POLISH ACADEMY OF SCIENCES - COMMITTEE OF MATERIALS SCIENCE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY

Conference Proceedings

12th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Effect of welding conditions on the formability characteristics of thin sheet steels: mechanical and metallurgical effects

E. Bayraktar[a*], M. Gauthier[+], J. Moiron[b] and D. Kaplan[b]

[a]Supmeca/Lismma-Paris, 93407 Saint Ouen, France

[b]Arcelor Group, Paris, France

The present study is undertaken with the objective of clarifying formability characteristics of welded thin sheet steels such as Interstitial Free Steels (IFS) and Ferritic Stainless Steels (FSS) based on the LASER, TIG and Resistance spot welding (RSW). The characterisation of base metal and welded parts has been carried out by hardness, Erichsen and impact tensile tests (ITT). Relationships between the materials and mechanical parameters derived from these tests are also discussed in this paper.

1. INTRODUCTION

Thin steel sheets are generally deep-drawn and manufactured by welding more often followed by forming operations. In the automotive industry, it was necessary to develop new grades of steels such as high strength IFS and FSS in order to realise certain or many complex deep drawn pieces. Recently, it has been seen the spectacular development of tailored blanks by means of LASER (>10kW) CO_2 welding and also general application of the LASER welding in this area. And, these steels naturally should be qualified also for the resistant spot welding, a process used largely for many parts of the car body. The desired behaviour can be obtained through an optimisation of the design of the part, and through the intrinsic quality of the materials and their welds. So, this study concerns the mechanical and metallurgical evaluation of the welds of thin sheet steels.

2. EXPERIMENTAL CONDITIONS

Three grades of IFS (IF-Ti, IF-HR and FEPO6G) and three grades of FSS (AISI 409-stabilised, 430Ti-stabilised and 430-non-stabilsed) elaborated by ARCELOR (SOLLAC+UGINE) have been studied. Their thickness varies between 1.2 and 2 mm.

The carbon and manganese values vary from $2.5*10^{-3}$ wt% to 40 $*10^{-3}$ wt% and from $150*10^{-3}$ wt% to 600 $*10^{-3}$ wt%, respectively. Welding speeds for LASER (Q=5.5kV) and for TIG vary from 4 to 11m/min and from 1 to 100 cm/min, respectively. The parameters for RSW were taken as Q=5.5 kW, I=4.8 kA and V=1.20V for all the grades of the steels studied here.

* Corresponding author; bayraktar@ismcm-cesti.fr
+ Formerly graduate student in CNAM, Arts et Métiers, Paris, France,

Hardness values were measured across the welds under 200 g of load (HV). Erichsen tests (ISO R 149) were carried out on the base metal and welded sheets by LASER and TIG processes for measuring deep drawability of base metal and welded parts. Finally, Impact Tensile Tests (ITT) were carried out at different temperatures on the special specimens with a special device mounted on an impact pendulum [1, 2].

3. RESULTS AND DISCUSSIONS

3.1. Hardness tests

Figures 1 (FSS) and 2 (IFS) show the hardness evolutions across the welded specimens as a function of linear energy for the LASER, TIG and RSW. In general meaning, the hardness value decreases when welding linear energy increases for all the processes. These grades can be ordered according to the carbon values of the steels studied here like HV(409)<HV(430Ti)<HV(430), the 430 has a greater value than the other grades whereas the hardness value of base metal for all grades is about 150 HV [3]. This grade gives a big hardness difference between weld bead and base metal. This result agrees with the microstructure containing an instable phase in the grain boundaries. In case of IFS, the same evolution was observed, hardness decreases when linear energy increases in other words, when the cooling rate decreases. This observation confirms the fact that the appearance of bainitic package increases with the welding speed and its amount in IF-Ti is more than that in FEPO6G (Figure 3). The hardness values of the base metal and the weld bead in LASER and TIG processes for two grades of IFS are compared as HV(FEPO6G)<HV(IF-Ti). And also, hardness differences between base metal and weld bead of IFS for all processes are greater than that of FSS. In other words, the modification of the microstructure of IFS is higher than that of FSS during the welding processes. However, the weakest hardness values found in 430 non-stabilised is related to the formation of the brittle martensite zone at the grain boundaries.

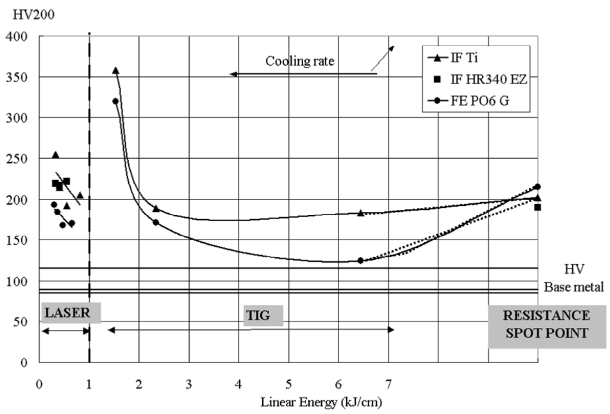

Figure 1. Hardness evolution depending on the linear energy for IFS

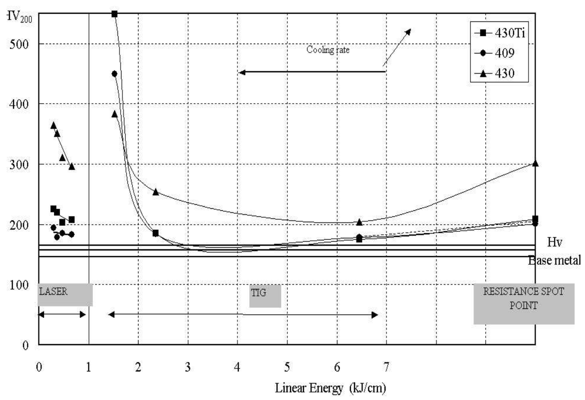

Figure 2. Hardness evolution depending on the linear energy for FFS

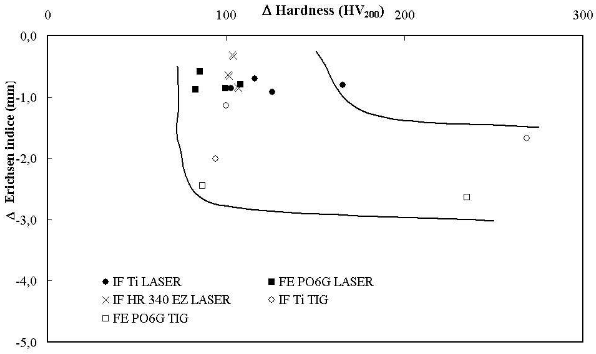

Figure 3.Relationship between Δ hardness and Δ Erichsen indices (IFS grades)

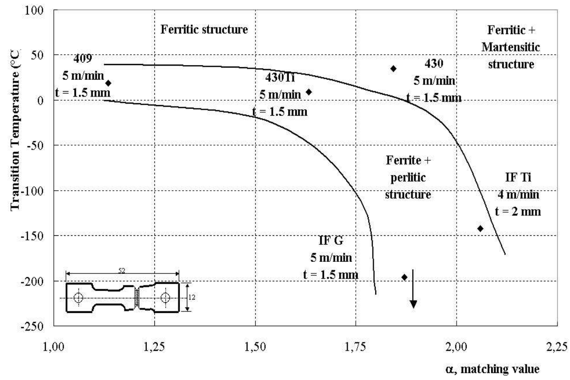

Figure 4 Evolution of the transition temperature depending on the matching value, α, (IFS+FFS).

3.2. Erichsen tests

Erichsen tests have been carried out on the LASER and TIG welded specimens at different linear energy levels. The thicknesses of the sheets (1.5 mm) were the same for the FFS and different (1.2, 1.5 and 2 mm) for the IFS. Erichsen indices were almost the same for the base metal of FSS but for the LASER and for the TIG welded specimens, these values (Ei(430)« Ei(430Ti)« Ei(409)) decreased when the linear energy increased.

In case of IFS, Erichsen indices increase with the thickness for the base metal as well as for the LASER and TIG welded specimens. There was no effect of the linear energy level of LASER on the Erichsen indices for the grades of IF-Ti and FEPO6G but these values for IF HR340EZ decrease when the linear energy increases. In fact, the values obtained on the LASER welded specimens are greater than that on the TIG welded specimens and also the difference of Erichsen indices between the welded specimens and base metal is higher in case of the TIG welding than that of LASER welding. So, these results show that the deep drawability of LASER welded sheets is greater than that of TIG welded sheets. And also, no important effect of zinc coating was found on the deep drawability of the zinc electro-galvanised sheets for both of the processes used here. [4-7].

3.3. Impact tensile tests (ITT) and correlations

The principle of the ITT has been explained formerly [1]. It has also been applied recently with success for testing of LASER, TIG and RSW welds of thick and thin plates [2]. In this study, the ITT tests were carried out on the IFS and FSS specimens including a smooth part and a notched (welded) part with a special device mounted on an impact pendulum. According to testing conditions and material toughness, fracture occurs in one of these two zones with a very sharp transition. This test allows studying easily the «matching» effects in welded parts [2].

Transition temperatures were found to be 10, 20 and 35°C for 430Ti, 409 and 430, respectively. These values are -142 and <-196°C for IF-Ti and FEPO6G, respectively. The figure 4 shows the evolution of the transition temperature of the different welded parts as a function of the matching value, (□) [2, 3]. The overmatching values of LASER welded joints of IFS are higher than that of stabilised FSS. This phenomenon is explained by the grain size effect and also by the overmatching effect of improved structure. Evolution of the transition

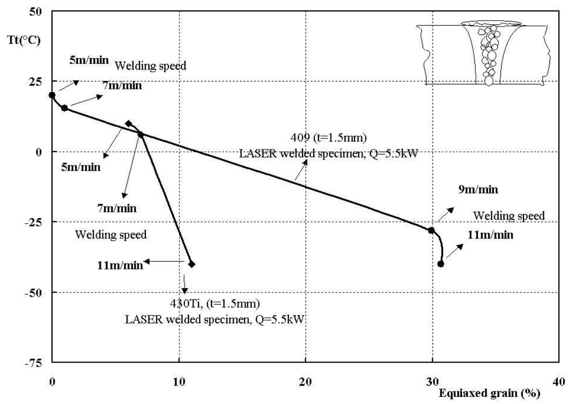

Figure 5. Evolution of the transition temperature depending on the equiaxed grain percentage in weld bead (FSS)

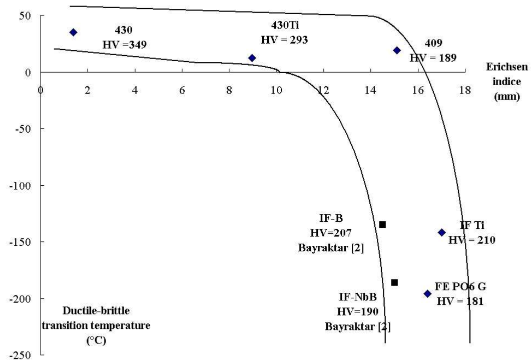

Figure 6. Correlation between transition temperature and Erichsen values for IFS+FFS

temperature depending on the percentage of the equiaxed grain in the weld bead is shown in the figure 5 for LASER welding process. It is seen that the higher percentage of the equiaxed grains is the lower the transition temperature.

The figure 6 shows a correlation, between transition temperature and Erichsen indices for different grades of steels. It indicates that the transition temperature decreases when the drawability increases. Naturally, ITT and deep drawability tests are not on the same plane. It means that ITT characterises a ductile-brittle transition mode in dynamic fracture conditions. So, it is sensitive to the physical parameters which play a role on the cleavage (defects in the Griffith direction, grain size..) when deep drawability tests of which ultimate point is the plastic failure by ductile fracture, are sensitive to the flow rule of materials during the deformation (at the presence of particles of the second phase). In fact, this relation should be considered as an indicative presentation, because it reflects micro-structural parameters which influent both of these two type of tests.

4. CONCLUSION

Main conclusions obtained in this study are as follows;

- This research will contribute to the selection of optimal welding conditions and to the development of new grade steels for automotive applications.
- Correlation realized between the transition temperature and deep drawability can be used for evaluating of the welding conditions and also of the material characteristics.

REFERENCES

1. M. Grumbach, G. Sanz, Rev. de Métall, 1 (1972) 145.
2. E. Bayraktar, D. Kaplan, and M. Grumbach, J. Mater. Proc. Tech. (2003) in press.
3. M. Gauthier, BS in Mater. Sci. and engineering, CNAM, Arts et Métiers, Paris (2000).
4. W.L. Chuko and J.E. Gould, Weld. J., 1 (2002) 1.
5. J.W. Morris, and Z MEI., (eds), The physical metallurgy of zinc coated steel, GB, 1993.
6. B. Aziez et R. Feen, (eds.), Weldability of 18%CR, 2%Mo FSS sheet, Sheet metals industries, (1983).
7. J.C Villafuarte, E. Pardo and H.W. Kerr, Met. Trans., 21A, (1990) 7.