

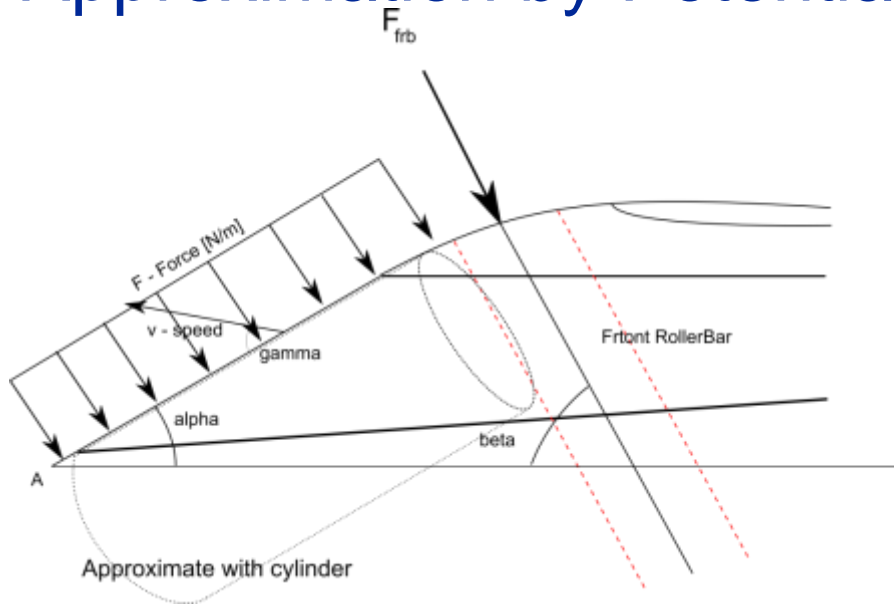


2011-03-27

# Cockpit Fluid & Solid mechanics considerations

Foto: [offshoreracing.se](http://offshoreracing.se)

# Approximation by Potential flow



## Uniform stream + Dipole

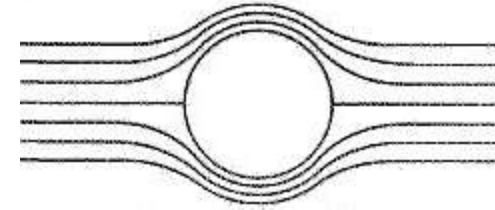
$$kar2pol := [x = r \cos(\theta), y = r \sin(\theta)]$$

$$\phi_{us} := V_{\infty} r \cos(\theta)$$

$$\psi_{us} := V_{\infty} r \sin(\theta)$$

$$\phi_d := \frac{C \cos(\theta)}{r}$$

$$\psi_d := -\frac{C \sin(\theta)}{r}$$



## Velocity on the surface (r=R) & some math

$$U_R := 2 \sqrt{V_{\infty}^2 \sin^2(\theta)}$$

## Example data from Hydrocat cockpit

$$V_b = 45 \text{ m/s} = 87 \text{ knots}$$

$$\rho = 1025 \text{ kg/m}^3$$

$$R = 0.32 \text{ m}$$

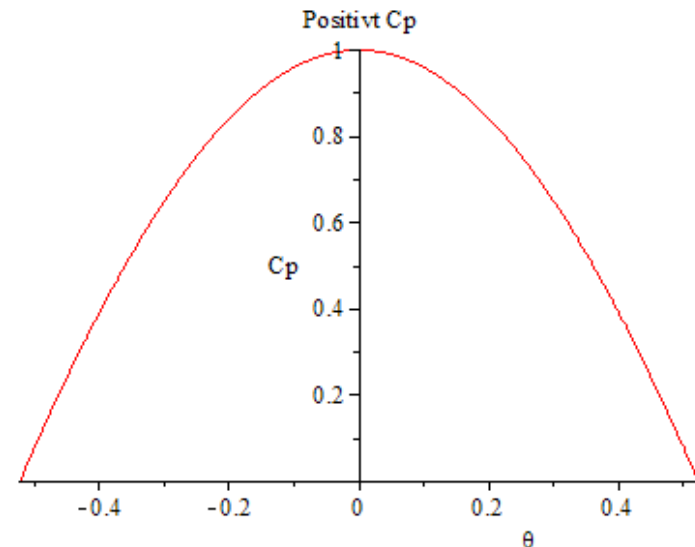
$$L = 0.8 \text{ m}$$

From Bernoulli equation we get Pressure Coefficient

$$C_p := 1 - \frac{U_R^2}{V_{\infty}^2} \quad C_p := 1 - 4 \sin^2(\theta)$$

Calculating  $\theta$ -values and solving for zero  $C_p$  to get integration boundaries (pressure -> dilatation)

$$\theta_{rv} := \frac{1}{6} \pi, -\frac{1}{6} \pi$$

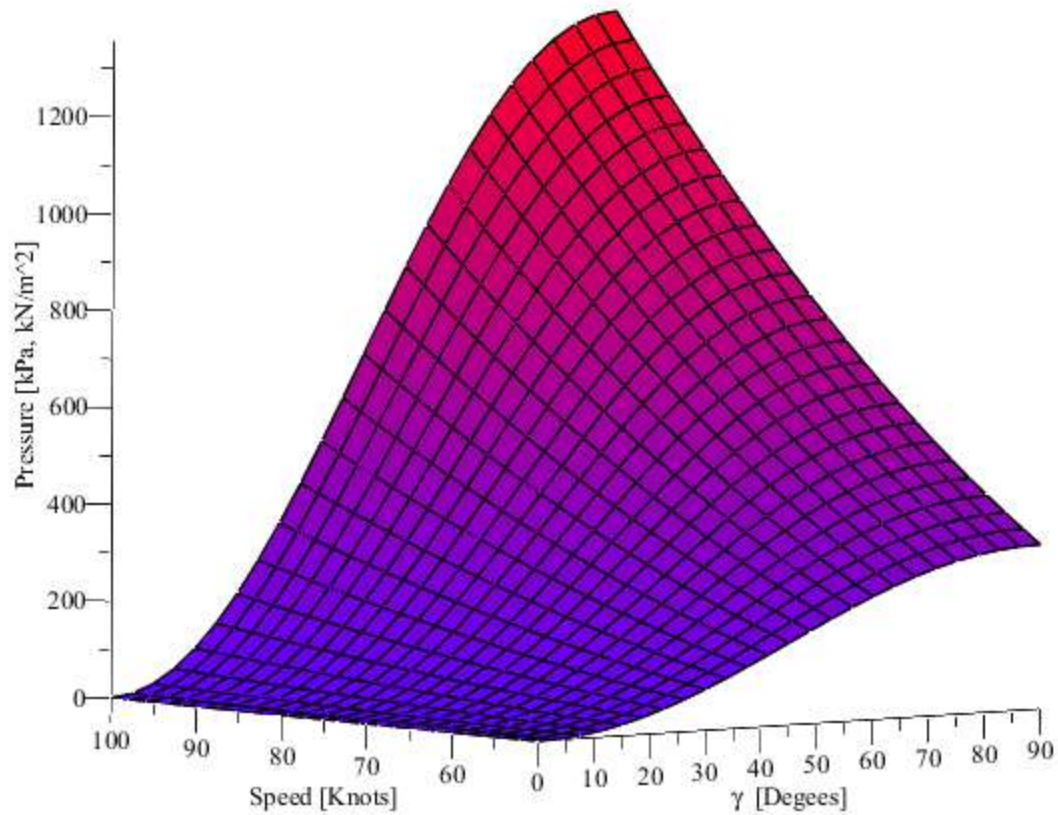


# Boat kinematics

Velocity  $V$  and dynamic pressure  $p := \frac{V^2 \cdot \rho}{2}$ ;

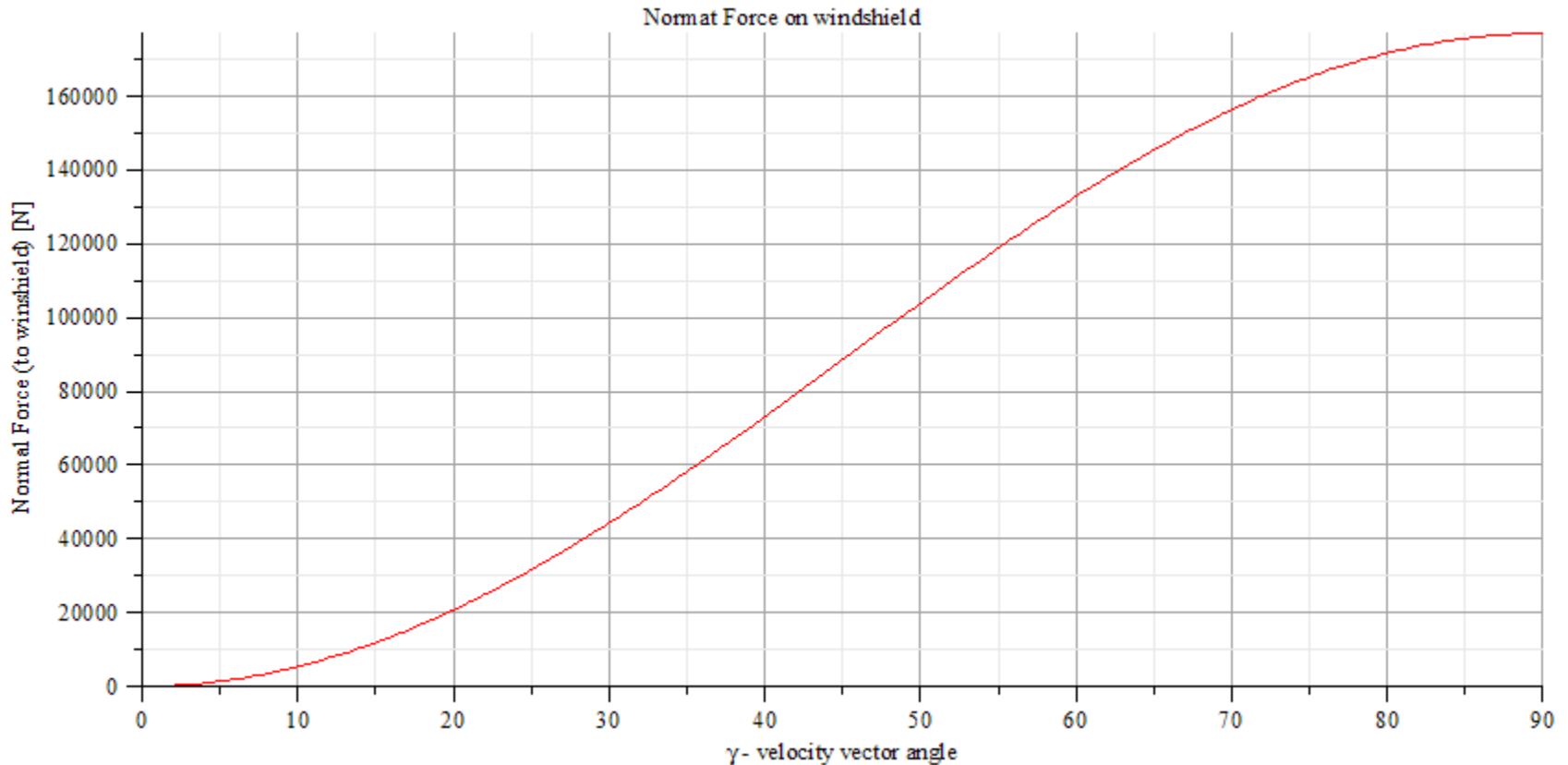
$$V := vb \sin(\gamma) \quad p := \frac{1}{2} vb^2 \sin(\gamma)^2 \rho$$

Dynamic Pressure ( $\rho=1025 \text{ kg/m}^3$ )



## Forces from the impact

$$F = \int p C_p dA = \int p C_p L R \cos(\theta) d\theta \quad F := \frac{1}{3} L R V b^2 \sin(\gamma)^2 \rho$$

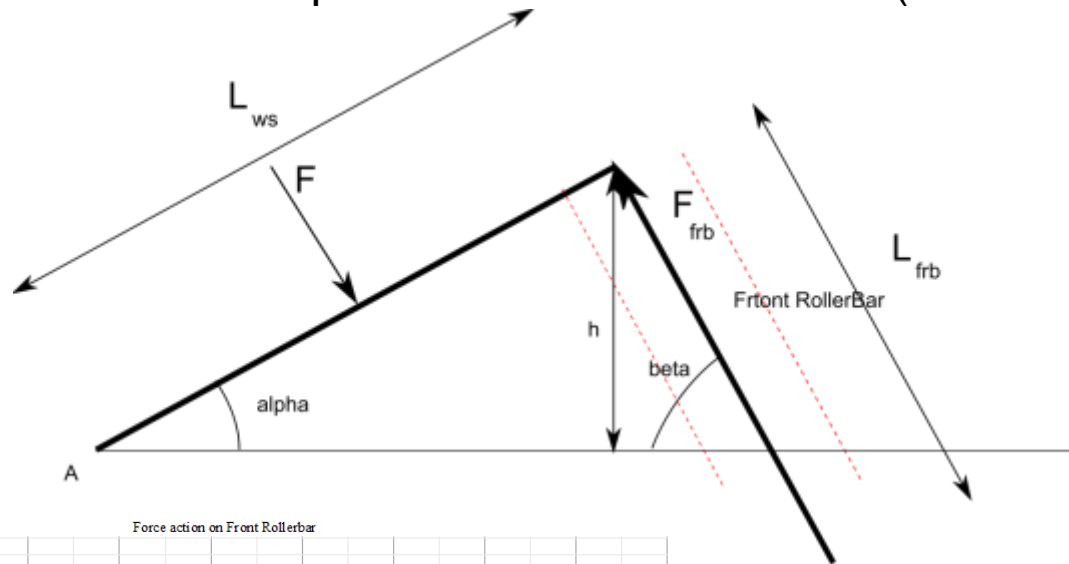


### Crash type “Roll“ in 45 m/s = 87 knots

Here we assume that the boat rotates 180 degrees around the x-axis (speed direction) and the whole of CP penetrates the water, this case can give  $\gamma = 40$  degrees  $\rightarrow$  Force  $\sim 74$  kN

More types of impact analysis for example dives, roll, loop, etc. ...

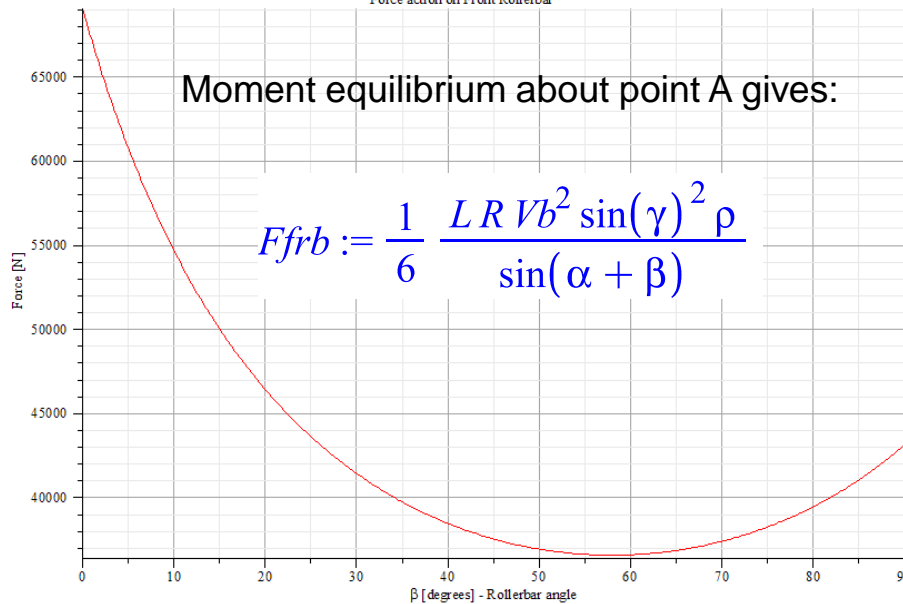
# Distribution of impact forces at the structure (ie front rollerbar)



Force action on Front Rollerbar

Moment equilibrium about point A gives:

$$F_{frb} := \frac{1}{6} \frac{L R V b^2 \sin(\gamma)^2 \rho}{\sin(\alpha + \beta)}$$



The minimal force in Rollerbar is at  $\beta = 58$  degrees, which means that the RB should preferably be orientated perpendicular windshield to minimize structural loads.

Due to other circumstances (vision field for the driver) it is not a good idea to choose this optimum  $\beta$ -value. For our geometry the most appropriate angle is  $\beta = 70-80$  degrees.

**Ffrb ~ 37 kN**

# FEM analysis on front roll bar

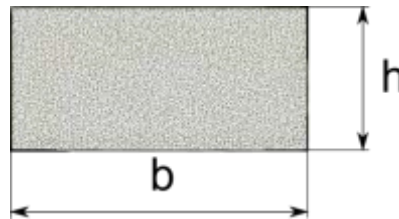
Roll bar with rectangular cross section, homogeneous (without core material) made of uni-axial E-glass and iso-polyester as matrix.

$F_n = -37000/0.5$ ; Distributed load [N/m]

$F_t = -37000/0.36/2$ ; Distributed load (half of  $F_n$ ) [N/m]

Element stiffness and element load matrices


- $E=23e9$ ; From ud\_01.pdf
- $b = 0.1$ ;  $h = 0.025$ ;
- $A1 = b*h$ ;  $A2 = A1$ ;
- $I1 = b*h^3/12$ ;  $I2 = I1$ ;



ISO 12 215-5

$w_f = 0.5$  fibre content by weight

$$\sigma = 1800w_f^2 - 1400w_f + 510 = 260 \text{ MPa}$$



Cert. No.: K-3363  
File No.: 332.50

**Product description**

EU; Uni-axial (0°) - (200-1500 g/m<sup>2</sup>) with and without chopped strand mats (100-500 g/m<sup>2</sup>).  
EN; Uni-axial (90°) - (90-750 g/m<sup>2</sup>) with and without chopped strand mats (100-500 g/m<sup>2</sup>).

Style no. example: S14EU990-00770-01300-487310 (ref. SAERTEX Style-Number-System)

**Legend:**  
S: Saerbeck  
E: E-Glass  
U: Unidirectional 0°  
N: Unidirectional 90°

**401 MPa**

The following indicative properties have been verified by **Type Testing of laminates:**

Property	Test Method	Result	Unit	Mean
Tensile Strength - Longitudinal	ASTM D3019	401	MPa	mmv
Tensile Modulus - Longitudinal	ASTM D3019	23 113	MPa	mmv
Tensile Elongation - Longitudinal	ASTM D3019	2.0	%	mmv
Glass content	ASTM D2584	50.1	%	mean
Resin	Synthesac 281 - 30			
Curing Procedure for Type Testing	24 hrs at room temperature, 24 hrs at 60°C			

msmv - Manufacturer's Specified Minimum Value (verified to be below mean - 2 standard deviation of Type Test results)  
msv - Manufacturer's Specified Value (verified to be within mean - 10% of Type Test results)  
mean - Mean of Type Test results

**Type Approval documentation**

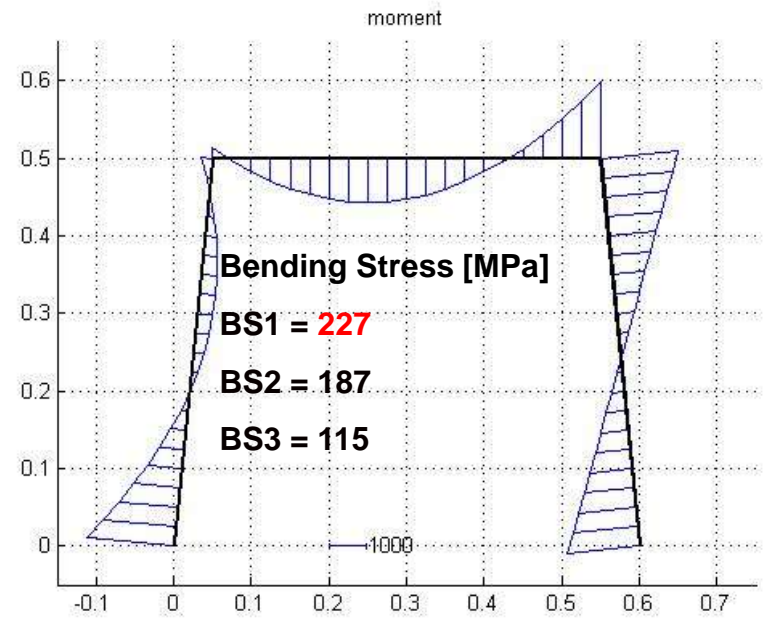
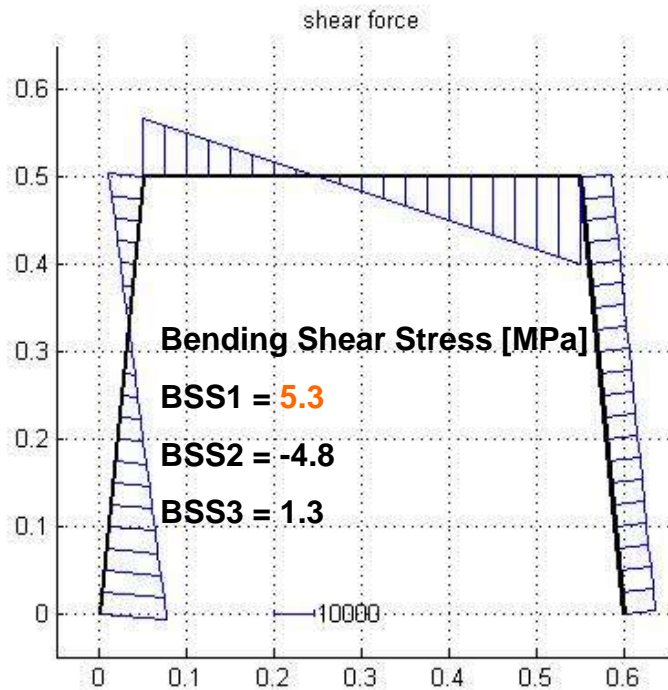
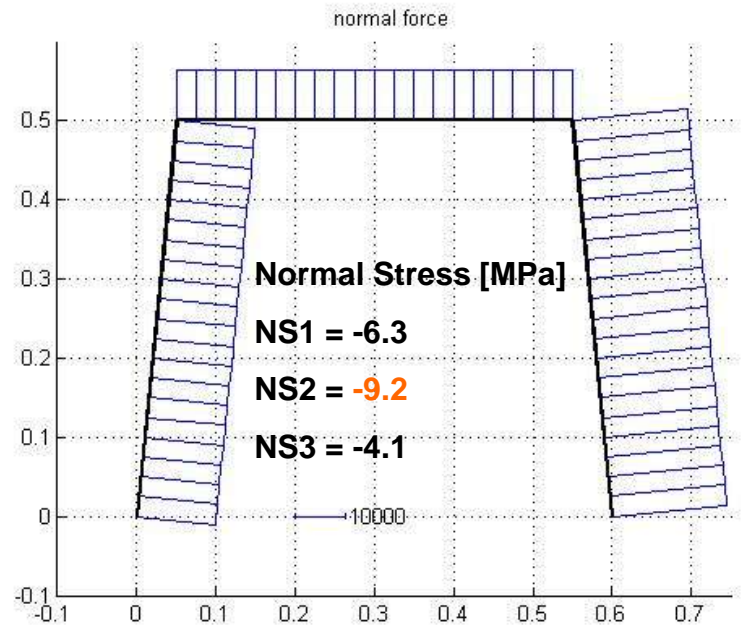
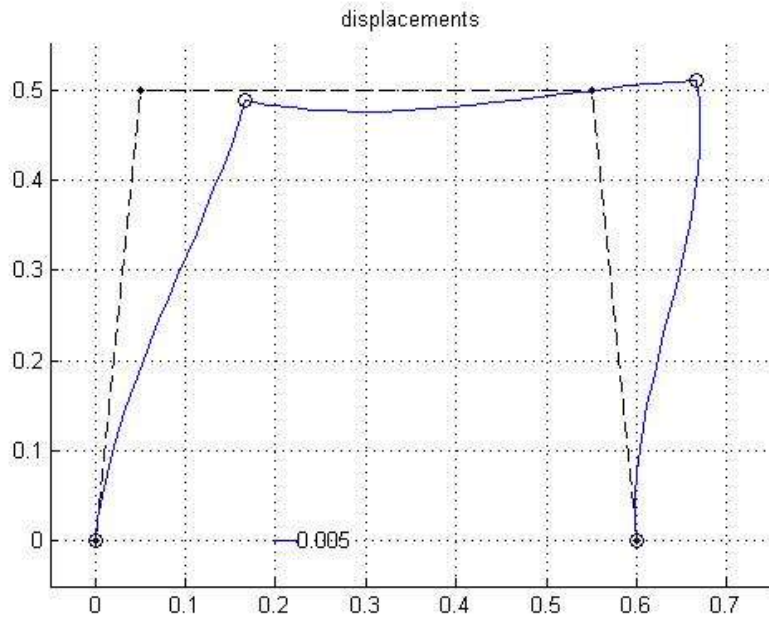
1. Previous Type Approval Certificate K-2902.
2. Telefax from SAERTEX of 2007-09-28.
3. Survey report from DNV Essen of 2007-11-02.

**Tests carried out**

Type Testing carried out according to **Type Approval documentation**.

**Marking of product**

Product shall be marked with *manufacturer's name*: SAERTEX GmbH & Co. KG, *Saerbeck, Germany* and *type designation*: EU; Uni-axial (0°) - (200-1500 g/m<sup>2</sup>) with and without chopped strand mats (100-500 g/m<sup>2</sup>), EN; Uni-axial (90°) - (90-750 g/m<sup>2</sup>) with and without chopped strand mats (100-500 g/m<sup>2</sup>)



# Some thoughts about hatches

