THE USE OF ADVANCED HIGH STRENGTH STEEL SHEETS IN THE AUTOMOTIVE INDUSTRY

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ABSTRACT

Thanks to the introduction of UHSS and a consequent design, FIAT AUTO can reach significant weight reduction (requested by the new emissions requirements) and an increased crash resistance (increased attention of the customers for Euro-Ncap evaluations).
The use of UHSS steels has increased in the recent FIAT AUTO models; in the memory we show the main characteristics of such steels.
We cooperated with the steel mills and the steel component suppliers that usually supply FIAT AUTO. Their resident engineers have chosen the materials with Technical Direction, in order to avoid some problems that caused the failure of these steels in the past projects.
Furthermore, the increased technical information given by Fiat Materials Engineering and the steel mills, allowed Fiat Technical Direction to build a reliable virtual model.
In the memory we describe the work done till today and our efforts in order to introduce more UHSS steels in our models, facing the increased spring back problem.
We'll show some examples explaining the importance of the involvement from the beginning of the suppliers that before were not part of the decision process.

KEYWORDS

CO_2 emissions – Materials – L.C.A. – Body in white – Steel sheets - Working Metodology – austenitic steels – Hot stamping

INTRODUCTION

According to Kyoto Protocol the most industrialized countries has to achieve within 2008-2012 a 5.2% gas emissions reduction.
For European Union the reduction has to be of 8%. The goal has become more difficult because of the CO_2 emissions increase during the last years.

Chart in Fig. 1 shows total energy emissions in European Union. Transport industry emissions are 30%; among them automotive share is only 10%.
European Union legislation doesn't rule CO_2 automotive emissions. In 1998 ACEA signed an agreement with European Union in order to reduce emissions to 140 g CO_2 / km. Further goal will be 120 g CO_2 / km within 2012 (Fig.2).

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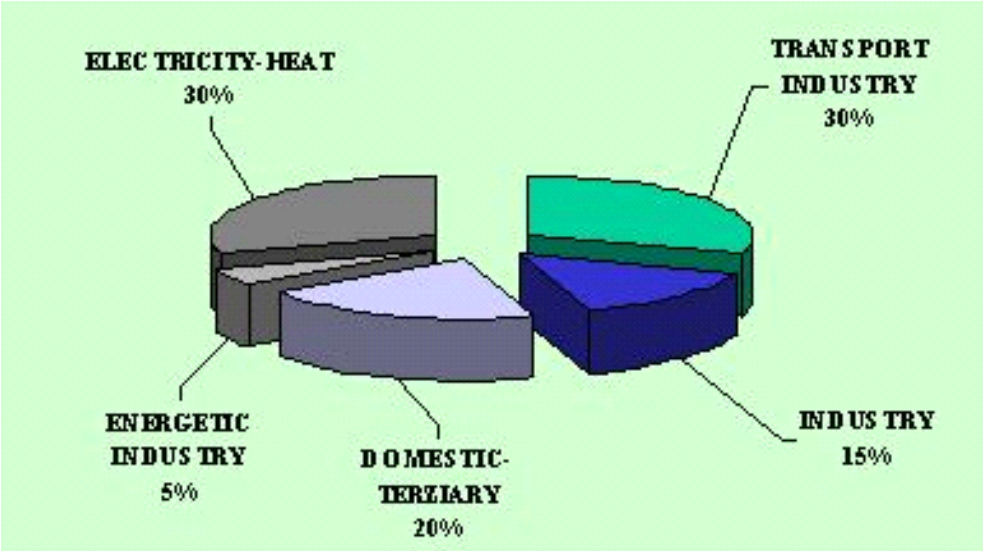

Fig.1 Total energy emission in European Union

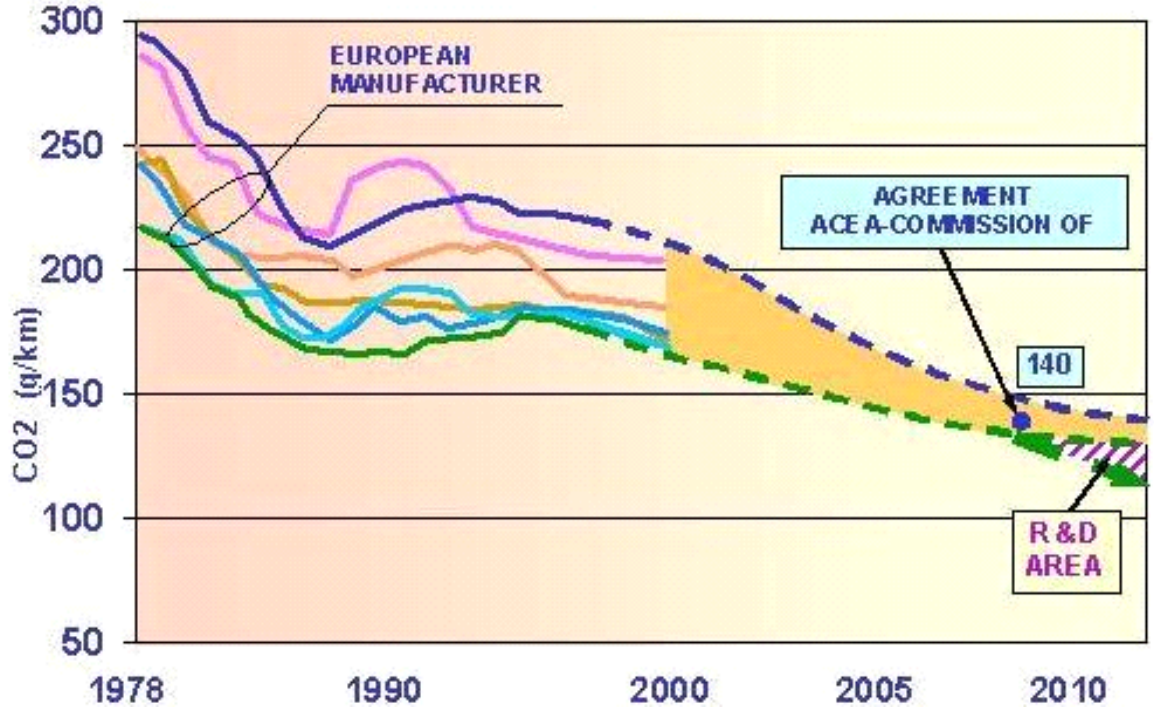

Fig.2 CO_2 emissions

In 2002 European Union introduced tax reductions related to a CO_2 emissions decrease.
Fig.3 shows how in some countries is applied (for A-B segments) .
Furthermore some guidelines has been studied in terms of Labelling. Each car dealer will have to expose the list of all models classified by its consumption, and on each car will have to be exposed its consumption and CO_2 emission. All advertising material will have to include these information.
Finally each Country will have to draw up and up-date a guide of consumptions and emissions for all the car models sold.

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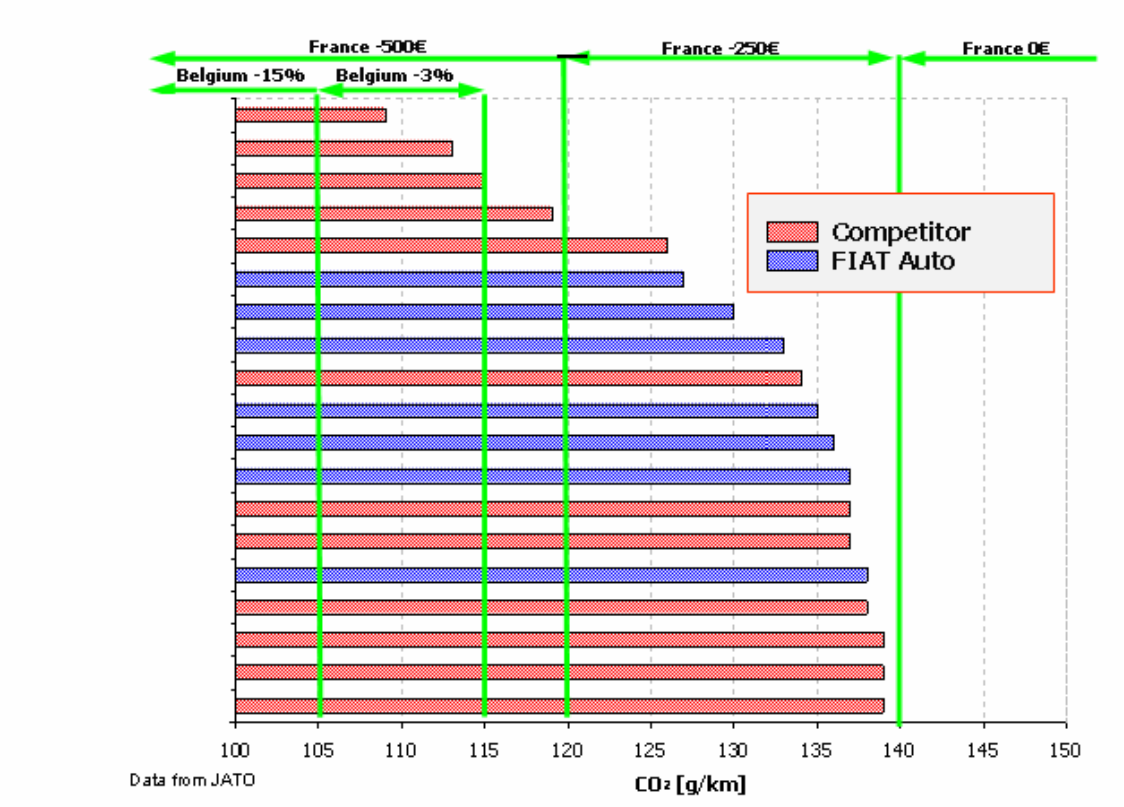

Fig.3 Example of tax reduction in Belgium and France

So reducing emissions and consumptions is a must for every car manufacturer. In the memory we analyze one of the most important aspects: car lightening through the introduction of innovative metallic materials for car Body In White.

1. MATERIALS IN FIAT AUTO CAR MODELS

Fig.4 shows how in the last 30 years the car materials mix hasn't changed very much.

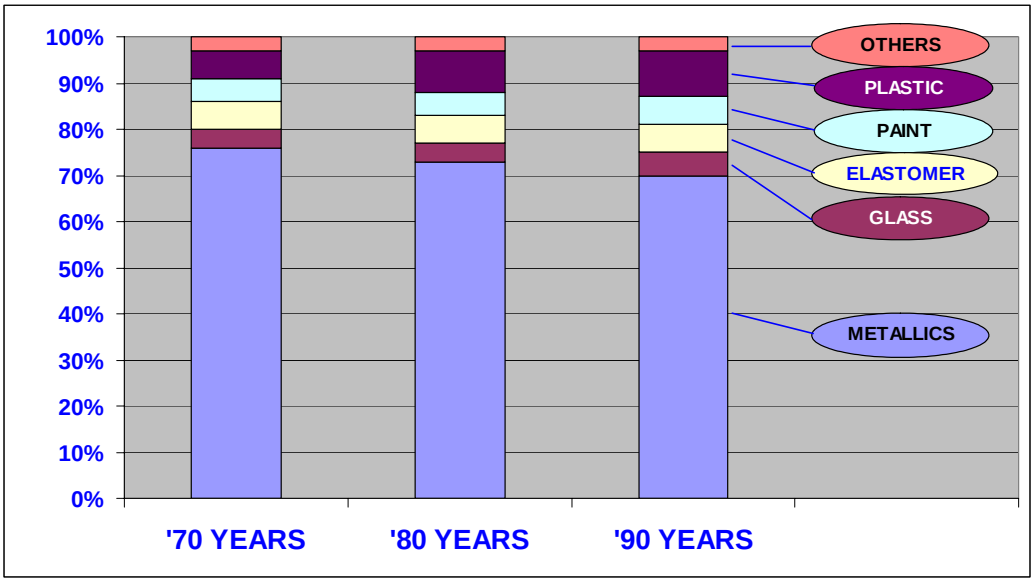

Fig.4 Materials mix in the last decades

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Fig.5 shows the plastic materials development. The last decade course indicates that in the future probably there won't be important changes.

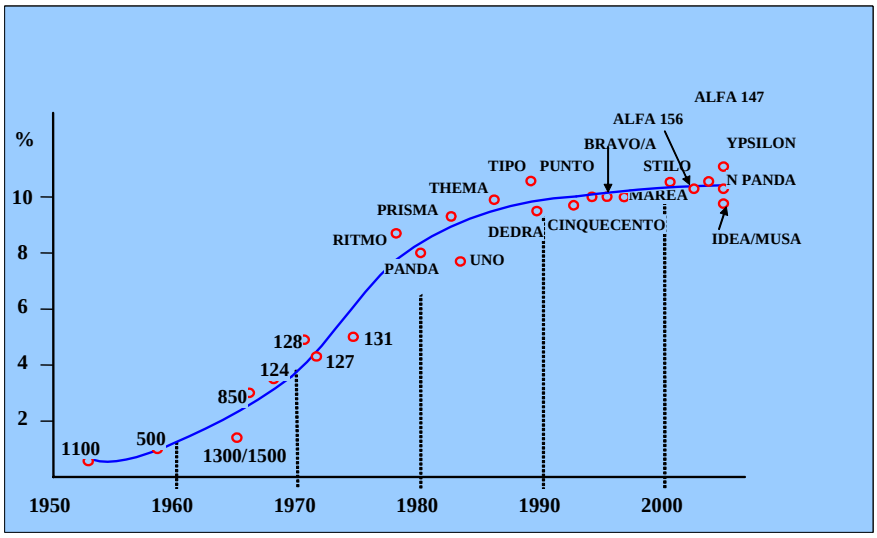

Fig.5 Plastic materials development

Metallic materials have always the biggest share (>70%). Within metallic materials, steel is the most used (75%); steel sheets are about 50% (Fig.6).

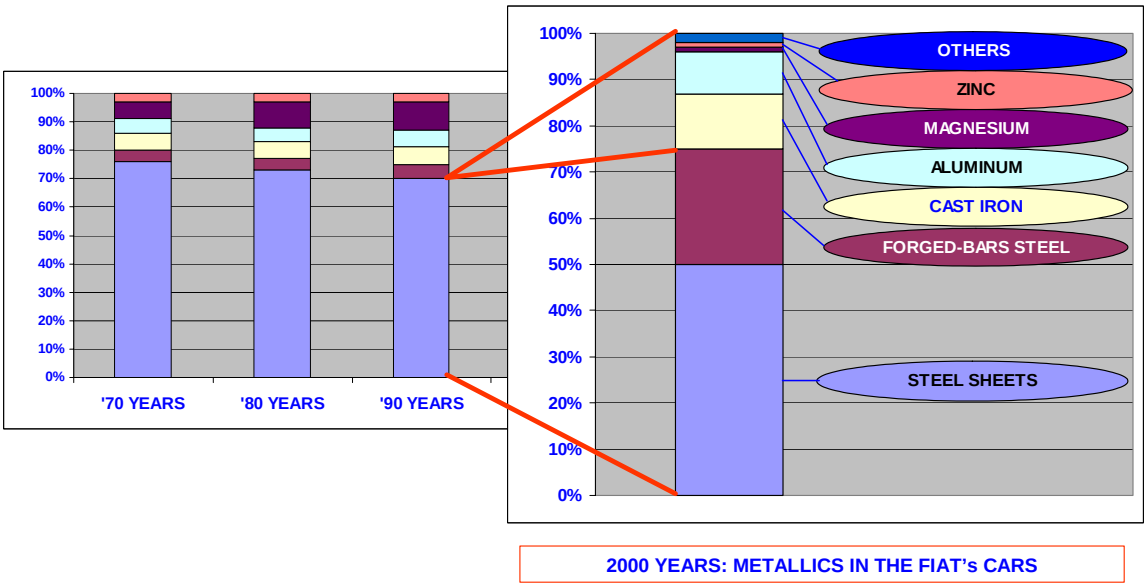

Fig.6 Metallic materials percentages

2. LIFE CYCLE ASSESMENT

If lightening is the solution in order to reduce emissions, its important to consider the complete LCA [1] of the lightweight components.
Below there's an example of a study done by Fiat Auto and Centro Ricerche Fiat where it appears how steel is better than Aluminum in terms of energy consumption (Fig.7) and greenhouse (Fig.8). The study has been done on a hood, assuming the optimized geometries for the different materials choices (steel, Aluminum, sandwich sheets).

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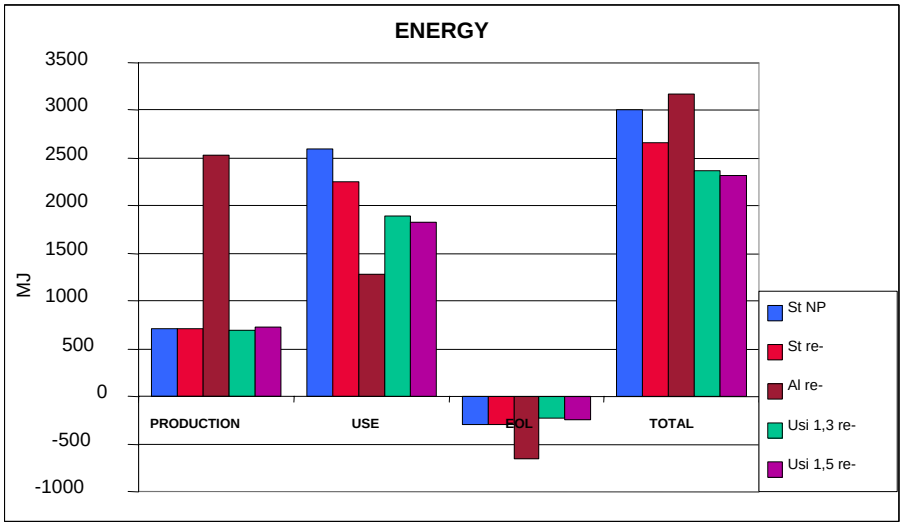
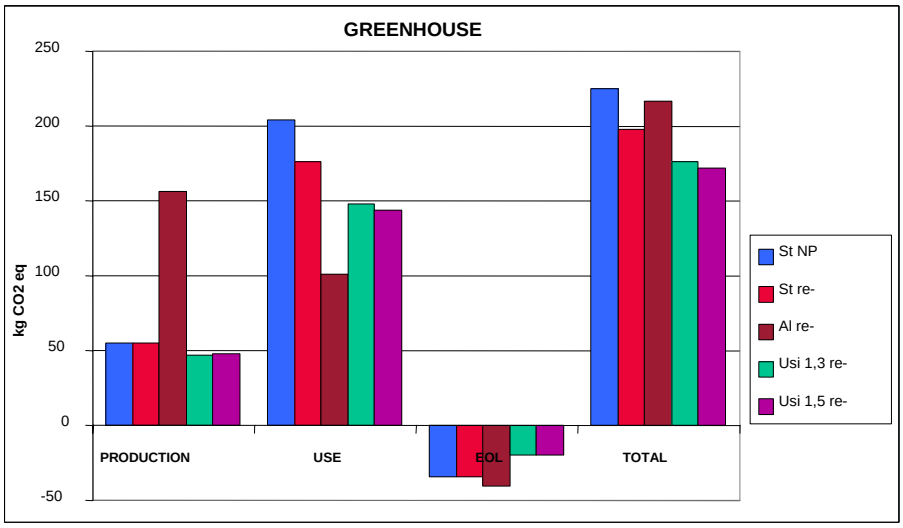


The Energy Consumption results, compared to N.P. bonnet, are:

1. Optimised Usilight 1.5 mm **(-22.9%)**,
2. Optimised Usilight 1.3 mm **(-21.7%)**,
3. Optimised Steel **(-11.8%)**,
4. Optimised Aluminium **(+5.4%)**

Fig. 7 Energy consumption of the different solutions



The Greenhouse Effect results, compared to N.P. bonnet, are:

1. Optimised Usilight 1.5 mm **(-23.7%)**,
2. Optimised Usilight 1.3 mm **(-22%)**,
3. Optimised Steel **(-12.3%)**,
4. Optimised Aluminium **(-3.6%)**

Fig.8 Energy consumption of the different solutions

A correct LCA of lightweight components imply a quantitative environmental assessment of the components' complete life cycles stages (production, use and end-of-life) and an evaluation of the credits from materials recycling, recovery and re-use.
Optimised Steel based solutions appear more environmentally-friendly and cheaper than aluminum ones, thanks to:

- the lower environmental impacts recorded all along the bonnets' life cycle

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- the higher environmental credits for steel prompt and obsolete scraps
- the well-established recycling routes for steel-base3d components, compared to aluminum.

3. NEW MATERIALS FOR BODY IN WHITE

Body In White weight reduction will always be an important subject, but recently the security aspects have become more and more important.
The EURO-NCAP crash standards published on the specialized magazines are one of the new decision factors for the customer. So the car manufacturers have to reach these goals and the steel manufacturers have to produce high energy absorption materials.

The use of HSS-UHSS steels has increased in the recent Fiat models. [2]
Fiat worked with the most important steel manufacturers (ARCELOR, ILVA, VOEST ALPINE, THYSSEN) in order to introduce on the new models the latest steel developments.

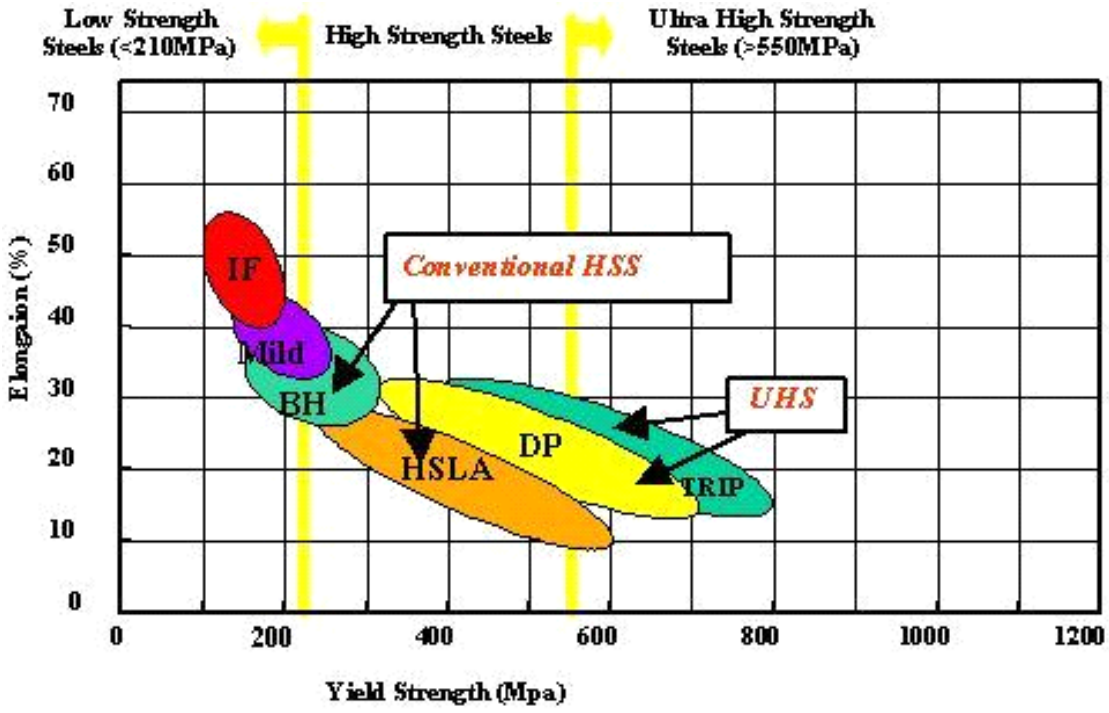

Fig.9 Steel sheets scenario

The steel sheets used by Fiat are the same of the others European cars manufacturers (Fig. 9).
- traditional: (deep drawing steel)
- high strength steel-HSS: (bake-hardening, rephosphorized and HSLA)
- ultra high strength steel-UHSS: (Dual Phase, Ferritic-Bainitic, Trip)

On the other hand the mix of the steel sheets is different between European cars manufacturers.

In the last years the need of lightening favored the usage of Ultra High Strength Steels, characterized by high mechanical characteristics and good stampability.
Fig.10 shows Fiat usage increase of such steels.
Fig.11 is an example of how these steels has been introduced by Fiat Auto on the different evolutions of the same model.
Fig.12 shows High Strength Steel and Ultra High Strength Steels usage in latest Fiat Auto models.

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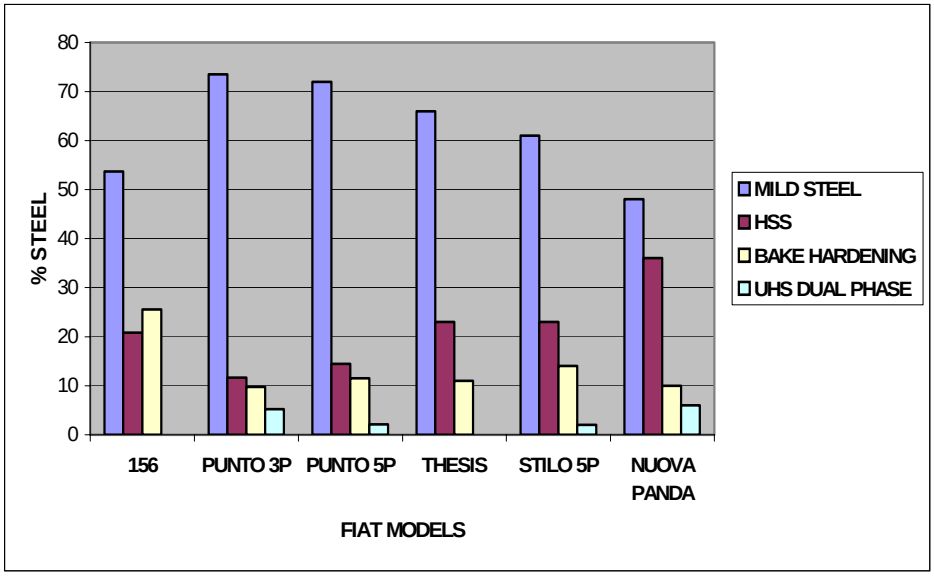

Fig.10 HSS-UHSS in Fiat Auto models

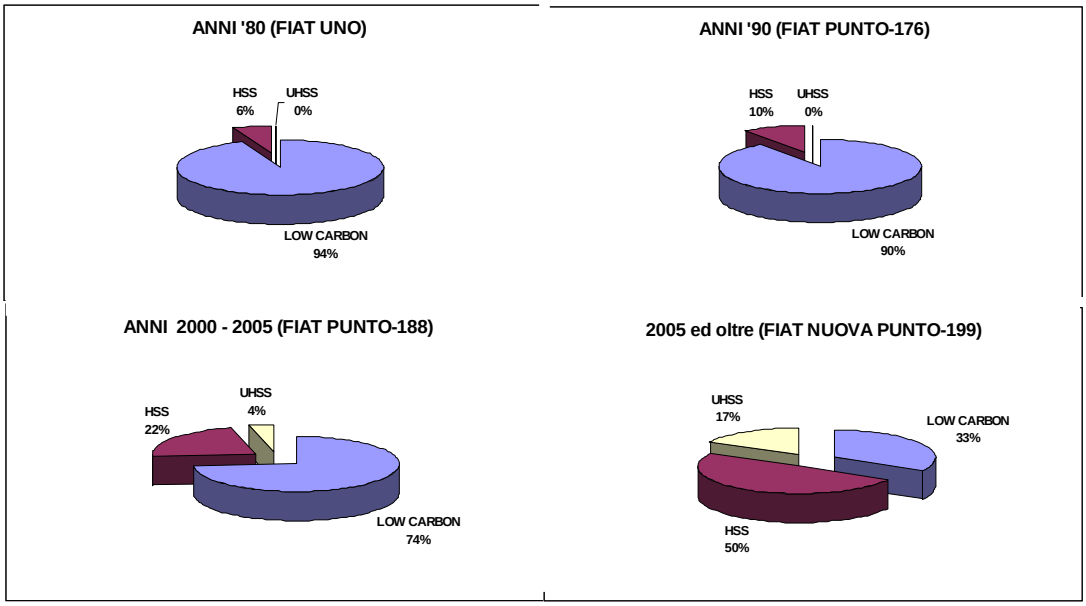

Fig.11 Increase of HSS-UHSS in Fiat Auto models

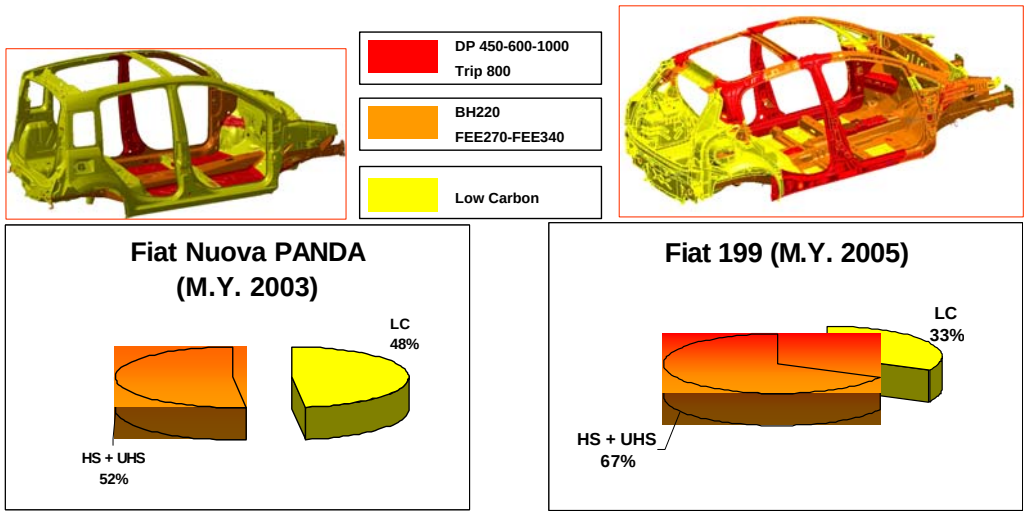

Fig.12 HSS-UHSS usage in latest Fiat Auto models

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4. FIAT AUTO STEEL SHEETS

Table I shows the mechanical and formability characteristics of these materials according to Fiat specifications. [2]

Tab. I – Mechanical properties of materials used by FIAT

DESIGNATION	MINIMUM YIELD STRENGHT		MINIMUM TENSILE STRENGHT		MINIMUM ELONG.$_{80}$		MINIMUM n VALUE		MINIMUM BH EFFECT
	from	to	from	to	from	to	from	to	
CR MILD STEEL (5 TYPES)	120	140	270		26	38	0,16	0,22	
HR MILD STEEL (3 TYPES)	180	210	270	310	25	34	0,14	0,18	
BH (2 TYPES)	180	200	300	305	32	34	0,15		80
HR DP (3 TYPES)	300	380	580	780	14	19	0,11	0,18	30
CR DP (6 TYPES)	250	820	450	1180	3	27	0,08	0,19	30
HR FB (4 TYPES)	310	600	450	780	12	25			
HR TRIP (3 TYPES)	400	450	590	780	15	23			
CR TRIP (3 TYPES)	380	480	590	780	20	26	0,17	0,19	30

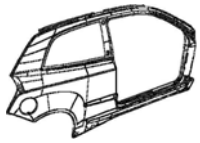
Fiat hasn't yet introduced in its models Multi Phase and Martensitic steel sheets, but their characteristics have already been evaluated (Table II) and their introduction is under development.

Tab. II – Mechanical properties of materials developed by FIAT

DESIGNATION	MINIMUM YIELD STRENGHT		MINIMUM TENSILE STRENGHT		MINIMUM ELONG.$_{80}$	
	from	to	from	to	from	to
MARTENSITIC STEEL (4 TYPES)	700	1200	900	1500	3	6
MULTIPHASE STEEL (5 TYPES)	620	1050	750	1350	4	10

Table III shows Fiat guidelines for steel sheets choice. In column 1 there are the names of the BIW components, in column 2 the main component functions, in the third the materials usually used, in the forth the materials lately introduced (in a weight reduction and crash increase perspective) and in the fifth the materials that will be introduced in the next future (when steel manufacturers will be ready to propose new reliable steels).

Tab. III – Estratto dall'archetipo FIAT di impiego lamiere

COMPONENTI		FUNZIONE	SOLUZIONI MATERIALE: STANDARD	FUNZIONALE	DI PUNTA
RINFORZO E SCATOLAMENTO MONTANTE CENTRALE		assorbimento energia, rigidezza, resistenza a sforzi eccezionali, fatica	LC	DP	TRIP
			BH	MP	
			HSLA		
RINFORZO MONTANTE ANTERIORE		assorbimento energia, rigidezza, resistenza a sforzi eccezionali, fatica	LC	DP	TRIP
			HSLA	FB	
			BH		
LONGHERINA E RINFORZO MONTANTE PARABREZZA		rigidezza, resistenza a sforzi eccezionali, fatica, indeformabilità	LC	DP	TRIP
			BH	FB	
FIANCATE ESTERNE		rigidezza dent resistance	LC	BH	DP
				P	
			OPPORTUNITA' TECNOLOGICA		TAILORED BLANK

5. WORKING METHODOLOGY

Nowadays in order to introduce new types of steel sheets in the automotive industry, a cooperation between car manufacturers and steel mills is essential.
In the last years we passed from a customer-supplier perspective to a co-design way of working.
These new steel sheets require an improved technical know-how, in order to evaluate different aspects such as spring–back, different hardening during drawing, increased mechanical characteristics.
So the designer job has been transformed in a team working done by designer, materials engineer and die-shop technician.
Furthermore, these new materials require more sophisticated software in order to take advantage of all the opportunities that such steels allow; so for this reason it's important the role of support that the steel mills resident engineers have in Technical Direction.

Fig.13 explains this concept, applied for the first time for Nuova Panda project, in cooperation with Arcelor and Magnetto [3].

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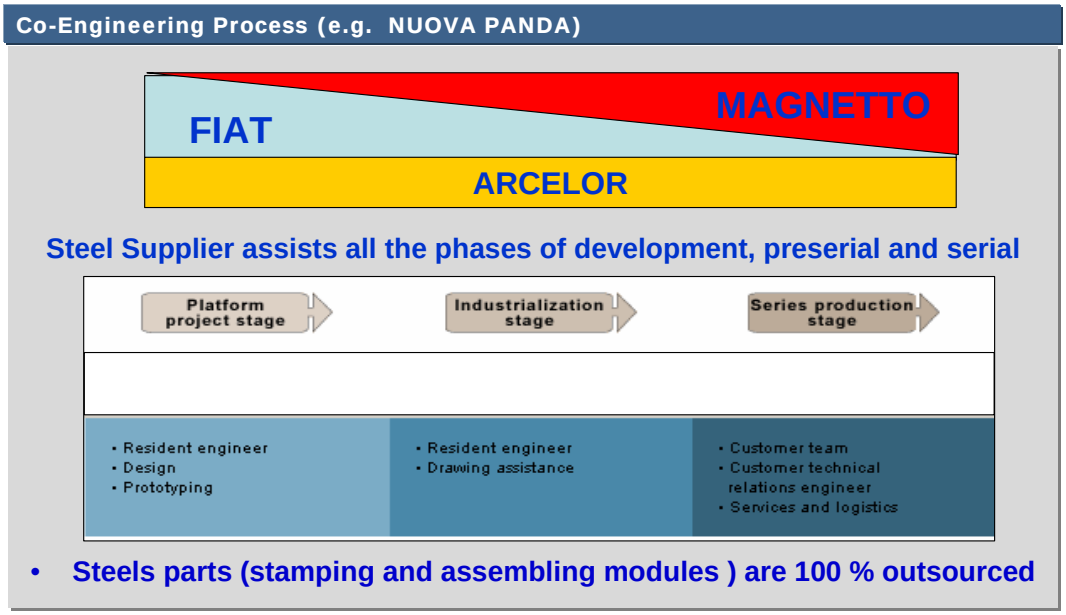

Fig.13 New working methodology

Next improvements are:
- involve in a strongest way the die manufacturer, in order to understand from the beginning all the aspects/problems related to the usage of such steels
- improve and up-date our software, in order to anticipate problems such as spring-back that inevitably appear. Only with reliable software is possible to manufacture dies with FEM model modified.

Fig.14 shows the steps that brought to the new steels development for Nuova Punto project.

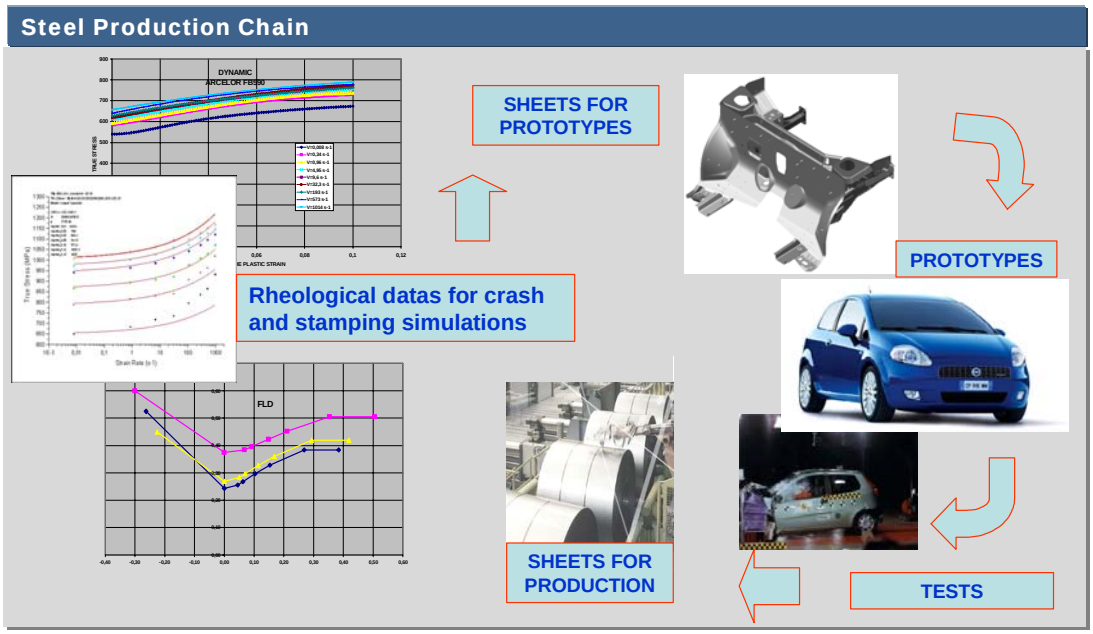

Fig. 14 Steel production chain

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6. NEW MATERIALS & THECNOLOGIES DEVELOPMENTS

Thanks to this approach, nowadays Fiat Auto is working along with the steel mills in order to introduce innovative steel sheets.
A typical example is the development of the austenitic steels. The steel manufacturer is industrializing the material and Fiat Auto is testing it in terms of metallurgy, weldability, paintability, corrosion resistance [4]; finally some prototypes will be made in order to evaluate its possible introduction in production.

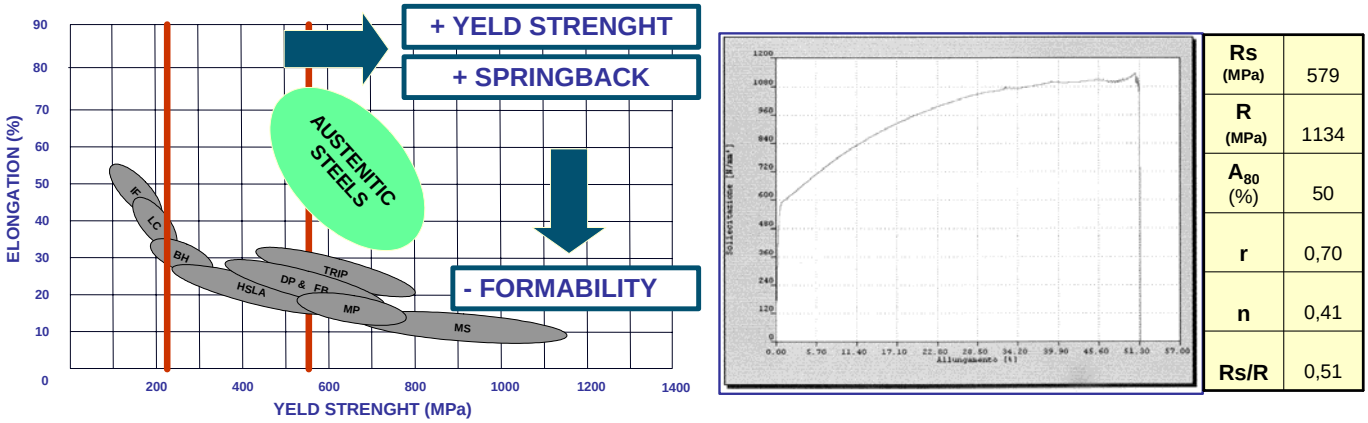

Fig.15 Austenitic steel

Austenitic steels is the limit that at the moment the cold-stamping allows.
Different scenarios (high mechanical characteristic, no spring-back problems) appears with the hot-stamping process.
Fig.16 shows the possible components that can be hot-formed.

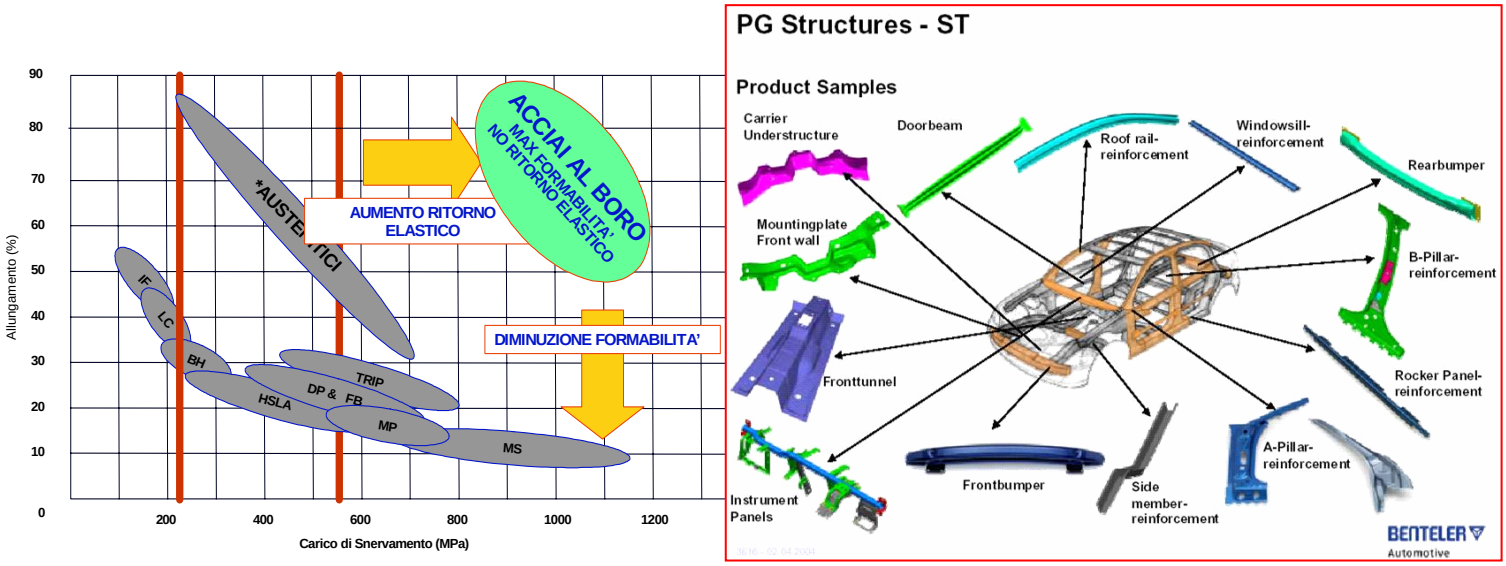

Fig.16 Hot-formed steel: characteristics and possible applications

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Fig.17 describes the hot-forming process (direct or indirect). It's essentially constituted by:
- trimming
- heating at more than 900°C
- hot-forming
- quenching in the water-chilled die

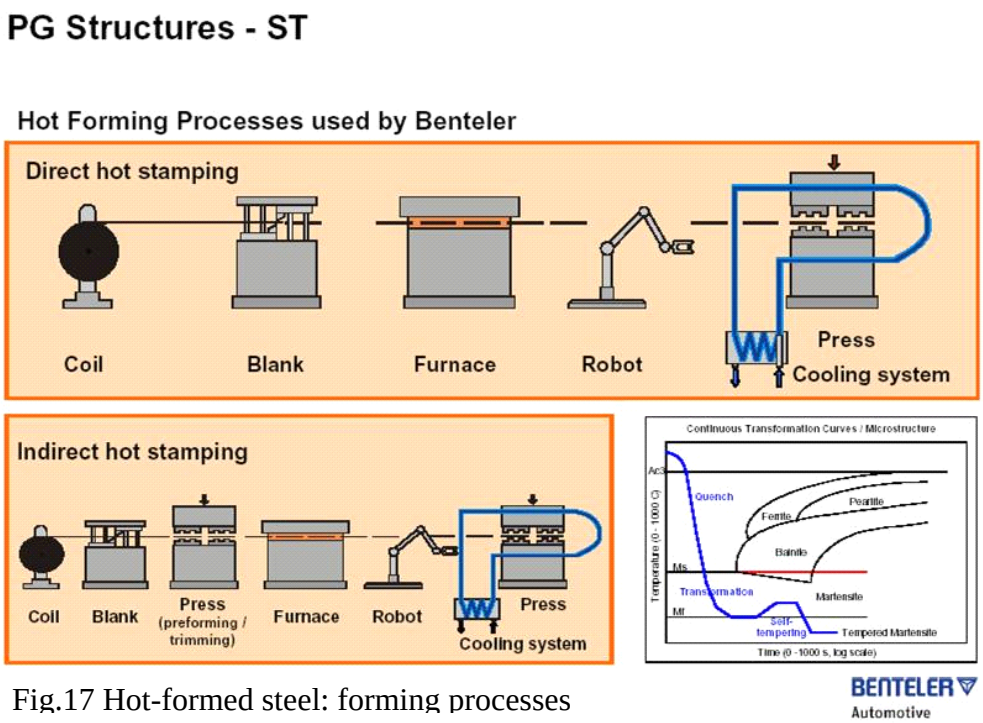

Fig.17 Hot-formed steel: forming processes

CONCLUSIONS

Cars emissions reduction and the growing security requirements have a great influence on the development of new classes of steels.
In order to achieve these two results, the best way is to lightweight the vehicles thanks to more performant materials. For this reason Fiat is passing from deep drawing steel sheets to more sophisticated steels.
But it's clear how in the steel production chain (from blast furnace to Body In White) it's necessary to involve new subjects not interested before: steel mills, die manufacturers and press-shop people.
This means a general change in terms of mentality and way of working that nowadays can't be delayed anymore.

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