TECHNICAL STUDY OF HIGH STRENGTH STEEL IN STRUCTURAL ELEMENTS IN VEHICLES

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***Abstract*—**Forming is the main problem when working with steel in sheet form. The friction between the working tool and the workpiece is very important, and a precise knowledge of friction in these fields for proper process design, tool design, surface quality and process control training is needed.

Forming causes tangential forces, which act between the die and the workpiece, in a resisting relative movement between the two surfaces.

The frictional force can be easily varied with adequate lubrication or altering the tool or workpiece surface roughness.

This research is carried out to study these phenomena to decrease manufacturing costs, and improve production and forming.

The material tested in this study is steel used in the automotive industry, more specifically in the manufacturing of car chassis.

***Keywords*—** steel, high strength, metal forming, friction.

I. Introduction

Steels for automotive industry need to have specific characteristics. Firstly, they are high-strength steels: it's possible to reduce the overall amount of material and therefore lighten the vehicle. Secondly, it's important that these steels can be able to deform and absorb large amounts of energy, which is important for maintaining the safety of vehicle occupants in case of accident or crash.

The variables that are going to be used in this study are: friction coefficient, surface roughness, tensile yield strength and breaking strength.

Traditional requirements for vehicle body have always been the strength in both static and dynamic terms, and the modulus of elasticity, which regulates the rigidity. These parameters can now add capacity for stretching and strengthening work. This last term has also an important effect on energy absorption and impact resistance.

Another important consideration is cost. TABLE 1 shows the type of data used by a European vehicle manufacturer. These data are key in their materials selection for the process; the wide range of materials and their influence on the design parameters illustrated by the broader view required by the contemporary design along with their knowledge of the costs.

TABLE I
DIFFERENT MATERIAL COSTS IN A VEHICLE

Material	Modulus E	Density	E/ρ	(E/ρ)/cost
FeP04 St 14	210.000	7,85	26.752	22292,99
ZstE 300 P BH	210.000	7,85	26.752	20578,14
S 420 MC ZstE 420 NbTi	210.000	7,85	26.752	19815,99
BTR 165 VHF – Stahl	210.000	7,85	26.752	19108,28
AlMg5Mn 10%kv	70.000	2,7	25.926	4320,98
AlSi1.2Mg0.4 10% kv, 190 ºC, 0.5hr	70.000	2,7	25.926	3703,70
AZ 91T6 Magnesium alloy	45.000	1,75	25.714	4675,32
TiAl6V4 F89 Titanium alloy	110.000	4,5	24.444	349,20
Kiefer – longitudinal	12.000	0,5	24.000	6000
Kiefer – transverse	12.000	0,5	24.000	6000
Al2O3 (Keramic, massiv) 'spröde'	370.000	3,85	96.104	480,51
GFK 55% force parallel to fiber	40.000	1,95	20.513	2051,28
GFK 55% force normal to fiber	12.000	1,95	6.154	615,38
AFK 55%, TM – Type parallel to fiber	70.000	1,35	51.852	518,51
	6.000	1,35	4.444	44,44
CFK 55% force parallel to fiber	110.000	1,4	78.571	1309,52
CFK 55% force normal to fiber	8.000	1,4	5.714	95,23
GF-PA-12 (54%) parallel to fibre	35.400	1,7	20.824	1041,17
GF-PA-12 (54%) normal to fiber	4.400	1,7	2.588	129,41
Glas (massiv) 'spröde'	70.000	2,5	28.000	18666,66

II. Dual Phase Steels (DP)

DP steels consist of a ferritic matrix containing a second hard martensitic phase. The DP steels (more martensite ferrite) are produced by controlled cooling of the austenite phase (in hot rolled products) or phase ferrite plus austenite phase (for products coated cold and hot dip) to transform some austenite to ferrite grains before rapid cooling transforms the remaining austenite to martensite.

Depending on the composition and process, hot rolled steel is obtained and it has greater ability to resist stretching.

Fig. 1 shows a schematic of DP steel microstructure containing ferrite with martensite islands. Soft ferrite phase is generally continuous, giving these steels excellent ductility. When these steels are deformed, stress is concentrated in the ferrite phase, of lesser force, surrounding the islands of martensite.

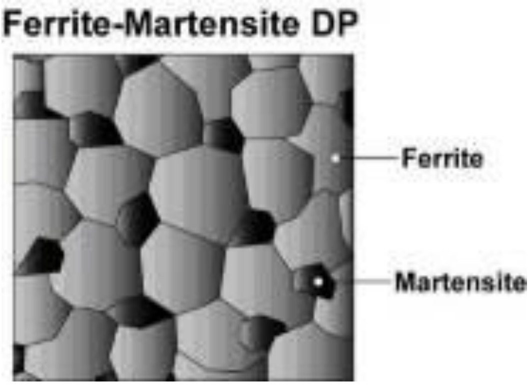

Fig. 1. Structure of DP Steels

Fig. 2 compares the stress-strain curve for HSLA steel to a similar curve for DP.

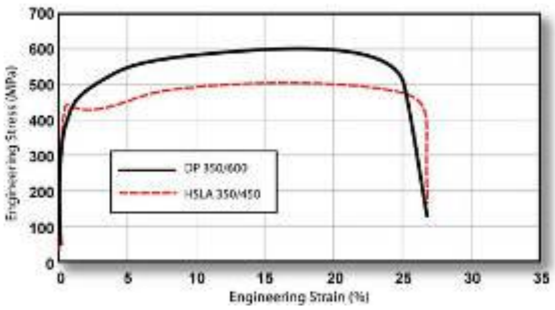

Fig. 2. Comparison of the stress-strain curve for HSLA steel and DP steel.

III. THE SMFS (SHEET METAL FORMING SIMULATOR)

There are several test models to evaluate the friction between the tool and the, through which it's possible to analyze the influence of the used lubricants and the surface textures of the workpieces.

These simulations of sheet metal forming are dependent on different areas and forms of tools. The SMFS is useful to know and investigate the coefficient of friction in different metals. Experiments will be performed to improve the sheet metal forming process, obtaining possible methods of optimization.

The sheet metal forming processes are used to shape a metal sheet in three dimensions, which will be useful in fields such as automotive, aerospace, construction, household appliances, etc.

An optimization in this field will provide a reduction in production cost, obtaining pieces with more sophisticated designs and to obtain parts with improved physical properties.

The machine used to perform the experiments has been designed by professors of the Department of Materials and Mechanical Engineering (Universitat Politècnica de València).


Fig. 3. SMFS Overview


Fig. 4. SMFS pin zone

The machine (fig. 3 and 4) consists of 2 major parts. The first is 2 arms that will hold the specimen at both ends; these arms are connected to two punches that are responsible for moving the specimen. The punches are equipped with force and displacement sensors, in order to have a greater control of the experiment and get accurate results. Secondly, between the two arms, it is located the pin, which is a metallic cylinder that is in contact with the specimen to generate friction to simulate the sheet forming.

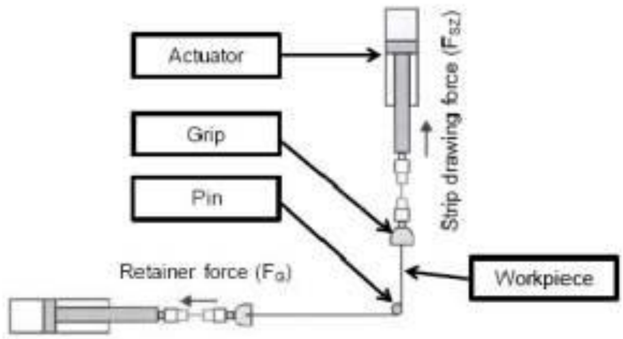

Fig. 5. Schematic drawing of a workpiece being tested

The tests are used for the study of friction conditions on the edge of the tools used (fig. 5). In this simulator, the specimens studied are anchored in the grips of linear cylinders.

IV. Experiments

Since we have a limited amount of material, it's impossible to make many tests, therefore, first, it is important to see what parameters could be changed and thus make the design of experiments. For this task, it has been used the Design-Expert software. It is a statistical application for the design of experiments (DOE) that provides in-depth analysis of the process variables and the components involved.

It is possible to modify the following parameters:

1) *Speed test (slow or fast)*
2) *Angle between the cylinders (30 ° or 90 °)*
3) *Lubricant (lubricant or without it)*
4) *It should also take into account a number of materials for the study, in our case, 4.*

The software indicates what tests we have to do, taking into account the possible combinations and response, as both the number of specimens and the number of parameters within each factor. With this we obtained a list of 24 experiments that reflected the effect of each of these parameters in the material.

TABLE II
Design of experiments

Number of Experiment	*Material*	*Angle*	*Speed*	*Lubricant*
1	DP 600	30	Baja	Without
2	14301	90	Slow	With
3	14301	30	Slow	With
4	DP 600	30	High	With
5	14512	90	Slow	Without
6	DP 1200	90	High	Without
7	DP 600	90	High	With
8	DP 600	30	High	Without
9	DP 600	90	High	Without
10	14512	30	High	With
11	14512	90	High	With
12	DP 1200	90	Slow	With
13	DP 1200	30	Slow	Without
14	14512	90	Slow	With
15	14301	30	High	Without
16	DP 600	30	Slow	With
17	DP 1200	30	High	With
18	14512	30	Slow	Without
19	14301	90	Slow	Without
20	14301	90	High	Without
21	DP 600	90	Slow	With
22	14301	90	High	With
23	14301	30	High	With
24	14301	30	Slow	Without

V. Results and Conclusion

24 tests have been conducted (TABLE III). This table compares the voltages of each of the materials (the values are negative due to calibration), but the value to take into account is the absolute value.

As we can see specimens of each material have broken with very similar resistance, being the material of least resistance the steel 1.4301 and higher resistance, the steel DP 1200.

TABLE III also compares the effect of test speed with the maximum voltage of each test, and there are no major differences between different speeds.

Apparently, the lubricant does not affect the results.

The Design-Expert software has performed an ANOVA (Analysis of Variance) analysis, examining the variance of the parameters and the influence they have within experiments. The results were (value F): Material (15351.67), Angle (67.53), Speed (11.79), Lubricant (1,36).

The value of F represents the importance of the variables in the final value of the maximum stress calculated. As shown, the greatest value corresponds to the material, although this is obvious since each material has a compressive strength or maximum stress different. Angle is also very important, and is the second parameter with more influence.

TABLE III
RESULTS OF EXPERIMENTS

	Force Cylinder 1 (KN)	*Display. Cylinder 1 (mm)*	*Force Cylinder 2 (KN)*	*Display. Cylinder 2 (mm)*
1	-3,558	-5,140	-4,003	29,062
2	-1,498	-34,015	-2,396	56,739
3	-1,651	-6,154	-2,018	35,841
4	-4,267	-1,089	-4,847	17,915
5	-2,465	-2,464	-3,434	14,147
6	-6,177	-0,633	-8,099	8,764
7	-3,332	-1,001	-4,377	14,431
8	-3,838	-1,583	-4,357	24,742
9	-3,023	-1,032	-4,102	15,001
10	-2,014	-1,851	-2,335	28,689
11	-2,529	-0,725	-3,501	10,652
12	-8,412	-2,456	-10,503	14,363
13	-9,177	-2,029	-10,235	12,075
14	-1,787	-3,883	-2,456	22,775
15	-3,050	-6,178	-3,521	89,544
16	-3,642	-3,015	-4,157	18,011
17	-8,924	-0,651	-9,814	8,828
18	-1,680	-5,190	-1,927	30,300
19	-1,820	-11,913	-2,752	68,960
20	-2,553	-4,540	-3,499	64,502
21	-3,357	-3,878	-4,376	22,113
22	-1,305	-2,110	-1,961	32,136
23	-2,659	-4,574	-3,160	66,480
24	-2,902	-2,855	-3,390	16,511

As a final conclusion, it’s possible to say that the material that performs better than others is DP600, not only for being the most economical of all, but it has fairly good mechanical properties, good surface finish, subsequently improved with the application of paint or varnish, and be a ductile material and easy to shape.

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