Hot Forming

Diffusion Bonding

Funded by ESA

Biaxial hot forming of AA2219 with SPF and other hot forming processes

Werner Beck, Sabine Wagner, FormTech GmbH, Germany
Andrew Norman, Graham Harris, ESA/ESTEC, The Netherlands

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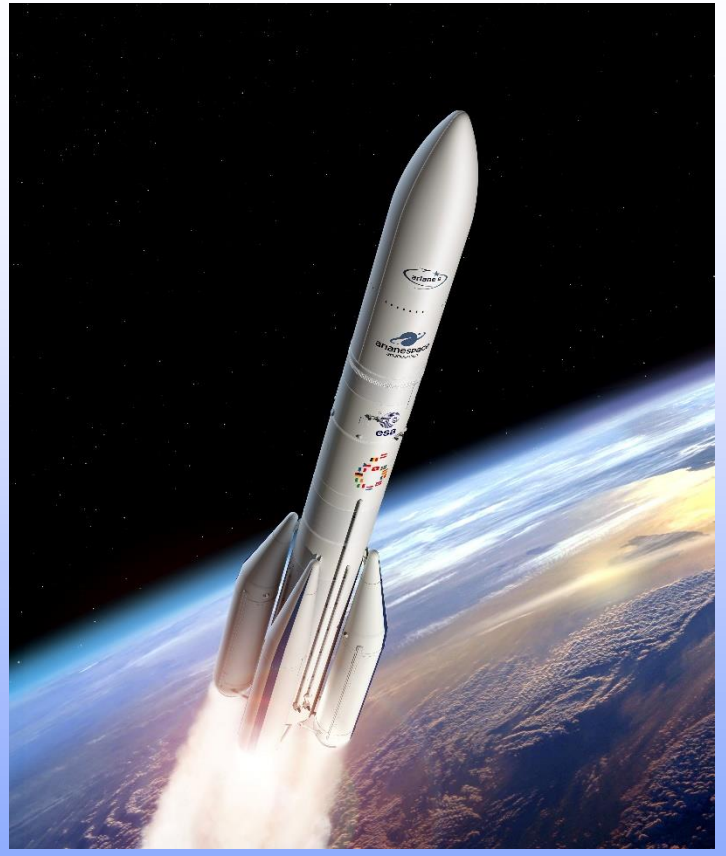
FormTech GmbH, Mittelwendung 26, D-28844 Weyhe
Tel: +49 (0)4203 8045 -0, Fax: +49 (0)4203 8045 -29, Email: info@formtech.de

ESA project AO9005

Advanced forming technologies for complex shapes

Development, manufacturing and test of new structural tank demonstrators for ARIANE 6 from AA2219



Consortium:

1. MT-Aerospace, Germany, Design and production of tank body
2. Omnidea-RTG, Germany, Project management
3. Omnidea Ltd., Portugal, Incremental forming of tank dome with magnetic pulse process
4. FormTech GmbH, Germany, Hot forming of tank dome

Hot forming of sheet metal AA2219

State-of-the-art / literature:

„Superplastic Blow Forming of AA2219 Aluminum Alloy“

R.Kaibyshev, I.Kazakulov, D.Gromov, D.R.Lesuer, T.G.Nieh

Summary:

- AA2219 = Al6,4Cu0.3Mn0,19Zr0,0,6Fe
- Material from special TMP treatment
- Investigation on ultrafine grain size (GS) ~12 µm~ASTM 9,5
- Test parameters: 450-540°C, p_{SPF} 0,2 to 0,4MPa, $\dot{\varphi}$ =2,2x10^{-5} to 1,1x$10^{-1}s^{-1}$
- Cone tests with and without backpressure
- Max achieved strain e=670%
- Max strain at 500°C and $\dot{\varphi}$ =2,2x$10^{-4}s^{-1}$ under backpressure
- Lot of cavities without backpressure
- Very few cavities with backpressure

ICSAM 2003

Project challenge

- Information from literature hardly transferable due to much coarser GS of standard sheet and plate material
- Application requires forming of a thin membrane inside a thick plate
- Thickness ratio „ring“ to „membrane“ is 100 to 5%
- Required bottom curvature is „Cassini shape“
- Part shape requires thickness strain of minimum ~e= 21%, $\dot{\varphi}$ =0,24 assuming constant wall thickness in formed region
- Cavities and „open porosity“ not acceptable for the application

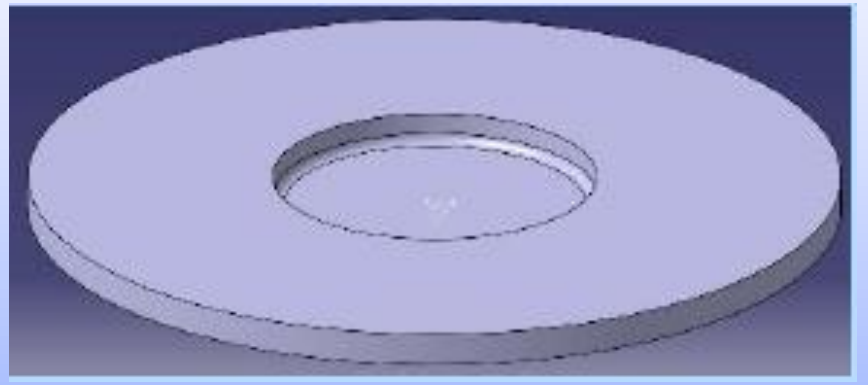


Plate material and machined membrane

Simplified approach:

- Test samples from standard sheet metal
- Validation of SPF, HDD, HSF process capabilities
- Metallurgical examination regading cavities
- If one HF process possible: Application on „like-real“ blanks with „plate“ ring and machined „membranes“

FormTechs´ equipment for HF processes

FT ´s R&D equipment is suitable for T_{max} ~1.100°C, p_{max} =6MPa, Max ram force 100t

- SPF (superplastic- / gas pressure forming)
- HDD (hot deep drawing),
- HSF (hot stretch forming)

SPF with single action press
HDD and HSF with double action press.

- Double action press is unique. Built in alliance with SCHULER

Evaluation of process parameters

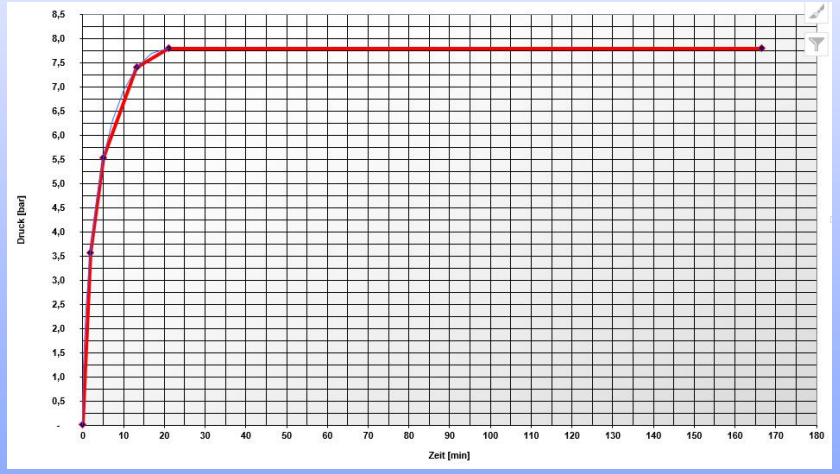
- „Cone“ for SPF
- „Swift“ for HDD and HSF

R&D actions:
Phase 1:
Standard sheet metal available in t_s=2mm, GS= ASTM 4-5
Phase 2, not yet finished/ results pending:
Forming of membrane machined down from plate material t_p=40mm

Material AA2219-O, t=2,03mm
provided by MT-A

Gas pressure forming/“SPF“ of AA2219

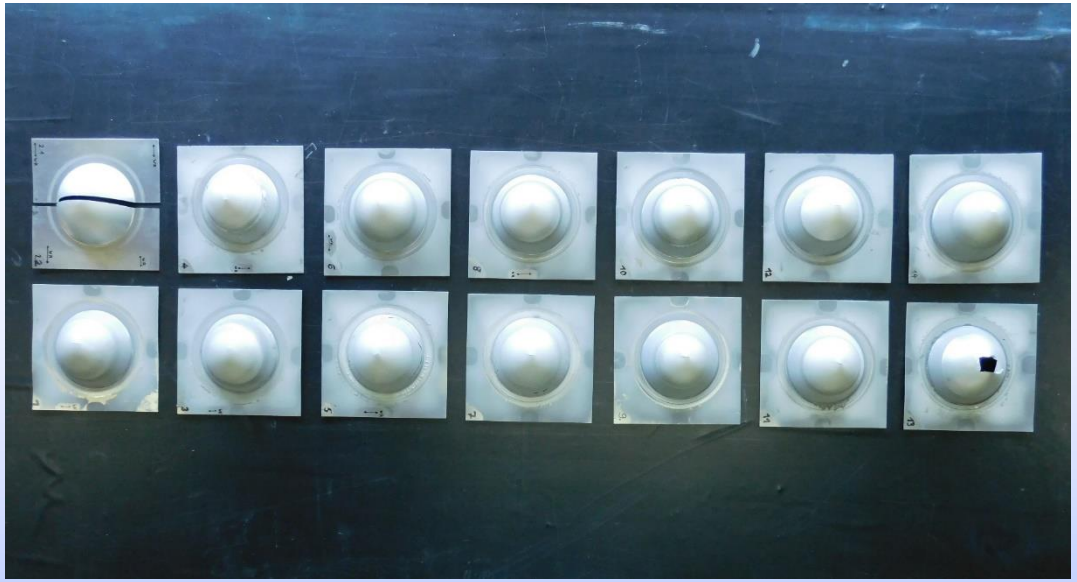
- SPF temperature for AA2219: ~500°C
- Variation of applied pressure-time-curve incl. back pressure
- Test result: Cone height 100% or premature failure



Example: time-pressure-curve

Sample cone Ti6-4 at ~850°C

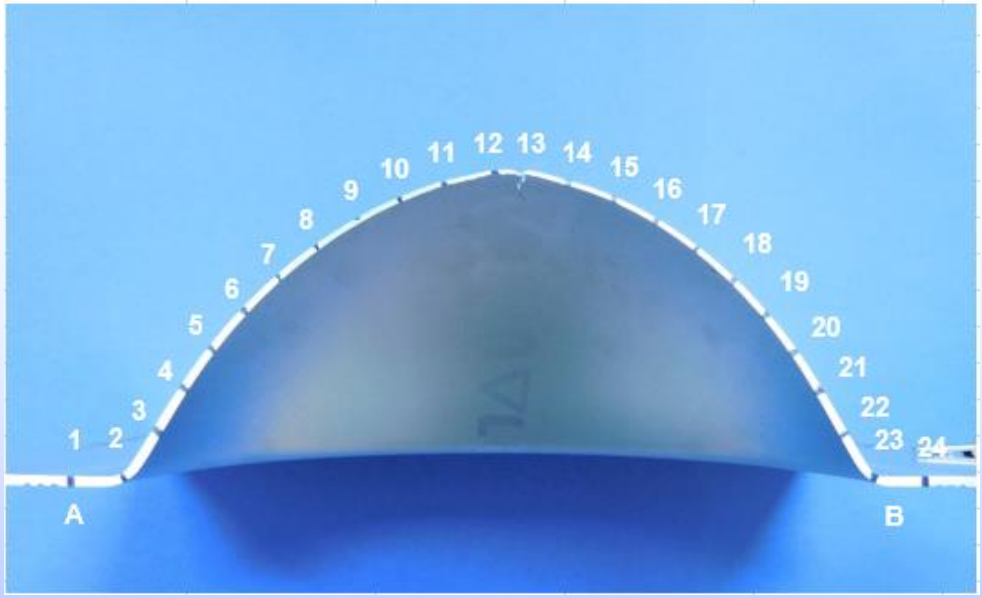
Test parts AA2219

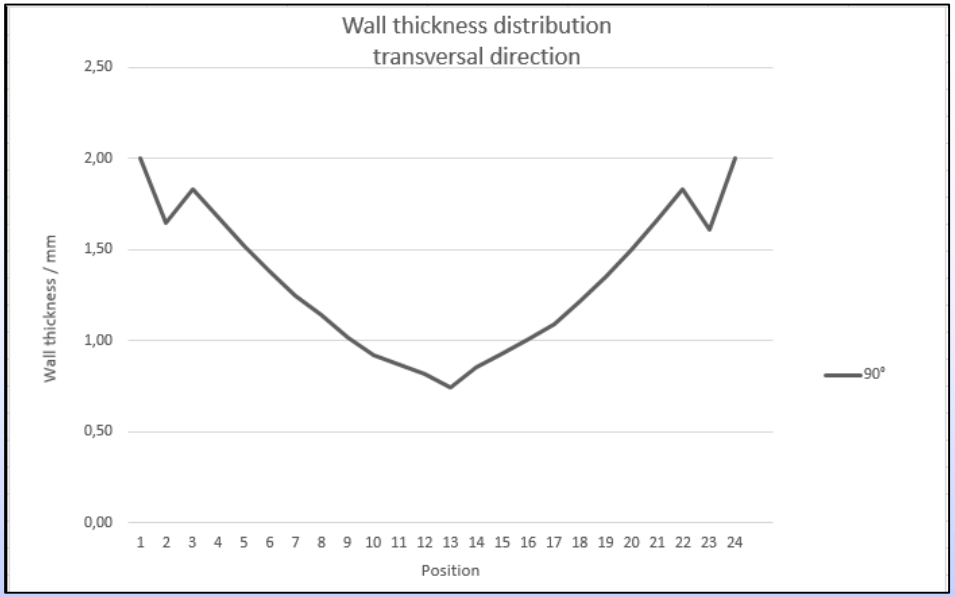


14 samples with and without backpressure

Extraction of microsections

Wall thickness distribution

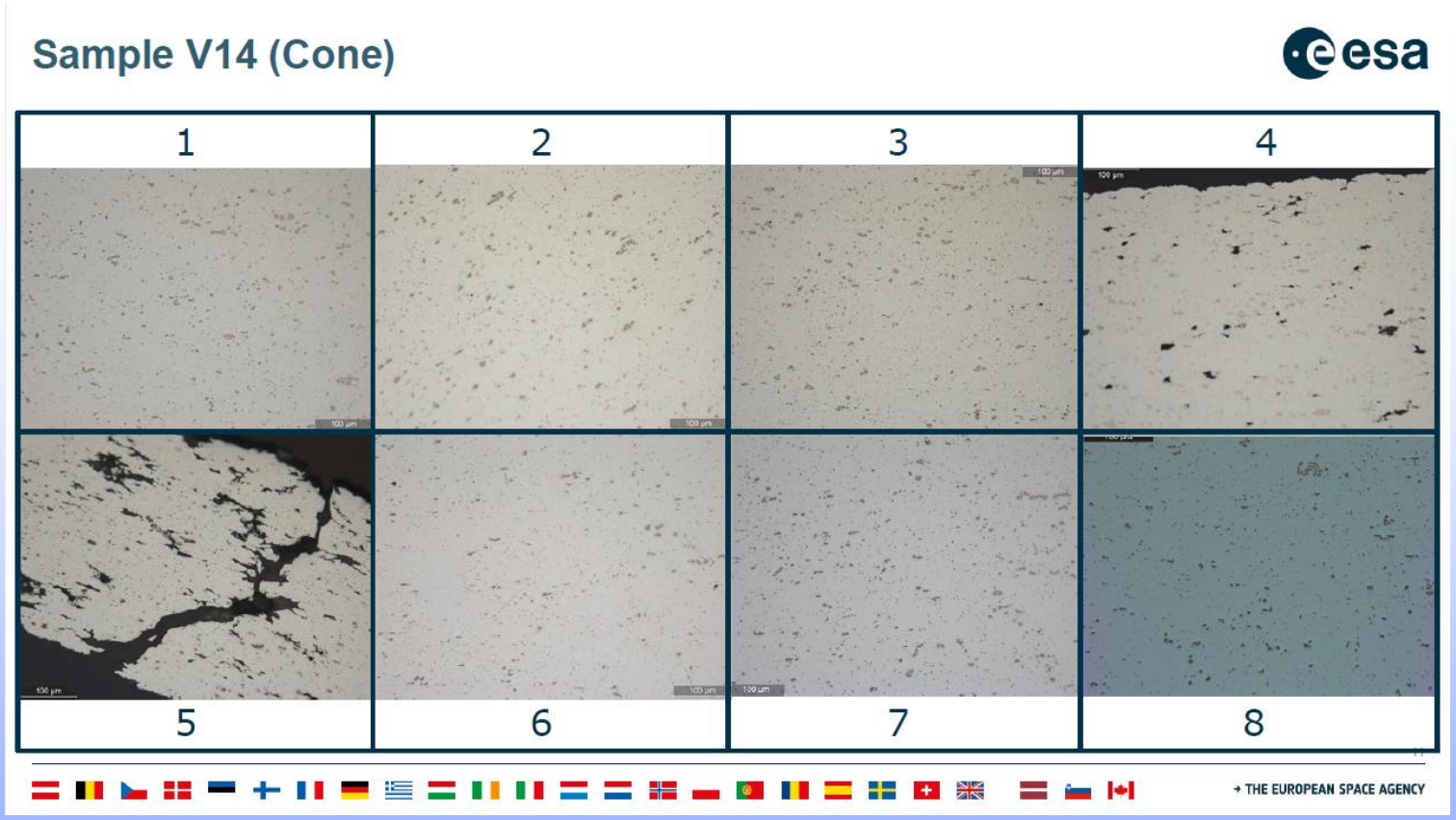




Wall thickness distribution:

- Minimum wall thickness of 0,74mm in pole near crack
- ~Linear reduction of wall thickness from radius to pole
- Failure initiation from cavities even with high back pressure

Micrographs of cone sample No 14



Cavities at strain > ~ϵ=0,2
Requirement no cavities at ϵ>/=0,24 →not achieved
SPF process with standard sheet not feasible

Test program HDD/HSF

- Definition of HDD process parameters
  - Constant wall thickness
  - Suitable forming temperature
  - Sufficient formability / cup height?
  - Forming without cracks
- Definition of lubricant
  - Smooth surface
  - No abrasion of tool and part
- Sufficient drawability
  - SWIFT – flat bottom
  - Hemisperical bottom
  - Cassini shape bottom
- Definition of HSF* process parameters
  - Controlled material flow of blank over curved punch head!!

Different punch geometries:
Flat, hemispherical and Cassini shape

*HSF ~ HDD without material from flange area

Test samples HDD/HSF

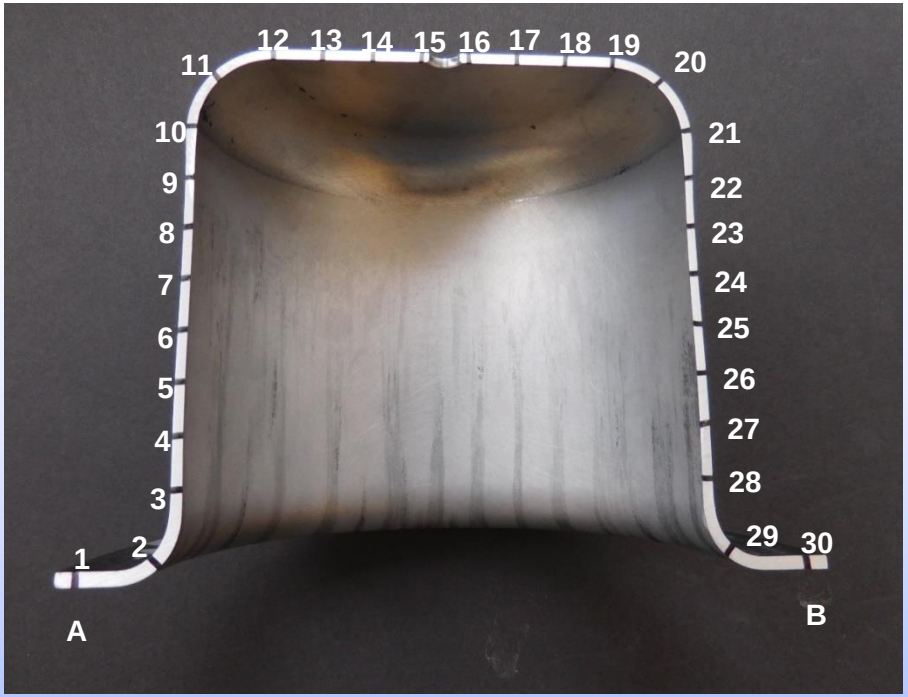
Forming temperature for HDD of AA2219

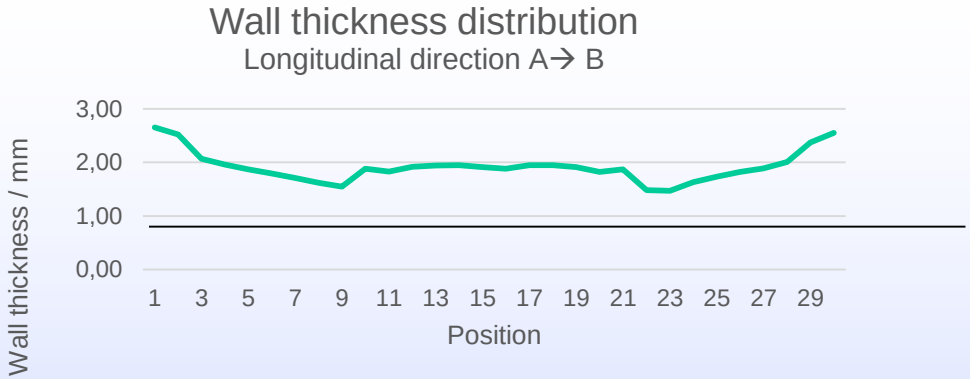
No. of samples	Blank diameter	Punch geometry
20	180	flat

Typical view of deep drawn cups

Temperature range: 180°C – 450°C
Result: Best formability/ highest cup at T= 230-240°C
Good repeatability.
Cracks in usual position: Short below bottom radius
Wall thickness near cracks t~1,4mm
→ Critical thinning ratio for crack initiation: ε~0,37

Wall thickness distribution HDD

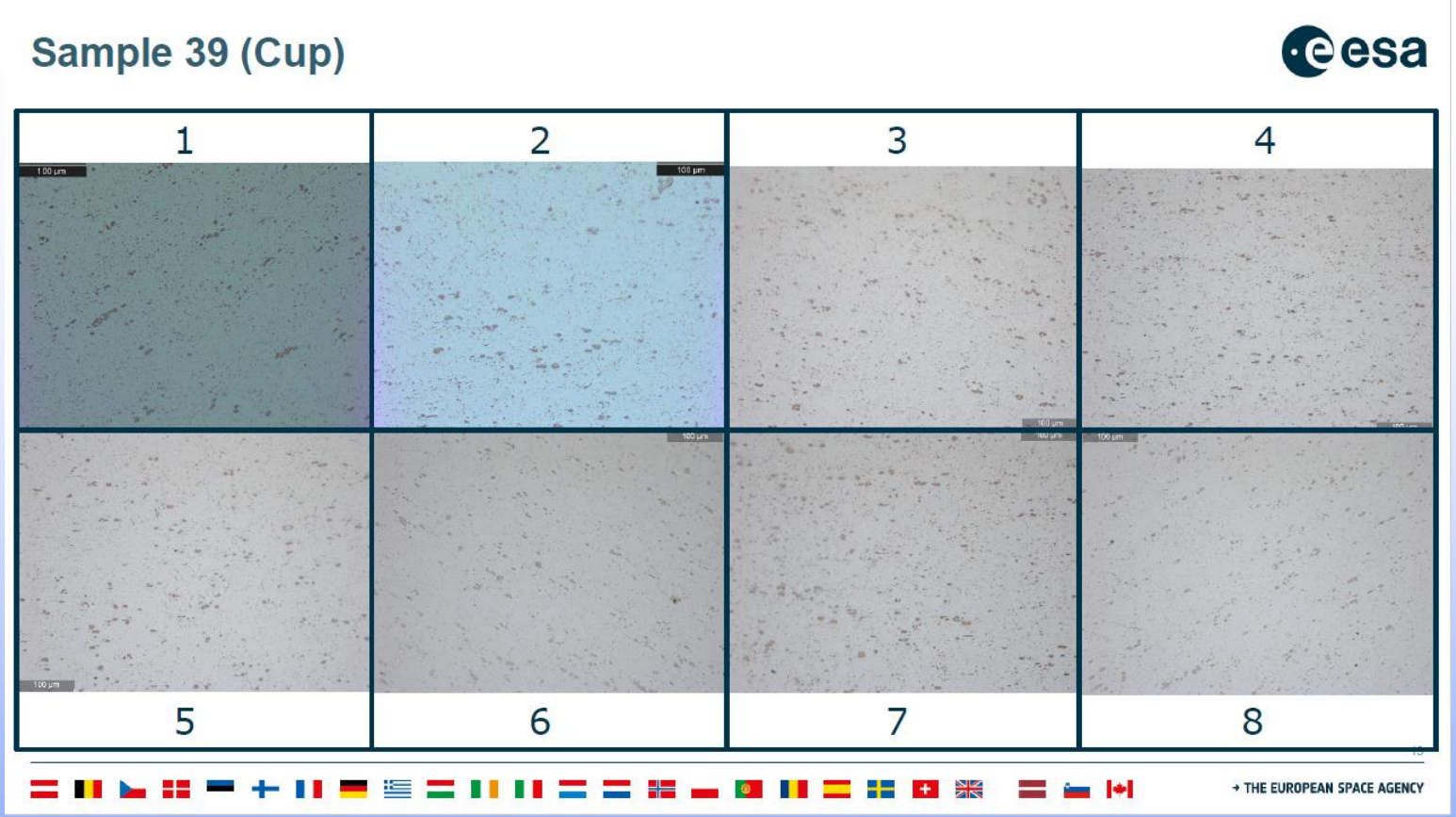




Wall thickness distribution:

- Thickening up to 0,65mm in the flange area
- Wall thickness
- Bottom area: ~Tconst
- Cup walls: decrease linear, minimum t~1,47mm, see 8/9 and 22/23

Micrographs HDD sample



HDD seems to show no cavities. Doubts be checked with SEM
Unfortunately HDD only possible with uniform blank thickness

Hot stretch forming

No. of samples	Blank diameter	Punch geometry
30	240	Cassini

Dome forming of machined membrane from plate material

- “No” material flow from flange possible due to “ring”
- Forming of Cassini dome curvature from flat blank requires stretching of membrane = thinning
- Acceptance level of test bodies→ similarity to real shape
- Required dome height=28mm

Test results:

- H=28mm(+) achieved.
- Min t=1,44mm
- Surface doesn´t show excessive signs of necking

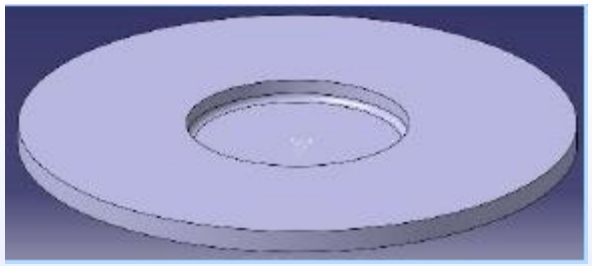
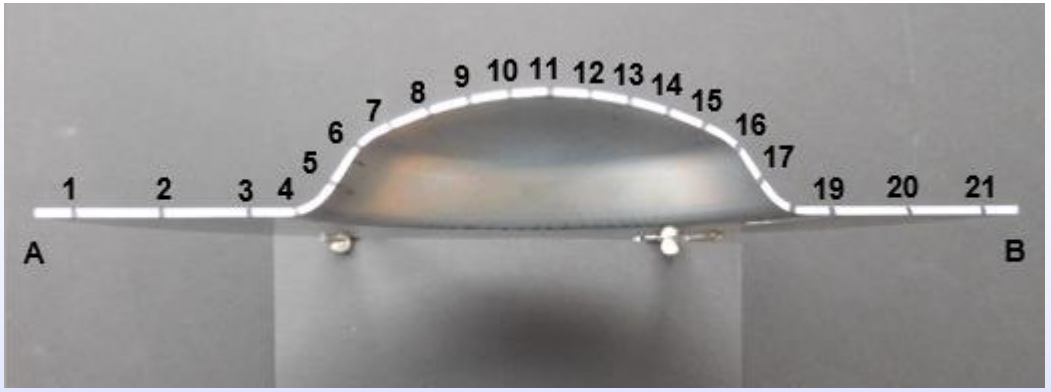
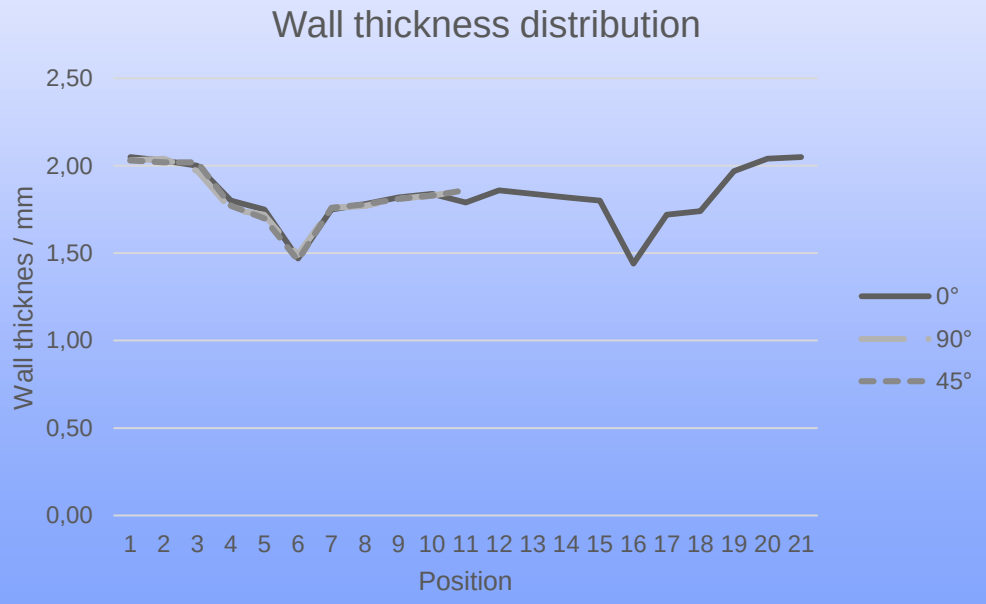


Plate material and machined membrane

Hot stretch formed part R28 with Cassini bottom

Wall thickness distribution HSF

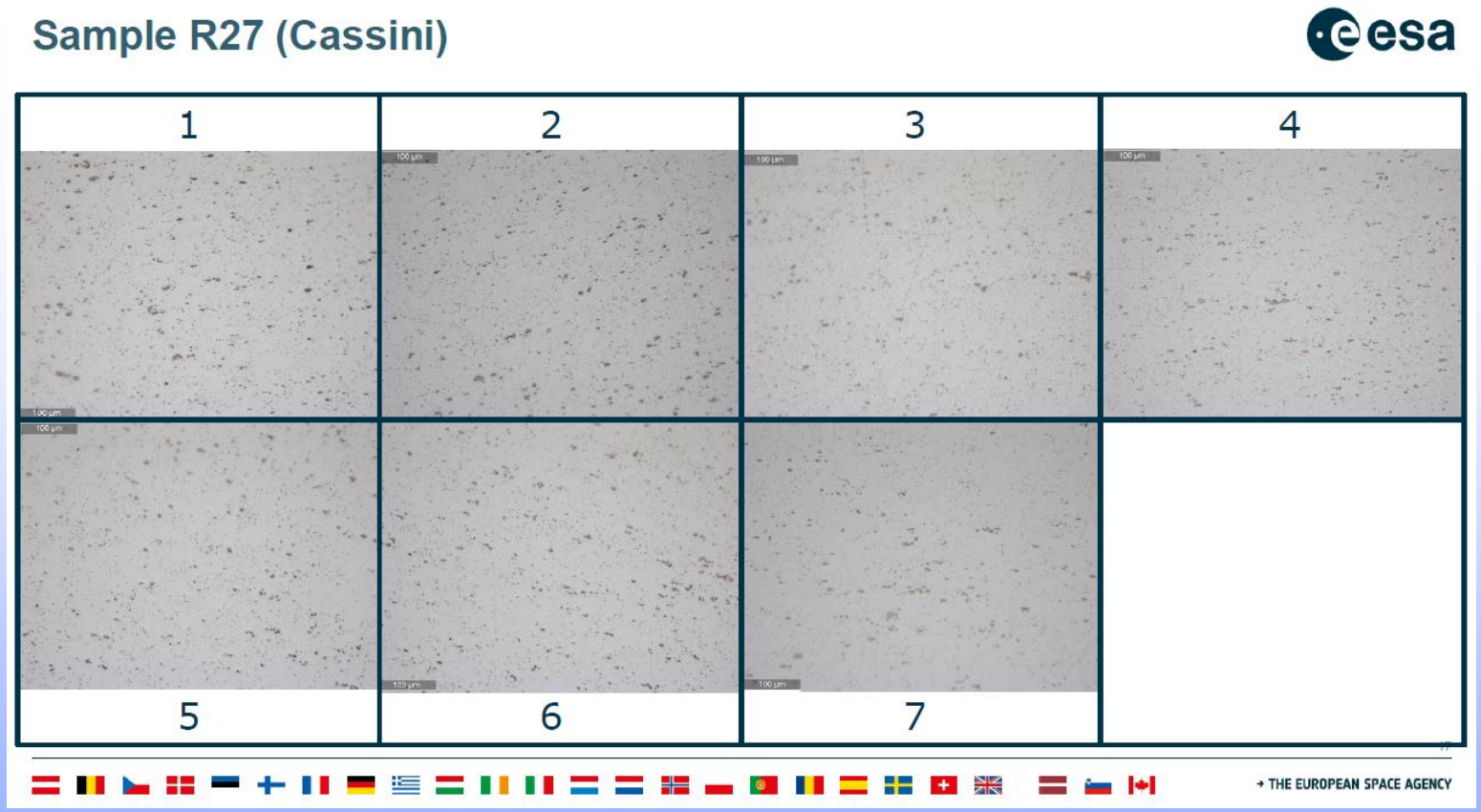




Wall thickness distribution:

- No variation on wall thickness in clamped area (pos. 1-3 and 19-21)
- Approximately constant wall thickness in the Cassini-shape bottom area (pos. 7-15)
- Minimum wall thickness t=1,44mm just below bottom radius (pos. 6 and 16)
- ε~0,34 is near to necking
- No anisotropy visible

Micrographs HSF

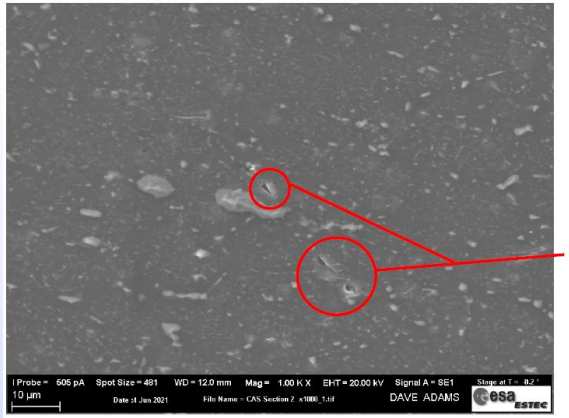


HDD seems to show no cavities. Doubts be checked with SEM as with HDD

HSF seems possible with „real“ blank geometry

SEM results HDD and HFS

SEM Analysis - Cassini Sample, Position 2



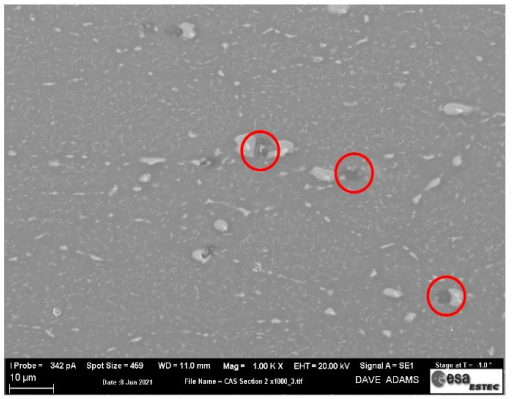
Coarse intermetallic phases

Some grain boundary precipitates

Occasional pull out of intermetallics

No evidence of any small pores

SEM Analysis - Cassini Sample, Position 2



Small pores seen in optical metallography are in fact intermetallic particles that have been pulled out during sample preparation

Small voids visible in micrographs are not at all microcavities

Distribution of pores. Summary SPF, HDD, HSF

Summary – After Metellography + SEM Analysis

Sample	Analysis Position 1	2	3	4	5	6	7	8
Cone 2.1 (SPF)								
Cone H3 (SPF)								
Cone V14 (SPF)								
Cup 39 (HDD)								
Cassini R27 (HSF)								

No Pores Occasional Pore Many Pores Very Bad

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→ THE EUROPEAN SPACE AGENCY

Summary SPF, HDD& HSF of standard AA 2219

Gas pressure forming/ SPF

Despite backpressure cavitation starts at $\epsilon \sim 0{,}2$

→ **Dome forming of given application with gas pressure forming/ SPF not possible**

HDD

HDD of sheet metal performed successfully with flat, hemispherical and Cassini-shaped punch

AA2219 hot deep drawing ratio is exceptionally good → $\beta_{max} \geq 2{,}4$ = max achievable

→ **HDD process of thin membrane machined inside thick plate not possible**

HSF

HSF successfully demonstrated for the real application, but with sheet metal blanks instead of machined plate

→ **tbd if even coarser microstructure of membranes machined from plate will work**

→ **HFS with samples from plate material to come**

Thank you very much for your attention

FormTech GmbH
Mittelwendung 26
D-28844 Weyhe
Germany

Phone: +49-4203-8045-0
Fax: +49-4203-8045-29
Email: info@formtech.de
Homepage: www.formtech.de