TESTING MECHANICAL CHARACTERISTICS OF HARDENED LGS PROFILE MATERIAL

M. Iliescu[1], L. Vlădăreanu[1], M. Pandelea[1], D. Marin[1]
[1]Institute of Solid Mechanics, Romanian Academy, Bucharest, ROMANIA, iliescumihaiela7@gmail.com, luigiv2007@yahoo.com.sg, marpius65@yahoo.com, marin_doina@yahoo.com

Abstract: Anti-seismic, sustainable eco-buildings, built on metallic structure get more and more interest on construction market. Basically, these buildings are made of Light Gauge Steel (LGS) profiles and their architecture enables so different and customized options. High attention is given to improving mechanical characteristics of LGS profile material – so that to reduce material consumption, process time and manpower required for manufacturing these profiles and, finally, reduce costs for building construction. The focus of this paper is on experiments and tests carried out in order to determine new mechanical characterisitics of LGS profile material, profile obtained in an innovative manufacturing process involving cold plastic deformation and induction hardening
Keywords: *mechanical characteristics, material, LGS profile, experiment design, regression model*

1. INTRODUCTION

At national and international level, in the context of European integration and support for environment-friendly technologies, there is special concern and attention to development of new / improved materials for construction.

Climatic changes in recent years that, so many times, have caused extreme natural phenomena - earthquakes, typhoons, abundant rainfall, have led to the need of finding new solutions for construction of buildings with recyclable materials whose improved physical and mechanical characteristics ensure higher safety and, more of it, are manufactured with as little energy as possible.

One of the solutions with a justified positive impact on the environment is the orientation toward eco-friendly and sustainable metallic constructions made of lightweight metallic structure. This involves one of the most sustainable worldwide execution systems, with main feature mentioned next [1]: recycling of materials and products used in execution; processing and production of the structure are based on efficient processing the raw materials; possibility of obtaining whole building structure components directly from the factory; high quality, innovative technological concept and guaranteed safety in execution; very low impact on the environment, low percentage of residual materials resulting from the execution-assembly process; possibility of dismantling the complete and / or partial construction or reuse of the structure and / or its components.

Example of a lightweight metallic structure for house is shown in Figure 1.

Figure 1: Lightweight metallic structure of building [2]

The market for construction products made of cold plastic deformed steel strip (cold formed) continues to develop worldwide. Typically, cold formed profiles have a thickness of up to 3 mm. Open sections (profile C, U), with thicknesses up to 8 mm, have begun to be used frequently in construction. The steel types commonly used in metal constructions are: S235 (OL37) - soft steel, ductile and S355 (OL 52) - hard steel, with characteristics according to SR EN 10025 + A1:1994 (STAS 500 / 2-80).

Compared with other construction materials such as wood or concrete, the following advantages can be highlighted for cold-formed steel elements: low weight; high strength and stiffness; light manufacturing; quick and easy assembly; increased accuracy of details; uniform quality; reduced transportation and handling costs; non-combustible, non-rotting, insensitive to insect action; recyclable

In the context of above mentioned, it is justified the research and, consequently, application in production, on a method of improving mechanical characteristics of Light Gauge Steel (LGS) profile's material, in certain areas of interest - for individual values of material thickness, section and / or length of metallic profile. The method is that of high / medium frequency currents hardening, note as CIF. The manufacturing process of these LGS profiles is real time controlled by virtual projection method [3].

Aspects related to concept and design of a mechatronic system for LGS profiles induction hardening, experiments design, experiments and tests on mechanical characteristics of hardened material, as well as resulted regression models and conclusion are further presented in this paper.

2. MECHATRONIC SYSTEM MODEL

Metallic structure of ecological anti-seismic buildings is based on U, or C type profiles. The study presented by this paper refers to C section LGS profiles, 420 mm length - as shown in Figure 2. This profile is, conventionally, named C420 profile.

These lightweight profiles are manufactured by cold plastic deformation – in successive stages through different punches and pairs of rolls, from strip to final part. Material characteristics have to be fit for cold plastic deformation, avoiding appearance of failures and cracks. Still, hardening process, more specific the transformation of perlite into martensitic must occur. This is why, estimation of carbon content is in between the interval [0.2 ÷ 0.3] %, so that LGS profile material has been selected to be S355 J2 + AR. Technological scheme for cold plastic deformation process is presented by Figure 3.

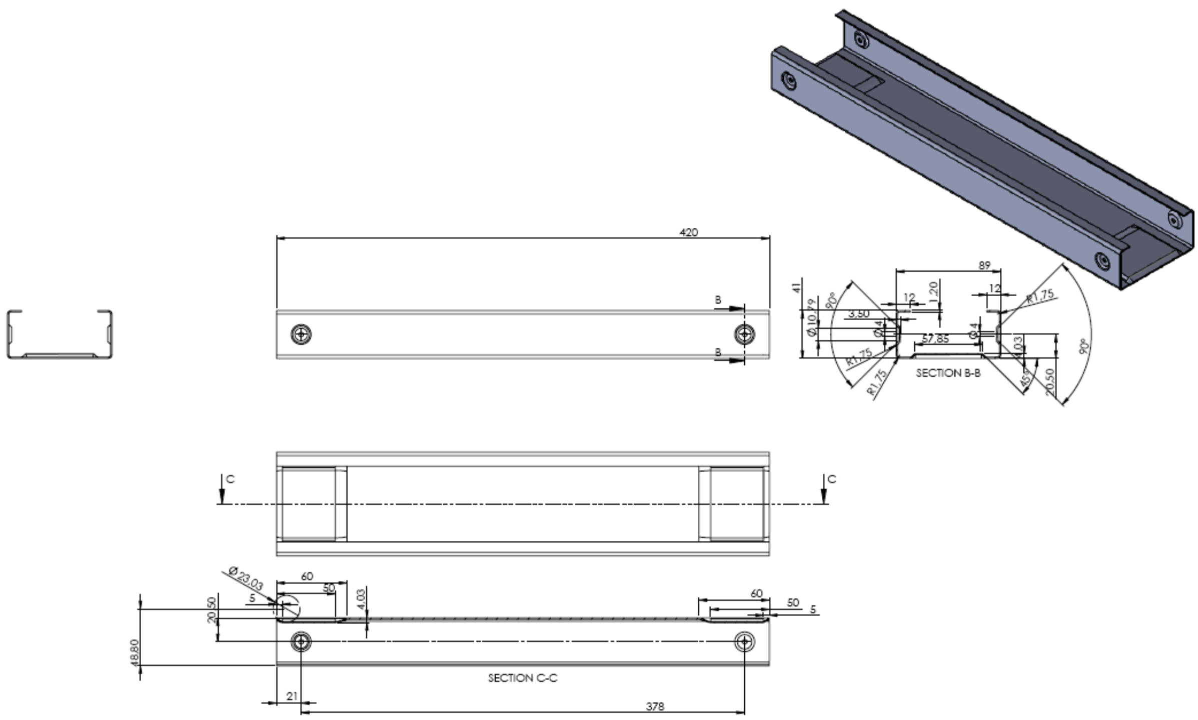


Figure 2: Drawing of LGS profile, C 420

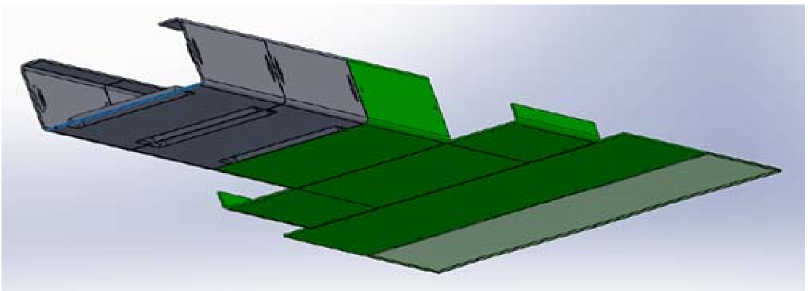
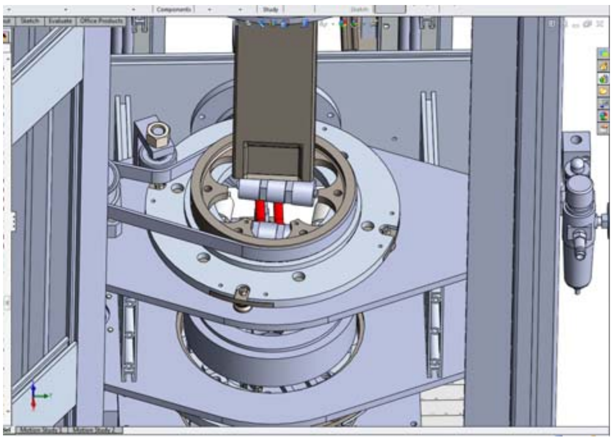


Figure 3: Technological scheme for cold plastic deformation of LGS profile, C 420

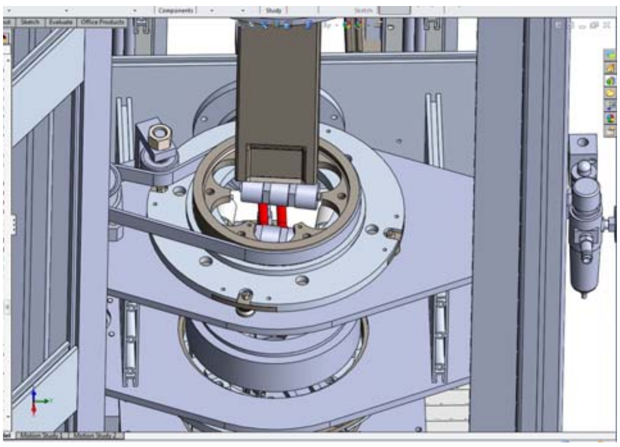
Once cold plastic deformation process is over, the LGS pofile is further processed by induction hardening with high / medium frequency currents. In order to efficient control the process so that optimum values for characteristic parameters to be set and monitored, a customized mechatronic system has been designed.

Usually, induction hardening is used for parts with thick walls, so that burnings and deformations caused by high process temperature to be avoided. These parts are shafts, gears, bolts, etc., mainly different from LGS profiles. The main issue with C 420 profiles, and all other similar lightweight profiles, is that of preventing material burning within its depth and / or deformation due to heat. So, concept and design of a customized mechatronic system [4] (see figure 4) have been done and some relevant aspects are mentioned next:

- C 420 profile is clamped so that its axis is the same with that of the mechatronic system;
- C420 profile is guided while passing through induction coil, so that to minimize heat deformation;
- C 420 profile, if necessary, can perform rotation around its axis;
- C420 profile translation speed is variable and can be correlated to its rotational speed;
- all motions and positions of system subassemblies are identifible by sensors;
- control is done by four axes controller, working with CAN, or PLCs;
- mobile heat generator, such as Minac [5], has to be used.

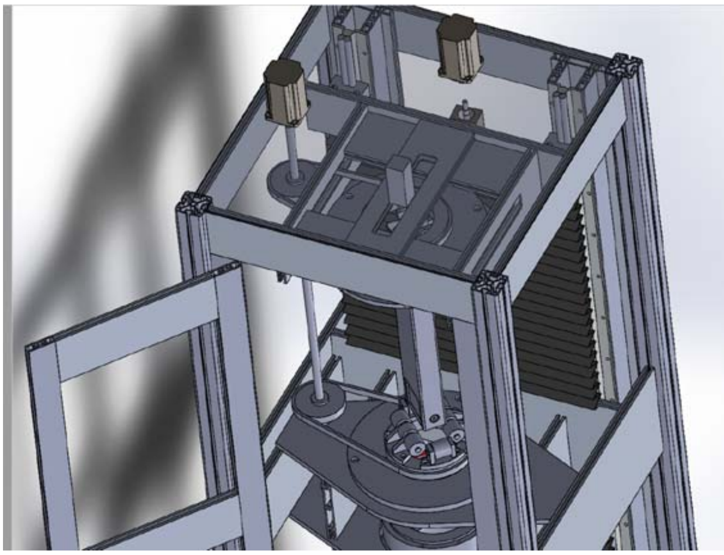


a. profile guidance – before passing through induction coil



b. induction hardening, CIF

Figure 4: Mechatronic system for induction hardening of LGS profiles (to be continued)



c. motion control components

Figure 4: Mechatronic system for induction hardening of LGS profiles

3. TESTING MECHANICAL CHARACTERISTICS

High frequency induction hardening equipment is available from DUROTERM SRL [6]. CIF experiments were carried out on this equipment to establish multivariable regression models for the LGS profile material characteristics, more specifically, hardness, HV, and tensile strength, R_m [N/mm^2].

Since profile thickness is relatively small, the superficial hardened layer should not exceed 0.5 mm and hence will apply to high frequency (medium) currents. For the same reason, cooling will be done quickly with water. By defining these working conditions, it is intended to avoid hardening in the entire thickness of material and its excessive brittleness, as well as the large, uncontrolled and irreversible deformation of LGS profile while heating (by induction).

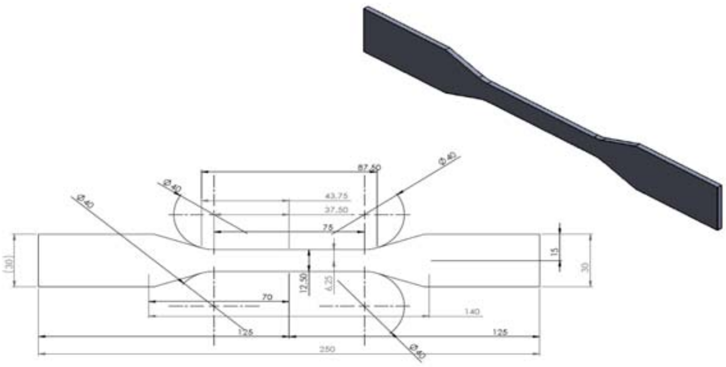
This paper will further be focused on tests for determining values of tensile strength, R_m, once material is hardened by induction and, further, for determining regression model so that interdependence of input and output process variables to be known. An image taken while experimenting the induction hardening process of material in LGS profile is presented in Figure 5.

a. CIF process of material in LGS profile

b. induction coil for LGS profile

Figure 5: High / medium frequency current induction hardening process, CIF

Tests for determining values of tensile strength in hardened material of LGS profile have to be done according to standardized condition. More specific, the samples submitted to tensile failure have shape and dimensions mentioned in EN ISO 6892 (see Figure 6).



a. drawing of samples

b. samples

Figure 6: Sample for tensile strength tests

The tensile strength, R_m, material tests were done at GRIRO [7] in RENAR accredited mechanical testing laboratory. Images taken while testing are shown in Figure 7.

a. samples while tensile loading

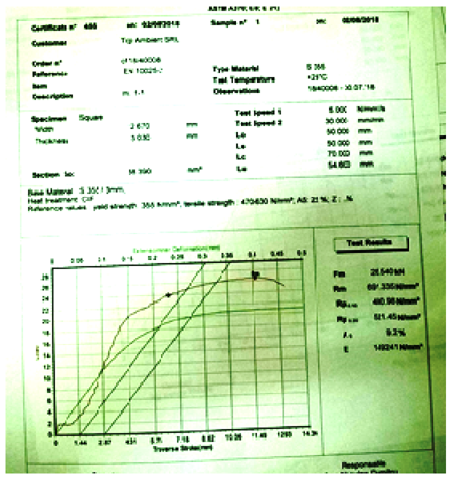
b. failure of samples

Figure 7: Tensile strength tests

Tests results are evidenced in Figure 8. There can be noticed values for hardened material tensile strength, R_m [N/mm^2] and, on the certificate, value for other material mechanical characteristics, like elongation, A_0 [%].

Exp. no. j	Input variables		Output variable
	x_1 P [kW]	x_2 v [mm/s]	y_j (average value) R_m [N/mm^2]
1.	-1	+1	682,7
2.	-1	0	732,7
3.	-1	-1	859,6
4.	+1	+1	764,6
5.	+1	0	904,5
6.	+1	-1	789,6
7.	0	0	660,5
8.	0	0	789,2
9.	0	-1	843,2
10.	0	+1	654,9
*** 02	„raw material” = reference		586,00

a. experiment design and results

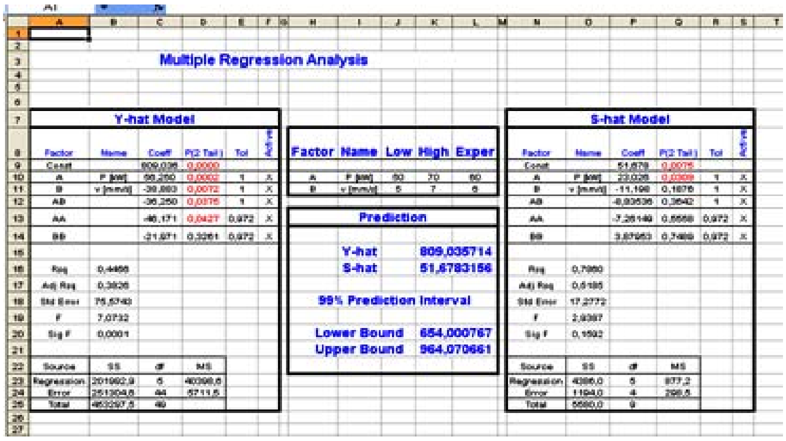


b. test certificate

Figure 7: Tensile strength tests

4. CONCLUSION

Regression analysis for tensile strength, R_m, has been done with DOE KISS software (see Figure 8) and proves that both input variables, as long as their interaction does significantly influence the output variable's values. The regression model obtained is polynomial type 2, with interactions.



a. regression coefficients

$$R_m = -2261{,}64 + 82{,}78P + 178{,}62v - 3{,}63Pv - 0{,}46P^2 \text{ [N/mm}^2\text{]}$$

b. regression model

Figure 8: Regression analysis results

Final conclusion on mechanical characteristics tests for hardened material of LGS profile are as follows:

- induction hardening with high / medium frequency currents, CIF, applied to S355 J2 + AR material does have significant influence on tensile breaking strength, the increase in the values being greater than 10% (compared to the value in the "raw material") - up to 50%;
- results of regression analysis highlight the fact that the strongest influence is that of the power, P, and the weakest influence is that of the Pv interaction, moreover, the second order parameter, v^2, does not have a significant influence on strength resistance, R_m;
- it is important to avoid situations when material becomes extremely fragile, so that it is intended to identify the CIF parameter values that induce a state of "balance" - between the high tensile strength values (compared to values for "raw") and acceptable values of elongation at tensile breaking, A_0, not less than 8-10%.

Acknowledgments

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