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STRUCTURE AND PROPERTIES OF STEELS FOR APPLICATIONS IN AUTOMOBILE INDUSTRY

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Key words: *automotive industry, metal materials, highly robust steels, TRIP – steels, martensite steels, optimization of composition.*

Abstract: *The paper presents information about the notations, the structure and the properties of steels applied in automotive industry. A modeling-based approach is recommended to design the composition and for a suitable processing improving the mechanical plasticity attributes of steels with martensite structures. The research is supported by the Scientific Research Fund, the ДВУ 02/11 project.*

The research about the design of new kinds of steel continues with respect to the necessities of the automotive industry in the steel production. The considerable batch production and competitiveness of this industry requires a reduction of the production expenses via innovations in the technological domain and improving safety in cases of road accidents [1]. The research must reduce the weight of the final product via implying highly strength steels. The highly-strength steel applications are increased for simultaneous satisfying the variety of rather contradictory requirements related to the improved plasticity, welding ability and strengthness for mechanical impacts, weariness and corrosion.

Various types of highly strength steel designed for the market requirements with a pull strength of 980÷1180 MPa are applied for separate automobile components or parts; the strength of the prevailing types of steel with general application varies in the range of 440÷590 MPa. Over strength sheet steels are an object of limited applications due to their restricted plasticity. Nippon Steel Corporation has created three types of a highly strength sheet steel with strength of 980 MPa that are applied for the production of automobile seats [2].

The present research paper focuses at a generalization of the information about the notations, the structure and the properties of steels applied in automotive industry. It also recommends an approach to design a composition and a suitable processing that improves their mechanical and plasticity properties.

1. Types of Steel and Contemporary Trends.

Ron Krupizer, the vice-president of automotive applications of the American Iron and Steel Institute (AISI), points in [3] innovative ways related to the requirements for economy of fuel, emissions and recycling. It is explained that implying highly strength stells it is possible to reduce the carosserie up to 25%; the new third-generation steels that are elaborated promise a reduction of the weight up to 35%. Fig.1 presents the volume of hostile emissions [kg/m] of different transport vehicles; the greatest share belongs to automobiles. The weight reduction for these transport vehicles improves significantly the combustion effectiveness which as a result is tied to the emissions' reduction for hothouse gases.

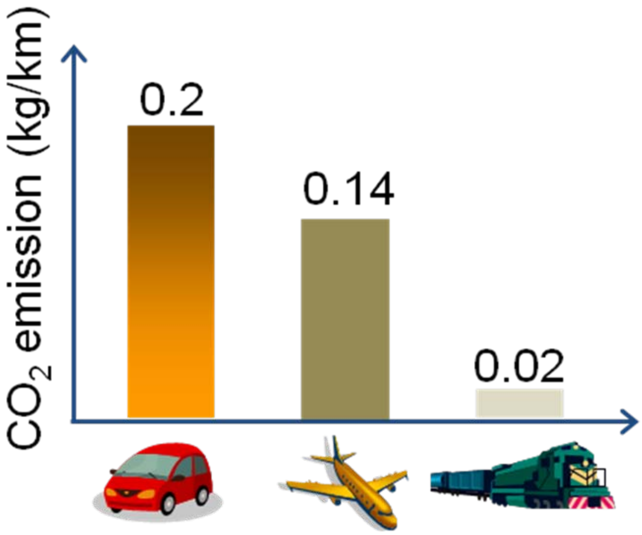


Fig.1. Values of the emitted CO_2 share for various transport vehicles [3].

To reduce the sequences from the global warm spell the Japan government has undertaken acts to improve the fuel consumption for gasoline engines with about 20% since 1995 and the actual value changed from 12.6 km/l to 15.3 km/l for 2010.

Table 1. Data about mechanical and plasticity indicators for steel related to applications in automotive industry.

№	Steel Signature	Re [MPa]	Rm [MPa]	A [%]	n
1	Mild 140/270	140	270	38 - 44	0.05-0.15
2	BH 210/340	210	340	34 - 39	0.23
3	BH 260/370	260	370	29 - 34	0.18
4	IF 260/410	260	410	34 - 38	0.13
5	DP280/600	280	600	30 - 34	0.2
6	IF300/420	300	420	29 - 36	0.21
7	DP 300/500	300	500	30 - 34	0.2
8	HSLA 350/450	350	450	23 - 27	0.16
9	DP 350/600	350	600	24 - 30	0.22
10	DP 400/700	400	700	19 - 25	0.14
11	TRIP 450/800	450	800	26 - 32	0.14
12	HSLA 490/600	490	600	21 - 26	0.24
13	DP500/800	500	800	14 - 20	0.13
14	SF570/640	570	640	20 - 24	0.14
15	CP 700/800	700	800	10 - 15	0.08
16	DP 700/1000	700	1000	12 - 17	0.13
17	Mart950/1200	950	1200	5 - 7	0.09
18	MnB	1200	1600	1 - 5	-
19	Mart1250/1520	1250	1520	1 - 6	0.07

Data about denotations and specific values for strength and plasticity characteristics of steels applied in automotive industry are shown in Table 1.

The weight reduction of separate components requires a preservation of the balance during the design stage via the system 'composition – processing mode – properties' thus aiming to improve strength and also plasticity characteristics of examined steels. Denotations are homogeneous worldwide so the data in Table 1 is related to the program ULSAB – AVC (Ultra

Light Steel Auto Body – Advanced Vehicle Concept). Word Auto Steel is an automotive group of 17 companies oriented at the automotive industry and also it is a part of the World Steel Association.

Steels designed for automotive industry in Fig.2 may be classified according to various features.

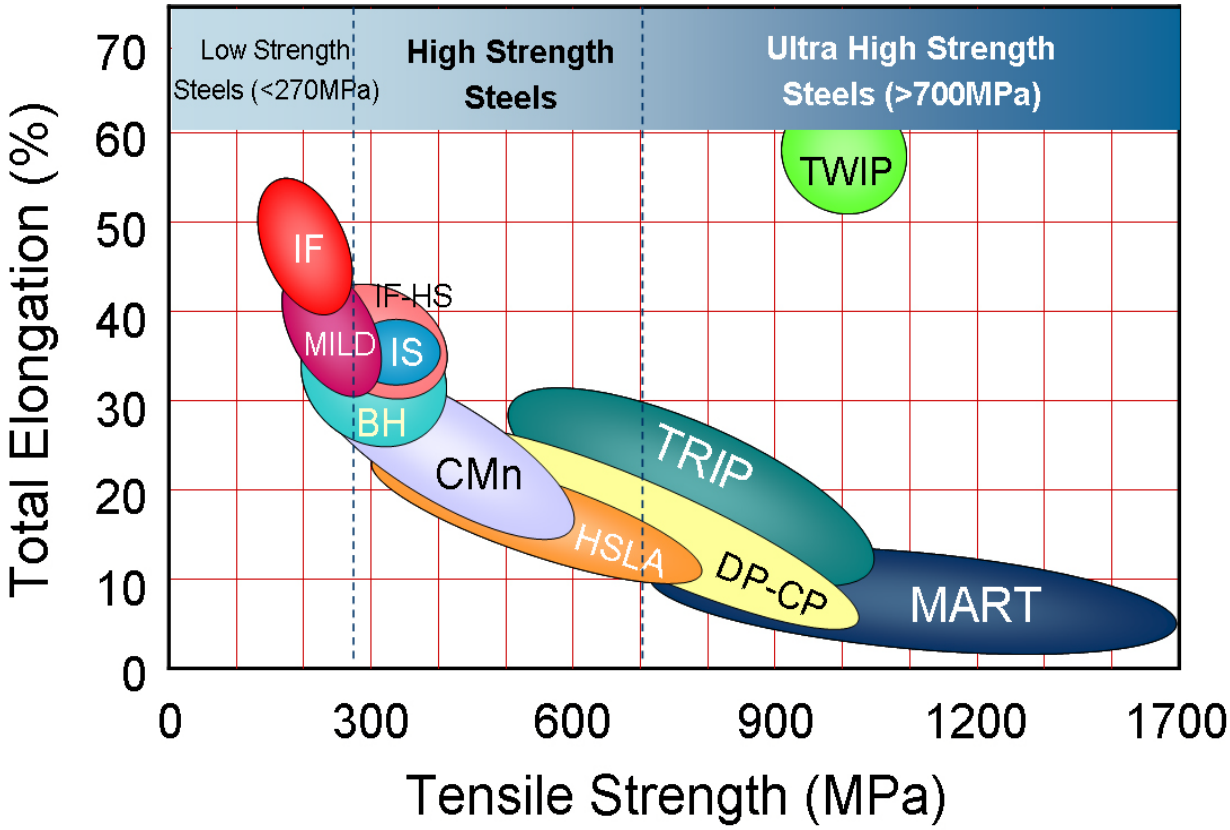


Fig.2. Areas to change qualitative characteristics of steel from the program ULSAB – AVC.

The impression from Table 1 and Fig.2 is that the strength increase for different types of steel is on the one hand linked to the reduction of elongation on the other hand. This unfavourable circumstance of steels with high strength leads to worsening plasticity of sheet and profile material but also it improves stability to mechanical impacts without growing the product mass. Cited indicators have a greater interval of changes due to the unification of specifications from various steel-casting enterprises with different possibilities for production.

The chemical composition of steels is decisive to guarantee the quality of the product. It is determined via mechanical properties obtained in fact after plasticity- and thermal processing of the material.

Manganese, chromium, molybdenum and nickel added as alloyed elements individually or in combinations assist to increase the strength. The percentage of carbon contributes to the martensite increase. Variations of carbon and also of other alloyed elements must not only improve mechanical properties but the most important for a future optimization is that technological properties like welding ability, plasticity, etc. must be preserved and even improved.

The object of scrutiny in the present research are steels with pull strengthness greater than 700 [MPa] graphically presented in Fig.3.

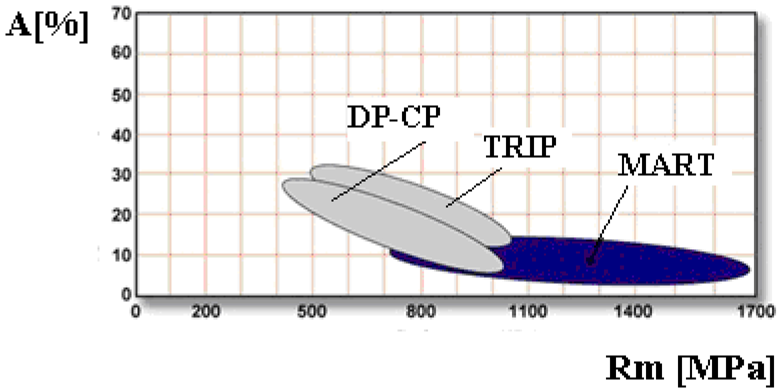


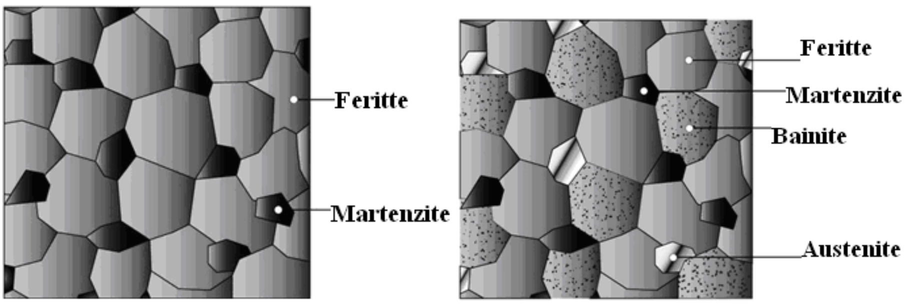
Fig.3. Notations and characteristics of different types of steel, the object of microstructure research.

2. Specifics of Steels with Extremely High Strength.

Double-phased (DP) steels consist of a ferrite matrix (Fig.4a) with a solid martensite component localized in separate areas. The soft ferrite phase of these steels adds good conditions for form plasticity. Tensions caused by deformations are concentrated near to the ferrite phase and the solid martensite phase is redistributed in a greater volume; the increase of the strength is a sequence forms this [redistribution]. The increase of the martensite volume leads to an increase of the steel strength.

The austenite transform for DP steels in ferrite and martensite is realized via a controlled cooling during the process of warm rolled sheet production. Depending on the chemical composition and the technological route of steel production it is possible that the microstructure will include also bainite.

With respect to the TRansformation Induced Plasticity (TRIP) of steels (with a general structure of the type shown in Fig.4b) the residual austenite of quantity about 5% is present in the composition of the ferrite matrix together with various quantities of the hard phases of martensite and bainite. During the process of deformation the residual austenite for such steels transforms in martensite.



a b

Fig.4. Schematic microstructures of DP (a) and TRIP (b) steels.

The quantity of residual austenite transformed in martensite is controlled via the carbon percentage in steel. In cases with TRIP steels containing smaller quantities of carbon the residual austenite begins to transform in martensite exactly after the deformation and the hardening speed is increased. For TRIP steels with higher percentage of carbon the residual austenite is more strength; its transform in martensite begins for tension thresholds beyond the ones caused by the deformation. For example hardening for this type of steels is realized in cases of impacts in road accidents (crash events). Based on the presented effect it is therefore possible to design the composition and the properties of TRIP steels so that on the one hand to receive very good conditions for deformations and on the other hand we shall have the hardening effect to swallow (absorb) the impact energy in the crash.

Complex-phased (CP) steels possess microstructures that are similar to the ones of TRIP steels but they do not contain any residual austenite.

MART steels have final structures that are obtained from the austenite which transforms completely in a martensite matrix with small amounts of ferrite and/or bainite. Martensite MART steels possess the greatest elongation strength up to 1700 MPa accompanied by the smallest possibility for plasticity deformations. The increased carbon percentage in martensite steels is simultaneous to an increase of hardening due to an increase of martensite.

3. Design of Martensite Steels with optimal Indicators.

The stage of design, research, production and implementation of highly-strength alloyed steels includes specifications of the chemical composition, the parameters of the thermal processing mode and the final mechanical characteristics. Steel with its elements and possibilities for thermal processing is a technological object and therefore it may be treated by an approach of modelling the properties and optimizing the composition depending on the specific application. The procedure for argumented specification of the chemical composition via the number and the quantity of alloyed elements is relatively new related to the search of connection with the final mechanical indicators.

[7] introduces a method, an algorithm to model via artifical neural networks (ANNs) the creation of an optimized composition of an alloy on an iron base and with a rational technological mode of operation. The chosen pilot example is from the area of metallurgy but the created instrumentarium may be successfully applied in intermediate-product and chemical-thermal productions. Based on the optimization of compositions of alloys with an iron base, new highly-strength types of alloyed steels are offered with high exploitation resources.

The presented procedure points to a multi-criteria optimal connection between suggested mechanical properties of the respective composition. The multi-criteria optimal relation ‘composition – properties’ is related to the complex of mechanical characteristics treated as a combination of goal functions to optimize customer’s qualities of steels for a specific application.

The research is based on a data base (DB) of 93 alloys located at the URL (Universal Source Locator) - http://www.splav.kharkov.com/choose_type.php. The cited DB contains the links between the chemical composition and the mechanical characteristics of the included alloys. The interval of variations for the elements is shown in Table 2 and in Table 3 we find the values for variations of the mechanical indicators in thermally-processed states: hardening and revulsion.

Table 2. Interval of variations for the elements from the composition of explored steels

Elements	**C**	**Si**	**Mn**	**Ni**	**S**	**P**	**Cr**	**Mo**	**V**
min [%]	0.12	0.27	0.27	0	0.025	0.025	0.15	0	0
max [%]	0.5	1.4	1.6	4.22	0.035	0.035	2.5	1.5	0.15

Table 3. Range of variations for characteristics of explored steels.

Mechanical characteristics	**Rm [MPa]**	**Re [MPa]**	**A [%]**	**Z [%]**	**Kcu [K J / m^2]**	**HB*10^{-1} [MPa]**
min	500	300	7	30	290	179
max	1670	1375	26	70	1830	541

The described multi-criteria computational procedure in [7] leads to selecting solution # 1 (Table 4) for its economic alloying obtained via the optimization of a neural model. This solution may be compared to solutions # 2 and # 3 obtained via optimizations of regression models following the approach described in [1]. Figu.5 and Fig.6 show a graph interpretation of the solutions from Table 4 related to basic alloying elements Mn, Ni, Cr and the characteristics Rm, Re, A.

The comparison of solutions obtained by the neural model and the regression models in relative units related to solution # 1 (Fig.6) leads to the conclusion that the composition from solution # 2 is more suitable for practical applications due to its better relative plasticity. In the case of the latter we have only a decrease of the flow bound with about 3 percents.

Table 4. Optimal compositions maximizing the flow bound

Solution / Parameters	#1	#2	#3
C	0.27	0.3	0.3
Si	1.10	1.02	0.9
Mn	1.06	1.2	1.62
Ni	2.36	2.35	3.41
S	0.02	0.02	0.02
P	0.02	0.02	0.02
Cr	1.04	0.96	1.6
Mo	0.15	0.18	0.2
V	0.0087	0.0087	0.015
Rm [MPa]	*1666.9*	*1678.*	1669.9
Re [MPa]	1370.3	1355	1125
A[%]	*11.4*	*12.8*	*14.6*
Z[%]	*51.1*	*52.3*	*53.8*
HB [/]	*281.6*	*284.3*	*273.8*

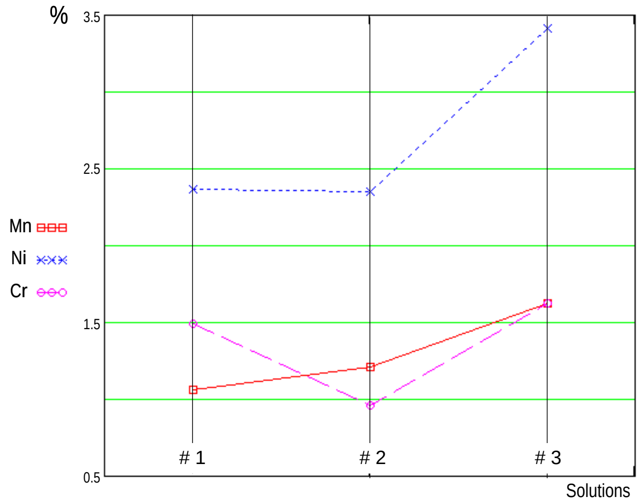


Fig.5. Variations of the quantity of Mn, Ni and Cr for the explored solutions

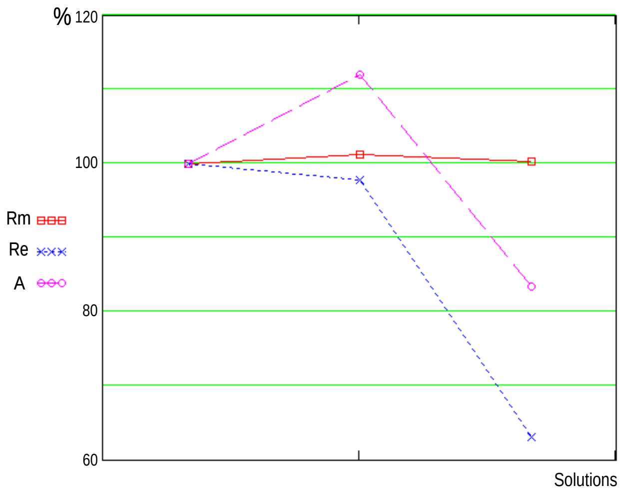


Fig.6. Variations of the relative strength s, the yield bound and the elongation for the explored solutions

4. Conclusion: The research generalizes the information about the notations, the structure and the properties of steels applied in automotive industry. A recommendation is introduced for the design of compositions and a suitable processing improving their mechanical and plasticity properties. Based on their chemical composition via optimization of the properties there is a preservation of the high values for the strength and the yield bound; there is a relative increase with about 12%. If this solution is confirmed experimentally then its implication in practice will improve steels' deformability with alloys guaranteeing a martensite structure.

REFERENCES

1. Tontchev,N., S.Popov, P.Koprinkova-Hristova, S. Popova, Y.Lukarski, Comparative Study on Two Approaches to Steel Alloys Mechanical Characteristics Modelling and Compositions Optimization, will be published in SAI`2010.

2. Takahashi,M., Development of High Strength Steels for Automobiles, Nippon steel technical report No. 88 July 2003.

3. Ron Krupizer, presentation titled ‘Steel and Fuel Economy’.

4. Dong-Woo Suh, Recent Development of Light-Weighting Steels, Graduate Institute of Ferrous Technology.

5. H.Takechi, Metallurgical Aspects on Interstitial Free Sheet Steel from Idustrial Viewpoints, ISIJ International. Vol. 34 (1 994), No. 1, pp. 1-8.

6. Meyerd,M., Influence of the Substitution of Si by Al on the Properties of Cold Rolled C-Mn-Si TRIP Steels, ISIJ International, Vol. 39 (1 999), No. 8, pp. 813-822.

7. Tontchev,N., P.Koprinkova, S.Popova, On the Possibility to Forecast Properties of Highly Strength Steels in Cases of Economic Alloying, Conference of the Department ‘National Security and Defense’, Military Academy, 2011, Sofia, Bulgaria under print (in Bulgarian).