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Problems of New Sheets for Automobile Parts in Europe*

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Synopsis:

The major concern of European automobile industries is on weight reduction and corrosion protection. Both aims can be achieved by using new qualities of materials, namely high strength and coated steel sheets.

The adoption of high strength steels, due to their intrinsic characteristics, cannot simplay replace ordinary deep drawing sheets, but involves tool design and in some cases, also, the design of the part.

Corrosion protection of some particular zones in the car body requires coated sheets. The major tendencies in Europe are to use electro or, in alternative, hot dip galvanized sheets for structural parts, while painted coated sheets are used for outer body panels.

I. Introduction

European car industry is presently concerned on lowering fuel consumption and ensuring a longer duration of the vehicle.

Lower fuel consumption can be achieved also through weight reduction of the car, which concept has been adopted in Europe only lately, because, firstly, the European automobiles are relatively small, thus rendering weight reduction more difficult, secondly because microalloyed steels, which were the first high strength materials available, are not fully applicable to car–bodies, because of their little formability and surface defects shown also after painting.

The development of other types of high strength steels is as yet in progress. On the other hand an economical usage of high strength sheets generally requires design changes, which can more easily be realized when new models are developed. Another factor limiting high strength steel applications is the lack of specific treating facilities in the European steel industry, and consequently of a complete range of qualities.

As far as corrosion protection is concerned, after a slow beginning, coated sheets are increasingly being used following the trend of the European auto makers who are willing to increase the average car life and to extend guarantee to corrosion resistance. This is possible thanks to a wide range of products now available. Scope of this paper is to bring into evidence all the problems related to the use of the above mentioned materials, as far as processing and service behaviour are concerned.

II. Weight Reduction

As mentioned before, the European auto industry is strongly involved in reducing the weight of their vehicles through the use of high strength steels of different classes and grades: precipitation hardened, solid solution hardened, dual phase.

The properties and metallurgical characteristics of such steels have been so much studied during the last ten years that a lot of information are available in the literature reguarding formability, weldability etc., but relatively scarce information are available on the approach to follow in order to achieve the best compromise from the point of view of weight reduction, cost and service performance. However there is a question that should be pointed out and is a consequence of large experience matured by auto industry materials engineers, that is high strength steels cannot simply replace ordinary low alloy mild steels, but their use is subordinate to a suitable design of the part.

The validity of this concept has been demonstrated several times and particularly when the substitution has been based on simple strength calculation leading to poor results or sometimes to sensational failures.

The need of specific design has limited their use in the car, but, at the same time, has allowed to collect several data on constraints and problems to solve in order to obtain the best

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use in the European automobile.

Low alloy precipitation hardened steels

These sheet steels can be considered the first generation of high strength steels and consequently they are the best known and investigated steels by both European auto industries and steel makers.

These steels are easily available in Europe as cold and hot rolled sheets with different strength levels ranging from 280 MPa up to 500 MPa yield point.

Today they are extensively used in the automobile mainly as hot rolled sheets for highly stressed structural parts; thicknesses commonly used are in the range of 2–4 mm; typical parts made from them are: wheel discs, suspension arms, bumpers, door reinforcement bars, engine supports.

Precipitation hardened cold rolled sheets are used by the auto industry to a limited extent for those parts having complex shapes, the formability of which is critical for hot rolled material.

A general policy of European automakers is to achieve weight reduction goals by using high strength steels at least at no additional cost. As consequence, while they are developing new models, the use of such steels tends to increase and their average weight in a typical medium size european car of about 800 kg will probably reach in the future approximately 50–70 kg.

The main problems to solve for allowing their extensive use in the vehicle are reported below:

Formability: the forming limit diagram of precipitation hardened high strength steels is 30% lower than a low alloy mild steels as shown in fig. 1. Besides their $\bar{r}$ value is less than 1 causing higher proneness to diffused necking during stamping.

In order to render such an effect, the two following examples are reported. Fig. 2 and 3 show

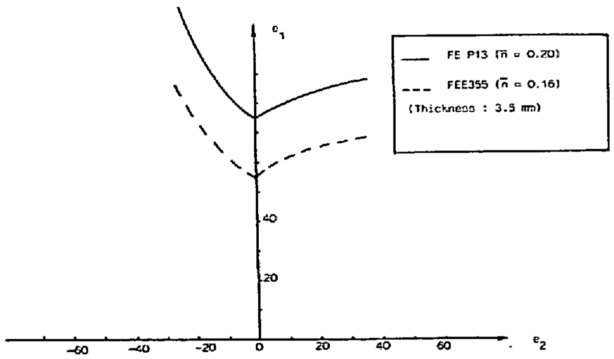

Fig. 1. Forming limit diagram of precipitation hardened high strength steel and low alloy mild steel.

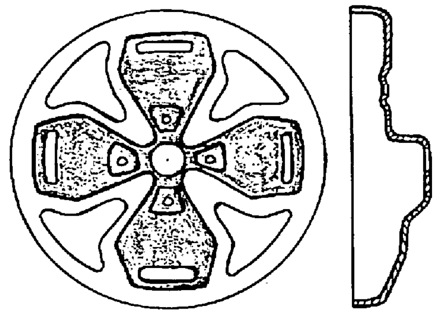

Fig. 2. Wheel disc not suitable for being manufactured with high strength steel.

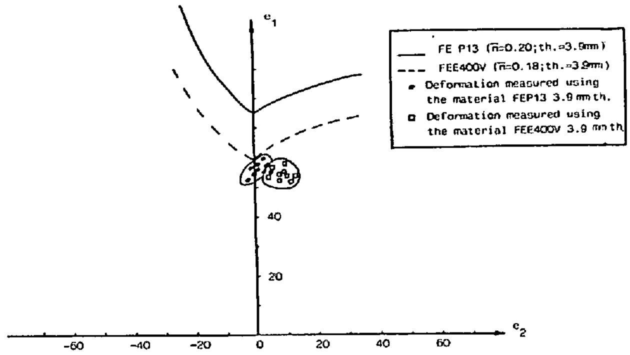

Fig. 3. Forming limit diagram and maximum strains measured on wheel disc (Fig. 2).

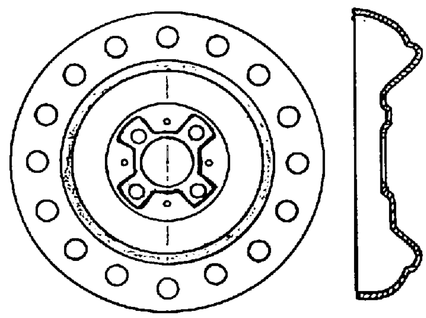

Fig. 4. Wheel disc specifically designed for high strength steel.

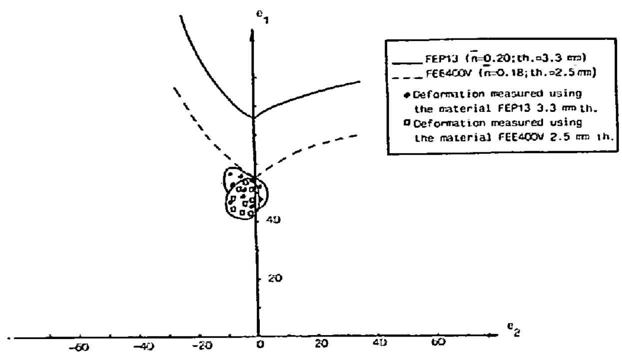

Fig. 5. Maximum strains measured on the wheel disc designed for high strength steel (Fig. 4).

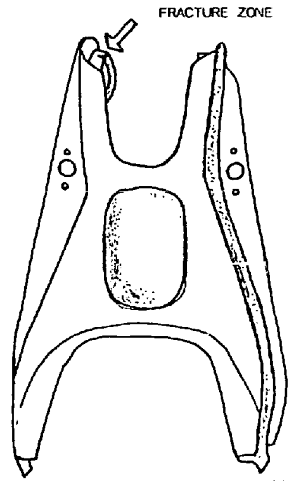

Fig. 6. Example of negative experience from using high strength steel (rear suspension arm).

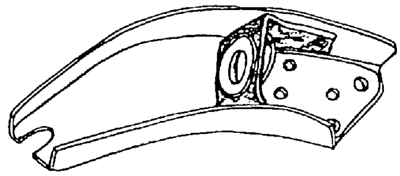

Fig. 7. Rafter connection support; fracture originates from the welded zone if hsla is used with reduced thickness of both parts.

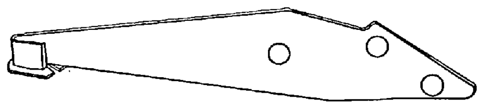

Fig. 8. (Engine support) : Service inflection stress has not allowed to use high strength steel reduced thickness.

a wheel disc with its maximum strains which are placed below the limit curve. In correspondence of these strains a remarkable thickness reduction is noticed, which has a detrimental effect on the fatigue resistance of the part.

Fig. 4 reports an example of a wheel disc purposely designed for high strength steels, while fig. 5 exhibits the relative strain analysis. The latter shows how the part has been drawn rather stretched with a more uniform thickness reduction. This resulted in a fatigue resistance equal to that of a 25% thicker than traditional deep drawing mild steel.

The last example of negative experience from using high strength steels is reported in fig. 6. In this case the part cannot be stamped due to the limited formability of material. As a matter of fact, during the forming of the part fracture occurred on the hole—30 mm diameter and 10 mm depth—which could not be avoided also through different strain paths.

The application of cold rolled high strength steels for body panels is limited by their poor formability. There are only few examples of such applications on european vehicles and we don't foresee any extension thereof.

Weldability: from the numerous studies on high strength steel weldability it appears that their weldability lobe is substantially the same as that of traditional mild steels.

However precipitation hardened steels properties get deteriorated in the welded zones dropping approximately to the level of low alloy mild steels. The performance of welded high strength steels is a problem for materials engineers every time they try to replace ordinary steels with high strength steels.

The example in fig. 7 shows a rafter connection support which is composed of two pieces welded together, from a material having 360 MPa yield strength and thickness reduced by 20% where fracture originates from the welded zone.

Stiffness: it is another parameter to be considered by materials engineers during the substitution process of low alloy mild steels. Being the modulus of elasticity the same for different classes of steels, stiffness is depending on the geometry of the part and on the material thickness. Fig. 8 reports a typical example of a part where service inflection stress has not allowed to use a high strength steel reduced thickness.

Low alloy solid solution hardened steels

Such a class includes rephosphorized high strength steels that have just recently been developed by the european steel industries and for which the experience of materials engineers in the auot industry is still limited. They are available in the cold and hot rolled version, but the major interest in Europe is for cold rolled sheets since the requirements of auto industry for high strength hot rolled sheets are fulfilled by precipitation hardened steels.

So far they are used at a very low extent to press body panel components but at the same time a large effort is carried out by European auto industries for studying their properties and extending as much as possible their use in the automobile. It is now possible to forecast for the next years a quantity of 60–80 kg/car with

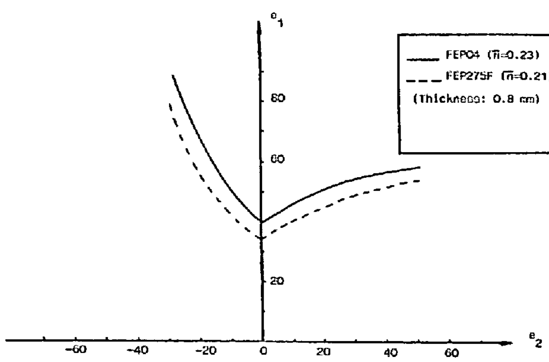

Fig. 9. Forming limit diagram of rephosphorized high strength steel and low alloy mild steel.

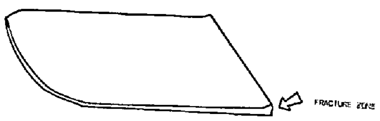

Fig. 10. Formability problems during stamping of hood.

a weight saving of 5-6 kg/car considering the average european car weight about 800 kg.

The level of yield strength generally considered is around 280 MPa; higher strength levels are not considered by the european auto industries since increasing phosphorus content worsen formability and weldability problems.

The main characteristics of this material and the related problems are reported below :

Formability : comparing the forming limit diagram of rephosphorized high strength and low alloy mild steels, as shown in fig. 9 it is possible to observe that they are very close to each other which means for rephosphorized steels a better formability than for precipitation hardened.

However formability problems emerge as consequence of the higher yield point of rephosphorized steels than of conventional mild steels.

A typical example of such a problem is shown in fig. 10, in which we observe the roof panel that, after stamping, is characterized by large underformed zones and a concentrated stretched area.

In order to induce plastic strain in the flat zones, blankholder pressure has been increased with the result of failures in the stretched area.

Thickness reduction is limited not only by the structural rigidity required by the panel, but also by the necessity of minimizing surface deflection, which depends on the shape of the part and on the geometry of the internal structure of the panel.

For what concerns dent resistance, rephosphorized steels, due to their higher yield point, offer a better performance than conventional mild steels, thus allowing thickness reduction at the same service conditions.

Weldability : phosphorus is a dangerous element in the welding process since it causes brittleness of spot welds. However weldability is a problem of secondary importance in many applications of rephosphorized steels. As a matter of fact, body panels like hoods, doors, deck-lids are assembled to the internal structure by adhesivation. In the particular case of roof panel for which weldings are highly stressed zones, a sistematic investigation is in progress in order to solve all emerging welding problems.

Dual Phase

The major problem of dual phase to-day in Europe is the limited availability of this product on the market since the steel makers don't have as yet the continuous annealing facilities which are required to process such a product. Just recently only few european steel industries have decided to invest in continuous annealing and probably in the near future "dual phase" steel sheets will be available on the market at a reasonable price.

It is important, however, to point out that the auto manufacturer's interest on dual phase is strongly dependant on its cost and it will be confirmed only if these materials will allow weight reduction at zero cost.

Today, dual phase steel available on the market is as cold and hot rolled sheets, but only the latter is more promising in the near future.

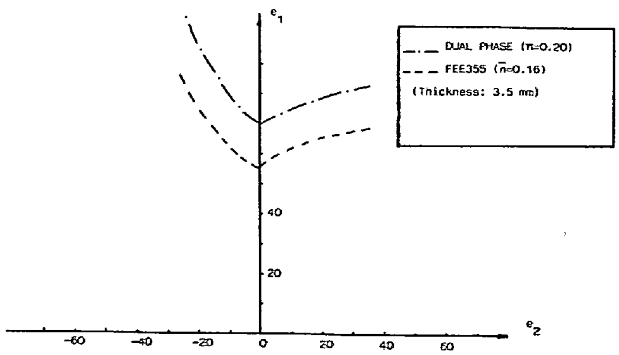

Fig. 11. Forming limit diagram of dual phase and precipitation hardened steel.

Its superior formability, showed in fig. 11, enables to form complex shapes which are not obtainable from precipitation hardened steels.

For what concerns hot rolled sheets, dual phase steel can be used for structural parts, but in any case, the particular work-hardening of such steels, requires a new conception of the stamping process, so as to induce maximum deformation in the early stage of pressing.

III Corrosion Protection

The application of coated steel sheets represents the most valid solution to the problem of rust prevention on car bodies, the more to nowadays, because of more aggressive environments and more severe legislation concerning both structural and cosmetic corrosion of automobiles.

The most commonly used coated steel sheets in the motor car industry are :

- Paint coated
- Electrogalvanized

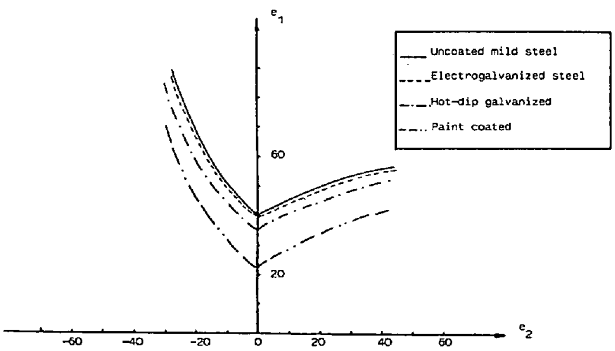

Fig. 12. Formablity of coated steels.

Table 1 Corrosion resistance testing.

Material	Testing: Undeformed sheets : red corrosion starts(hours)	Deformed sheets by Erichsen test: red corrosion start (hours)	Cross scribed sheets : red corrosion start (hours)
Un-coated mild steel	5	5	5
Electrogalvanized 7μ	150	150	150
Hot-dip galvanized 10μ	200	200	200
Paint coated	500	150	200

Table 2. Welding parameters modifications using coated steels in comparison to bare sheet sheel.

Material	Electrode force	Welding time	Current intensity
Electrogalvanized 7μ	+15%	Equal	+10%
Hot-dip galvanized 10μ	+20%	+10%	+20%
Paint coated	+25%	+25%	+25%

- Hot-dip galvanized

Hence to follow the main characteristics of these products are described.

Formability of coated steels : testing carried out to assess formability of coated steels without galling have brought into evidence that electro and hot-dip galvanized materials are capable to deform with coat detachment occurring close to the forming limit curve unlike paint coated sheets where coat failure happens at far lower sheet strains (fig. 12).

The better performance of hot-dip and electrogalvanized sheets has been confirmed through scribing, conical mandrel and 180° bending, as well as through galling tests.

Corrosion resistance

This property has been evaluated with exposure to salt spray of undeformed, deformed through 6,5 mm. Erichsen cup test and cross scribed samples.

The results of these tests are reported in table 1, where paint coated sheets exhibit a better corrosion behaviour than galvanized as long as the coating has not been deformed. On the contrary, deformed areas of the formed product show a worse corrosion performance than the latter.

Weldability

Welding parameters, such as electrode force, current intensity, and welding time, must be increased as compared to the ones pertaining to bare sheet steel welding, in the case in which the electrodes contact the coated surface (table 2). Electrodes used for paint coated and galvanized sheets must be from a Cu, Cr, Zr alloy. In any case their consumption is 50% higher than for traditional uncoated material.

Fumes from paint coated sheet welding are more polluting than from galvanized material because of organic substances and chromium contained in the paint.

Paintability

Paintability test results from the standpoint of adherence and corrosion resistance, can be summarized as follow : paint adherence is quite satisfactory on paint coated and electrogalvanized sheets, while slight peeling occurs with hot-dip galvanized.

For what concerns corrosion resistance a better performance is to be expected by undeformed

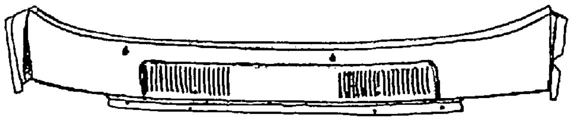

Fig. 13. Lower wind screen cross member made with paint coated steel.

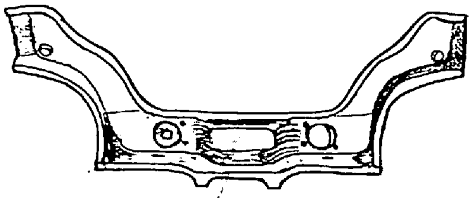

Fig. 14. Floor cross member made with hot-dip galvanized steel.

paint coated samples which property is deteriorated on deformed parts. Galvanized sheets cannot be applied when parts are painted through anaphoretic process, because paint saponification and consequent detachment occur in paints. This phenomenon does not take place with cathaphoretic painting process. On the basis of the reported characteristics the optimum applications for each product are indicated below :

Paint coated : suitable for shallow parts where pressing is carried on without any sliding between tooling and coated surface; due to better paintability is preferable for exposed parts.

Electrogalvanized : can be formed in deep drawn parts where galling occurs to a very limited extent. To be used with cathaphoretic painting process.

Hot-dip galvanized : suitable for non exposed deep drawn parts where galling can occur on galvanized surface. To be used with cathaphoretic painting process.

IV Application Examples

To this purpose the below described parts are presented.

Lower wind screen cross member : exposed part with no galling problems, for which paint coated material has shown the best performance both from adherence and corrosion resistance standpoints (fig. 13).

Floor Cross Member : in this part galling occurs during stamping (fig. 14). The best material for this component is hot-dip galvanized which can easily be applied if painting is carried on through cathaphoretic system, but also using anaphoretic system it is preferable to use as exeption the same material due to severe galling problems.

V Conclusions

On the basis of the above reported considerations the following conclusions can be drawn :

The use of high strength steels is at present practically limited to low alloy precipitation hardened steels; a large effort, however, is being involved to develop the application of cold reduced rephorphorized sheets.

For what concerns dual phase steels, their use in European car industry depends on the investiments in the European steel industry on special treatment facilities; in any case, their application is dependent on the possibility of weight reduction at zero cost.

Corrosion protection is taken care of through :

- paint coated sheets, which, although giving some pressing problems, exhibit a good paintability and for this reason will continue to be used for lightly drawn outer body panels;
- electro and hot-dip galvanized sheets, both on one and two sides, are and will be more and more extensively used for structural components critical from corrosion standpoint.

There are however aspects of new materials that need still be investigated in order to evaluate advantages and constraints consequent to their applications. And this can only be done through a close co-operation between auto and steel industries with significant advantages for both.