DD3MAT – a code for yield criteria anisotropy parameters identification.

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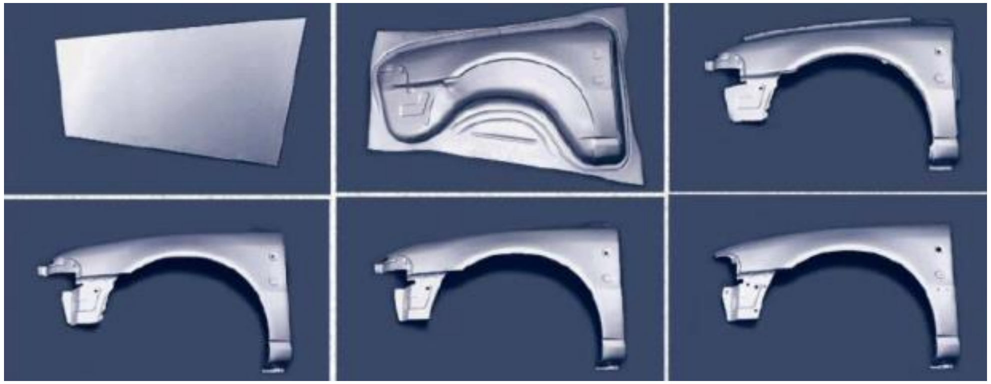
Agenda

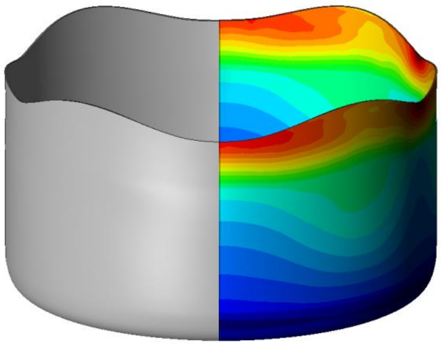
- Motivation
- Objectives
- DD3MAT code
- Results
- Conclusions

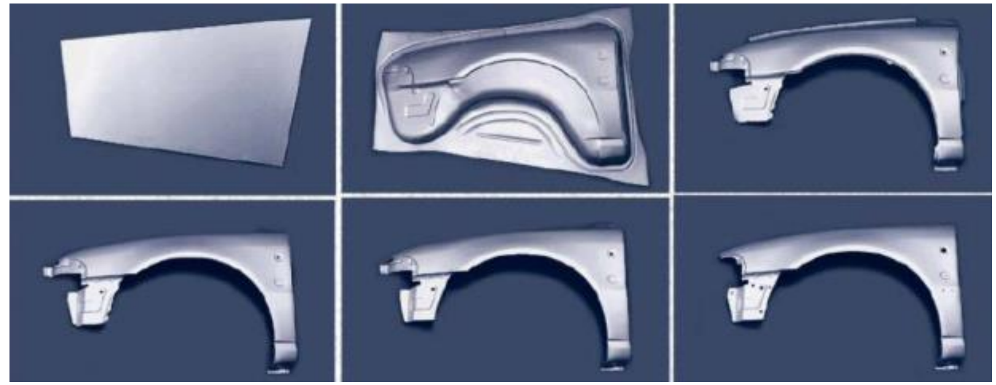
Nowadays, sheet metal forming processes are designed and optimized virtually.



The use of Finite Element Analysis allows

- Decrease in time to market life cycle;
- Notable savings in terms of money, time and effort in the design, production and set-up of new formed parts.





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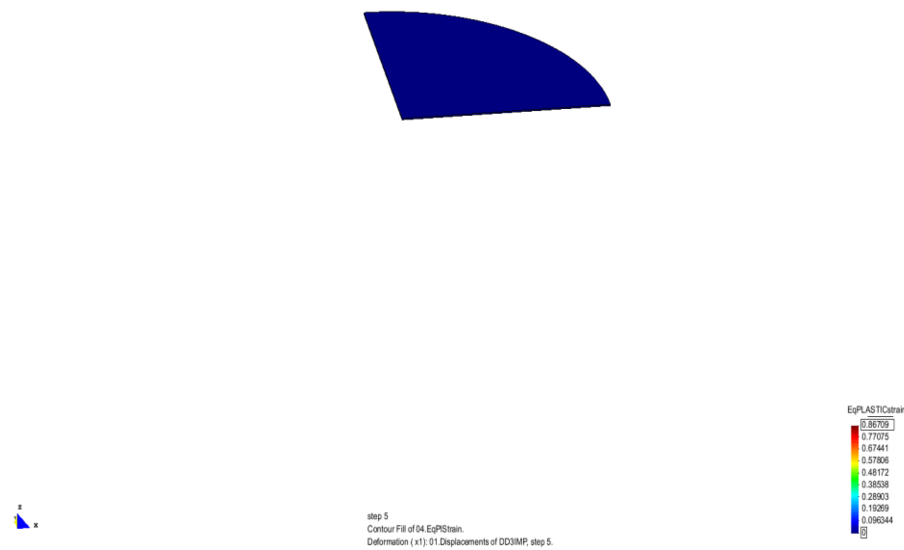

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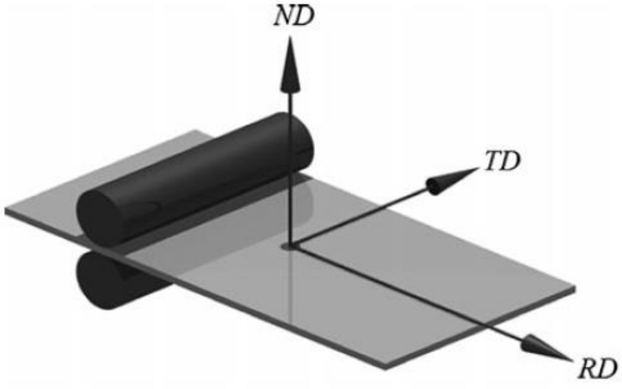
Sheet metals generally exhibit anisotropy of their mechanical properties.

The rolling process induces a particular anisotropy characterized by the symmetry of the mechanical properties with respect to the three orthogonal planes, i.e. orthotropy.



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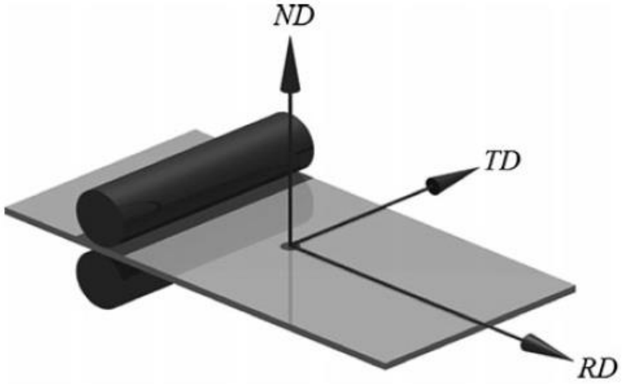

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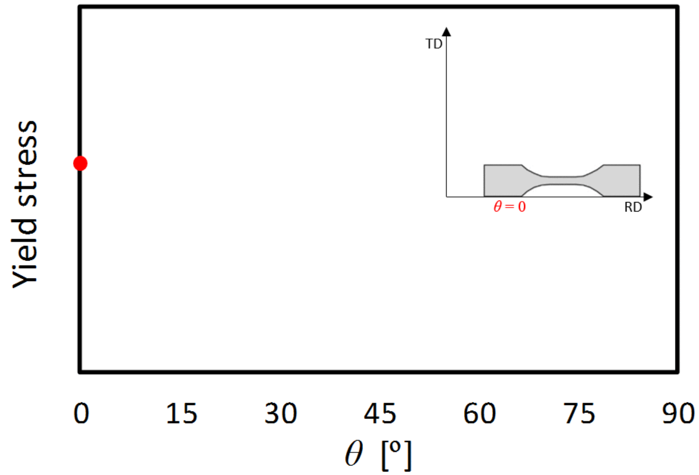


Plastic response in metals

Micro scale

Polycrystalline texture models

- More precise
- More complex
- Numerically expensive

Macro scale

Phenomenological models

- Less precise
- Less complex
- Much more numerically efficient

Plastic response in metals

Phenomenological models

- Yield surface
- Flow rule
- Hardening law

The anisotropy parameters must be identified such that the yield criterion reproduces the material's mechanical behaviour as close as possible

Anisotropy parameters identification for three different yield criteria:

- YLD91
- CB2001
- CPB06

Material: 2090-T3 aluminum alloy

- Verify the capability to predict variations of the Uniaxial Tensile Stress and *r*-values in the plane on the sheet metal
- Sensitivity to user’s input on the experimental data fitting
- Impact of the yield stress and *r*-values directionalities in the drawing of a circular cup

The DD3MAT code allows identifying anisotropy parameters for several yield criteria implemented in the FE in-house code DD3IMP:

- Hill' 48
- YLD91
- KB93
- CB2001
- Drucker+L
- CPB06 and CPB06ex2

- User's input through weighting coefficients
- Possible to consider the identification for given levels of plastic work
- Downhill Simplex Method

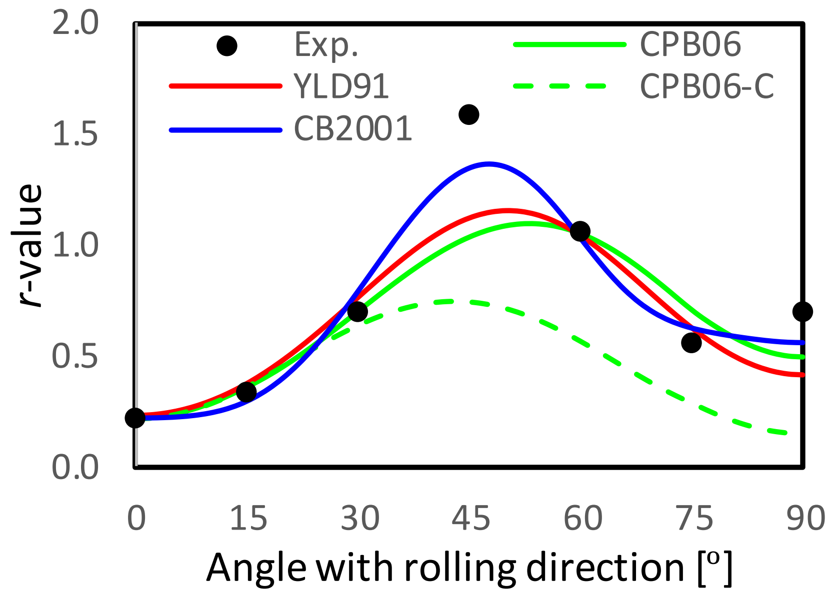
Objective funtion

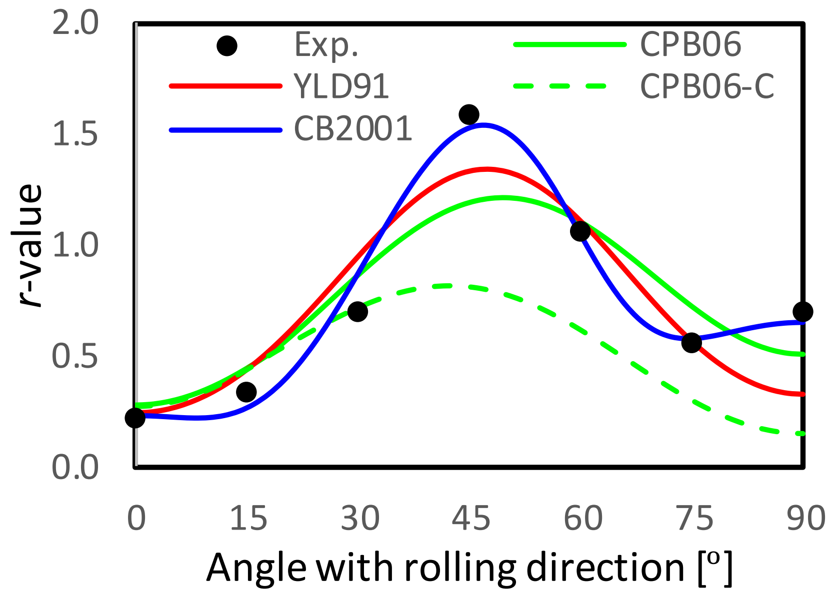
$$F(\mathbf{A}) = \sum_{\theta=0}^{90} w_{\sigma_\theta^T}\left(\sigma_\theta^{Y_T}(\mathbf{A})/\sigma_\theta^{Y_T} - 1\right)^2 + \sum_{\theta=0}^{90} w_{\sigma_\theta^C}\left(\sigma_\theta^{Y_C}(\mathbf{A})/\sigma_\theta^{Y_C} - 1\right)^2 + \sum_{\theta=0}^{90} w_{r_\theta}\left(r_\theta(\mathbf{A})/r_\theta - 1\right)^2$$
$$+ w_{\sigma_b}\left(\sigma_b(\mathbf{A})/\sigma_b - 1\right)^2 + w_{r_b}\left(r_b(\mathbf{A})/r_b - 1\right)^2$$

$\mathbf{A}$	- set of anisotropy parameters
$\sigma_\theta^{Y_T}$, $\sigma_\theta^{Y_C}$	- experimental yield stresses in tension and compression
r_θ	- experimental *r*-values
σ_b	- experimental biaxial yield stress
r_b	- experimental disc compression test *r*-value

Minimization of an error function, which evaluates the difference between the estimated values and the experimental ones

r-values evolution

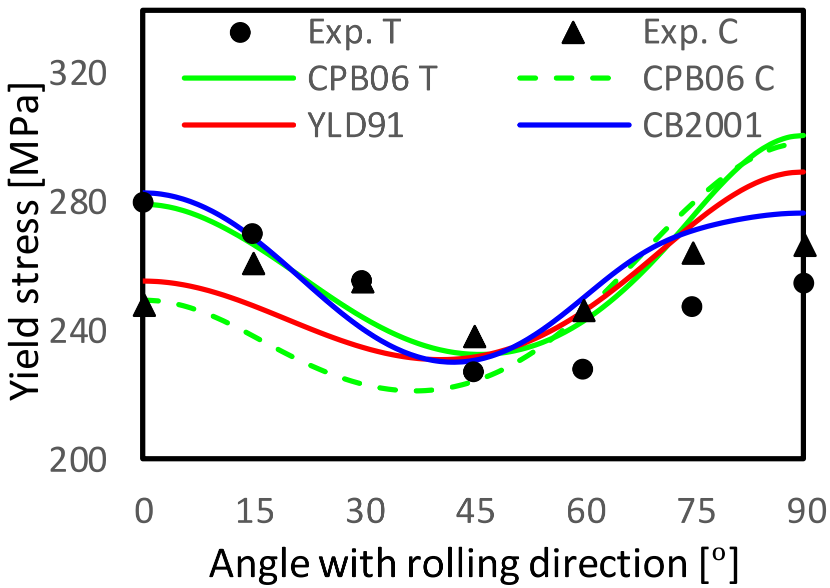


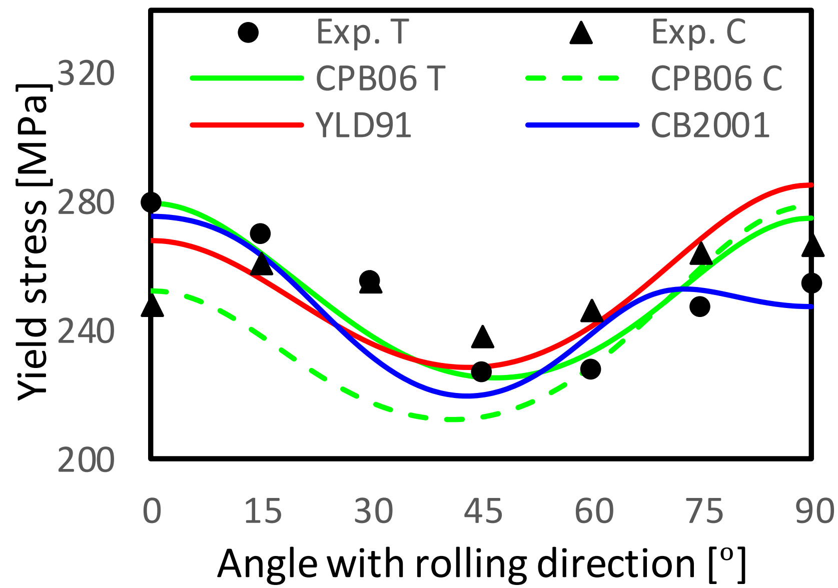


All weights equal to 1.0.

CPB06 $w_{r_{45}} = 5$

Yield stresses evolution





All weights equal to 1.0.

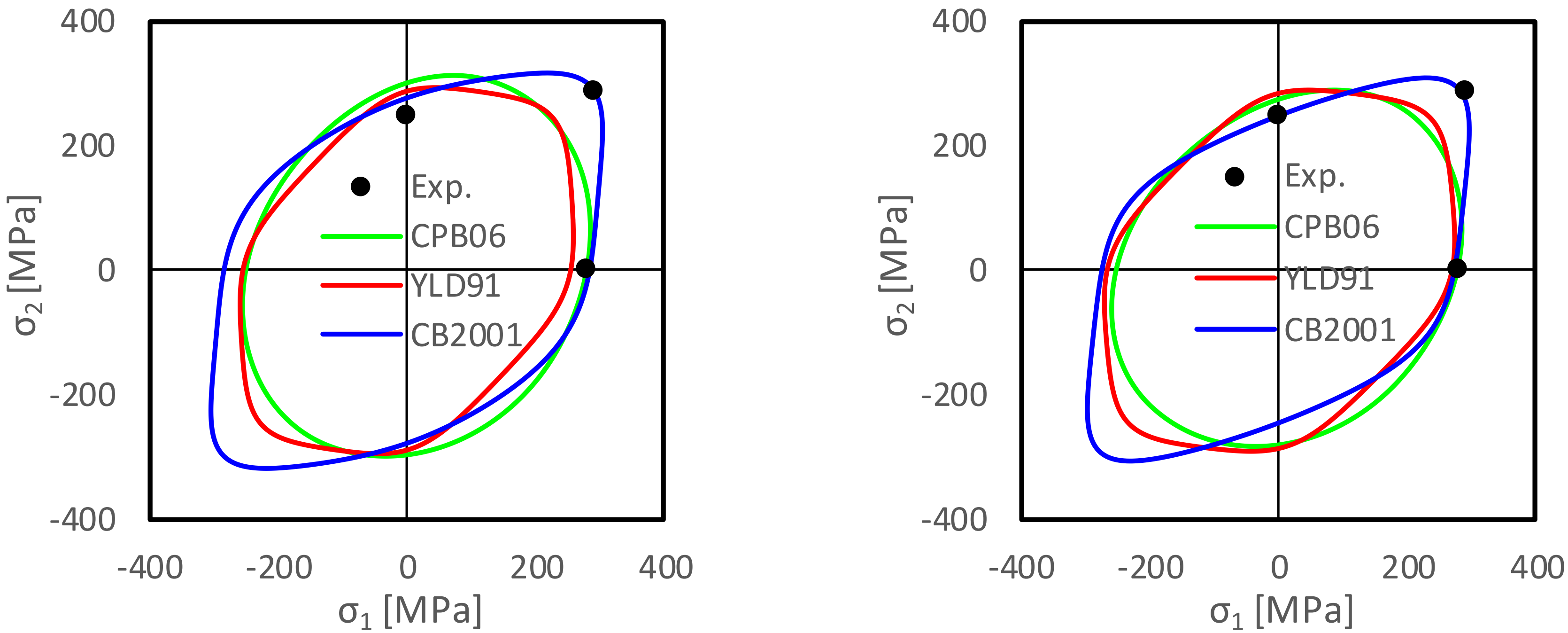
CPB06

$$w_{\sigma_{15}^C} = w_{\sigma_{90}^C} = 40$$

$$w_{\sigma_{30}^C} = w_{\sigma_{45}^C} = w_{\sigma_{60}^C} = w_{\sigma_{75}^C} = 5$$

$$w_{\sigma_{90}^T} = 30$$

Yield surfaces



All weights equal to 1.0.

CB2001 $w_{\sigma_b} = 20$

YLD91 $w_{\sigma_b} = 20$

CPB06 $w_{\sigma_b} = 20$

Yield criteria parameters

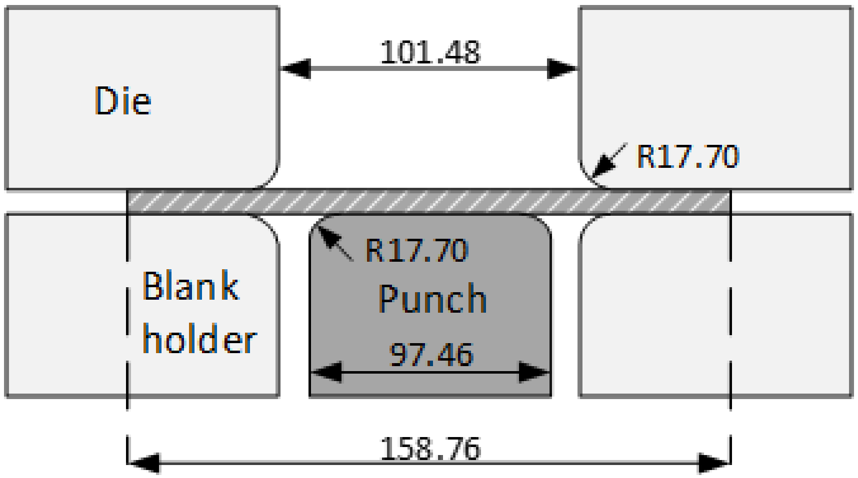
Anisotropy parameters identified for the considered yield criteria

	Set	a_1	a_2	a_3	a_4	b_1	b_2	b_3	b_4	b_5	b_{10}	c
CB2001	1	0.728	1.402	1.334	1.525	3.576	-0.838	-1.983	-0.581	-4.580	-0.567	0.608
	2	1.358	1.848	1.075	1.709	5.357	-0.623	-4.386	-3.654	-6.046	-0.882	0.857

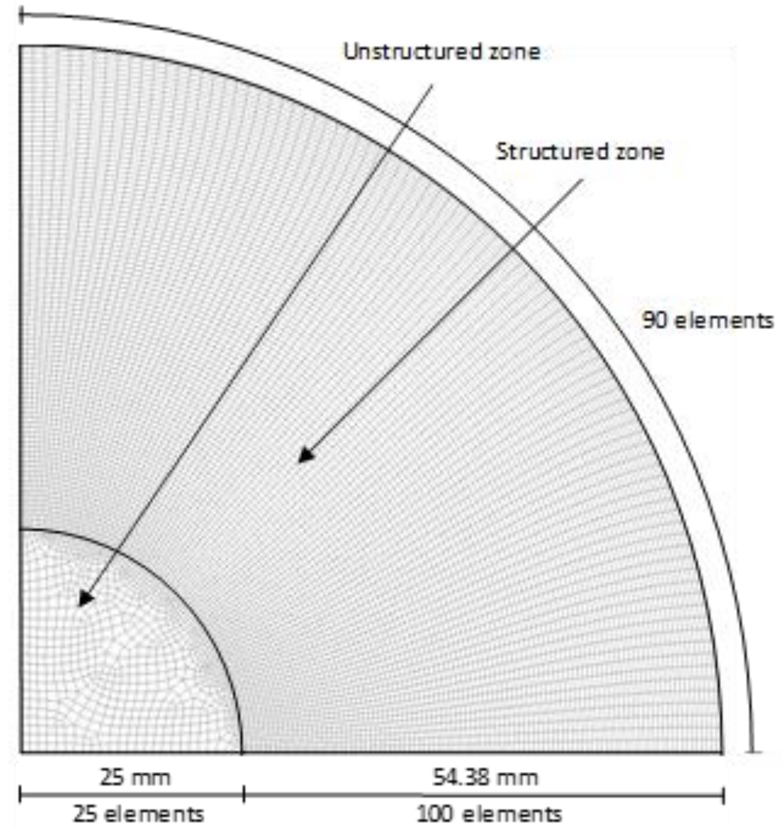
	Set	c_1	c_2	c_3	c_6	m
YLD91	1	1.069	1.300	0.856	1.213	8
	2	1.110	1.224	0.835	1.238	8

	Set	C_{11}	C_{22}	C_{33}	C_{66}	C_{23}	C_{13}	C_{12}	k
CPB06	1	-1.010	0.475	1.199	-1.082	-0.102	0.104	-0.012	-0.057
	2	-0.818	0.449	1.232	-1.224	-0.088	-0.060	-0.819	-0.050

Numerical simulation

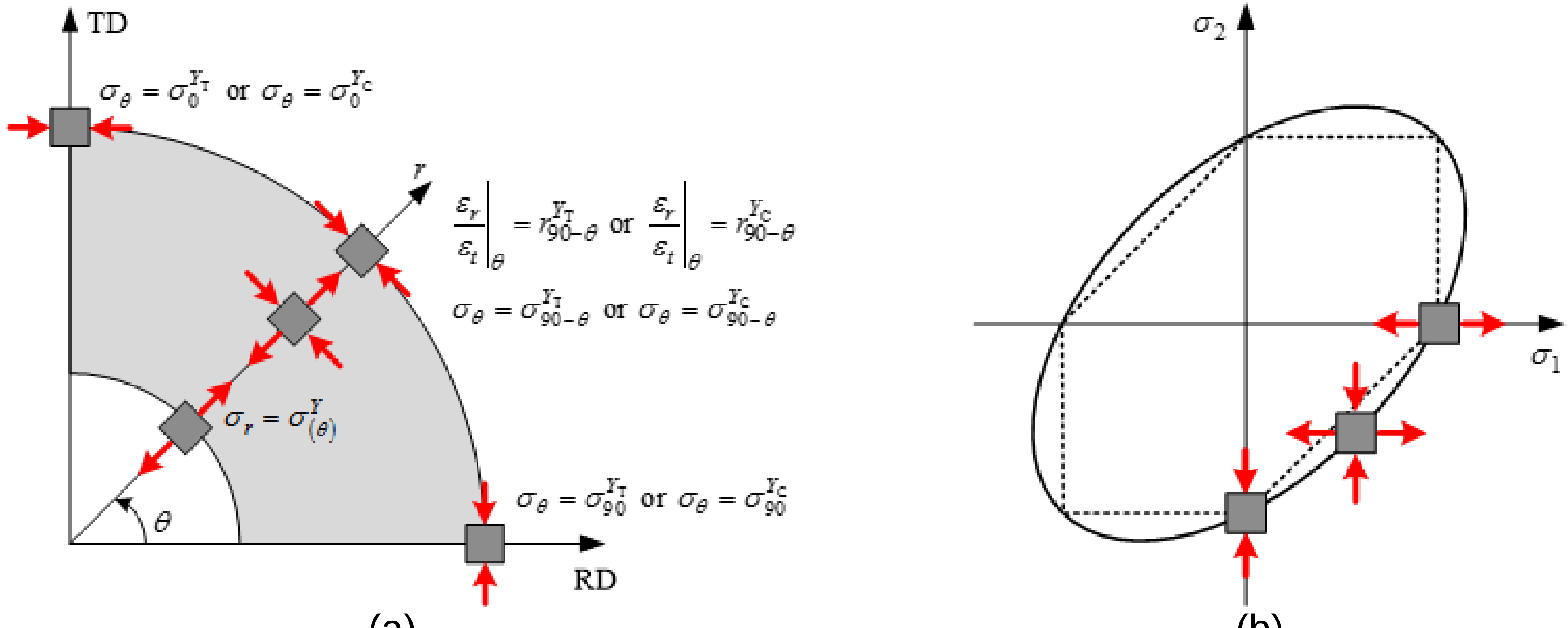


Schematic of the cup drawing and main dimensions.



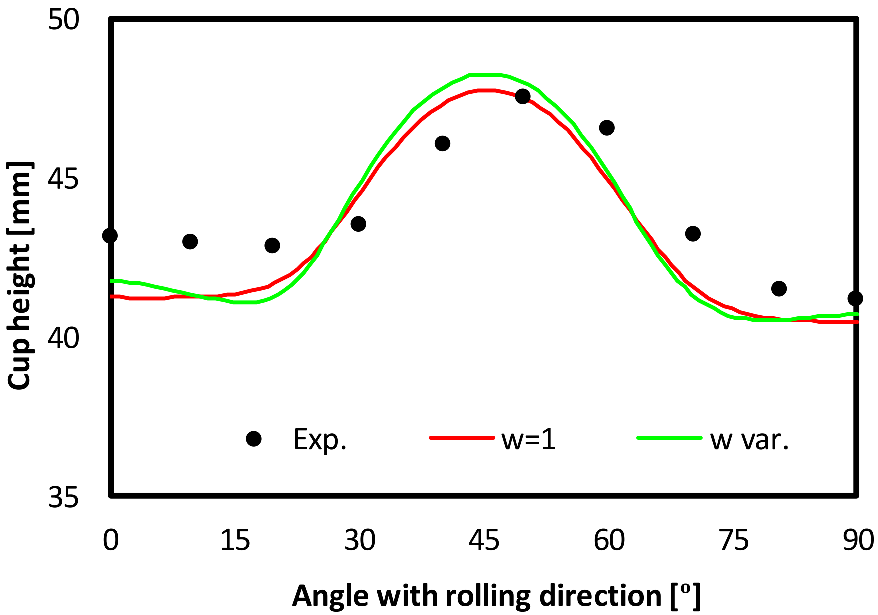
In-plane blank sheet discretization.

Numerical simulation

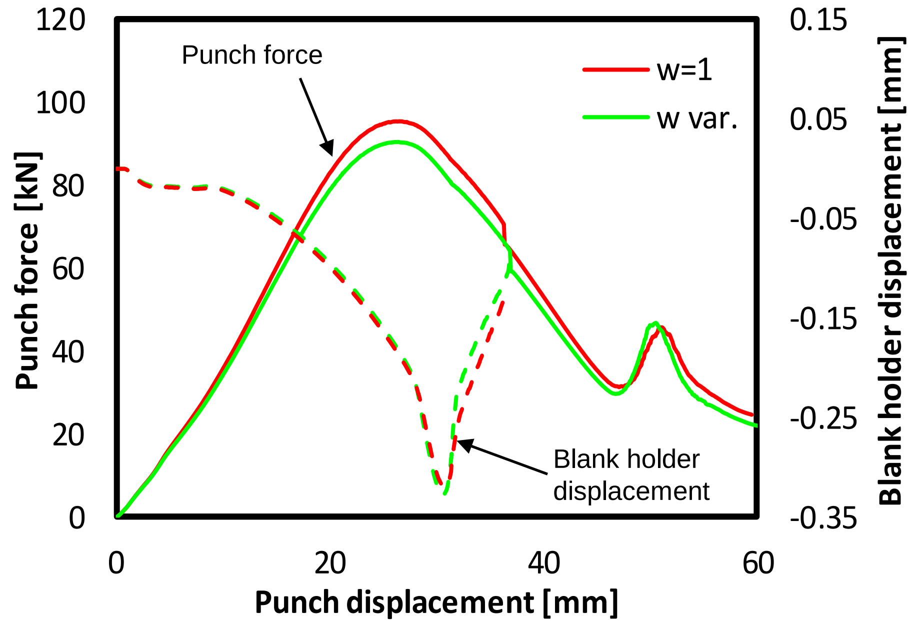


Deformation of an element on the flange: (a) stress states on the flange and (b) stress states on the yield surface (adapted from Yoon et al. 2011).

Numerical simulation



(a)



(b)

Numerically predicted, for the CB2001 yield criterion, (a) earing profile and (b) punch force evolution and blank-holder displacement with punch displacement.

- The accurate prediction of the material's mechanical behaviour is crucial for the evaluation of the material flow;
- … which is dependent on the yield criterion flexibility;
- The impact of the weighting coefficients (users sensitivity) becomes more important for more flexible yield criteria;
- The numerical simulation of a circular cup shows the impact of small differences on the fitting, even for such a simple stamping operation,
- The users' input and knowledge is only as good as the flexibility allowed by the yield criterion considered.

Thank you for your attention!

The authors gratefully acknowledge the financial support of the Portuguese Foundation for Science and Technology (FCT) under projects with reference PTDC/EMS-TEC/0702/2014 (POCI-01- 0145-FEDER-016779) and PTDC/EMS-TEC/6400/2014 (POCI-01-0145-FEDER-016876) by UE/FEDER through the program COMPETE 2020. The first author is also grateful to the FCT for the PhD grant SFRH/BD/98545/2013.