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Resistance spot welding of steels with individual thicknesses up to 3 mm
Spot weldability

DVS
Technical Code
DVS 2902-2

Contents:

1 Purpose of the technical bulletin

Together with its accompanying parts:

1: Overview
3: Design and calculation
4: Preparation and execution

this technical bulletin has the task of providing information about the application possibilities of and the problems associated with the spot welding of steels with thicknesses up to 3 mm. Separate DVS technical bulletins were elaborated for a number of steels: DVS 2910, DVS 2920, DVS 2923, DVS 2926, DVS 2927 and DVS 2933; for details, see Section 9.3 of the technical bulletin.

2 Scope of application

This technical bulletin applies to unalloyed and alloyed, uncoated and surface-coated steels with individual thicknesses up to 3 mm.

3 Definition of weldability

Weldability for resistance spot welding depends, in particular, on the chemical, metallurgical and physical material properties as well as on the surface finish of the steels. Weldability exists if a spot weld satisfying the requirements can be manufactured while paying attention to qualitative and economic aspects.

4 Steelmaking and surface coating

The manufacture of steels [1] is divided into individual process steps:

– Metallurgical manufacture (melting, special treatment and casting)

  The steel exists in the liquid state. The specified chemical composition and the demanded degree of purity are set. Special treatments of the steel melt (such as desulphurisation, the defined addition of alloying elements and vacuum treatment) may be carried out in order to obtain certain steel properties.

  The steels are cast almost exclusively in the continuous casting process. This guarantees a high degree of purity, a uniform chemical composition and a good surface finish of the slabs.

– Hot rolling – Cooling – Coiling

  The steel properties (strength, toughness, deformation behaviour etc.) as well as the structure, thickness and surface of the hot-rolled strips are produced.

– Cold rolling – Annealing – Dressing

  After the cold rolling, the steel strips are subjected to recrystallisation annealing and dressing.

  The steel properties (strength, forming behaviour, planarity, corrosion resistance etc.) as well as the structure, thickness and surface of the cold-rolled strips are produced.

– Coverings and surface coatings

  Metallic coverings made of tin, lead, zinc, aluminium, copper, nickel, chromium and alloys as well as organic coatings made of weldable primers, lacquers or thermoplastics can be applied to one or both sides. The most important processes for the application of metallic coverings are hot dipping and electrolytic deposition. Organic coatings are applied in the "coil coating" process as a liquid coating or as a film coating.

  The main reason for the utilisation of surface-refined steel sheets is the increased corrosion resistance. However, requirements on a decorative appearance, on adhesive properties for subsequent lacquer coats and on scale resistance may also be reasons for the use of coated steel sheets.

  The demanded product properties are achieved by means of the targeted interaction between the individual process steps described.

5 Relationship between material properties and spot weldability

The steel materials dealt with here [2] are basically characterised by the following material properties which are frequently superimposed on each other and exert different effects on the spot weldability:

– Chemical composition

  The chemical composition has a considerable influence on the weldability and basically determines the structural formation, hardening, nugget formation, cracking and strength of the spot-welded joints.

  In many cases, the carbon equivalent (CE) is used for the characterisation of the weldability of the steels. With unalloyed and low-alloyed steels, the hardening of the weld spot can be estimated with the aid of the carbon equivalent. The following simplified formula is recommended for this purpose:

  $CE = C + Mn/6$

  As an example, Fig. 1 shows the dependence of the maximum hardness in the weld nugget on the carbon equivalent.

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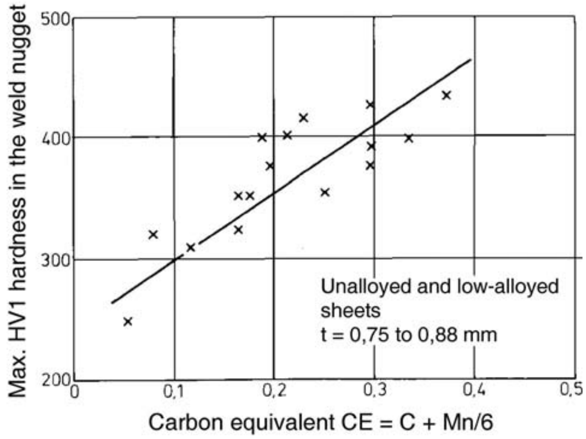

Figure 1. Maximum hardness of the weld nugget depending on the carbon equivalent.

– Strength

The strength of the steels is achieved by the chemical composition in conjunction with the rolling and annealing treatment. The strength can be increased by means of cold forming or by the addition of alloying elements. In particular, the latter measure may lead to a restriction of the spot weldability.

– Deformability

The deformability is frequently the most important requirement criterion on the steels. The deformation properties are basically determined by the chemical composition, the structural formation and the surface finish of the steels. In general, a decrease in the alloying elements improves not only the deformation properties but also the weldability. The carbon content which exerts a strong influence may be cited as an example.

– Structure

The structure of the steels is determined by the chemical composition in conjunction with the rolling and annealing treatment. Structural differences may influence the spot weldability. Small changes in the structural formation, such as usually arise within one steel grade (e. g. DC01 according to DIN EN 10130), exert only a slight effect on the spot weldability.

– Transformation behaviour

In the case of the unalloyed and low-alloyed ferritic/pearlitic steels, the quick heating and cooling cycle during spot welding leads to several phase transformations which no longer take place in equilibrium conditions. The shape and structure of the weld nugget and of the heat-affected zone are determined by the chemical composition and the cooling rate after the welding.

Alloyed ferritic and austenitic steels do not exhibit any phase transformations.

– Degree of purity

The degree of purity is characterised by the type (oxides, sulphides etc.), quantity, shape and distribution of the non-metallic inclusions in the steel. Permissible degrees of purity and segregations do not influence the spot weldability. The current passage and thus the nugget formation may be disturbed by very extreme segregations (laminations).

– Electrical and thermal conductivity

The electrical and thermal conductivity is directly related to the material resistance and thus exerts a considerable influence on the spot weldability. For example, the electrical conductivity of steels with an austenitic structure is six times lower than that of unalloyed steels.

Only slight fluctuations in the electrical and thermal conductivity arise within one steel grade (e. g. DC01 according to DIN EN 10130).

– Surface finish

The steel surface may have very different finishes. After the hot rolling, the surface of steel strips exhibits a rolling skin consisting of scale and rolling residues in a very irregular distribution. Those interface resistances between the electrode and the sheet as well as between the sheet and the sheet which are decisive in the case of spot welding are influenced by this and display extreme local differences. These result in scaling and deposits on the electrode faces which shorten the electrode life. There are fluctuations in the quality of the weld spots. Hot-rolled steel strips without any aftertreatment are therefore not suitable for spot welding.

A substantial improvement in the resistance weldability is achieved by the pickling of the hot-rolled strips. The rolling skin is removed and the material possesses a metallically bright surface which is usually oiled for protection from corrosion.

A further improvement in the surface finish is achieved by cold rolling, annealing and dressing. The surface is usually oiled here too in order to be protected from corrosion and to offer improved prerequisites for forming processes. In the event of improper transport and storage, the surface may be altered by rust, dirt and dust and this may exert a detrimental influence on the spot weldability.

In the case of the unalloyed strips and sheets, the anti-corrosion oils which are usually applied as thin films do not impair the spot weldability or the electrode lives at all or only negligibly. Any oils and greases applied additionally (e. g. in order to improve the drawing behaviour) may shorten the electrode life.

In the case of the stainless, austenitic steels, the surface is of crucial importance for the weldability. These steels must have metallically bright surfaces and must be free from contaminations and deposits since these may otherwise lead to non-uniform heating and, in connection with this, to molten areas and increased temper colours. An electrochemical potential exists between the uninfluenced surface and the surface with temper colours and may bring about a decrease in the corrosion resistance. In conjunction with the welding heat, oil may cause carburisation which leads to a reduction in or even to the loss of the chemical resistance.

The surface finishes arising in the case of cold-rolled steel strips according to DIN EN 10130 from "particularly smooth" to "rough" with mean roughness values R_a up to 1.6 µm have only a subordinate influence on the weldability. Even higher surface roughnesses can be spot-welded without any defects.

– Sheet thickness

The sheet thickness (max. 3 mm in the present technical bulletin) exerts an effect on the spot weldability. With the same chemical composition, the hardening of the spot-welded joint falls as the thickness rises. This may be attributed to the greater heat input and to the proportionally smaller cooling effect of the electrodes. With an increasing sheet thickness, the electrode life is decreased by the higher thermal and mechanical loads on the electrodes.

– Coverings and surface coatings

Depending on the thickness, the uniformity, the composition, the electrical conductivity and the inclination to alloying with the copper electrodes, metallic coverings have a considerable influence on the spot welding behaviour. The electrode life is shortened, in particular, by the alloy formation on the electrode faces. The change in the contact resistance necessitates an adjustment to the welding data. Steels with organic coatings only possess limited spot weldability when the coating consists of a weldable lacquer containing zinc dust or other conductive pigments. Steel sheets coated with different lacquers or with thermoplastics are not suitable for spot welding.