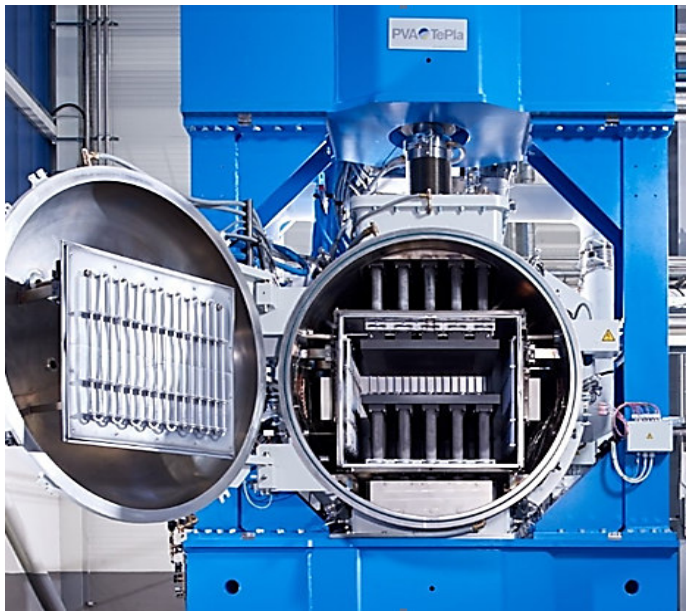
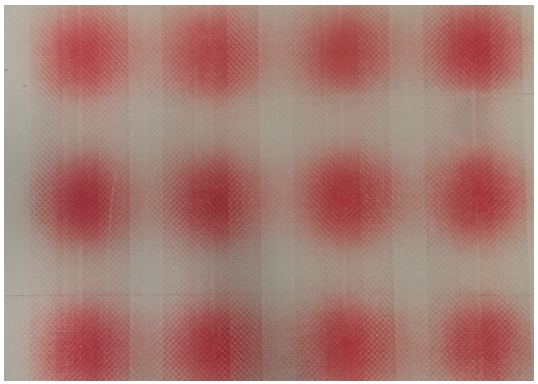
Design and manufacturing large scale diffusion bonding hot presses



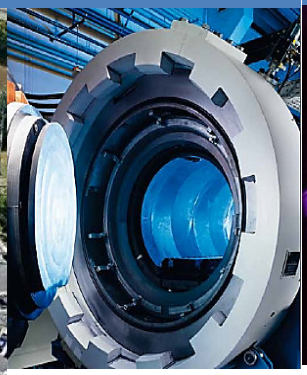
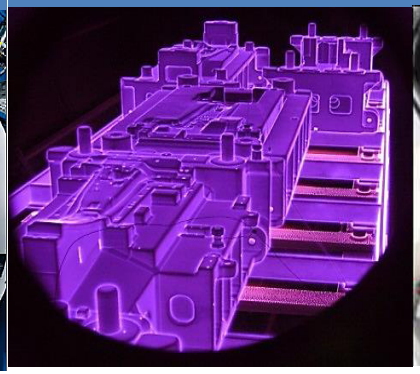
Dr.-Ing. Jan Pfeiffer
(PVA TePla Group)



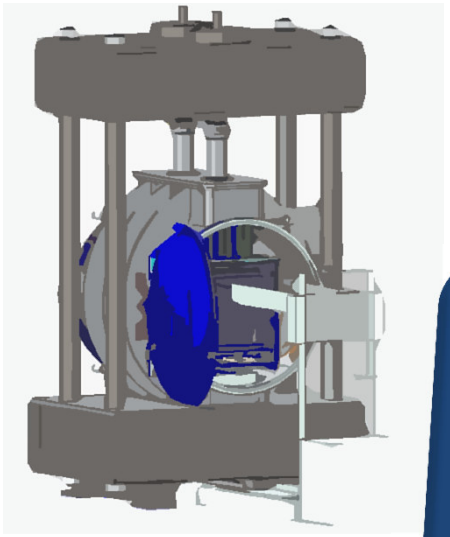
Vakuum systems and contract services for heat treatment of High-End Materials:

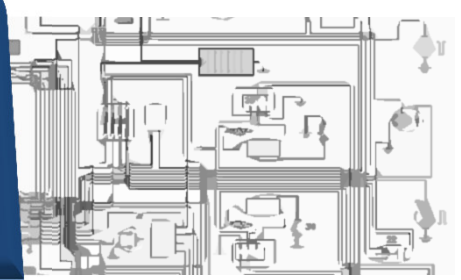
Headquarter, assembly and contract service workshops

(Wettenberg, Germany)

COD Sinter-HiP Furnace	PPN PulsPlasma Nitriding Furnace	VSG Melting and Casting Furnace
		
		
COV Graphite-Heated-Vacuum-Furnace	MOV Metal-heated-Vacuum-Furnace	MOV-HP Hot-Press-Vacuum-Furnace

THE PVA TEPLA DIFFUSION BONDING "TASK FORCE"





Machine design

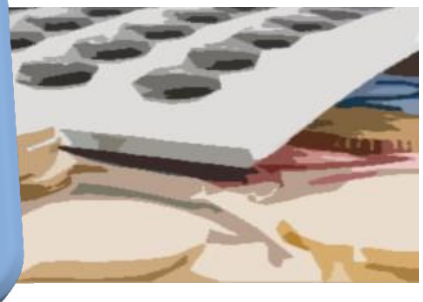
Control design

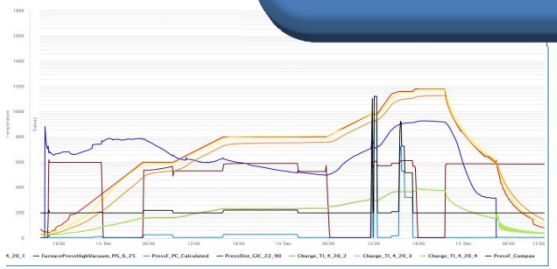
Customers

Application

Process engineering

Customer relations/Marketing





AGENDA:

I. Overall design procedure

II. Pressing System

- A) Multicolumn designs
- B) Methods
- C) Materials Data
- D) Control system

III. Heating System

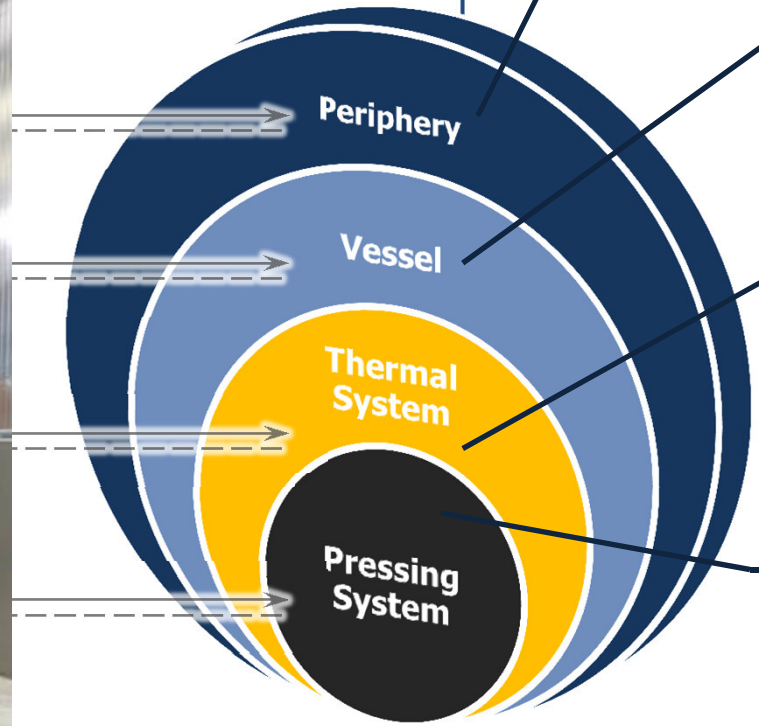
IV. Manufacturing

I.) Design Procedure

DESIGN APPROACH FOR DIFFUSION BONDING EQUIPMENT

Product driven bottom up design:

- The defined product portfolio dictates the sizing and the complexity
- Customer requirement input



- Vacuum pumping unit
- Pressing unit
- Gas, liquid and power connection
- SPS/Hardware

- Cold wall stainless steel
- Doors, flanges and feed-throughs

- Heaters and thyristors
- Thermal couples
- Cooling system

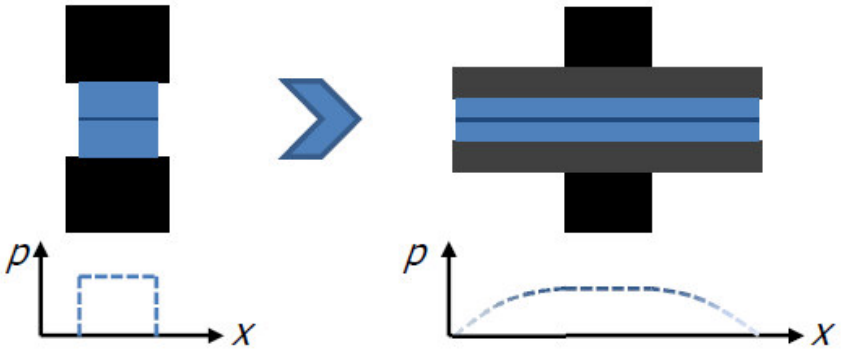
- Force distribution system
- Measurement systems (Load and positioning)

II.) Pressing System

LARGE SCALE DIFFUSION BONDING

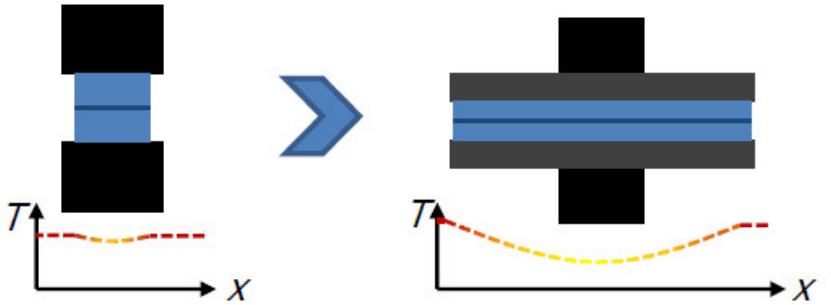
LOAD:

- If the size of the part is bigger than the ram size → load is lower on the boarders of the part.
- Bonding not sufficient.
- Risk of distortion.



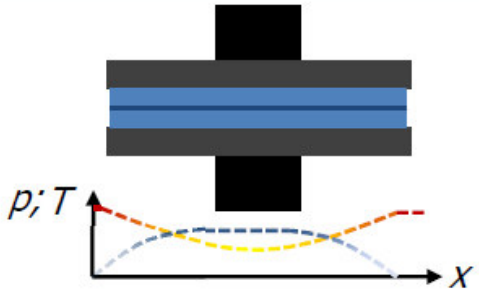
TEMPERATURE:

- Excessively higher dwell times have to be considered.
- Microstructural differences between outer and inner part (e.g. grain growth).
- Residual stresses



TEMPERATURE-LOAD-INTERDEPENDENCE:

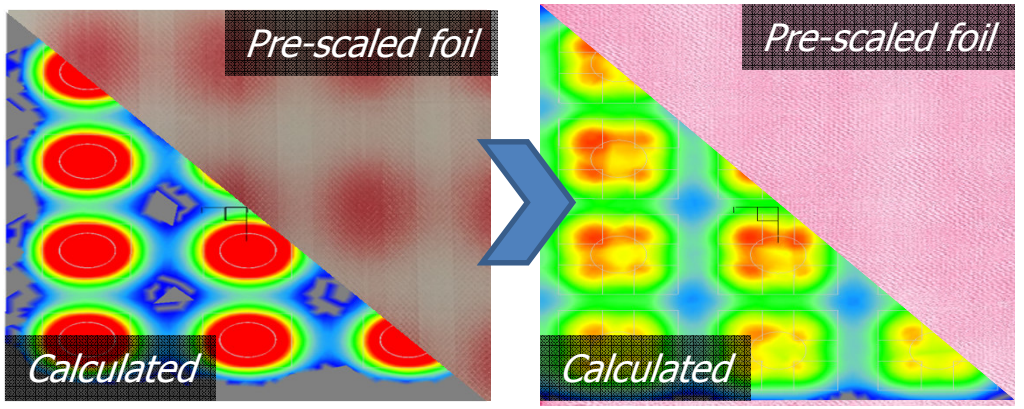
- Yield-strength is a function of temperature.
- Non uniform joining results

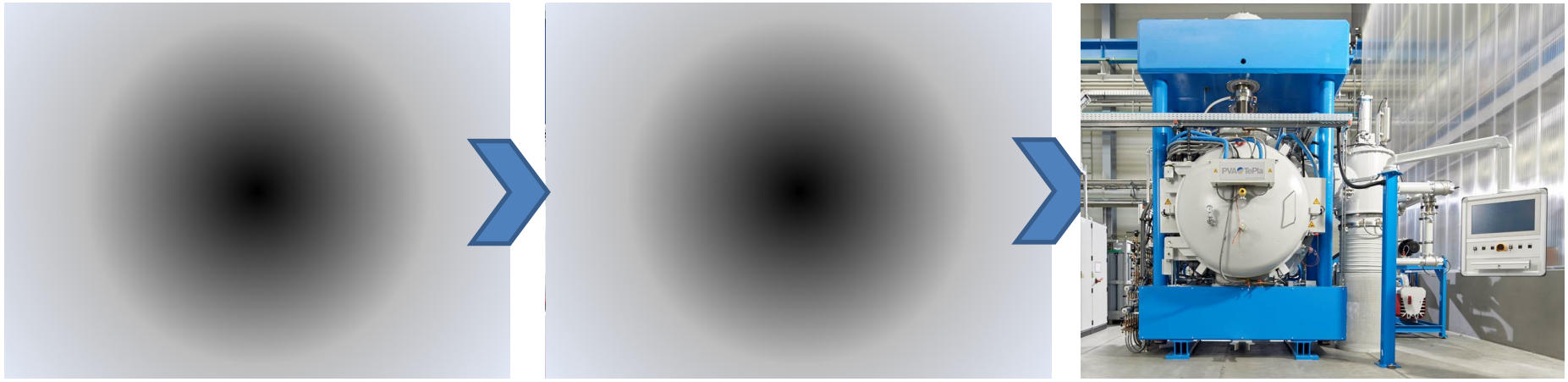


MULTICOLUMN PRESSING SYSTEM

Multicolumn design:

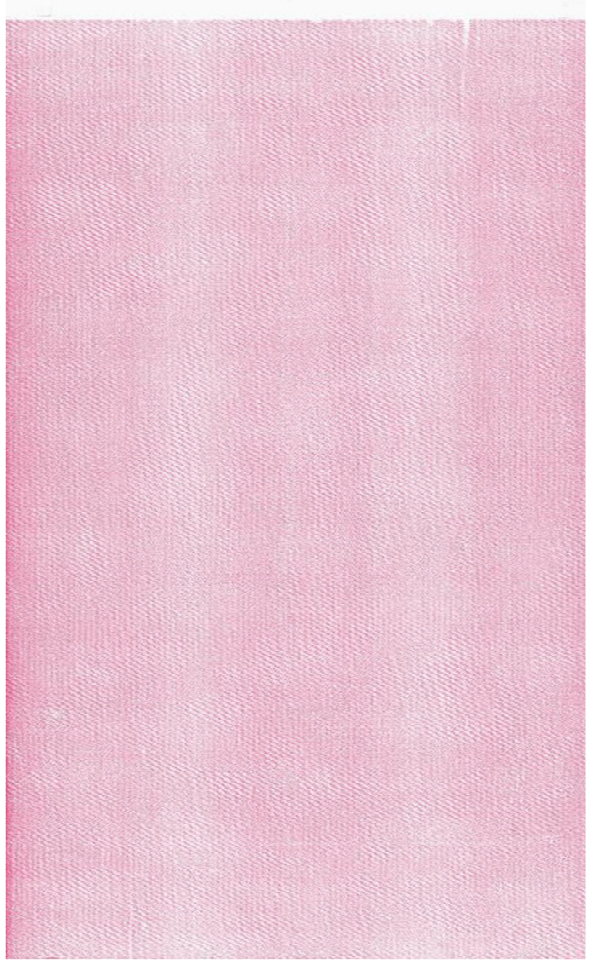
- Reduction of the overall inhomogeneity of the force distribution
- Less thermal mass in the furnace, thus effective heating and cooling
- Size is limited only by the available pressing plates





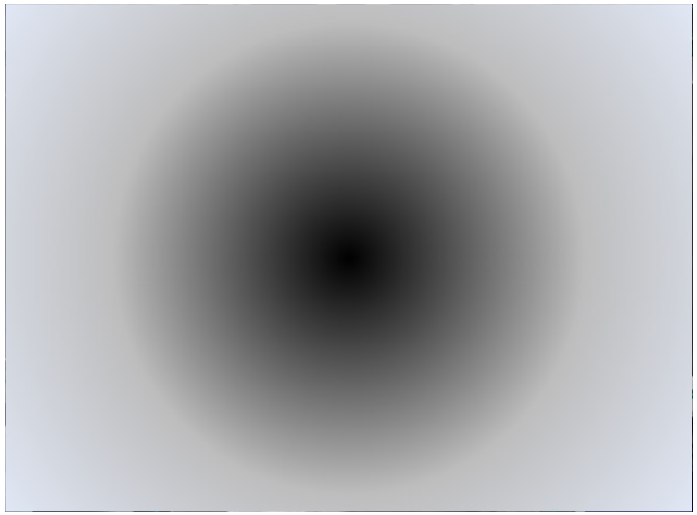
800 x 600 x 400 mm³ ***1000 x 900 x 480 mm³*** ***1500 x 600 x 500 mm³***

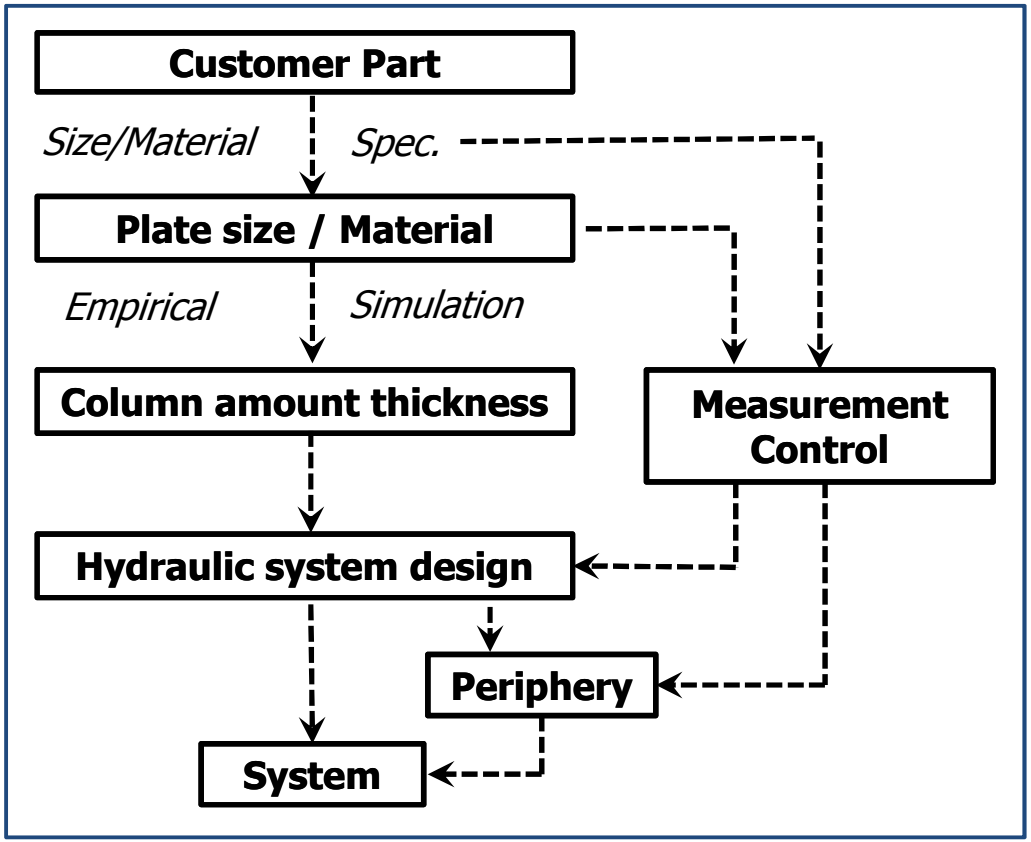
Development of columnar designs:



PRESSING SYSTEM DESIGN

- With Larges-Scale systems, the deciding factor is the stiffness of the pressing plates and pillars.
- Starting point of design is the part size and material as well as customer specifications.
- Calculation/Implementation of the necessary force via numerical simulation (FEM) becomes unavoidable.





PRESSING SYSTEM – THERMAL STABILITY (SiC based plate)

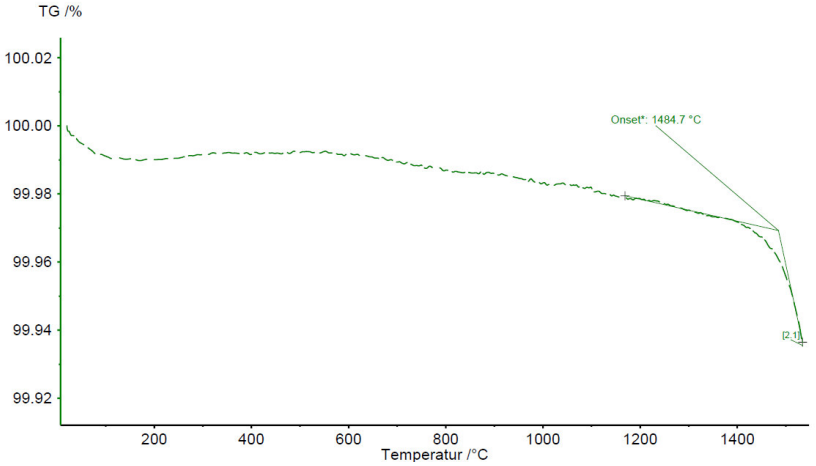
Experimental:

- Thermogravimetric analyses of the decomposition and/or melting
- Microstructural analyses using a SEM (Usually in backscattered mode for material contrast)

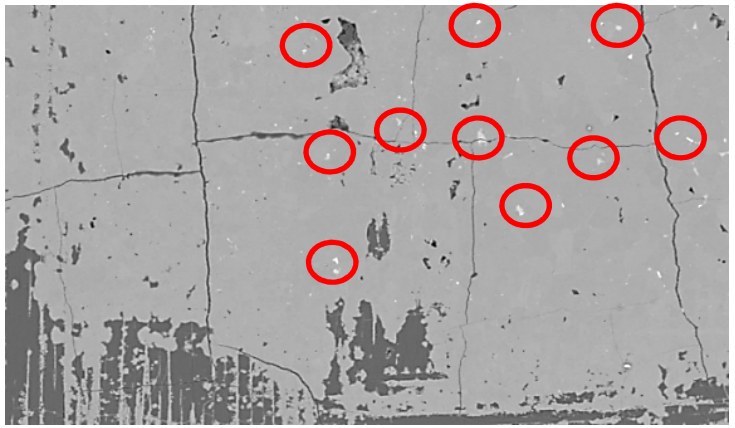
Ref: Netzsch

Ref: TU Dortmund LWT

- Results



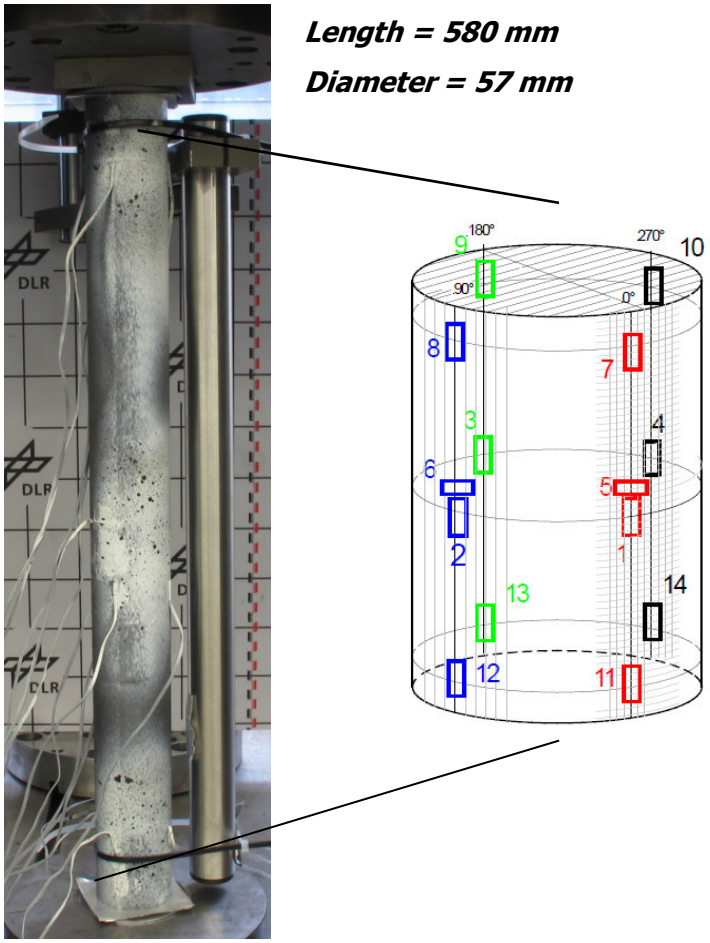
- Decomposition under Vacuum above 1400°C indicating metallic or silicon impurities



PRESSING SYSTEM – Mechanical stability of CFRC Pillars

Experimental:

- LCF testing under compression

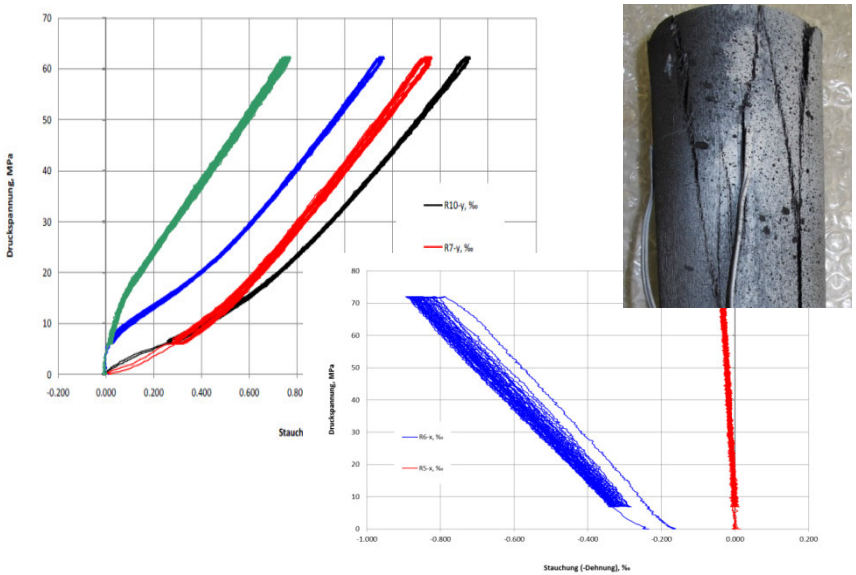


Length = 580 mm

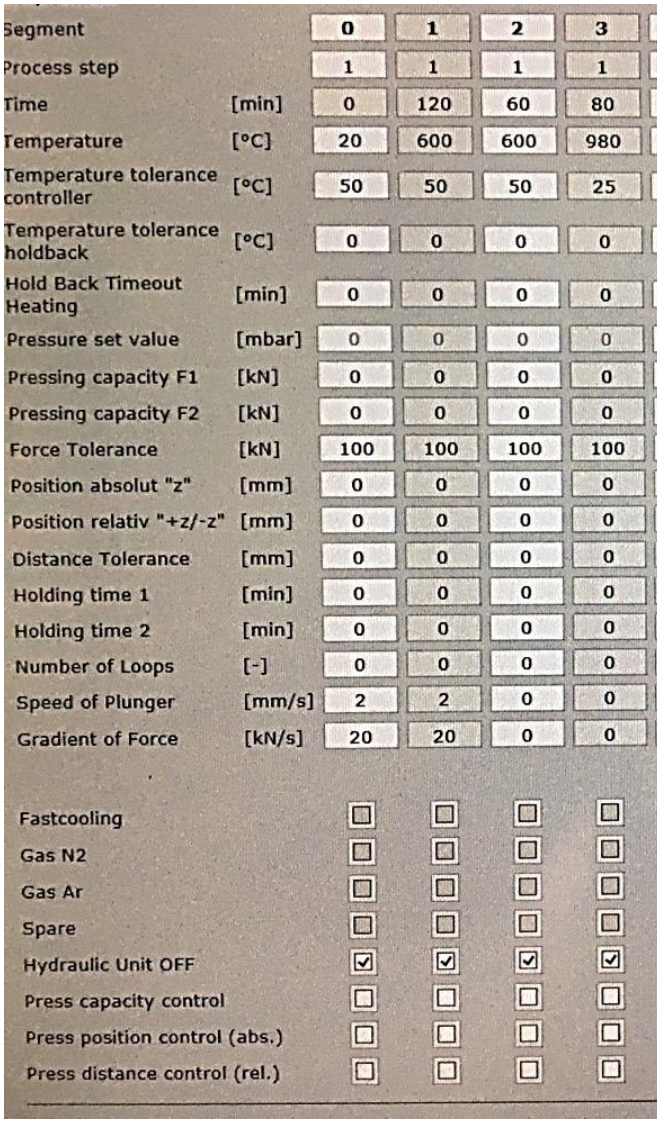
Diameter = 57 mm

Results:

- Force needed to delaminate one isolated pillar = 800 KN
- Maximum compression stress = 148 MPa
- Youngs modulus = 86,2 Gpa
- Due to laminated structure anisotropy effects occur (Different compression on different positions around the circumferenece)
- Very low ratcheting or creep effects



PRESSING SYSTEM – CONTROL AND OPERATION OPTIONS



Segment		0	1	2	3
Process step		1	1	1	1
Time	[min]	0	120	60	80
Temperature	[°C]	20	600	600	980
Temperature tolerance controller	[°C]	50	50	50	25
Temperature tolerance holdback	[°C]	0	0	0	0
Hold Back Timeout Heating	[min]	0	0	0	0
Pressure set value	[mbar]	0	0	0	0
Pressing capacity F1	[kN]	0	0	0	0
Pressing capacity F2	[kN]	0	0	0	0
Force Tolerance	[kN]	100	100	100	100
Position absolut "z"	[mm]	0	0	0	0
Position relativ "+z/-z"	[mm]	0	0	0	0
Distance Tolerance	[mm]	0	0	0	0
Holding time 1	[min]	0	0	0	0
Holding time 2	[min]	0	0	0	0
Number of Loops	[-]	0	0	0	0
Speed of Plunger	[mm/s]	2	2	0	0
Gradient of Force	[kN/s]	20	20	0	0

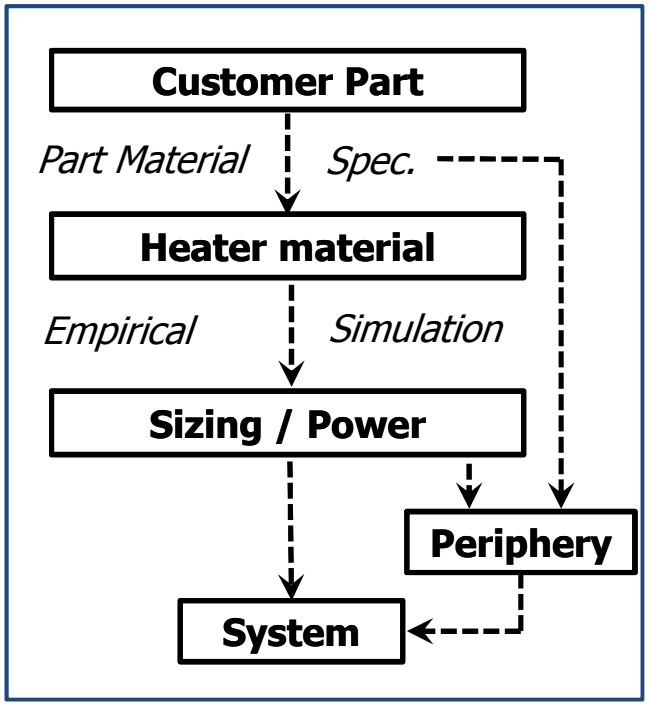
Fastcooling	☐	☐	☐	☐
Gas N2	☐	☐	☐	☐
Gas Ar	☐	☐	☐	☐
Spare	☐	☐	☐	☐
Hydraulic Unit OFF	☑	☑	☑	☑
Press capacity control	☐	☐	☐	☐
Press position control (abs.)	☐	☐	☐	☐
Press distance control (rel.)	☐	☐	☐	☐

Control of the pressing – measurement:

- Two main values – applied force and position of the pressing plate
- Transformation from the calculated force (based on the hydraulic pressure of the system) to direct measurement using load cells (precision and safety).
- Due to modern positioning sensors a measurement with a resolution ~1 µm becomes possible (until now ~10µm)
- Operating strategies:
    - Force controlled systems (standard)
    - Position controlled (absolute/relative)
    - Combined force-position controlled

III.) Heating and cooling

HEATING SYSTEM:



Mo-Heated:

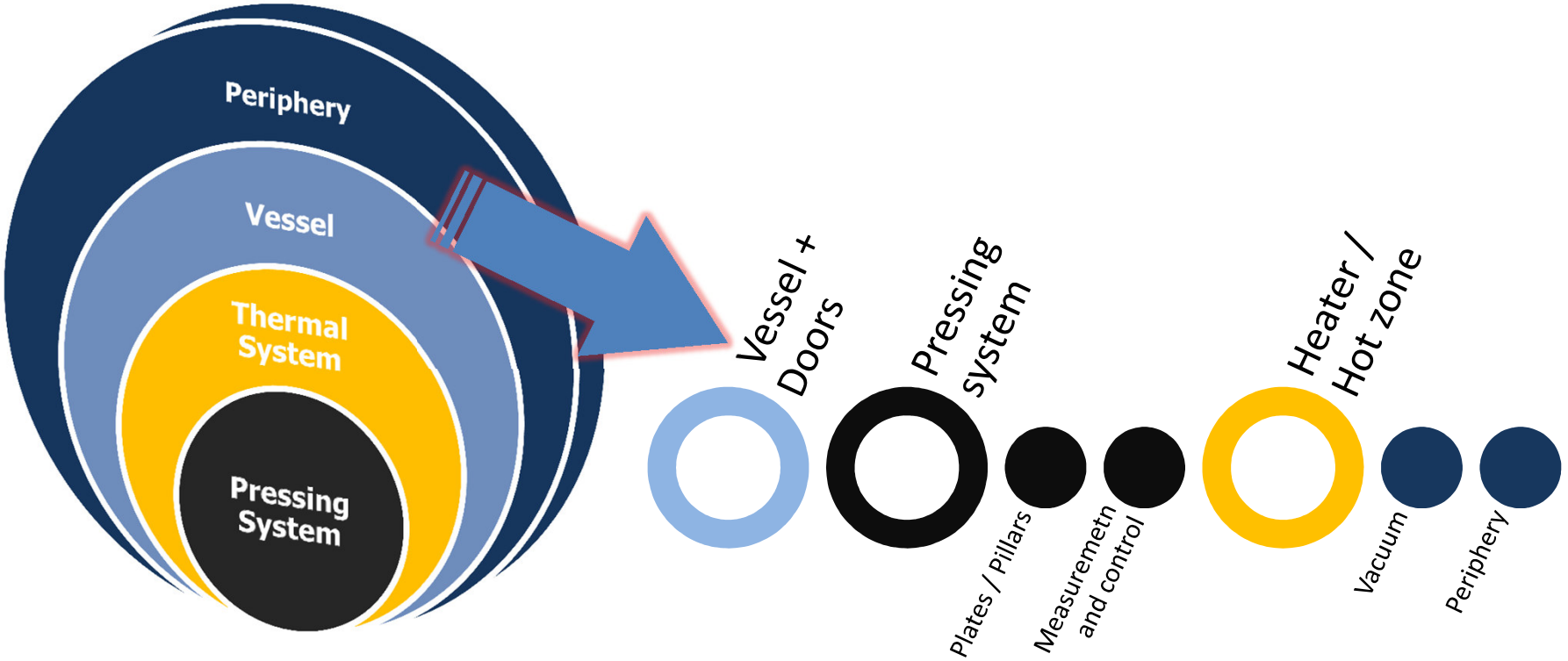
- Hydrocarbon-free high vacuum atmosphere possible.
- Highest flexibility of possible materials to bond (Ti, highly alloyed steels, Ni-based super alloys).
- More complex and more expensive heating set-up

Graphite/CFC-Heated:

- High vacuum atmosphere possible.
- Usable for robust processing, thus for serial and mass production
- Less complex and less expensive

IV.) Manufacturing

MANUFACTURING PROCEDURE – PRIORIZING



- "Bottleneck" structures have to be treated with special attention (Heaters, Vessel and Doors, Force distribution system).
- Periphery manufacturing/buying can be delayed or pre-prepared
- Assembly phase
- Factory acceptance


Thank you for your attention!
Questions?