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A new cracking resistance index based on fracture mechanics for high strength sheet metal ranking

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Outline

1. Introduction
2. Materials and methods
3. Results and discussion
4. Conclusions

1. Introduction

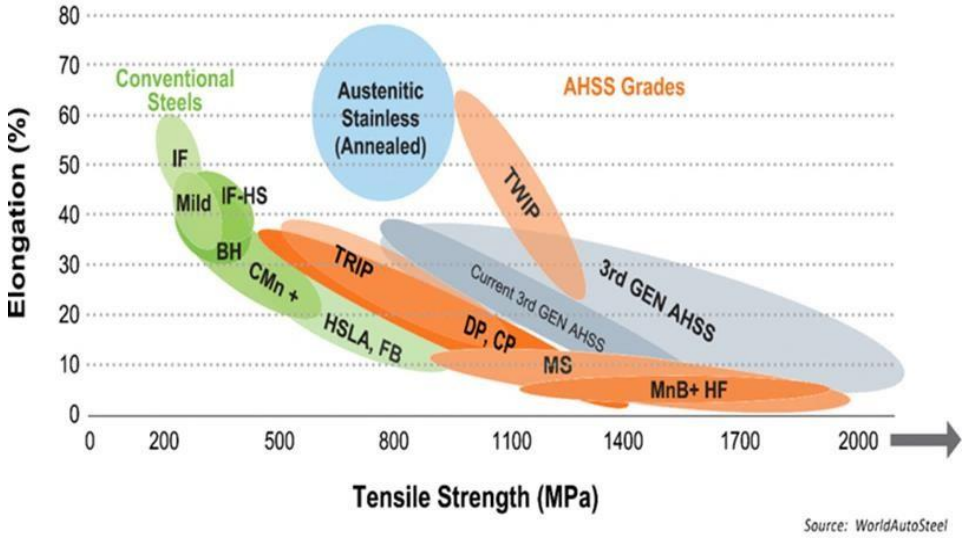
1. Introduction

Advanced High Strength Steels (AHSS)

- Complex multiphase microstructures
- High strength and good formability
- Excellent crash performance
- Great lightweight potential

Safety

Weight



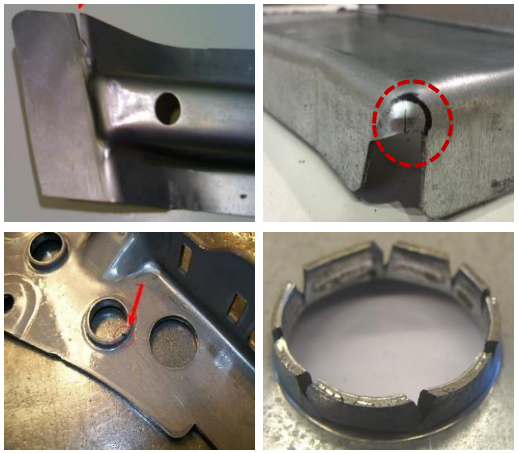
1. Introduction

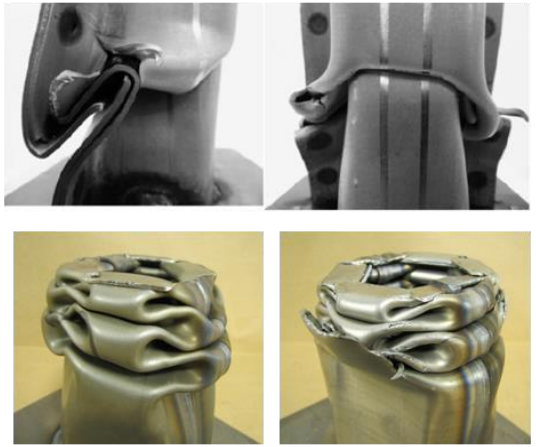
New challenges:

- Moderated ductility
- Higher cracking susceptibility
- Cracking in cold forming and crash

NEW FRACTURE CRITERIA ARE NEEDED!!

Cracking resistance ⇨ Fracture toughness

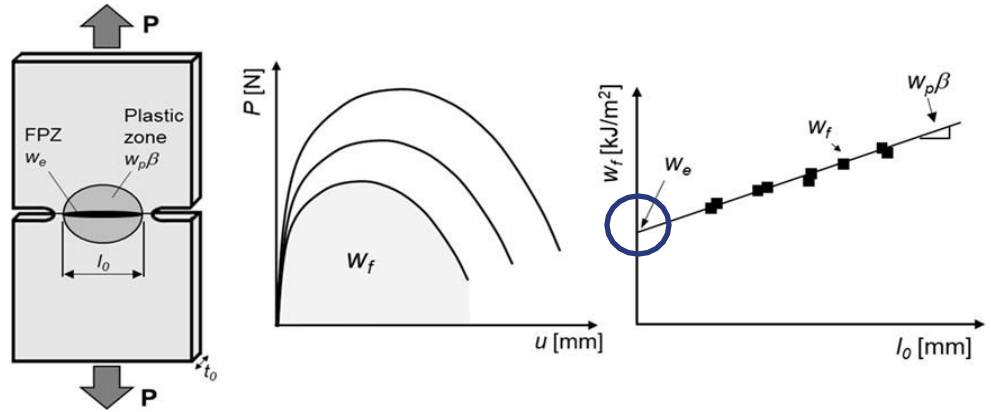




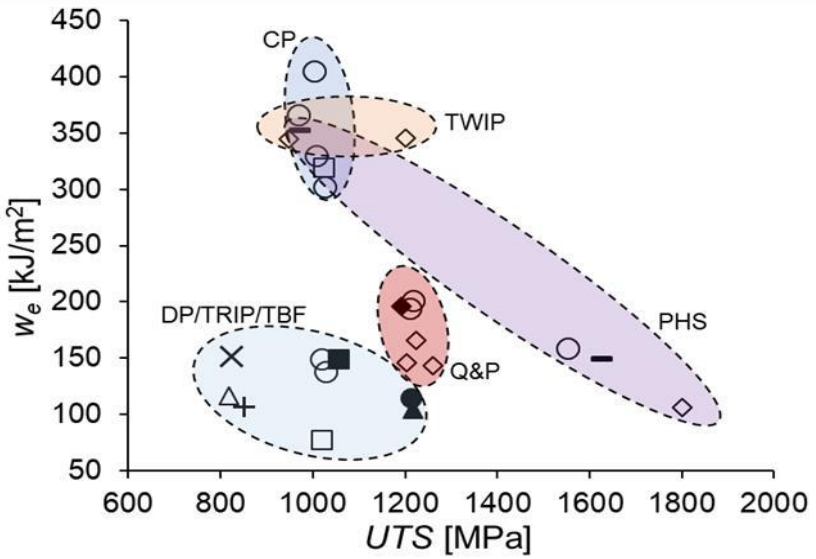
1. Introduction

How to measure fracture toughness in AHSS sheets?

Essential Work of Fracture (EWF) methodology



New classification map for AHSS



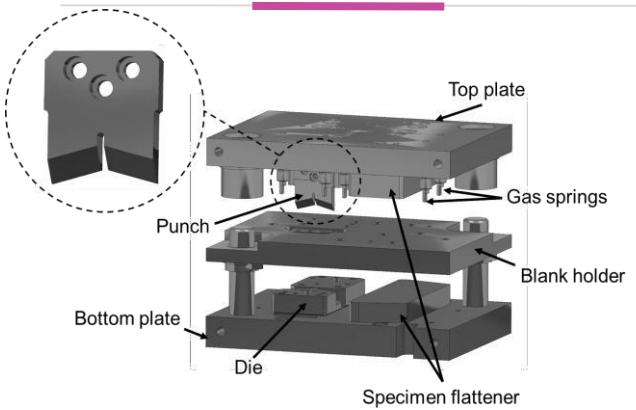
w_e : crack propagation resistance ➡ Indicator of fracture performance

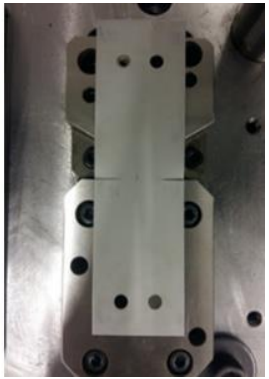
⬆ w_e ⇧ Cracking resistance (edge cracking, crash failure)

1. Introduction

Fracture toughness tests

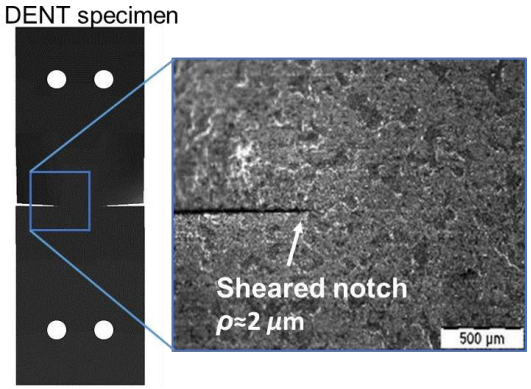
- Complex specimen preparation
- Expensive and time consuming fatigue pre-cracking operations





New notching tool for specimen preparation

- Fast and simple procedure. Testing time equivalent to a tensile test
- Easy to install in a universal testing machine
- Results equivalent to the obtained with fatigue pre-cracked specimens



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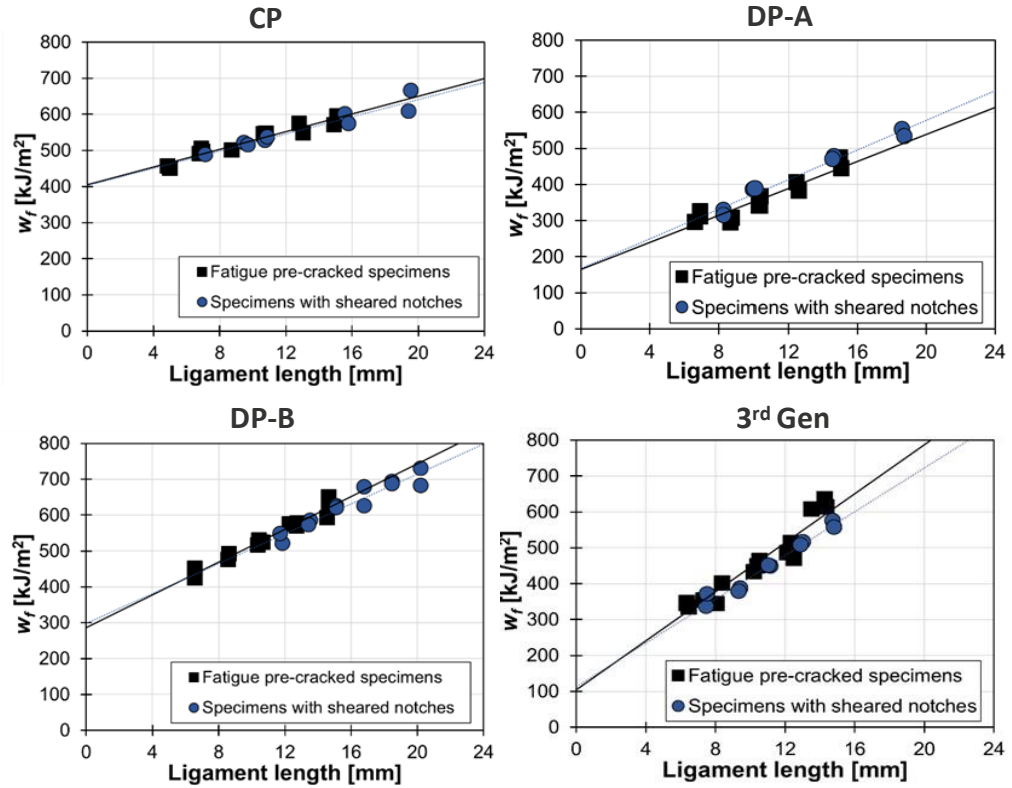
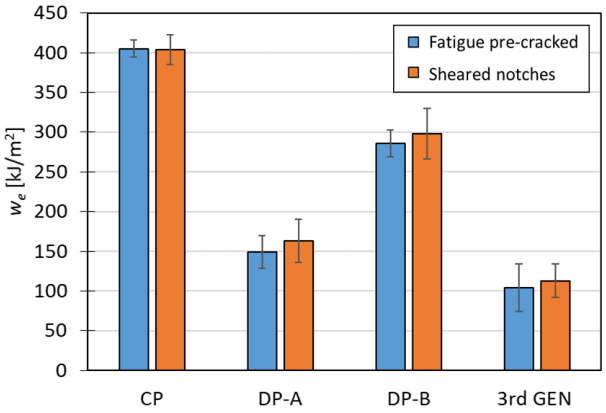




Time for specimen preparation			
Procedure	Average time per specimen	Average time for 10 specimens	Time saving
Fatigue pre-cracking	90 min	900 min (22.5 h)	-
Notching tool	1 min	10 min (0.25 h)	99%

2. Materials and methods

2. Materials and methods

Materials

Fracture toughness characterizations:

- 4 AHSS
- 1000-1800 MPa UTS
- Thickness 0.8-1.5 mm
- 1 DP, 2CP, 1 PHS1800

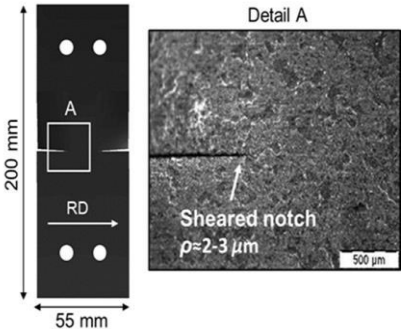
Cracking Resistance Index (CRI) investigations:

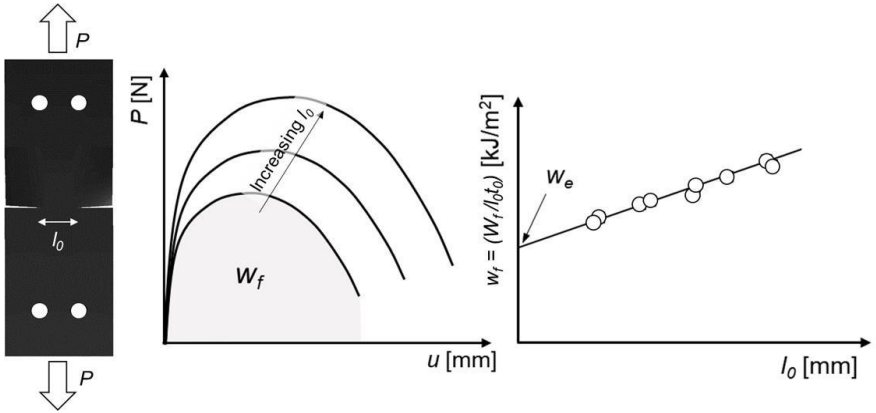
- 19 AHSS
- 800-1800 MPa UTS
- Thickness 0.8-1.5 mm
- DPs, CPs, TBFs, Q&Ps, TRIP

Steel	*t* [mm]	*YS* [MPa]	*UTS* [MPa]	*UE* [-]	*TE* [-]
DP1000 A	0.8	735	1074	0.08	0.11
CP1000HD	1.5	909	1062	0.07	0.11
CP1180	1.5	1079	1215	0.05	0.08
PHS1800	1.2	1499	1800	0.05	0.06
TRIP800	1.6	542	851	0.21	0.26
DP800HD	1.5	513	823	0.14	0.20
DP1000 B	1.4	773	1020	0.06	0.10
DP1000 C	1.4	775	1015	0.07	0.11
DP1000 D	1.2	697	1067	0.09	0.12
DP1000 E	1.4	816	1055	0.07	0.10
CP1000 A	1.4	915	1008	0.05	0.09
CP1000 B	1.2	904	986	0.06	0.08
TBF1000	1.5	755	1012	0.11	0.16
TBF/Q&P1000	1.4	876	1026	0.08	0.11
PHS1000	1.5	988	1007	0.05	0.07
DP1180HD	1.2	895	1212	0.08	0.14
Q&P1180 A	1.4	920	1202	0.05	0.09
Q&P1180 B	1.5	1034	1184	0.09	0.13
TBF1180	1.4	987	1216	0.09	0.13

2. Materials and methods

Experimental procedure: Essential work of fracture (EWF)



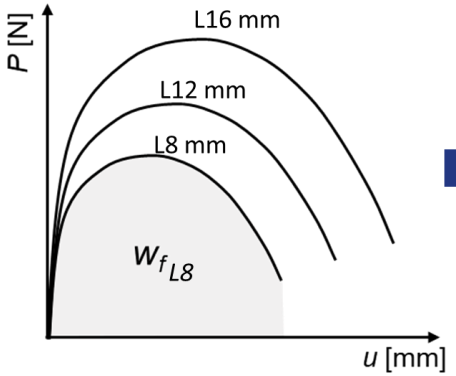


Testing conditions:

- Ligament lengths: 8-18 mm
- 2-3 specimens per ligament length
- Displacement rate: 1 mm/min

2. Materials and methods

Cracking Resistance Index (CRI)



$$CRI\ [\%] = \frac{W_{fL8}}{UTS \cdot TE \cdot t_0 \cdot l_0^2}\ x\ 100$$

W_{fL8}: Fracture energy for a ligament length of 8 mm

UTS: Ultimate Tensile Strength

TE: Total Elongation

t_0: Specimen thickness

l_0: Ligament length

CRI [%]	Cracking resistance level
>50	High
25-50	Medium
<25	Low

3. Results and discussion

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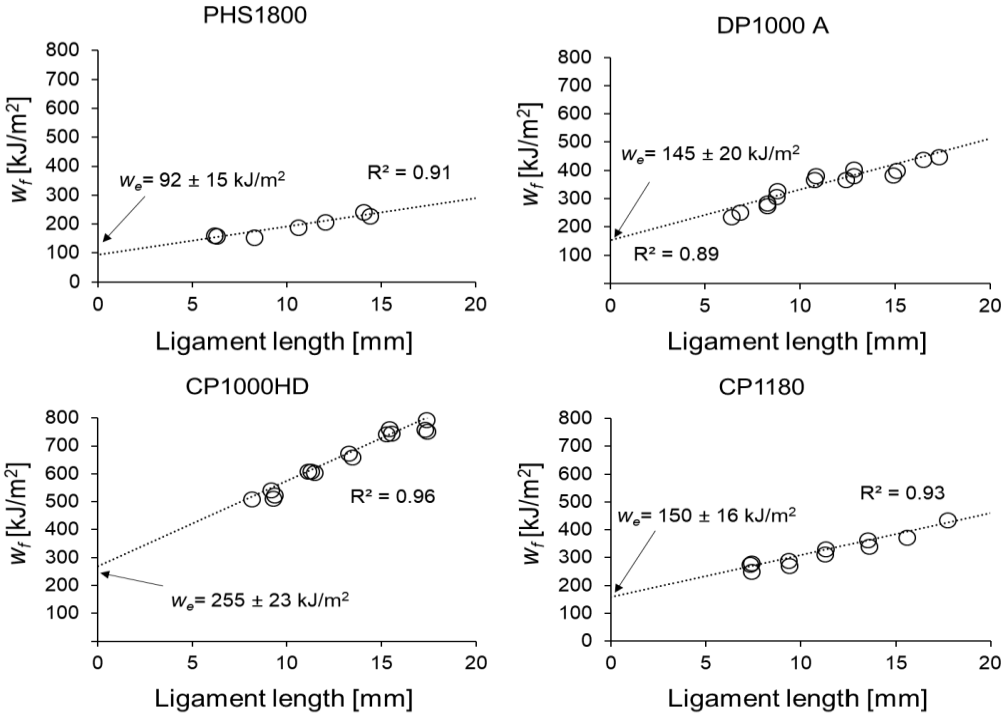
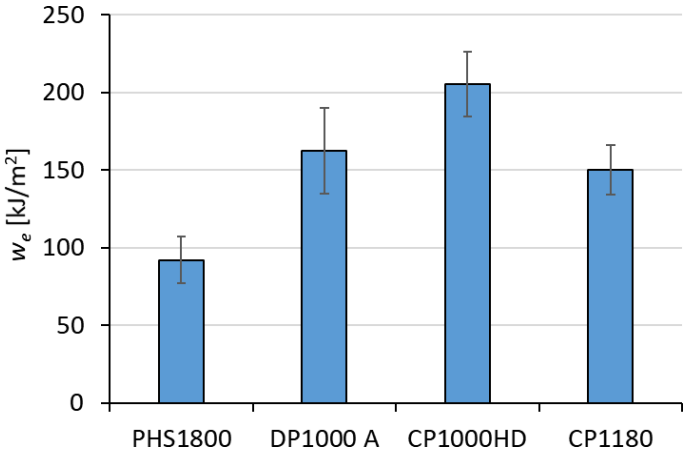
Essential Work of Fracture for mechanically notched specimens

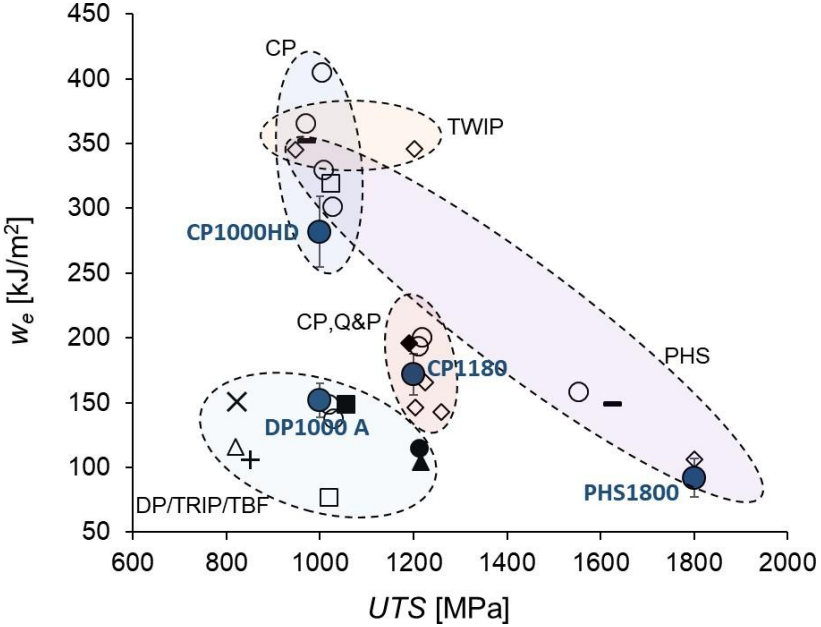




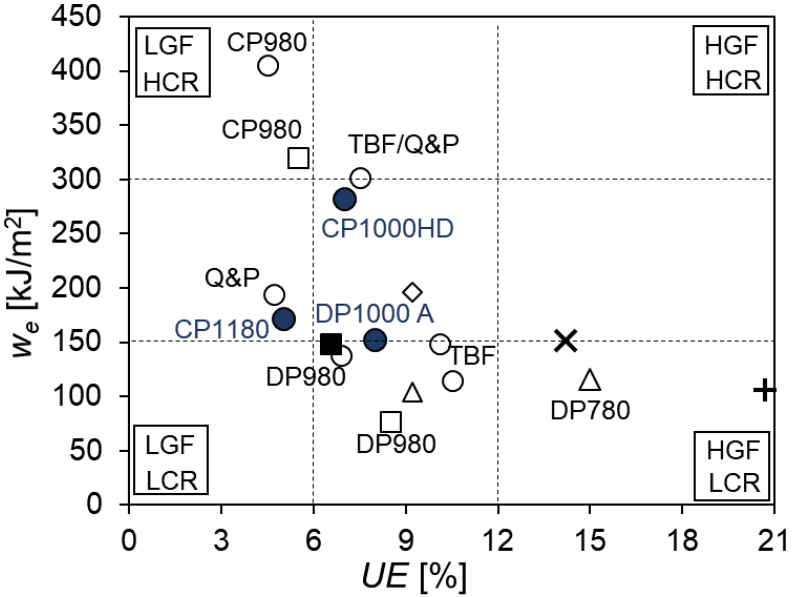
3. Results and discussion

AHSS classification

w_e vs *UTS*

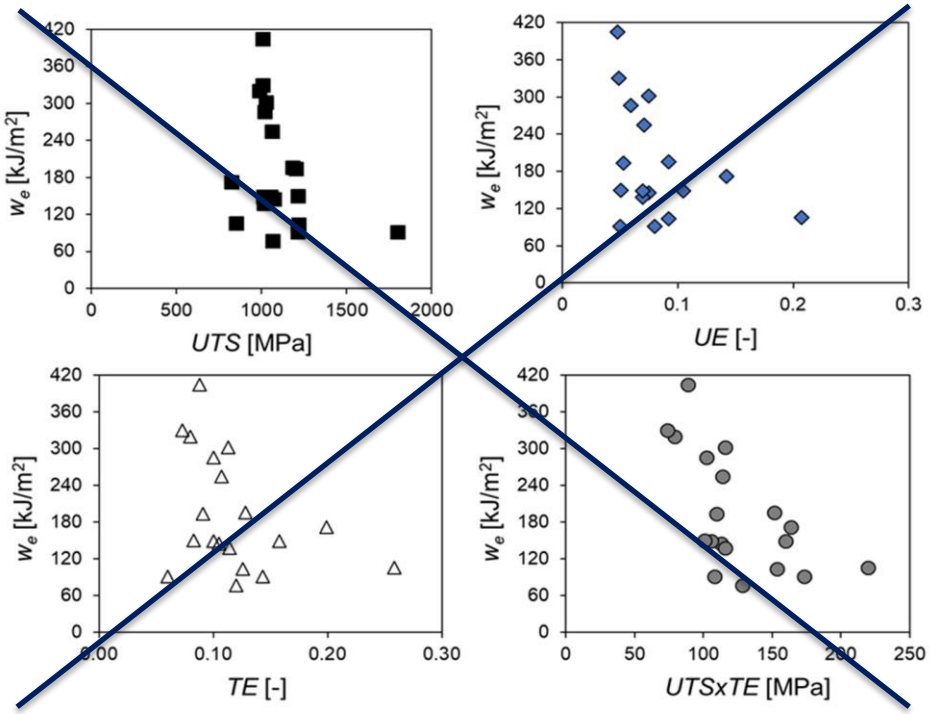


w_e vs *UE*



3. Results and discussion

EWF vs tensile properties

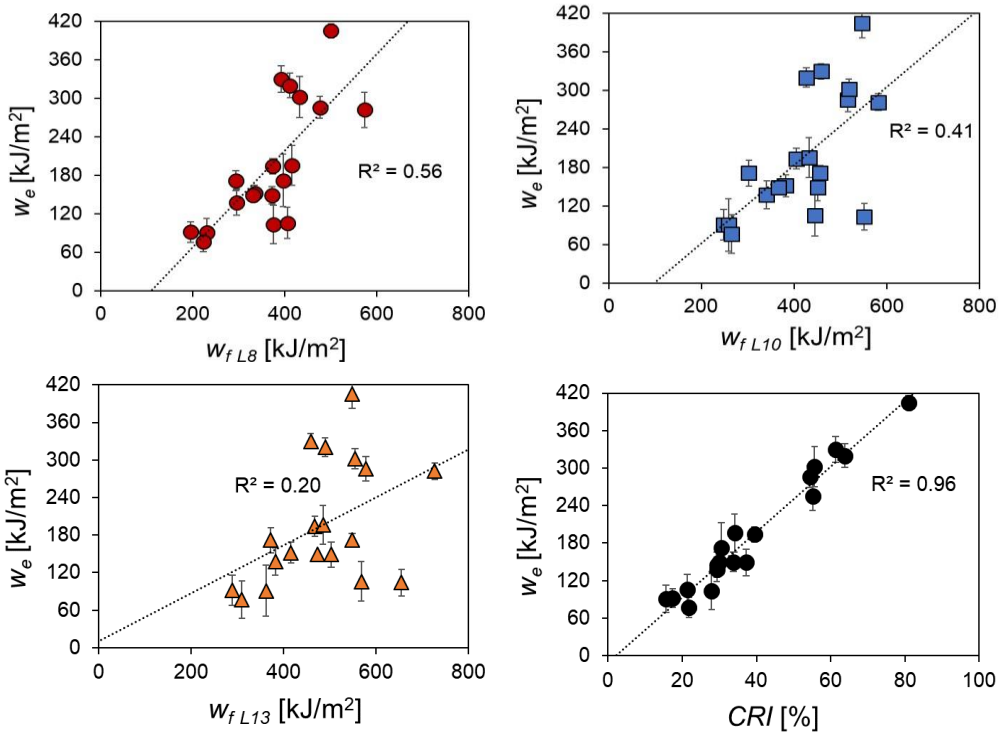


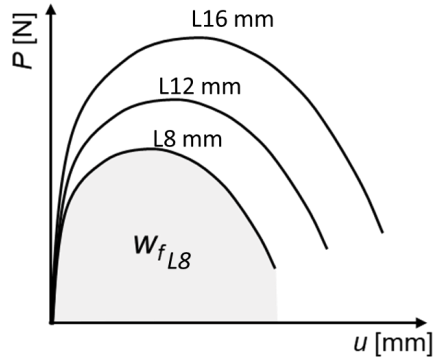
No correlation between tensile properties and fracture toughness

Fracture toughness must be measured in the frame of fracture mechanics

3. Results and discussion

Fracture energy from a single ligament length vs w_e





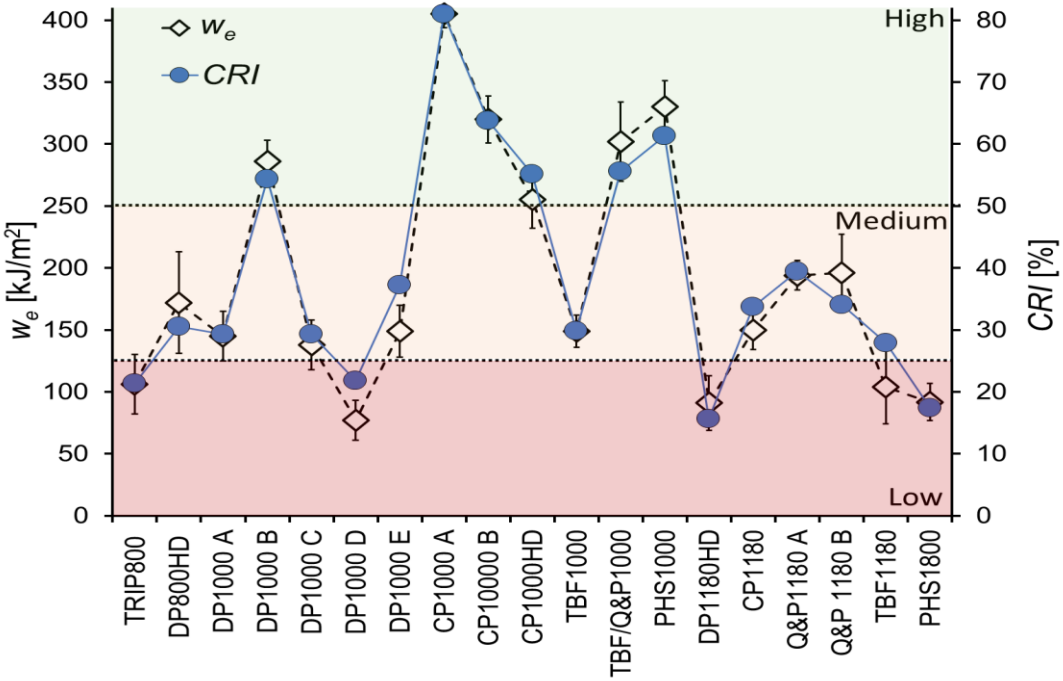
$W_f = We + Wp$

Fracture toughness *Plastic work*

$$CRI\ [\%] = \frac{W_{fL8}}{UTS \cdot TE \cdot t_0 \cdot l_0^2}\ x\ 100$$

3. Results and discussion

Material ranking: *CRI* vs w_e

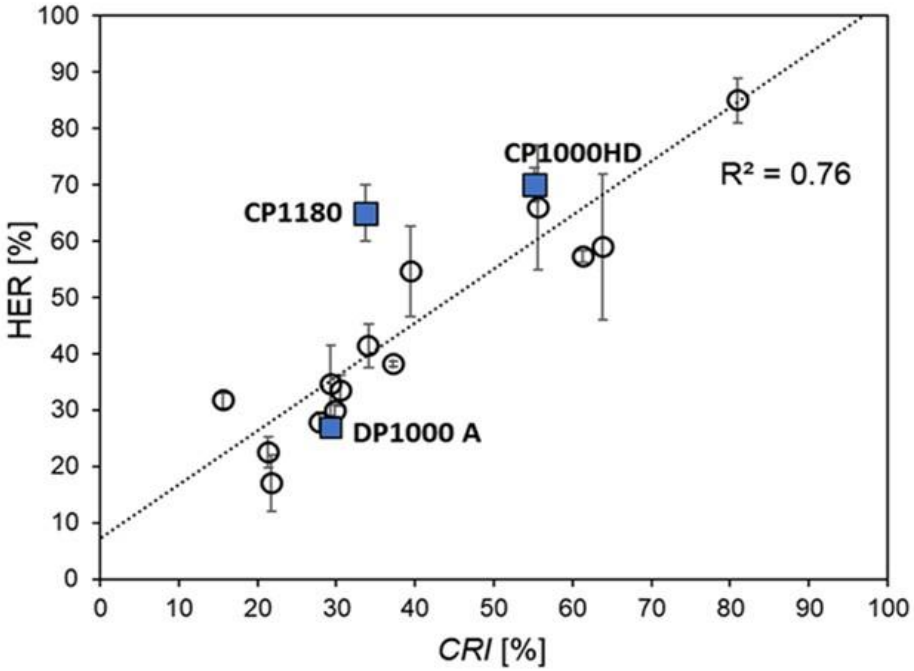


- The *CRI* provides similar material ranking to w_e
- Different cracking resistance levels can be defined by the *CRI*

CRI [%]	Cracking resistance level
>50	High
25-50	Medium
<25	Low

3. Results and discussion

Correlation between CRI and HER



- Good correlation between *CRI* and HER
- The *CRI* can be used to estimate edge cracking susceptibility

4. Conclusions

4. Conclusions

Conclusions

- The rapid notching procedure is a suitable tool to evaluate the crack propagation resistance of AHSS in a simple and fast manner.
- A new Cracking Resistance Index (*CRI*) has been proposed for AHSS classification.
- The *CRI* has shown to be useful to predict the crack propagation resistance of AHSS sheets and it can be used as a fracture toughness indicator for material ranking.
- The *CRI* shows a good correlation with HER, which allows using it as a parameter for edge cracking resistance estimation.
- The proposed *CRI* must be used only as a fracture toughness index for material screening.
- The combination of the rapid notching procedure and the use of the *CRI* offers a fast and cost-effective method to estimate the crack propagation resistance of AHSS.

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Thank You!

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