About the Feasibility of Thermoplastic Composite Fan Structures

VITAL Workshop

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Company: DLR Institute of Structures and Design in Stuttgart (Germany)
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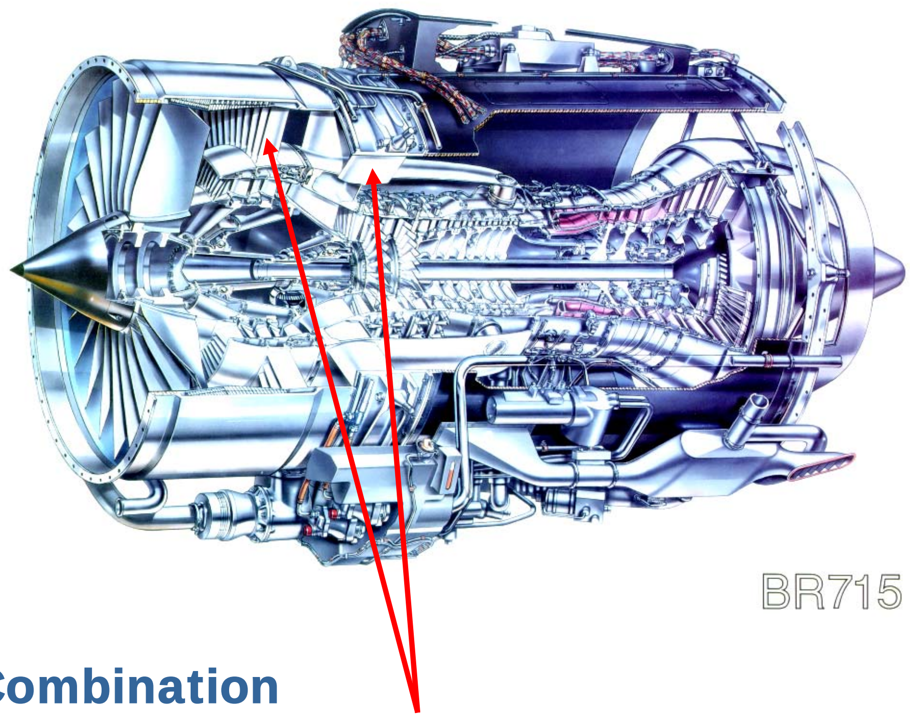
Contend



- **General Remarks**
- **Different Design Approaches**
  1. **Titanium / CFRP Material Combination**
  2. **Overall Thermoplastic OGV Design**
- **Manufacturing of a Thermoplastic Vane**
- **Cost Assessment**
- **Conclusion**

Topic of SP 4.2:

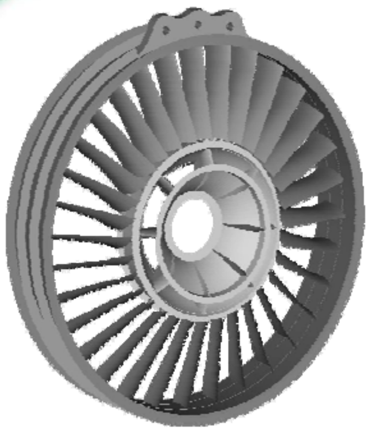
Structural OGV – combining aerodynamic and structural features

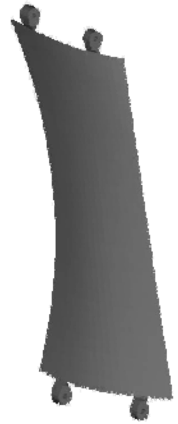
General Remarks

Why using thermoplastic UD CF-PEEK material?

- Material is well known in aerospace application
- Comprehensive material variants available in Europe
- Excellent mechanical properties
- Excellent chemical resistance
- Low moisture pick up with negligible impact on material performance
- Potential for alternative joining technologies and reparability
- No waste with a view to recycling capability
- Processes can be automated with a view to high quantities

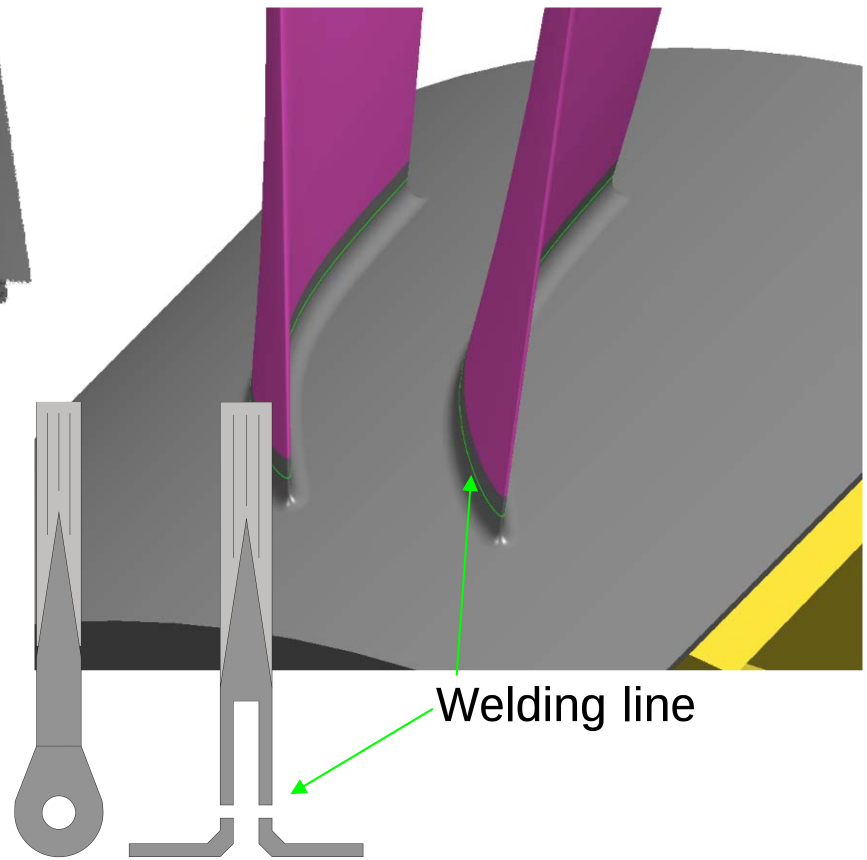
Titanium / CFRP Material Combination





Advantages:

- Conventional metallic welding technique applicable
- High inherent stiffness of the joint
- Practicable with a view to simple manufacturing
- Variants for attachment possible

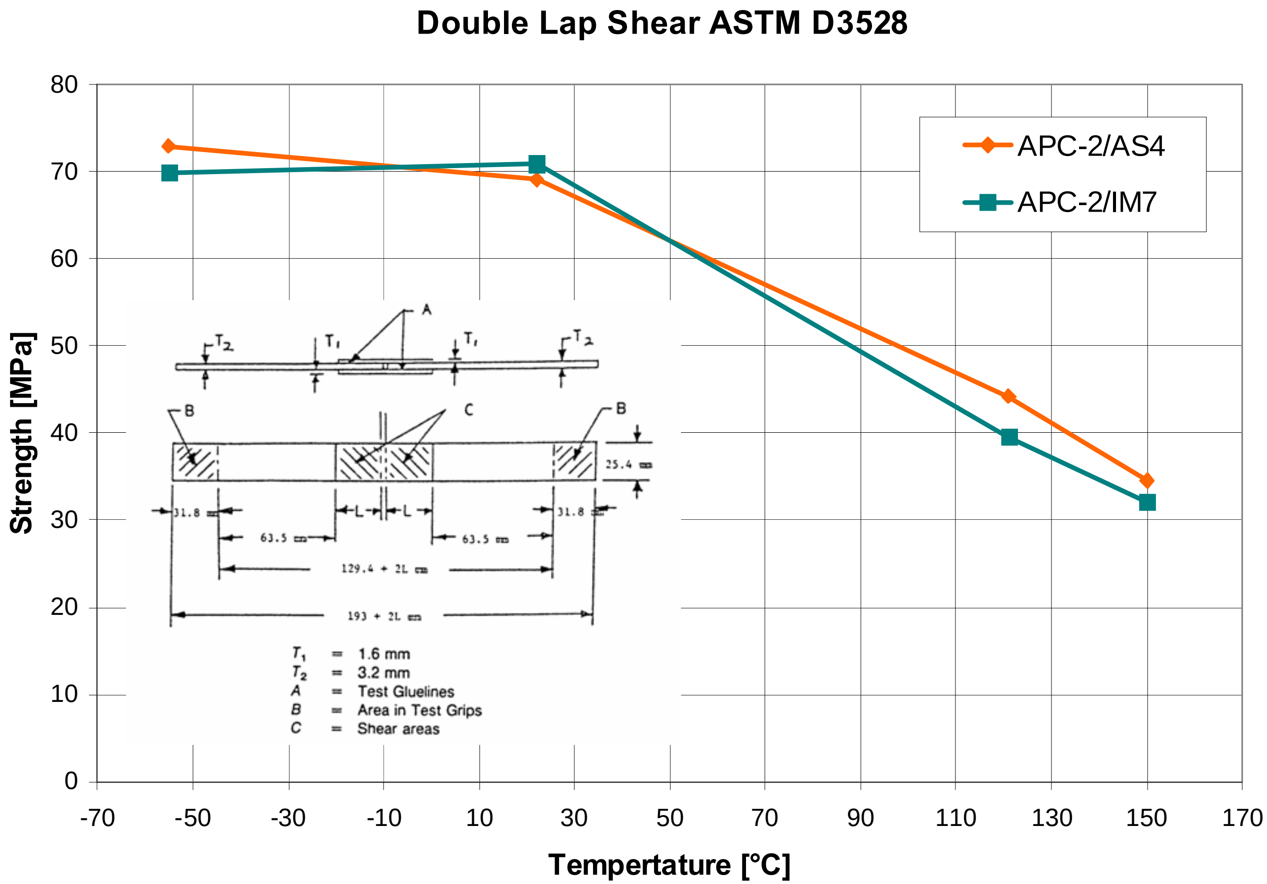


Disadvantages:

- Not easy to remove from full component in case of welded joint
- Hybrid joint still need to be tested intensively

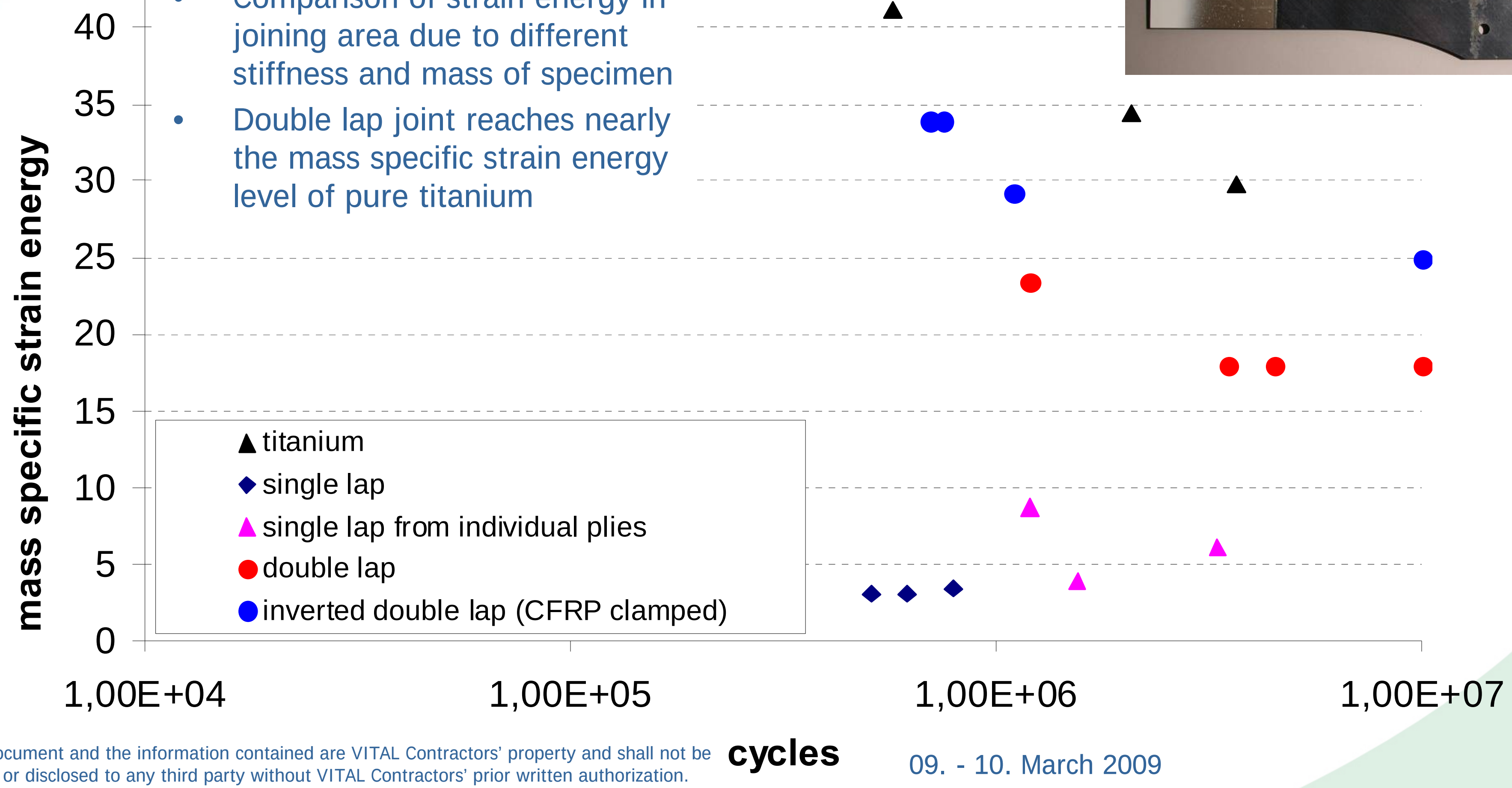
Static Test of Metal to Composite Joint
(Contributed from SP 3.3)

Results of Tested Hybrid Specimens



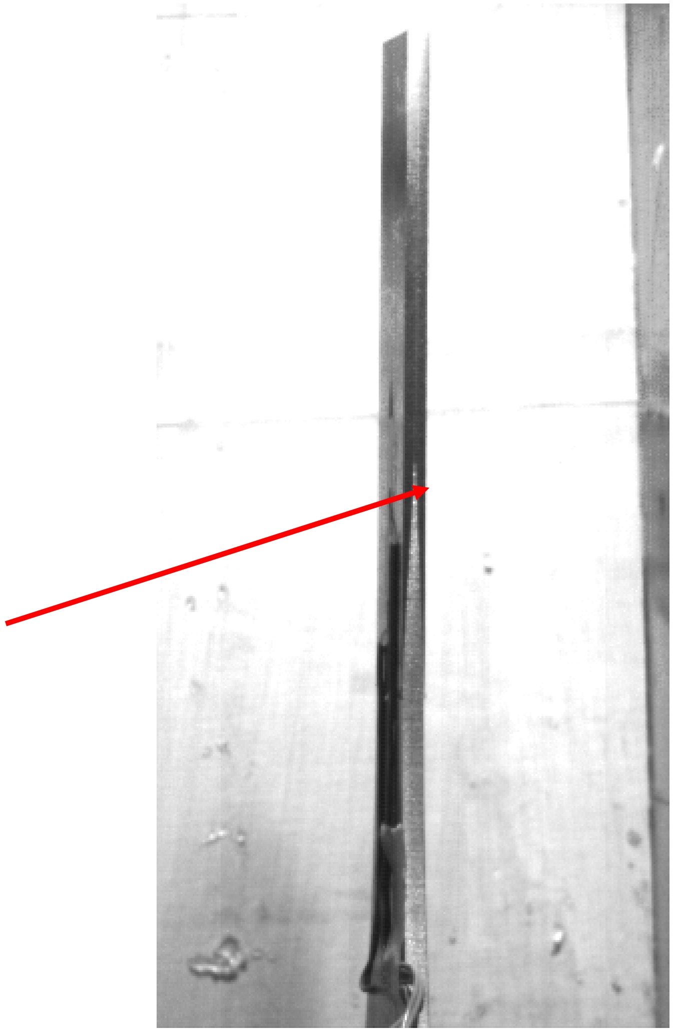
Mass Specific Strain Energy in Joining Area

- 2nd Mode Testing
- Comparison of strain energy in joining area due to different stiffness and mass of specimen
- Double lap joint reaches nearly the mass specific strain energy level of pure titanium

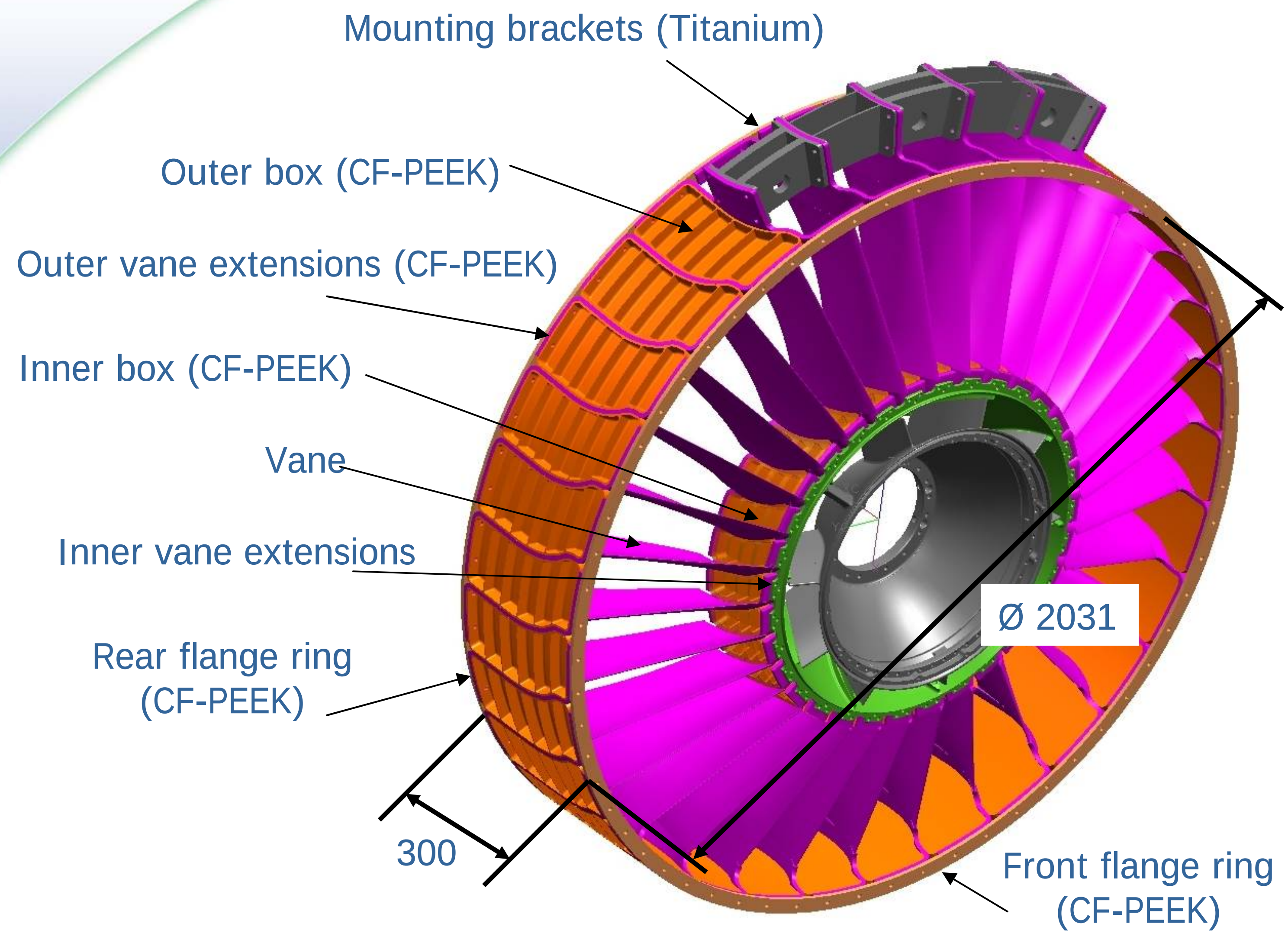


Impact Tests on HCF Specimen

- Impact velocity from 104 to 151 m/s
- Impactor (galantine) mass ranges from 25 to 33 gr
- Energy ranges from 139 J to 306 J
- No failure occurred due to 0.9% strain within CFRP material



Composite OGV with Titanium Inner Casing and Mounting Brackets

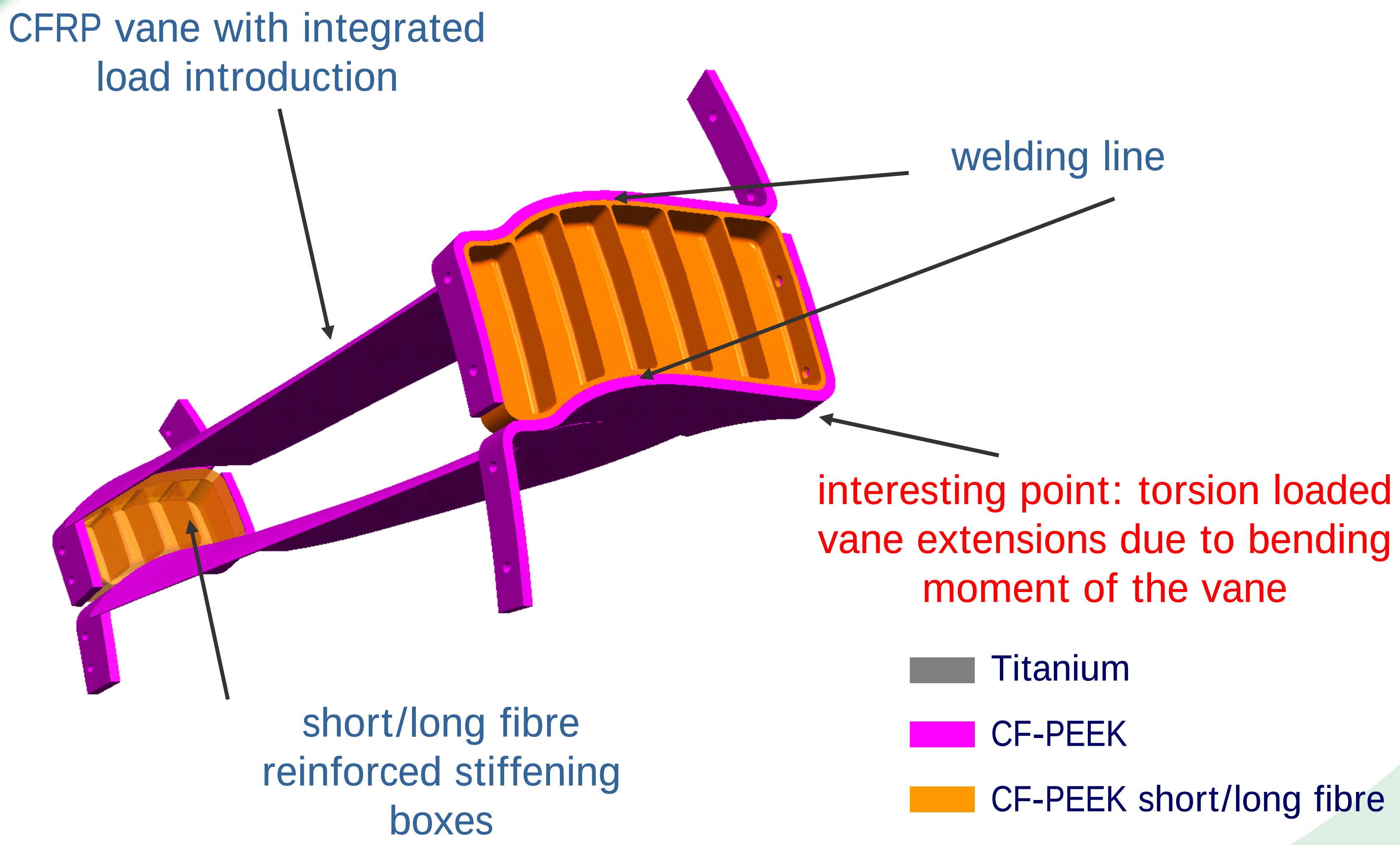


Composite OGV with Titanium Inner Casing and Mounting Bracket

Main characteristics:

- Endless fibre reinforced vane with integrated load introduction
- Uninterrupted fibre structure between the two OGV flanges
- Usage of high inherent in plane stiffness of the vane between the flanges to avoid additional circumferential ribs
- Welded short/long fibre stiffened elements are used to increase the frequency of first vane bending mode
- There is the possibility to arrange several vanes to a cluster
- Exchanging a single vane or a cluster of vanes for repair can be guaranteed
- Cost-effective manufacturing
- No additional joining fittings
- Load introduction for mounting can be done directly in elongated vanes
- Problems of tolerance are solved
- Acoustic liner can be integrated in stiffening boxes

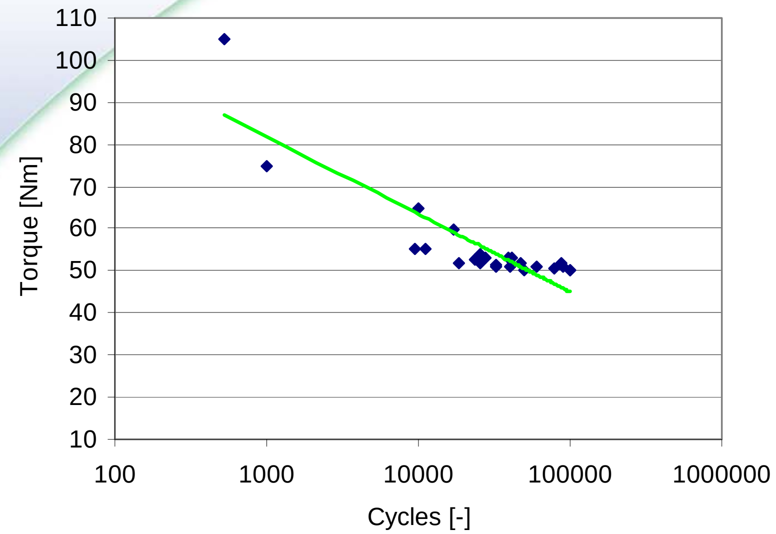
Composite OGV with Titanium Inner Casing and Mounting Bracket



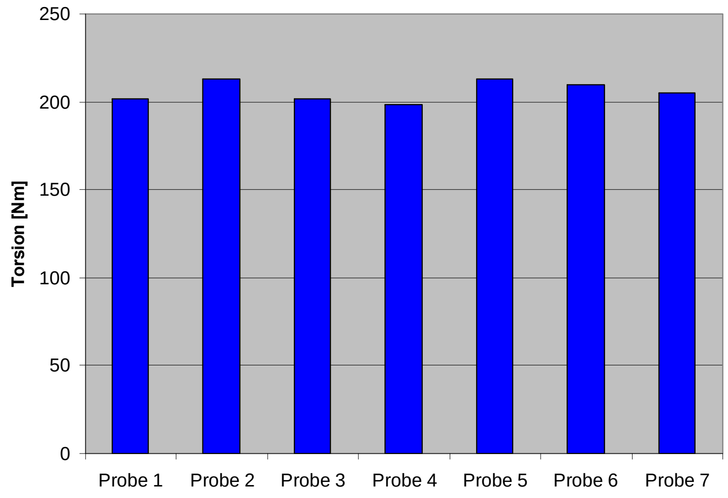
Verification of Vane Extensions

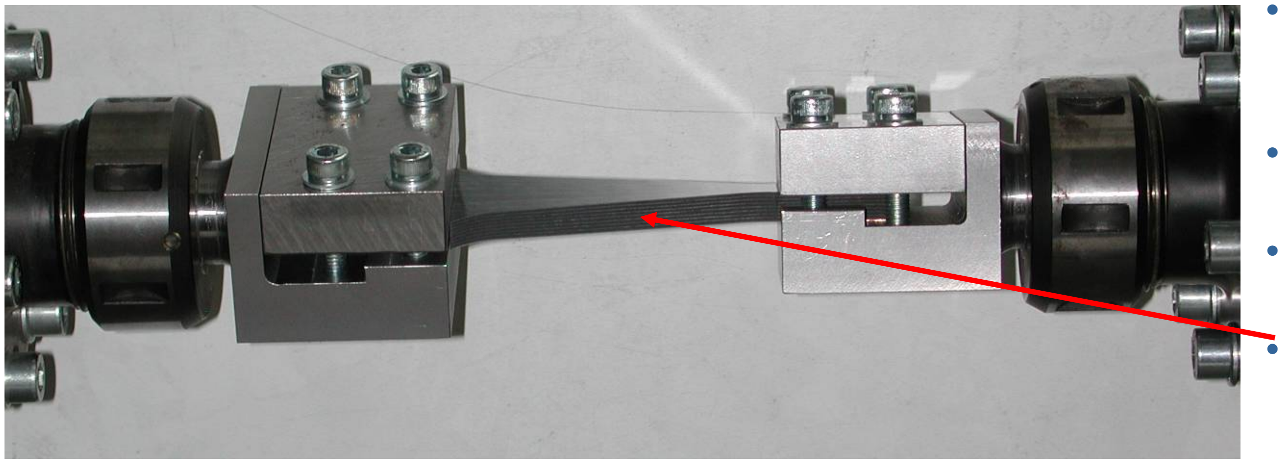
Experimental Results

LCF-Test



Static-Test





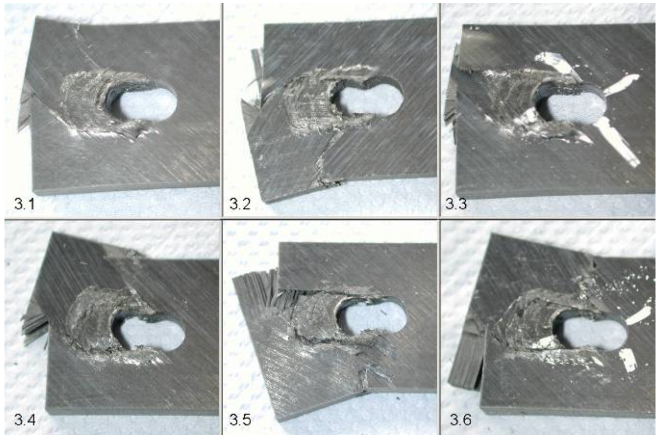
- Cross section in the middle of specimen
  9 mm x 30 mm
- Material APC2 AS4 –quasi isotropic lay-up
- Crack appears in the middle of specimen as expected
- Plastic deformation can be observed as from 70 Nm

Bearing Strength of CF-PEEK

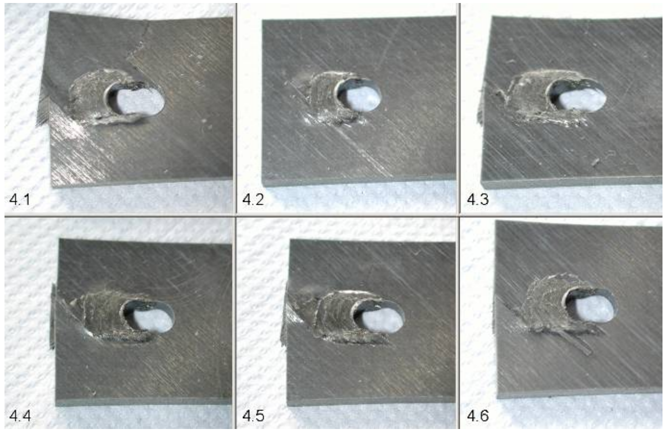
Results of Tests

W/D / t / e/D	σ_{max} [N/mm²]
3,5 / 4 / 3	1074,47
4 / 4 / 3	1125,19
5 / 4 / 3	1144,31
6 / 4 / 3	1106,07
6 / 9 / 3	830,21

- Highest stress value for W/D = 5
- Lower maximum stress for thicker specimen at constant W/D = 6 ratio



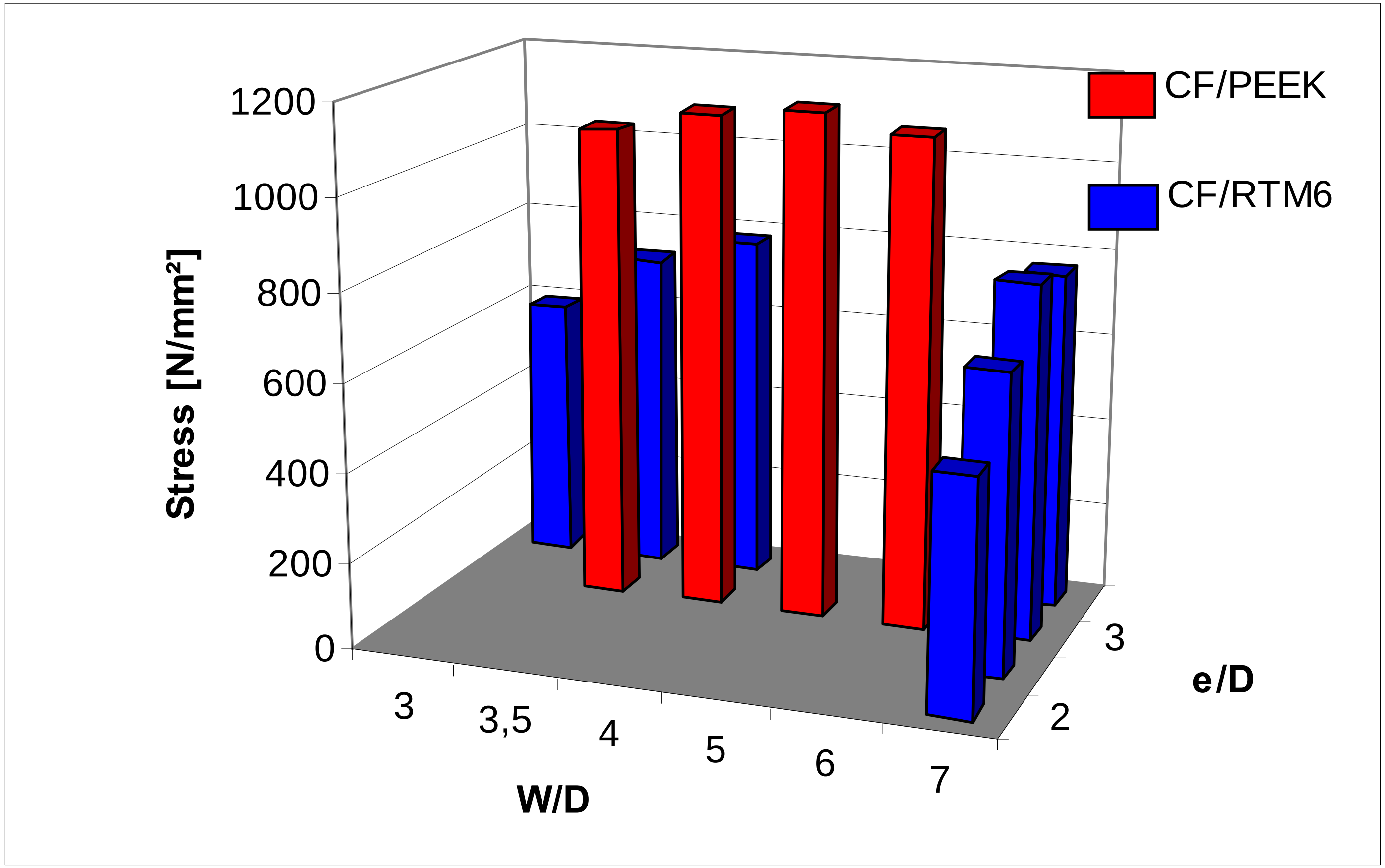
Failure mode for W/D=4



Failure mode for W/D=5

Bearing Strength of CFRP

Comparison of CF/RTM6 and CF/PEEK Specimens



Resistance Welding as a Basis for Assembling

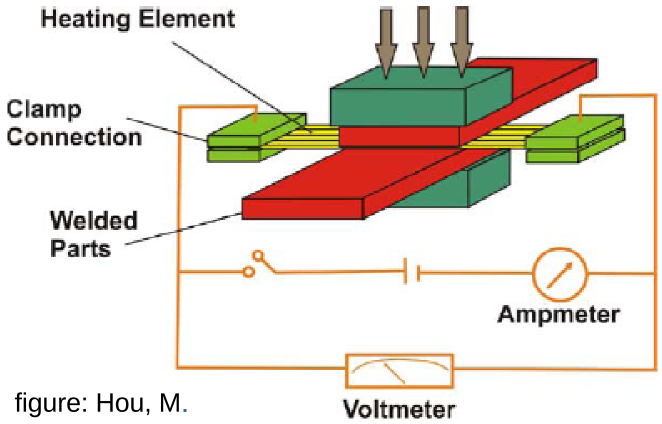
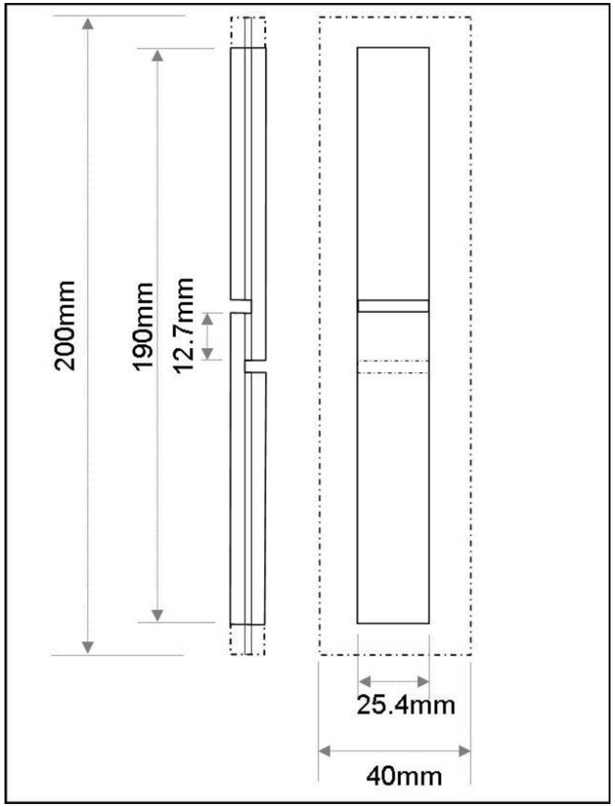


figure: Hou, M.

CF prepreg as resistive element	VA-mesh as resistor with PEEK matrix	VA-mesh as resistor with GF-PEEK
		
+ no additional material + acceptable strength - leakage current possible - insufficient process reliability - fibers may blow	+ high process reliability + acceptable strength + easy to manufacture - leakage current possible - additional material remains in structure	+ high process reliability + no leakage current + no corrosion problems + acceptable strength + constant melt on - additional material remains in structure

Resistance Welding as a Basis for Assembling – Shear Test
(Partly contributed from DLR Internal Projects)

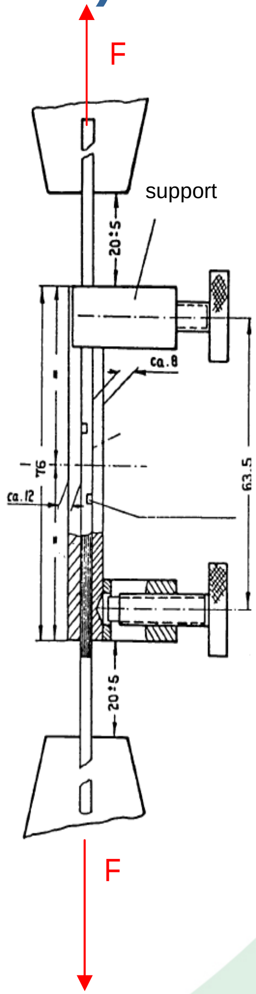


Generals

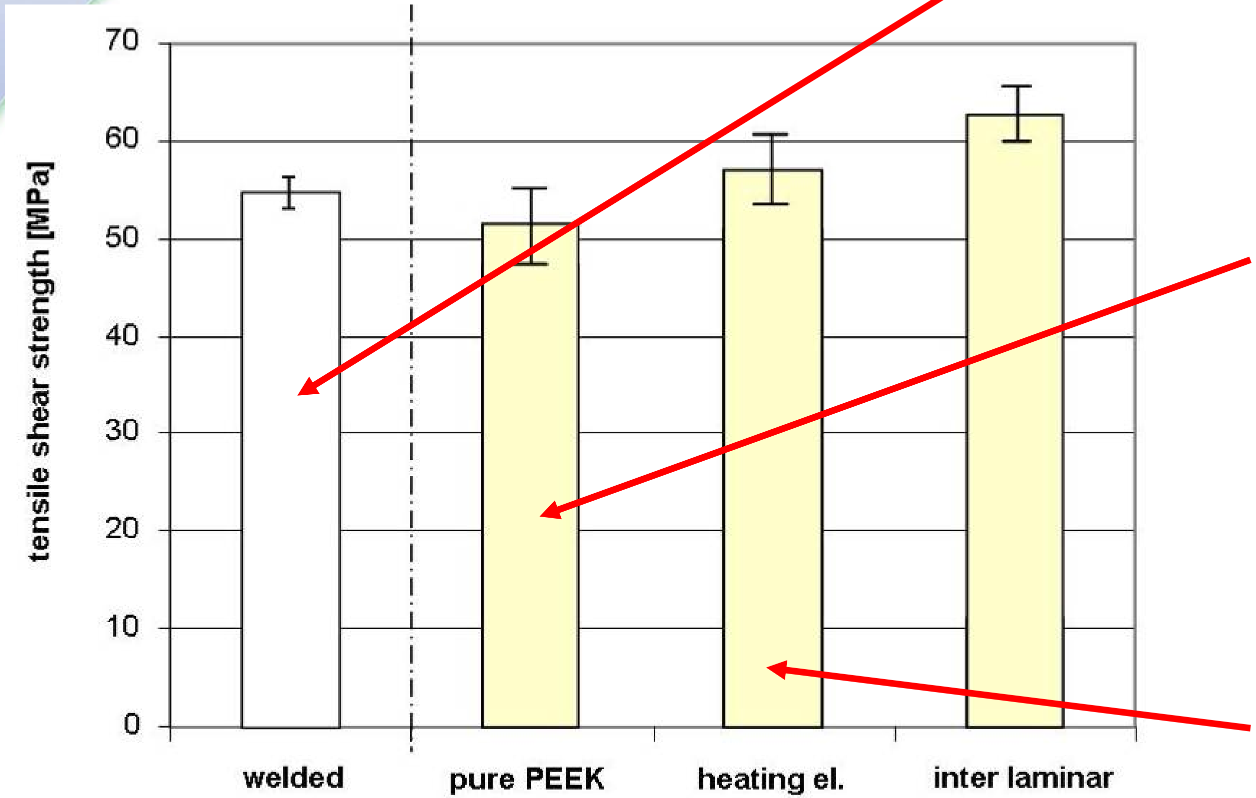
- welding size: 200mm x 40mm
- specimen preparation and testing according to ASTM D1002 and QVA-Z10-46-9

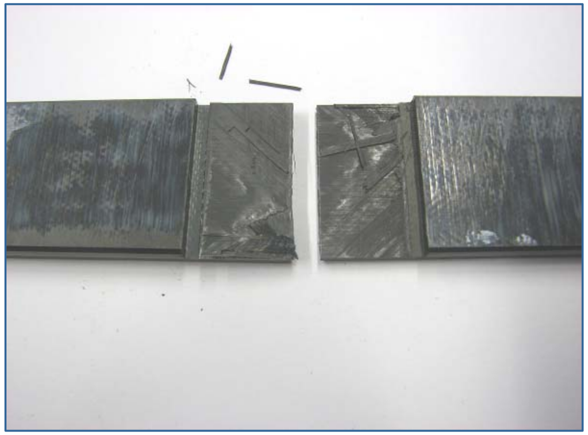
Advantages

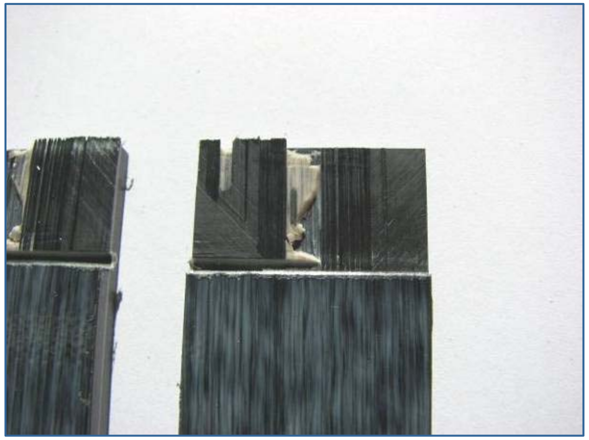
- no fringe effects in the test area
- larger welding areas

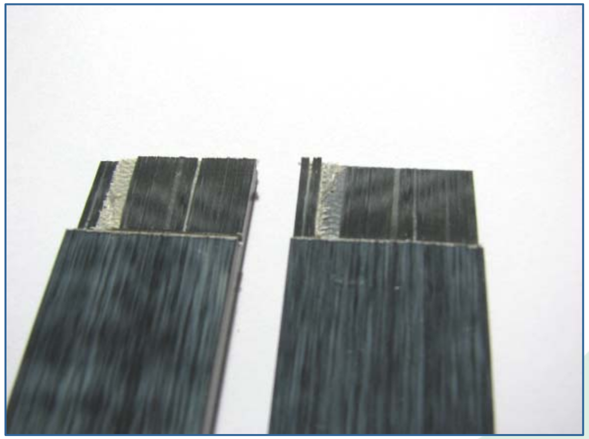


Shear Strength of Welded Joint



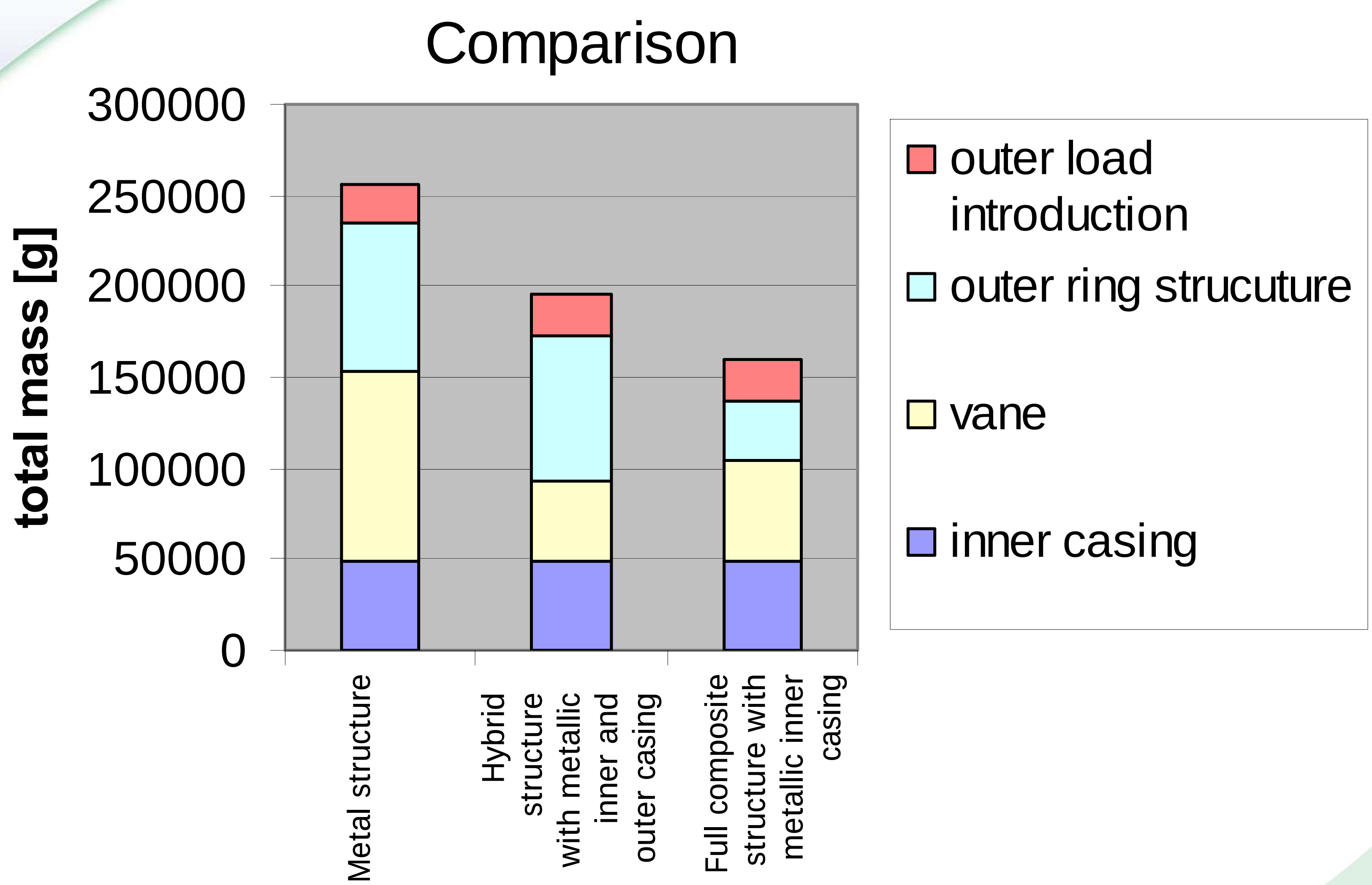






consolidated references   welded specimen

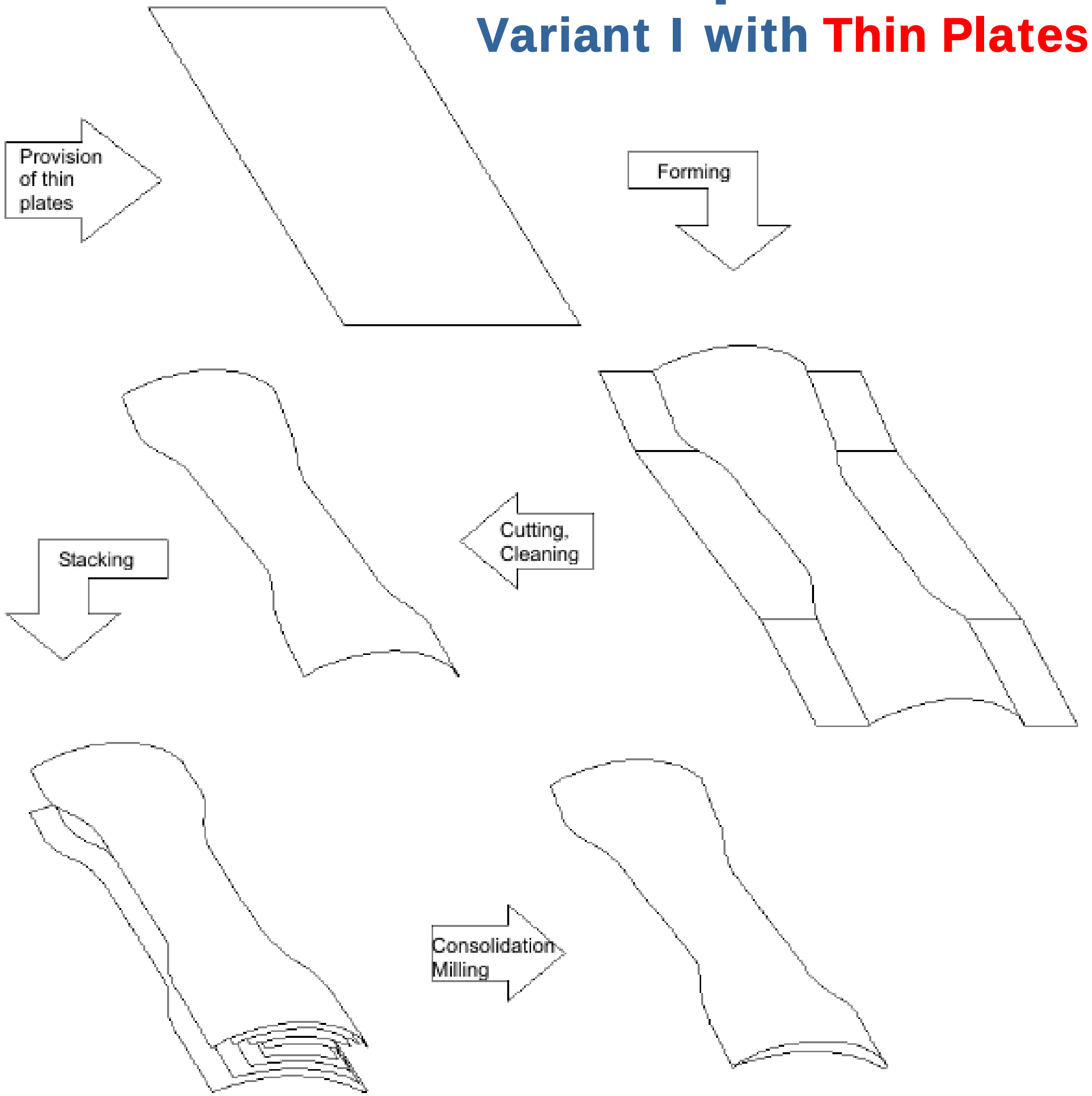
Weight Estimation of Different Design Approaches



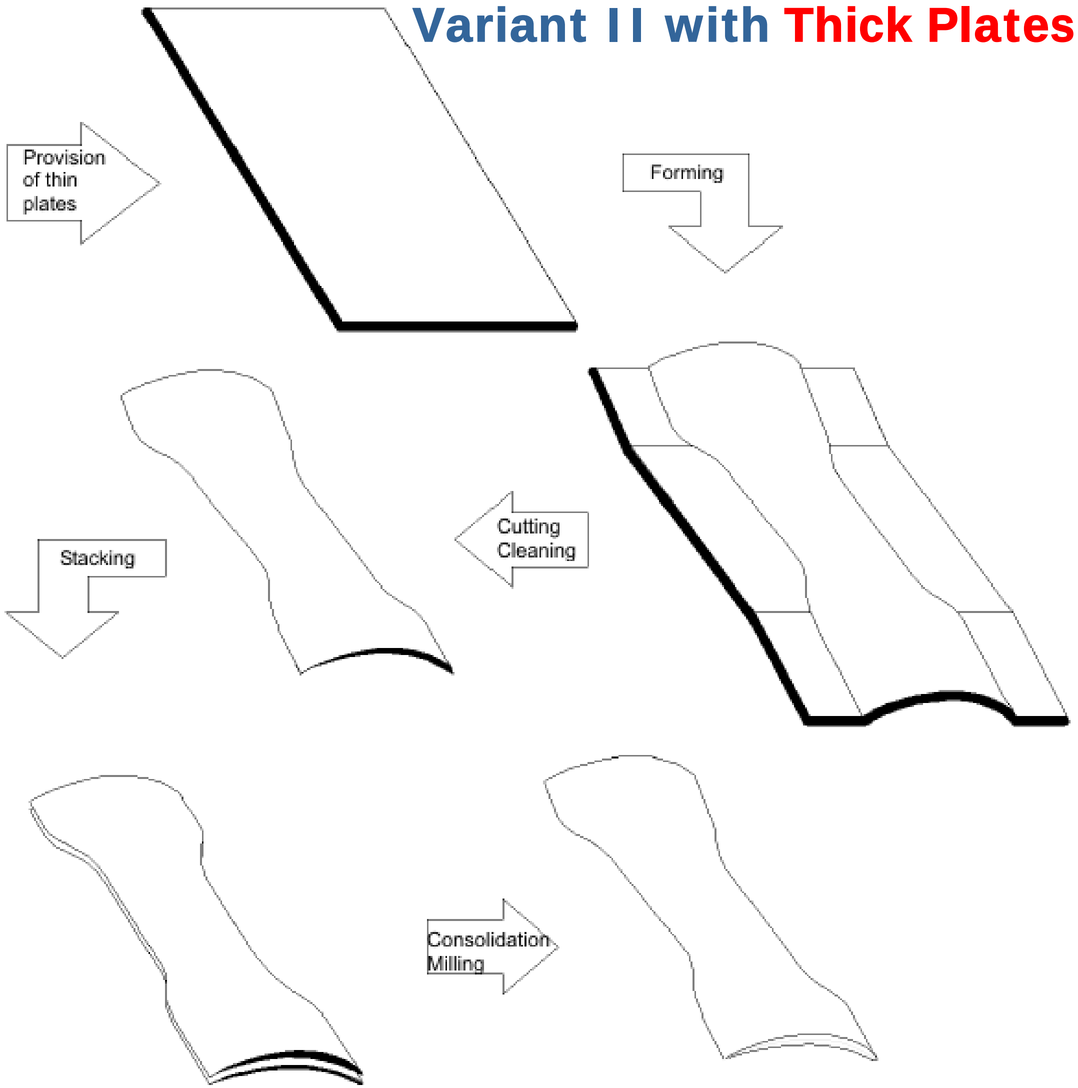
Manufacturing of a Thermoplastic Vane

Variant I with Thin Plates

- Provision of thin plates
- Forming of thin plates
- Cutting of thin formed plates
- Cleaning and surface preparation of pre cuts
- Stacking of pre cuts within a mould
- Consolidation of the vane
- Final milling of edges and drilling of holes



Manufacturing of a Thermoplastic Vane
Variant II with Thick Plates



- Provision of thick plates
- Forming of plates
- Cutting and milling of formed plates
- Cleaning of milled pre cuts
- Stacking of pre cuts within a mould
- Consolidation of the vane
- Final milling of edges and drilling of holes

Manufacturing Facility for Production of thermoplastic Vane

transport unit where the plates are mounted

infrared heat field

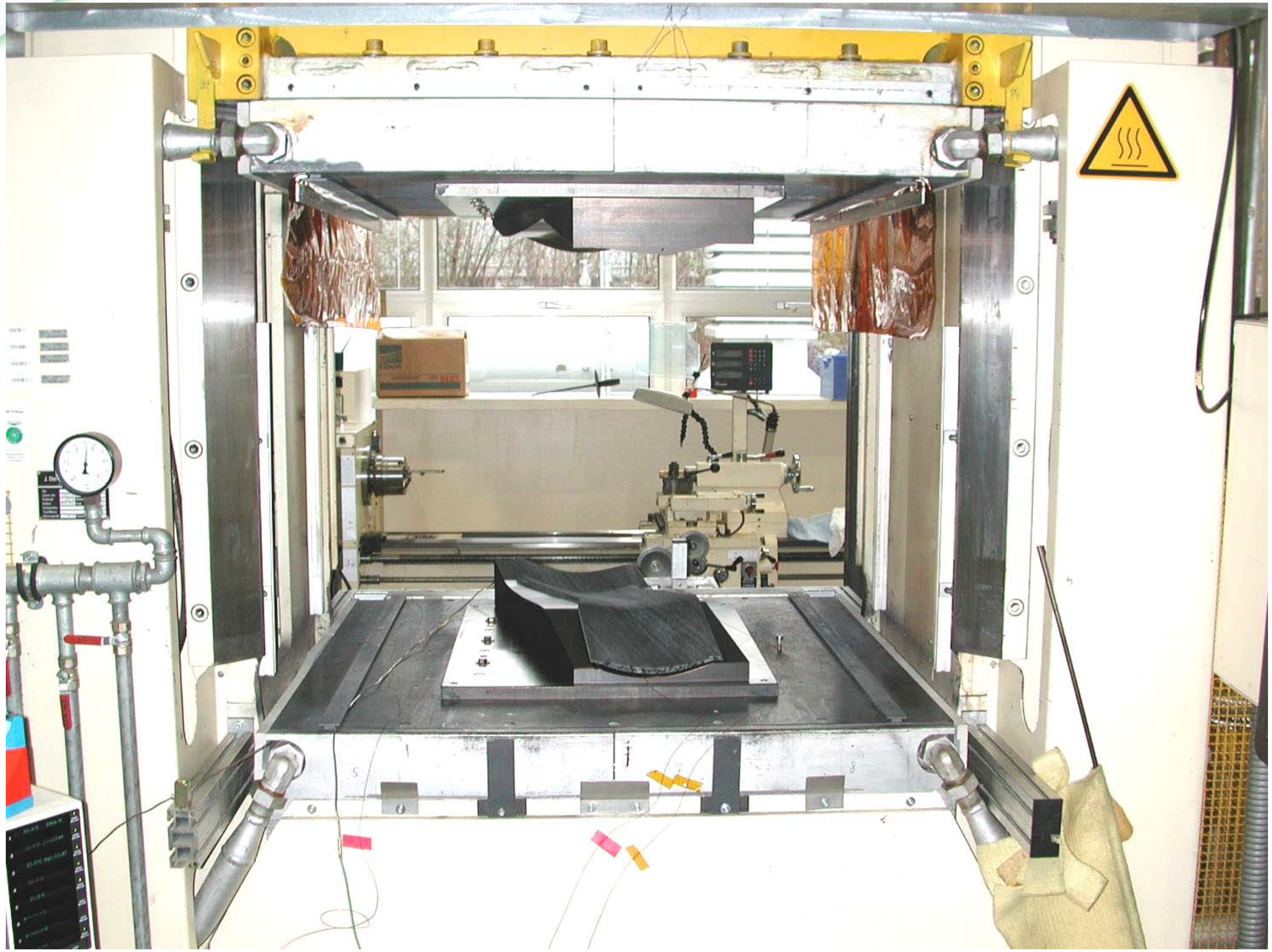
heatable press

Forming, Cutting and Positioning of Thin Pre-Cut Plates

Manufacturing of prototype variant I

- Positioning of single layers has been done by laser projection – Optimisation by using simple centring bolts
- Additional matrix material was added in terms of piecewise foil – Need to be replaced by coating technology
- Geometry of vane need to be adapted to material characteristics – minor change of vane geometry respectively change of ply thickness is necessary to reduce manufacturing complexity

Consolidated Blade in the Open Press

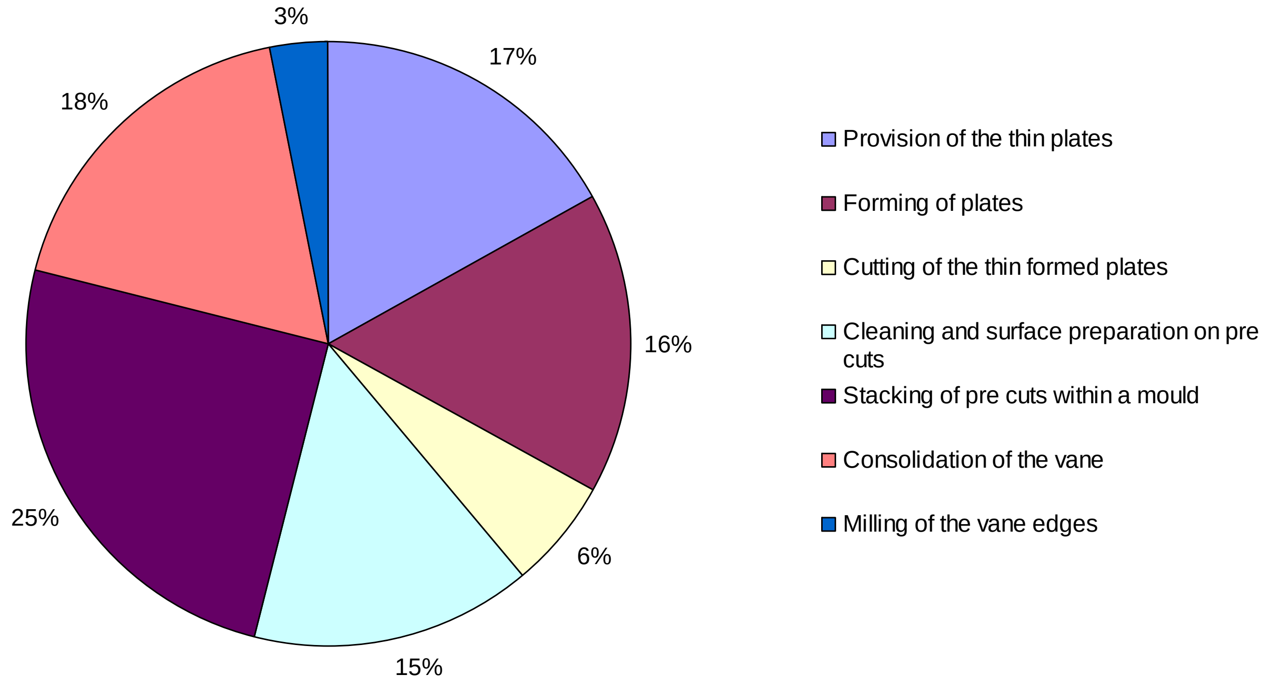


Final Vane for Test

- Two vanes were manufactured up to now
- Final processing step consists of machining leading and trailing edge respectively clamping areas of the vane
- Processing of the vane geometry was the fundament of cost estimation together with RRD

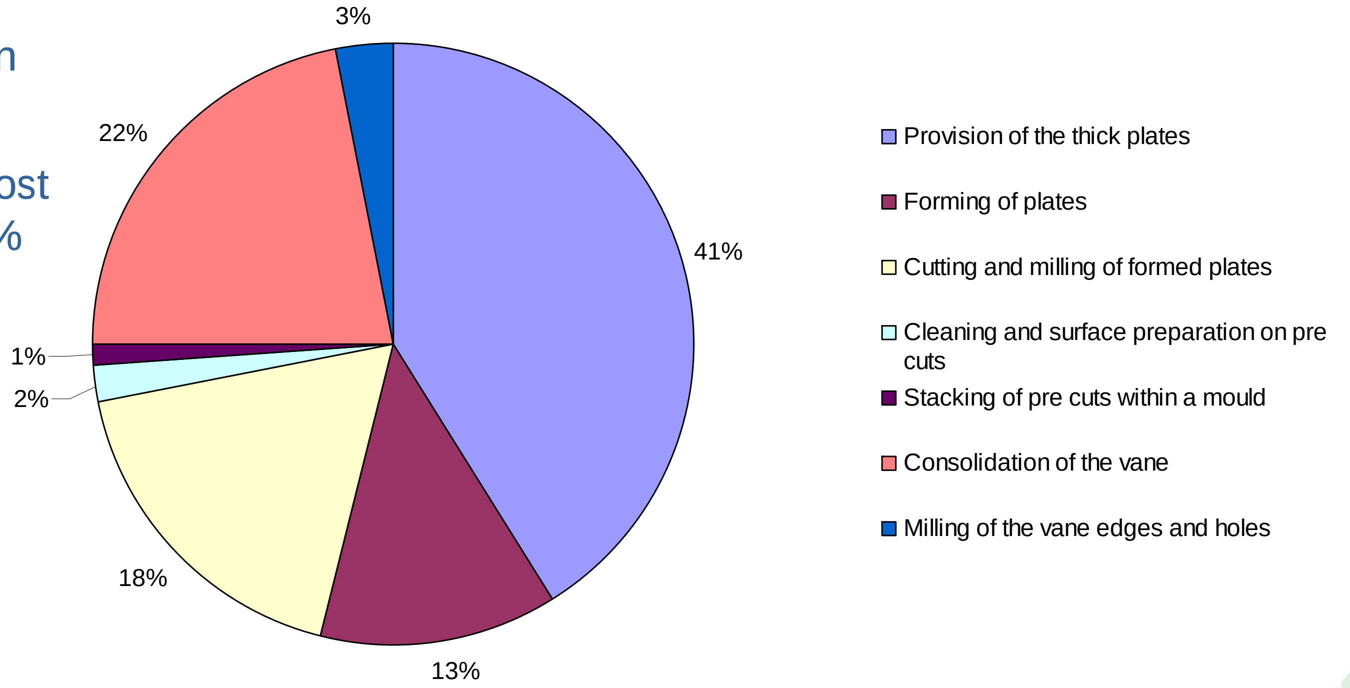
Cost Assessment Variant I

- Estimated costs are competitive to existing design alternatives (statement RRD)
- Cost assessment based on measured time during production of prototype and detailed analysis of procedures
- Optimization of manufacturing processes were taken into account too
- handling systems need to be integrated in an automated manufacturing process



Cost Assessment Variant II

- Cost assessment based on experience of variant I
- Variant II offers further cost reduction potential of 17% with a view to reduced stacking effort



Conclusion

- Technical feasibility of thermoplastic fan structures could be demonstrated
- Further optimisation with view to automation is necessary to reach maximum cost effectiveness
- Technological potential offers possibility of new design concepts