Toughness properties influence on the automotive stamped components

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The CO_2 emissions of passengers cars and commercial vehicles are becoming more and more important year by year because they have a direct effect on climate change. For this reason, the main OEMs are increasing the usage of Advance High Strength Steel (AHSS) to replace the common low carbon steels (mild steel) in order to reduce the vehicle weight and so in parallel reduce the CO_2 emissions in compliance with the international requirements that are becoming more restrictive than the past.
AHSSs forming operations are complicated due to their lower formability (global and local). , Therefore, it is crucial to be able to predict and select the best material for the components based on their shape and mechanical properties. This is the reason why CRF and Eurecat are working on several projects together, such as ToughSteel, to implement new fracture criteria for edge cracking sensitivity prediction in order to prevent and/or solve potential problems during forming.
In this paper, case study in which the Essential Work of Fracture (EWF) measurement was essential to define failure'sroot cause during the forming operation will be presented.

KEYWORDS: FRACTURE, TOUGHNESS THIN SHEETS, EDGE CRACKING, HIGH STRENGTH SHEET METAL FORMING, TOUGHSTEEL;

INTRODUCTION

Global climate change issues leading to catastrophic natural disasters in recent times have transformed consumer awareness and their priorities.
Transport represents almost a quarter of Europe's CO_2 gas emission and is the main cause of air pollution in cities. The transport sector has not seen the same gradual decline in emissions as other sectors. The EU aims to achieve a 90% reduction in greenhouse gas emissions from transport by 2050, compared with 1990. This is part of its efforts to reduce CO_2 emissions and achieve climate neutrality by 2050 under the European Green Deal roadmap.
CO_2 emissions from passenger transport vary significantly depending on the transport mode. Passenger cars are a major polluter, accounting for 61% of total CO_2 emissions from EU road transport.
At the moment, the average occupancy rate was only 1.6 people per car in Europe in 2018. Increasing it by car sharing or shifting to public transport, cycling and walking, could help to reduce emissions [1].

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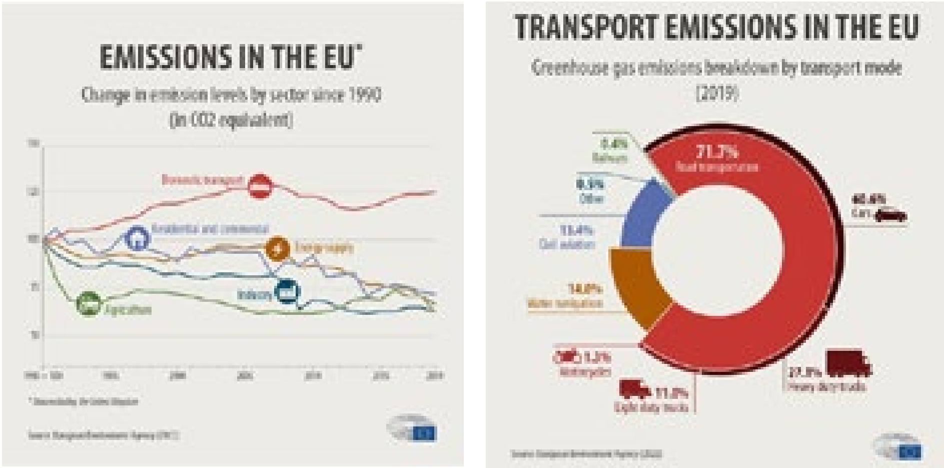


Fig.1 - CO_2 emission trend in different sectors (left); transportation emissions in Europe (right)

Nowadays, the well-informed customers of automobiles place fuel efficiency and environmental friendliness design among their top four priorities, as reported by a recent comprehensive assessment of the global automotive industry by KPMG International [2]. By the year 2020, the automotive market is expected to grow to 100 million new vehicles per year. "Lightweighting" in the transport industry has become a major theme of research in recent years; the main motives being anticipated fuel savings and meeting stricter environmental legislations in various jurisdictions such as Europe, North America, and Asia. In order to meet the CO_2 emission targets set for Europe in 2020, i.e., 95 g CO_2/km, a 200 - 300 kg weight reduction of the vehicle is required.

Innovative steel designs must achieve significant increases in strength while offering thinner gauges to reduce vehicle mass. During the next ten years, applications of Advanced High-Strength Steels (AHSS) in OEM and supplier plants will increase, and users of AHSS will need to rapidly accumulate application knowledge.

AHSSs are characterized by their complex multiphase microstructures containing a mix of different microstructural constituents, such as martensite, bainite, tempered martensite, and retained austenite, which provide them with unique mechanical properties in terms of tensile strength, fatigue, forming and crashworthiness. Formability is highly impacted by microstructure. This is especially critical in multiphase AHSS and has made it necessary to divide this important material characteristic into two: global and local formability. Global formability refers to forming modes where deformation occurs in the plane of the sheet over relatively large regions of material. Local formability failure modes are an entirely different failure condition, where fractures occur out of the plane of the sheet in response to concentrated deformation created when forming localized features like stretch flanges, extruded holes, or bends around a radius too small for the selected steel grade. These failures typically occur without any observable thinning or necking [3]. Therefore, they cannot be predicted through conventional global ductility approaches based on necking instability, like elongation values from uniaxial tensile tests or Forming Limit Curves (FLCs).

Over the last years, several research studies have demonstrated that fracture toughness, measured through the Essential Work of Fracture (EWF) methodology, is a well-suited property to predict this kind of fracture related to the material's local formability, such as edge fractures or crack formation during crash tests [4-6].The present work aims to show how the the EWF methodology was used as a tool to identify the problem's root cause during the failure analysis of a Stellantis' automotive component.

COMPONENT & MATERIAL

The component under investigation was the under-seat beam, highlighted in red in Figure 2. This is a fundamental component because it has the goal to absorb energy during the lateral crash and limit the intrusion to safeguard the vehicle occupants.

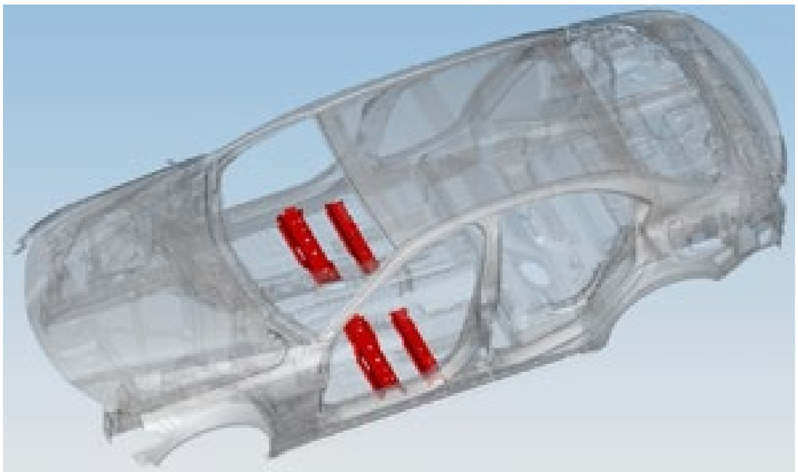


Fig.2 - Under-seats beam position on the vehicle

Generally, these components are done in a Dual Phase (DP) steel, DP800 or DP1000. DP steels have a ferritic matrix with embedded islands of martensite to increase the tensile strength while time ensuring good formability. To reduce the weight and so save CO2 emission for the vehicle, the higher grade of dual phase (DP1000) was chosen to manufacture the component analysed in this study. In the table below, the comparison between the mechanical properties of the two materials (DP800 and DP1000):

Tab.1 -Mechanical properties comparison between DP800 and DP1000.

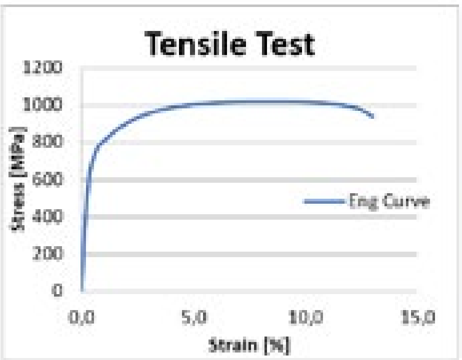
DUAL PHASE STEELS COMPARISON		
	DP800	DP1000
Yield Strength [MPa]	420 – 550	700 – 800
Tensile Strength [MPa]	Min. 780	Min. 980
Elongation [A80]	Min. 14%	Min. 7%

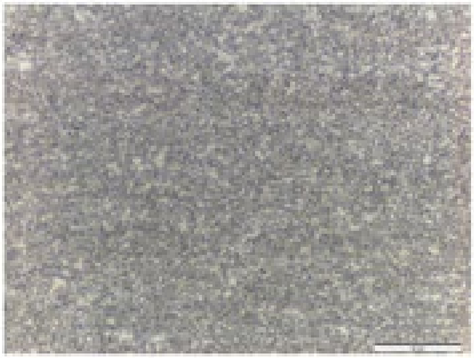
FAILURE ANALYSIS

During forming simulation, the component resulted feasible without the presents of any cracks or wrinkles. The most common material cards used for the formability study take care about: elasto-plastic curve, anisotropy, biaxial plane deformation and the forming limit diagram.

During the component physical forming operation, sometimes, cracks occurred. To investigate the reason for this failure, different investigations were performed to check if the material was compliant with the standard: tensile tests, chemical and micrographic analysis. The results are reported below.

Fig.3 - Cracks during the forming operations.



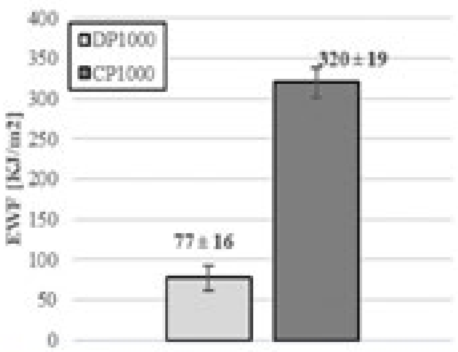


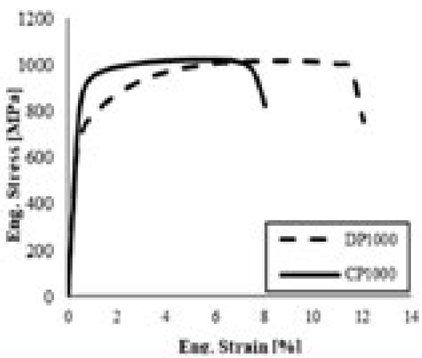
TENSILE PROPERTIES		
	DP1000 (Standard requirement)	DP1000 (Material tested)
Yield Strength [MPa]	700 – 800	736
Tensile Strength [MPa]	Min. 980	1012
Elongation [A80]	Min. 7%	12%

	C	Mn	P	S	Si	Al	Ti + Nb	B	Cr + Mo
Standard ref.	Max. 0.23	Max. 2.9	Max. 0.08	Max. 0.015	Max. 1.0	0.01 – 2.0	Max. 0.15	Max. 0.005	Max. 1.4
Coil Check	0.169	2.28	0.009	0.001	0.820	0.043	0.024	0.0002	0.28

Fig.4 - Mechanical properties, chemical composition and microstructure of DP1000

As observed, all the material characteristics are in compliance with DP1000 specifications. To solve the problem, the DP1000 was substituted by a CP1000, a complex phase steel (bainite, martensite, and retained martensite) that has higher fracture toughness than DP1000. Using the EWF methodology, together with Eurecat, it was possible to quantify this difference in fracture toughness and understand the reason behind the higher cracking sensitivity of the DP1000. The EWF for the CP1000 is 4 times more than the DP1000, this means that its crack propagation resistance is much higher than the one of DP1000. The CP1000 has slightly lower global formability compared to the DP1000, as can be observed from the elongation during the tensile test, but higher local formability as shown by the EWF measurement.





STEEL COMPARISON		
	DP1000	CP1000
Yield Strength [MPa]	700 – 800	780 – 950
Tensile Strength [MPa]	Min. 980	Min. 980
Elongation [A80]	Min. 7%	Min. 6%

Fig.5 - Comparison between DP1000 and CP1000.

CONCLUSION

In this case study, the EWF methodology was fundamental to selecting the appropriate material for the under-seat beam. This method is able to quantify the fracture toughness of thin sheet materials and predict their edge cracking sensitivity without using the Hole Expansion Test which has a higher scatter, and the results depend strongly on the operator. According to this, the EWF is a basic test for material selection in components in which edge stretching and bending are applied and it is a key parameter for the safe implementation of high strength sheet metal products. The next step is to work on implementing the fracture toughness values obtained by this methodology on conventional virtual forming software to be able to anticipate edge cracking problems during the development phases.

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