International Symposium on Niobium Microalloyed Sheet Steel for Automotive Application
Edited by S. Hashimoto, S. Jansto, H. Mohrbacher, and F. Siciliano
TMS (The Minerals, Metals & Materials Society), 2006

MATERIAL APPLICATION DEVELOPMENT FOR WEIGHT REDUCTION OF BODY-IN-WHITE

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Keywords: Body, Material, metallic material, mechanical property, chemical analysis, press working, welding

Abstract

The development of high strength steels and their application has proceeded aiming at weight reduction and better crash performance. This paper summarizes the requirements and studies the issues relevant to the recent development of a 980 MPa Dual Phase grade, which is being applied to the NISSAN TIIDA. The developed grade not only meets the requirements concerning material characteristics and formability, but also has an improved weldablity due to its lower absolute carbon content and lower carbon equivalent as compared to conventional grades. The application of this new grade is expected to expand from thin to thick gauges, including platform parts.

Introduction

In the recent years, the situation surrounding the car industry became more and more complicated. To quote some typical factors, there is the diversification of customer needs, various demands to improve the vehicle performance like, e.g., the crash resistance, countermeasures to global environment problems such as the reduction of CO_2 emission, and a supply-and-demand problem with materials.

This paper reports on the development of steel sheet materials and the present condition of the application in such a situation. Steel sheet plays the major role as body-in-white material and especially the ratio of high strength grades is expanding.

History of Material for Body in White

Figure 1 shows the history of materials used for body-in-white applications at NISSAN. Steel is being used historically as material for the body-in-white and is still making further progress thus remaining the major material. The main approach of reducing weight with steel is the reduction of sheet gauge by applying higher strength steel. Generally, high strength steel is difficult to form and often causes weldability problems. Nevertheless, the application of higher strength steel became possible thanks to the development of materials and manufacturing technologies as well as part design conforming to these manufacturing technologies. In recent years, as shown in Figure 2, steel with a tensile strength of 980 MPa has commenced to be applied. Other technologies, like the die quench technology, where rapid cooling occurs in the die during the stamping of a preheated blank resulting in a tensile strength of 1500 MPa in the final part, are also applied more frequently. Advanced technologies of microstructural control or ultra fine grained structures are being researched [1]. Also in the future, steel is expected to remain the major material for the body-in-white.

Sort \ AD	~ 1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005?
environment and safety	• NCAP • CAFE		• SINCAP		• JNCAP				• EURONCAP		
Steel	• 440MPa steel • DURA steel ('80)			• 590MPa DP steel	• GA steel			• 780MPa DP steel	• GI steel (EURO)	• 980MPa DP steel • 590MPa BH steel • Die quench	
Aluminum	• 5000series (HOOD) • 6000series (FDR) • 7000series (D/ G BAR)				• Extruding, Casting (BIW)	• 6000series (HOOD, T/ LID)					• 5000, 6000 series (DOOR)

Figure 1. History of material utilization for the body-in-white at NISSAN.

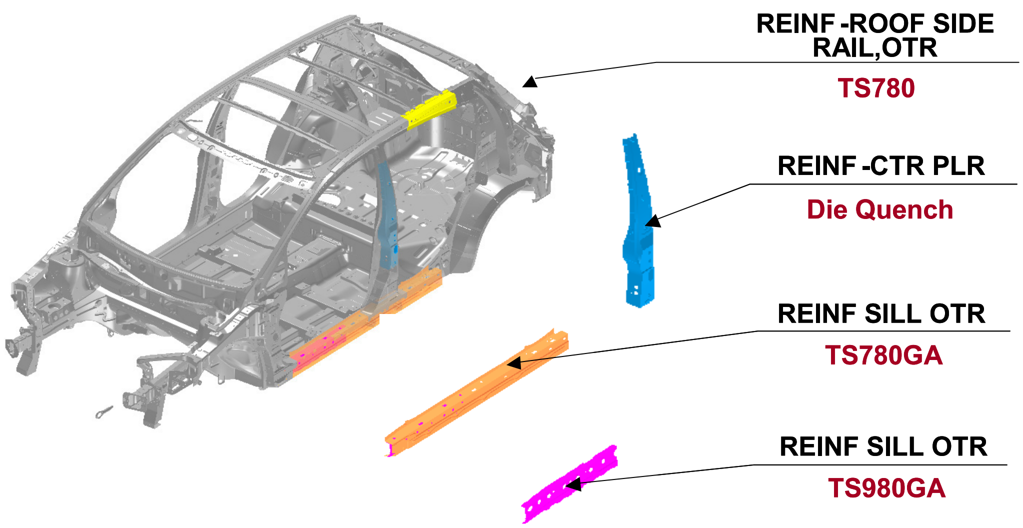


Figure 2. High strength steel application for the NISSAN TIIDA.

Tailor welded blank technology assists the designer in achieving part weight reduction through the application of high strength steel. The tailored blank optimizes the material and gage. For example, by the combined application of formable and high strength steel in a tailored blank sheet, significant weight reduction can be achieved. Thus tailored blanks became an established product for weight reduction of the body-in-white.

In the case of low-density materials, aluminum alloys of the 5000 series and 6000 series find increasing application particularly in luxury cars being used for outer panels such as hood, trunk lid and door parts. However, aluminum exhibits forming and joining problems as well as higher cost compared to steel.

Mechanical Properties of High Strength Steel and Engineering Problems

<u>Types and mechanical properties of high strength steel</u>

Figure 3 shows the relation between elongation and yield stress of major high strength steels. This section mainly focuses on the mechanical properties of materials of 780 and 980 MPa tensile strength coming nowadays to application. These materials can be classified into Dual Phase (DP) steel, TRansformation Induced Plasticity (TRIP) steel, and precipitation hardened steel. At NISSAN, the material and application development for DP steel is mainly driven from the viewpoint of strength, formability, weldability, corrosion resistance, and procurement. NISSAN believes DP steel has a superior balance of strength and elongation because it is mainly consisting of two phases, namely ferrite and martensite.

The DP steel adopted by NISSAN is a material originating from a co-development with the steel supplier and is designed to have a low absolute carbon content and a low carbon equivalent value, important with respect to weldability. Its mechanical properties and chemical composition are indicated in Table I.

The result of the new 980 MPa DP steel was a 20% weight reduction of the body-in-white as compared to that the weight achievable using a high strength steel of 590 MPa (Figure 4).

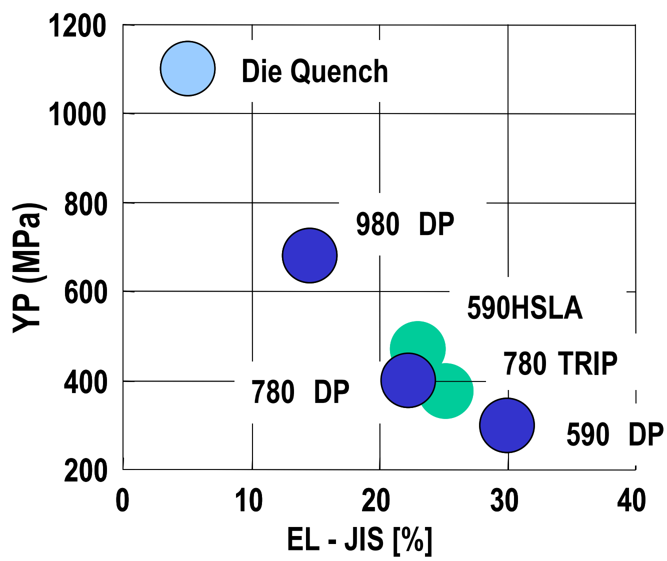
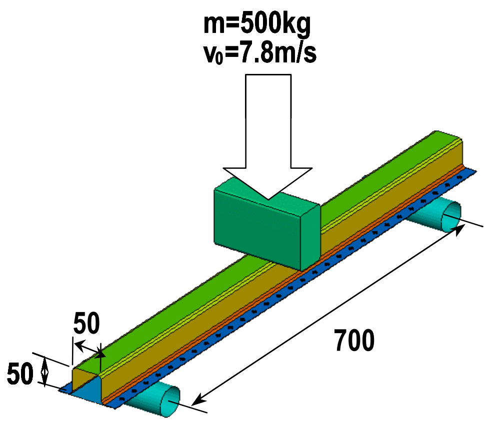


Figure 3. Properties of high strength steel.

Table I. Mechanical properties and carbon content of developed DP steels.

	C wt%	YP (MPa)	TS (MPa)	YR	El (%)	n	$\bar{r}$
980MPa-DP	0.07	700	1020	0.69	14	0.11	0.98
780MPa-DP	0.07	490	840	0.58	19	0.22	0.87



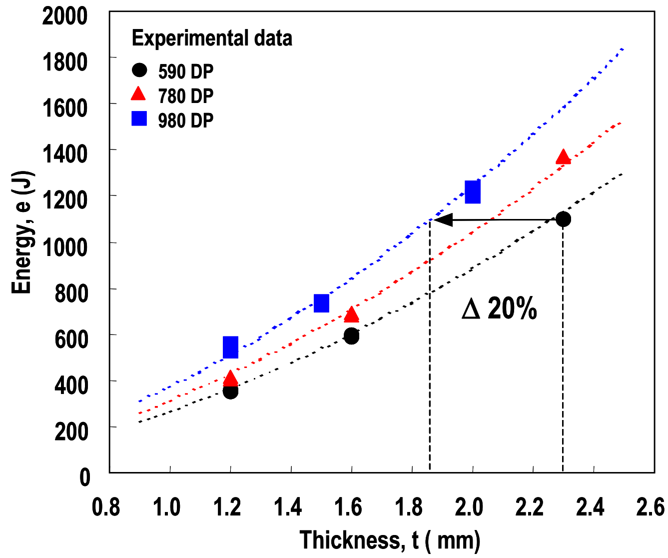


Figure 4. Weight reduction potential in function of gauge for various high strength steels.

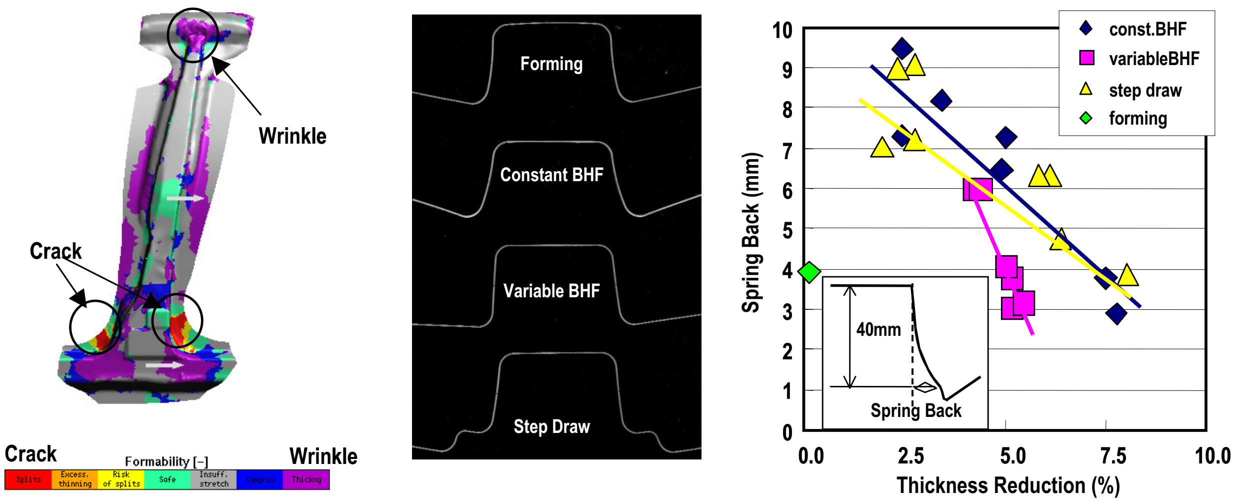
<u>Formability</u>

NISSAN experienced significant formability problems using high strength steel. From a material characteristics point of view, NISSAN plans to improve the ductility of the steel by microstructural control through grain refinement. However, both the prevention of splitting and wrinkling as well as the achievement of good shape accuracy are key factors to accomplish a good QDC condition. Those are the phenomenon, resulting from a low elongation and a high TS, respectively and are of particular relevance for 780 or 980MPa steel grades. If only the cracking and wrinkling problems are considered, it is possible to predict and prevent these problems by reviewing the part shape and die design using specific forming technologies and simulation systems (Figure 5a). However, it is difficult to predict and prevent deviations from the shape accuracy. Thus, a trial and error approach is necessary to modify the die by various measures and project the shape accuracy by anticipating the die surface shape using data of conventional strength panels (440, 590MPa).

With regard to good shape accuracy, there are several problems caused by springback such as wall warp, opening, twist and camber causing deviations. Experiments show that the accuracy can be improved by using specific technologies, for example, adding tension to the part wall to reduce wall warp and opening (Figures 5b and 5c). However, when this experimental technology was used to achieve good shape accuracy in the die for actual body parts, splitting and wrinkling would be encountered alternately at the same time. Thus, it is still difficult to use the experimental countermeasure for controlling the shape accuracy, since the avoidance of splitting and wrinkling has priority. Additionally there is a problem of the scattering of the mechanical material properties and the thickness of steel sheet.

In order to apply the technology for shape accuracy control in the future, it will be necessary to develop high strength steels having a good drawing formability, a narrow tolerance of the mechanical properties and sheet thickness, and an improvement in the forming technology and parts design.

On the other hand, when the strength of the steel sheet is increased, the stamping force becomes larger, and so does the load applied to the die. Thus, the die material and structure need to be adapted to prevent galling and die wear by using steel inserts on the sliding faces of the die, surface finishing, and sometimes lubrication. It is important to improve the die characteristics to better facilitate the formation of the steel sheet used for the final body part.



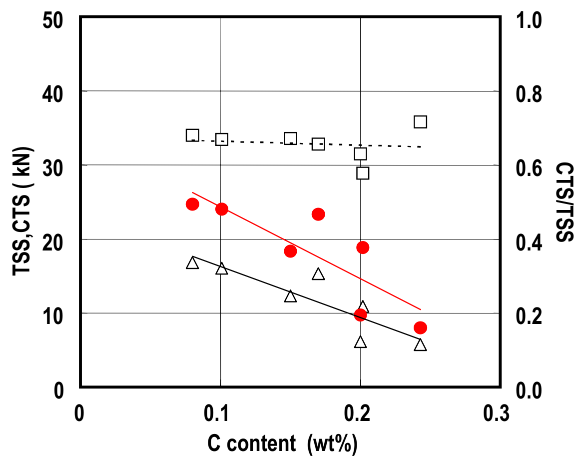
(a) (b) (c)

Figure 5. (a) Simulation results for wrinkling and splitting; (b) Spring back from hat shape parts (980 MPa); (c) Spring back by stamping process (980 MPa).

Weldability

The spot weldability of high strength steel can be a problem due to the increased material strength and thickness. The strength of a spot-weld joint is evaluated by the tensile-tear-strength (TSS) test and cross-tensile-strength (CTS) test, in general. The weld strength of high strength steel is particularly weak under cross-tensile testing and is becoming unstable in the expulsion range, when welding at too high of a current. This trend becomes even more pronounced when the material strength increases.

The welding behavior can be improved by decreasing the hardness of the spot weld nugget, which is partly achieved by reducing the carbon content in the steel alloy (Figure 6a). Figure 6b shows the spot-weld strength of a 980 MPa DP steel optimized according to this knowledge. Thus, sufficient weld strength under TSS and CTS conditions is obtained over a wide range of welding currents. The standard concept at NISSAN is to continue with the development of low carbon high strength steels. It is necessary to apply these 980 MPa and 780 MPa class steels to many structural parts, including thick sheet frame parts designed in platforms. Further investigations and developments for the optimization of spot welding conditions, alternative welding technologies such as laser welding, and other joining technologies are necessary and should be advanced continuously.



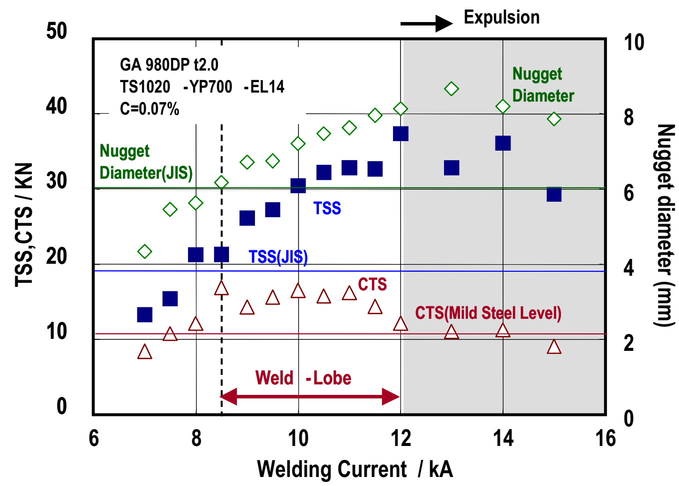


Figure 6. (a) Influence of carbon content on the spot weld strength; (b) Spot weld strength of a 980 MPa DP steel.

Corrosion resistance

Regarding the rust prevention performance, there is an increasing tendency of using parts made from coated steel. Many of the high strength steels used in practical applications are coated. This also holds for the 980 and 780 MPa high strength grades discussed before as these are particularly used for the frame parts in the body. In the case of galvannealed steel (GA), which is well established in Japan, Several aspects have a large effect on the steel specification. The heat record in the CGL has to be taken into account and additional alloying elements that obstruct the adhesion between the zinc layer and the steel sheet have to be controlled. Thus, these aspects are considered in the specification of steel grades under development.

Other aspects

Thus far, the material performance and quality considerations have been discussed. However, the aspects of cost and procurement must be considered as well when applying these steel grades in automotive production. From a cost point of view, it is clear that the steel price needs to be competitive, but also, the steel part performance improvement has to be taken into account as well.

From a procurement point of view, improvement of the local supply ratio in foreign countries, the proper decision of steel sheet grades selected and the elimination of steel grades of low productivity are requested. Specifically, the global availability of materials will attract further attention considering the accelerated global expansion of the automobile companies.

From both the material/quality and procurement points of view, it will be necessary to further develop “easy-to-use and easy-to-make” high strength steel sheets.

Conclusion

NISSAN has started to apply a 980 MPa Dual Phase steel grade in its TIIDA model and is also planning to expand its application to the next generation of cars currently under development. DP steel with a carbon content of less than 0.1% have been developed still reaching a tensile strength of 980 MPa. Moreover, this alloy is well suited for surface treatments including galvannealing. Its application is making progress globally including countries outside Japan. Regarding the property profile, NISSAN believes that DP steel has the best property balance at present. Its further improvement, development, and application within Japanese carmakers as well as the global steel and parts suppliers were studied.

In the future, the automotive manufacturing process will advance its revolution in addition to innovations on the material side, e.g., ultra-fine grained steel. Considering this progress, it is clear that material requirements will change. New technologies need to be challenged without restraining conventional common sense.

Reference

1. Website of the Japan Research and Development Center for Metals.