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POSSIBILITIES OF APPLICATION OF MODERN FINE GRAINED STEELS FOR THE PRODUCTION OF CAR SEMITRAILERS

Robert ULEWICZ, Paweł SZATANIAK, Frantisek NOVY

Institute of Production Engineering, Faculty of Management, Czestochowa University of Technology
WIELTON S.A.
Department of Materials Engineering, Faculty of Mechanical Engineering, University of Zilina

Changing market conditions, increased competitiveness force designers to look for new solutions in the design of means of transport. We can distinguish several trends in the design of means of transport. Most important of these is to reduce the kerb weight of the means of transport in order to achieve greater load capacity and also to reduce fuel consumption and CO_2 emission. An important element is the limitation in resistance to the means of transport, but here on the way stand the EU provisions related to the maximum length of the road transport sets. From the point of view of realized processes of production, it is appropriate to design structures such that in maximal way simplify the production process and assembly. We can assume that the economic factor as well as the maximum extension of the lifespan is essential when selecting the right material of construction. The consequence of this situation was the implementation of modern metallurgical technologies and metallurgical processing, which led to the creation of new groups of steel with a wide range of mechanical properties and formability technology. Despite use in structural elements of cars, machinery and also semi-trailers light weight metal alloys the mass of these structures in 60% are parts made of steel sheets of increasing strength [1, 2]. The strategy of companies producing means of transport as well as the company Wielton SA is the design and production of more efficient transport sets through the use of lighter constructions, interchangeable modules and greater specialization of transport semitrailers. Such an approach requires concurrent planning within the construction, technology and material. The automotive industry, as one of the most dynamically developing sectors of the world economy, determined the direction of expansion of new construction solutions using modern materials. Significant decrease in the weight of cars over the last 30 years has resulted from the development of new steels, especially microscopic (HSLA - High Strength Low Alloy). Figure 1 shows the possibility of using high-strength steel in this HSLA type steels in car semi-trailers.

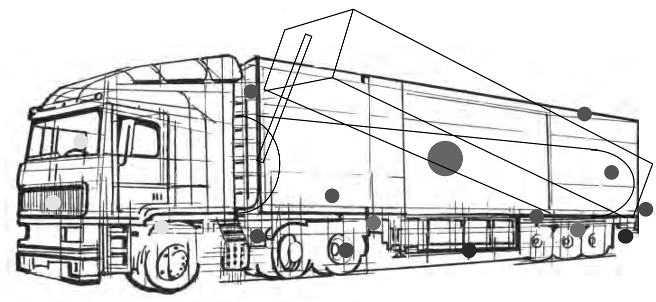


Fig. 1 *The potential of applications of new materials in supply semitrailers [3]*

Obtaining such effects in the form of reduction in the kerb weight of the semitrailers is only possible when there is a connection between construction development with optimization of manufacturing processes, which guarantee the profitability of the chain connection of construction-material-technology-exploitation (Figure 2)

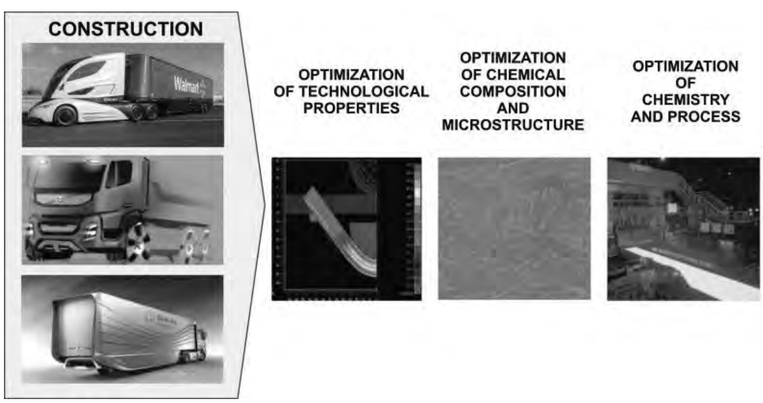


Fig. 2 *Connecting the construction development with the development and optimization of manufacturing processes [4]*

1.Characteristics of fine grained steels

HSLA steels (High Strength Low Alloy) have good mechanical properties obtained as a result of grain refinement and precipitation hardening involving micro additives introduced into steel [5].

Industry currently uses in addition to HSLA also steels of BH type (Bake Hardening), strengthened by the cold work aging, and IF types (Interstitial Free) and IS

(Isotropic), with high susceptibility to pressing [6-8]. The expectations of the automotive industry, as well as the industry of car semitrailers manufactures and agricultural equipment were met as a result of the development of modern group of steel with multiphase structure [9]. These include steels with ferritic-martensitic structure of DP type (Dual Phase) [6,10,11], ferrite-bainite with residual austenite of TRIP type (Transformation Induced Plasticity), undergoing strengthening during technological forming, as a result of martensitic transformation γ phase [12], with a comprehensive participation of various phases of CP type (Complex phase) [13] and the martensitic of MART type (martensitic Steel) [14].

High demand for DP steel products is the result of unique combination of mechanical properties, which provides a two-phase structure, such as the lack of a defined yield point, high strength combined with excellent ductility, or very good technological plasticity in cold forming operations, much better than the plasticity HSLA steel, characterized by comparable strength [1]. For this reason, DP steels are increasingly used in the automotive industry for the manufacture of body parts, and items of particular importance; for example, bumpers, rims and special sections which increase the rigidity of the vehicle structure or protect against the effects of collisions.

Multi-phase steels contain in their structure ferrite, bainite, martensite and also sometimes retained austenite of shares ensuring the achievement of desired properties of strength and plastic. Figure 3 shows a comparison of conventional and modern properties of steels used in the automotive industry.

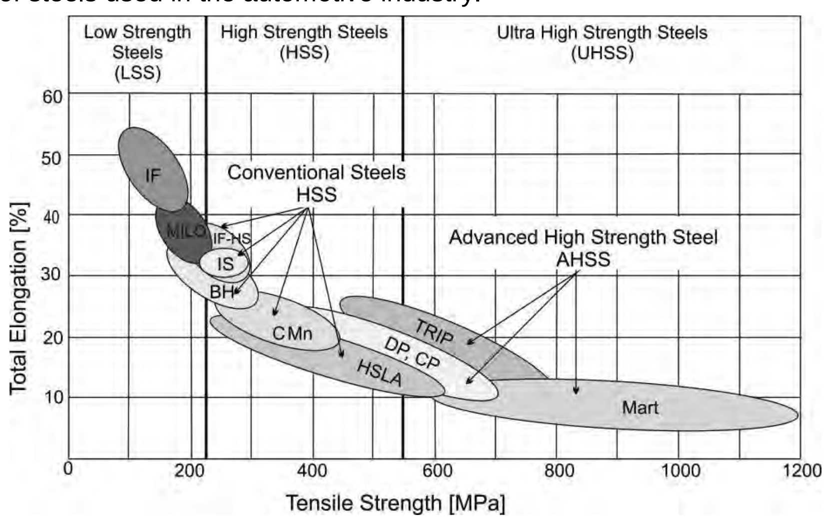


Fig. 3 *Comparison of the properties of conventional and modern steel: LSS (Low Strength Steels), HSS (High Strength Steels), UHSS (Ultra High Strength Steels) [1]*

Until then there has not been systematized division of steels for the automotive industry. According to the current state they can be classified into three basic groups:

- First group: they are soft steels, ductile low carbon steels (DQSK IF steels) of immediate strength on tensile Rm of less than 300 MPa and total elongation of A ranging from 30 to 60%.
- Second group: these are conventional steels, high strength HSS (BH CMn IF with mi microadditives, HSLA) with 300<Rm<700 MPa and reduced A compared to first group of materials.
- The third group: these are advanced steels with a very high strength AHSS (Rm above 700 MPa, even up to 2000 MPa) and elongation contained in a relatively wide range of 5 ÷ 30%, wherein the increase in strength is accompanied by a reduction in ductility.

The first two groups may already be called classical: these materials are widely used in the construction of self-supporting car bodies in a mass scale. Steels from group III are being successively implemented in the production and their share is growing steadily.

DQSK steels (Drawing Quality Special Killed) and IF steels are steels with very low carbon content, high susceptibility to pressing and ferritic structure, wherein IF steels do not contain in the solution the elements forming the interstitial solutions, including also practically carbon (C <0.005% N <0.005%, S <0.005%). Their development are steels with increased strength from the second group (IF-HS and BH). They contain microadditives (Ti, Nb, V), binding residues of interstitial elements, forming carbides, carbon-nitrides and carbon-sulfides in wrap of ferritic matrix. HSLA steels are also a group of steels with carbon content below 0.1%, reinforcing Mn and various microscopic additives such as: Cr, Nb, Al, Si in an amount of several tens%. CMN steels owe their properties to the ferritic structure solution strengthened Mn.

All of them have a low carbon equivalent and consequently a good weldability. The use of minor amounts of alloying elements, which are primarily aimed at inhibiting grain growth (hence the appearance of the name "steels fine-grained"), provides a significant increase in mechanical properties.

2. Impact of grain size on selected properties of the steel

Ultra-fine-grained steels have often been shown to have mechanical properties superior to conventional structural steels with common microstructures. Yield strength and fatigue strength have been shown to increase markedly with reduced grain size, and impact toughness has improved radically. The effect of ferrite grain size on yield strength and impact transition temperature (tough/brittle), extrapolated to ultra-fine grain sizes, is shown in Fig. 4.

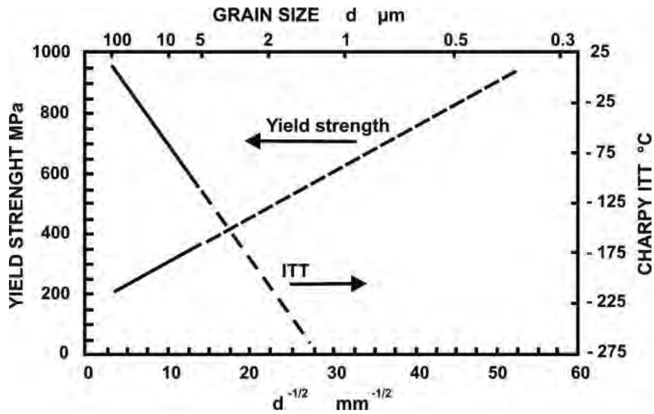
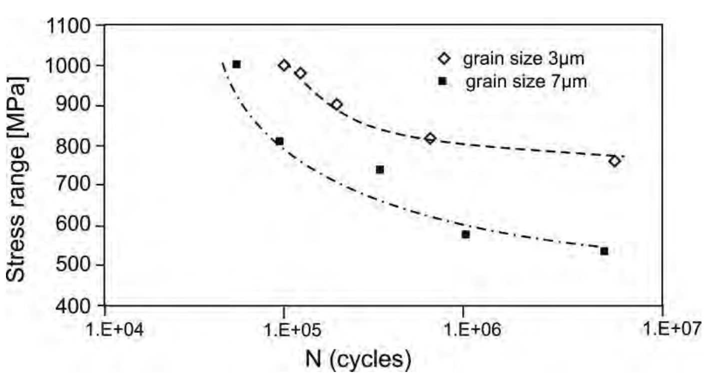


Fig. 4 *Dependence of yield strength (YS) and Charpy impact transition temperature (ITT) on ferrite grain size, extrapolated to ultra-fine grain sizes [15]*

Fatigue properties are a very important factor in determining the use of new materials for the responsible structures in this carrying frame of car semi-trailers. The grain size substantially influences the fatigue life of materials.

Malle with co-authors [16], while researching steel with different grain size (3 and 7μm), linked the grain size with the load that causes fatigue. He found out that to cause the fatigue effect in the fine grained steel there is the need for higher stresses, whereas a coarse grained steel has lower resistance to crack propagation. Fatigue of the two variants of graphs was shown in Figure 5. The grain effect size depending on the da / dN = f (Ka) function was shown in Figure 6.



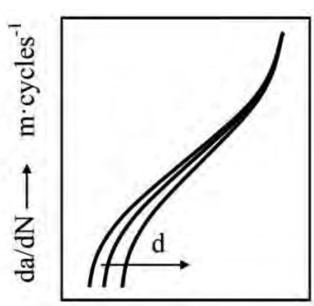


Fig. 5 *Fatigue diagram of steel with a grain size 3 and 7μm*

Fig. 6 *The influence of different factors on the da /dN = f (Ka) function course: the size of the grains*

3.Fatigue properties of HSLA steels on the example of DOMEX 700 MC Steel

Domex cold forming steels are rolled in a thermomechanical process, where the heating, rolling and cooling are carefully controlled. The chemical composition of the steel containing low levels of carbon and manganese is precisely complemented by enriching ingredients such as niobium, titanium and vanadium.

Due to the high mechanical properties and clean structure, is the Domex steel the best alternative for cold formed and welded products. Domex 700 MC with designation D and E meet and even exceed the requirements for steel S700 MC according to the standard EN-10149-2 . Domex MC can be supplied as wide coil, slit coil and cut sheet. The steels are available with as rolled or pickled and oiled surface. Wide coil and sheet are available with mill or cut edge.

To fatigue tests was used DOMEX 700MC steel with chemical composition and mechanical properties shown in Table 1. Domex of 700MC Steels is characterized by fine-grained structure.

Table 1. DOMEX 700MC chemical composition and mechanical properties

C [%]	Si [%]	Mn [%]	P [%]	S [%]	Nb [%]	V [%]
0.08	0.35	1.67	0.018	0.0037	0.06	0.014
Re [MPa]		**Rm [MPa]**		**A_5 [%]**	**Z [%]**	
376		564		28.5	41.7	

Fatigue characteristics (dependence σ = f (N)) of steel DOMEX700MC was determined by low-frequency ofcyclic load (VHCF). Fatigue tests in high-cycle field were carried out on the machine ROTOFLEX implementing load in the rotating bending mode. In the stress cycle asymmetry coefficient was R = -1, samples were loaded with the frequency of 30 Hz at a temperature of 20 °C ± 10 °C. To fatigue test in terms of high-cycle fatigue (using low frequencies) were used samples of the shape and dimensions shown in Figure 7.

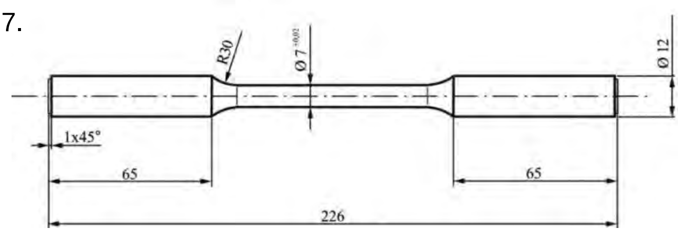


Fig. 7 *Shape and dimensions of samples used in the fatigue test on the device ROTOFLEX*

Experimentally determined Whöler dependence curve shows a decrease in value of damaging stresses of the sample together with the increase of the number of cycles of load changes to the level of fatigue limit for this material (440 MPa) Fig. 8. On the same graph for comparison were presented the results of fatigue tests of constructional steel S355J2.

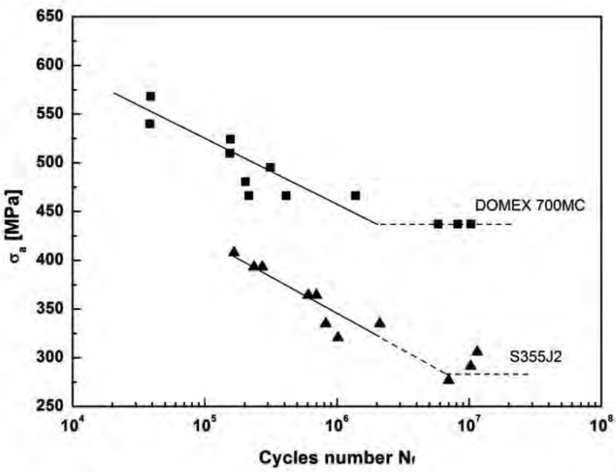


Fig. 8 *Fatigue life of DOMEX 700MC and S355J2 steel, cantilever test, rotating bending in the field of high-cycle [f = 30 Hz, T = 20°C ± 10 °C, R = -1].*

4.Conclusion

Literature indicates the numerous information on innovative material solutions for the automotive industry, but they are constantly predominant material in this branch of industry. This is caused not only by economic factors but especially by properties which are competitive in relation to other groups of materials. From the point of view of the automotive industry there should be taken such properties as:

- mechanical properties, so-called tenacity that is the ratio of ultimate strength to its density, which is important from the point of view of reducing the weight of the vehicle,
- energy absorption capacity in the event of a collision,
- good technological properties in manufacturing and high plastic workability, weldability,
- good exploitation properties, abrasion resistance, high resistance to fatigue.

Currently, the automotive industry is still dominated by conventional steels with low carbon content, to be treated for cold and hot forming. However, manufacturers have recognized the advantages of modern material solutions in the form of HSS, AHSS and HSLA and implement them in their constructional solutions. We can observe the declining share of soft low carbon steel, which already lost their primacy in favor of HSS steels, especially IF-HS and HSLA. There is aslo increasing share of AHSS steels which would in the nearest future take over the primacy in the automotive industry. An important factor are also the fatigue properties and consequently suitable service life. Fine-grained steels compared with conventional costruction material have much better fatigue properties. This is resulting in a reduction of kerb weight of the structure as well as an increase in the period of safe operation of the construction.

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Summary

Possibilities of application of modern fine grained steels for the production of car semitrailers

Robert Ulewicz, Paweł Szataniak, Frantisek Novy

The paper presents the outcome of the literature research concerning the possibility of using modern steel grades in the automotive industry. Based on carried out research on the possibility of application of fine-grained steel there was presented a positive effect of grain refinement on selected properties of the steel. An important factor in determining the applicability of the material is the ratio of strength to weight and resistance to fatigue. The paper presents results of fatigue tests of DOMEC 700MS steel and they were confronted with the results of research on constructional steel S355J2.