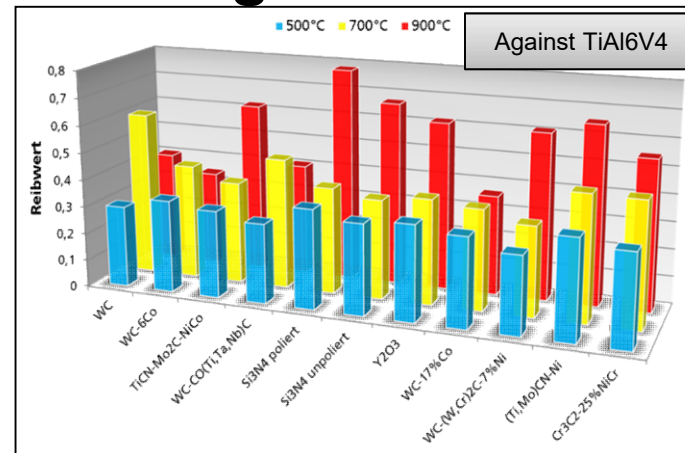
Tribological examination of ceramics and hard metals:

- Tungsten carbid:
 - Low friction
 - No adhesion
- Full materials and thermal spray layers unsuitable due to strong oxidation tendency

Tungsten as Magnéli phase maker *:

- Oxidation leads to the formation of shear structures on the surface
 - Self-lubricating effect
 - Avoidance of adhesions
 - Reducing friction

* Non-stoichiometric binary oxides

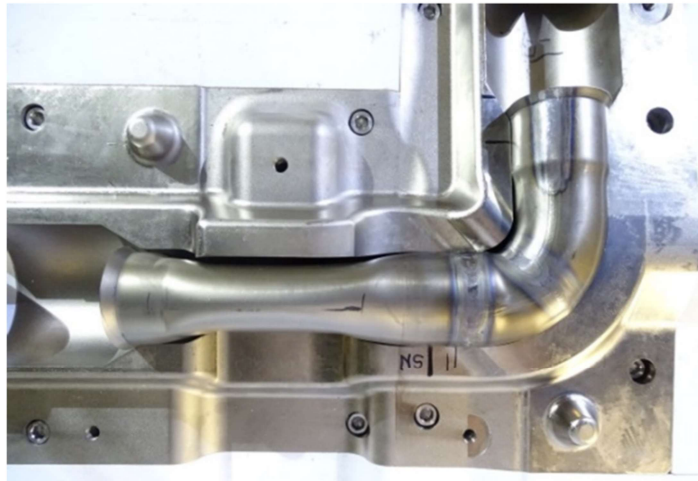


grey WO_3 blue $WO_{2.90}$ → $W_{20}O_{58}$ → $\beta-WO_x$

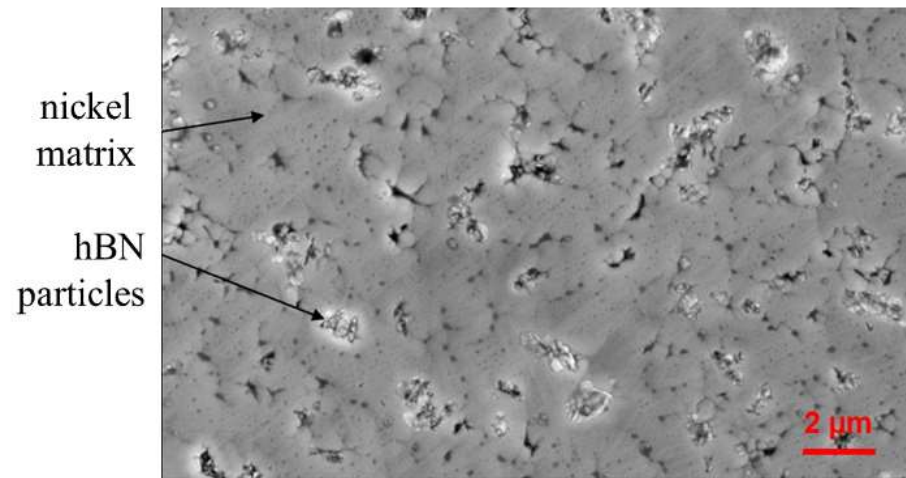
4. Tool materials and surface coatings

Titan forming – optimized tool coatings

Inconel tool material and chemical Nickel / hBN dispersions



Inconel tool insert with chemical Nickel / hBN dispersion



Chemical Nickel / hBN dispersions layer for coating of the tool segments

- 70 – 80% by vol. nickel phosphorus matrix (of which 90% by vol. **Nickel**, 10% by vol. **Phosphorus**)
 - 20 – 30% by vol. **hexagonal Boron nitride** hBN
- coating procedure is a **wet chemical**, so-called **autocatalytic process**, whereby the **boron nitride** is embedded in the coating by means of **sedimentation**.

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5. Conclusion and Outlook

In Principle...

- ✓ **Gas** (i.e. nitrogen or air) is suitable as active medium
- ✓ Forming temperatures **up to 1200 °C** are accessible
- ✓ **Influence** of the **forming pressure on the forming accuracy** is higher than the tube temperature
- ✓ Tempered hydroforming processes are **repeatable**
- ✓ Temperature supports a considerably **positive shift of forming limits**
- ✓ Significant **influence of the temperature on material properties** especially in radii zones
- ✓ Cycle times **below 20 s** are realistic and proved for the Hot Metal Gas Forming, because **pressure built up time** is now possible **below 2s**, also for large parts
- ✓ **Energy intensive** multi-stage cold hydroforming **processes can be replaced** by hot forming processes
- ✓ Equipment and **tools-technology qualified** for the requests of **series production** regarding process stability and life time

5. Conclusion and Outlook

Trends for the next years

- New process combinations (e.g. gas forming + injection moulding)
- Process developments for hybrid parts (polymer – metal)
- Hot Metal Gas Forming HMGF close to series productions for exhaust parts
- Hot Metals Gas Forming - Press Hardening HMGF-PH in series production
- Increasing efficiency for Superplastic Forming SPF (reduced cycle time)
- New Materials / semi finished parts (polymer tubes)

TRL6

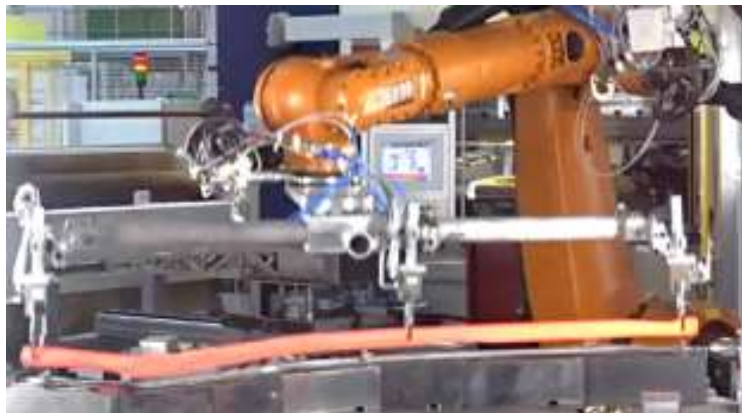
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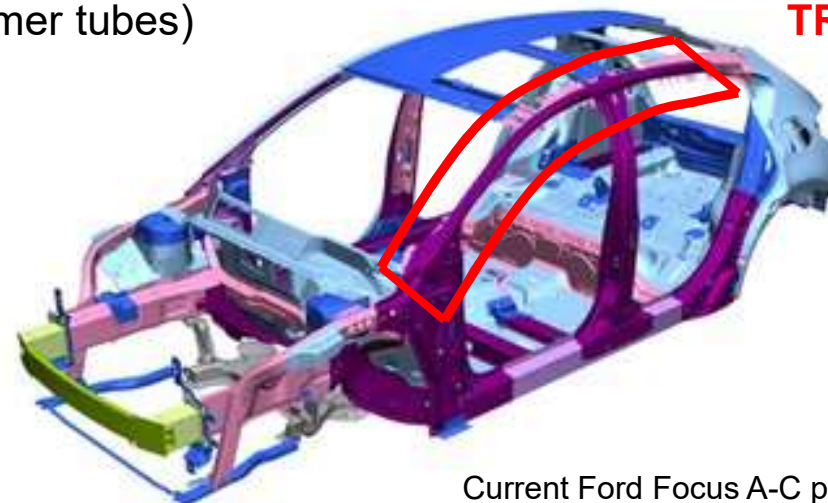
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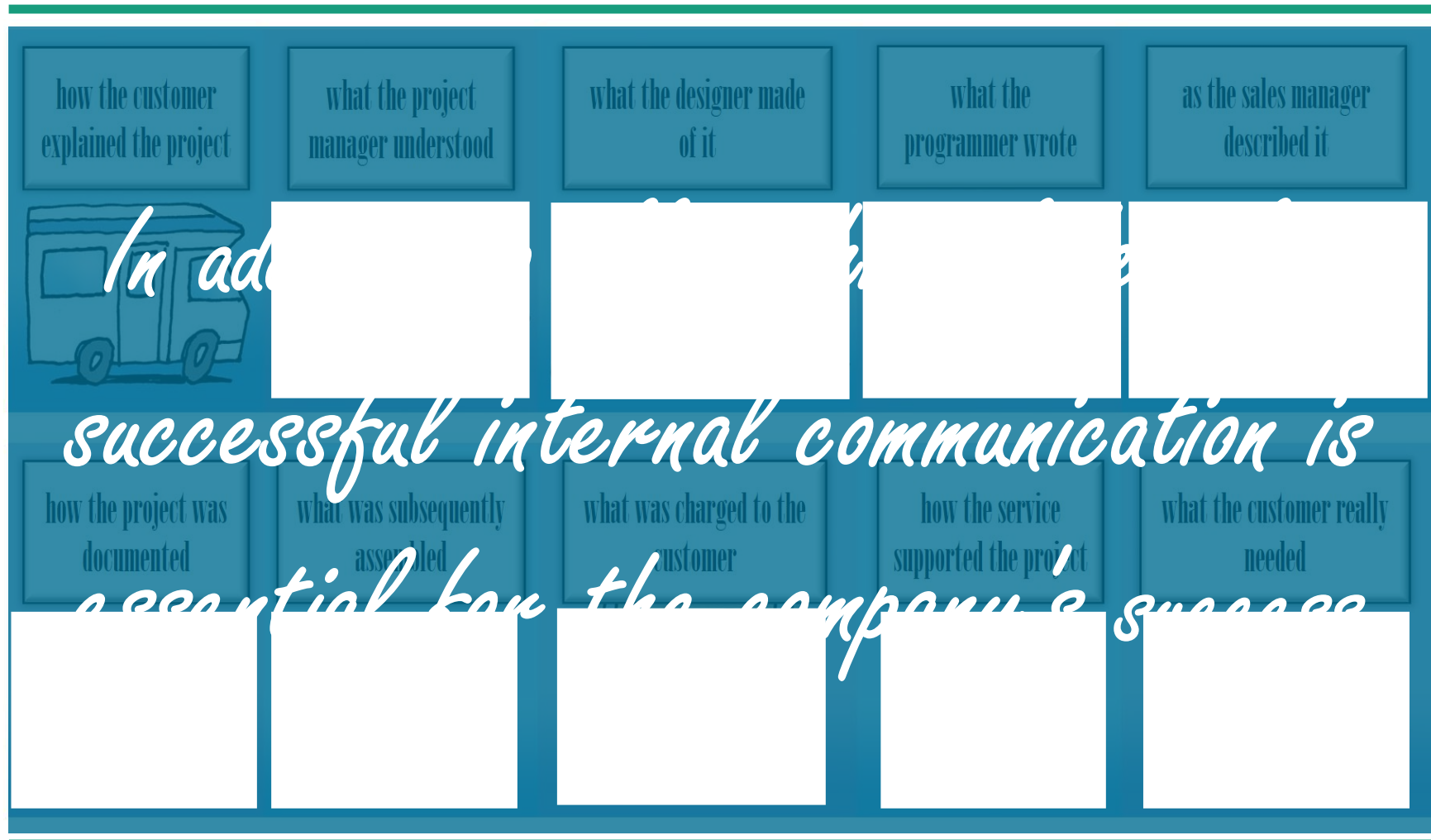
TRL5



Prototyping A-C pillar HMGF-PH with MAGNA-COSMA



Current Ford Focus A-C pillar
HMGF-PH in series production by Linde&Wiemann



Finally... do you know how to produce a car?



Thank You for Your Kind Attention!



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