Development and status of the "Testing and documentation guideline for the joinability of thin sheet of steel (SEP1220)" - Standardization of the material release process

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Abstract: The development of new steel grades and their application in automotive industry demands more than the knowledge of base material characteristics, although knowledge of joining properties is essential, because the customer requires a proof of compatibility for the whole process chain. Up to now, these investigations were made by slightly deviant specifications, for example in regard to specimen geometry or welding parameter, of the individual OEM. Hereby a time- and cost-intensive effort was generated, which results at last in a delayed introduction of new materials. Because of that, the „Stahl- und Eisenprüfblatt (SEP) 1220" was made in a teamwork between the VDA (Verband der Automobilindustrie) and the VDEh (Stahlinstitut Verein Deutscher Eisenhüttenleute), in which the methods for the determination of joinability are described. Aim of this teamwork is the establishment of a standardized, generally accepted process for testing the joinability of a new material. Thereby not only the introduction of new materials was accelerated, also the exchange of data as well as the comparability of the investigations is simplified.

The present contribution describes the actual status of the „Stahl-Eisenprüfblatt 1220" and illustrates the system of the agreed material release process starting with the laboratory trials up to the serial production. Furthermore several results of such an investigation using the example of resistance spot welding are presented.

Key words: SEP1220, application properties, car production, joinability, steel, material release process, resistance spot welding, standardization

1. Introduction

Due to the increasing requirements concerning reduction of energy consumption and CO_2-mission as well as increased crash demands several new steel grades were developed in the recent years. This expanded application range can be seen in the BIW, where high strength steels are processed in serial production, in order to achieve a lightweight construction.

However, in order to exploit the lightweight construction potential, it is necessary to be familiar with more than the fundamental material parameters. It is also imperative to know corresponding joint properties. The stringent requirements on quality and cost efficiency during the manufacture of sheet components can only be satisfied by optimal planned processes. The application of new materials demands more than the knowledge of material characteristics, although knowledge of joining properties is essential. The joining technology is a challenging theme, which is subjected to versatile influences. Already high requirements to quality and cost saving are continuously enhanced. These demands can only be achieved by means of optimal designed processes and a zero defect production. In terms of the material release process production has no other demands on a new material than complete compatibility with the existing processing chain "[1].

Therefore the "Testing and Documentation Guideline Joining" was compiled as part of the material release process [2]. This guideline, published as SEP1220 by the VDEh, is meant as a basis for material characterization by welding, brazing, mechanical joining and adhesive bonding. In the „Stahl- und Eisenprüfblatt (SEP) 1220", which was made in a teamwork of the VDA (Verband der Automobilindustrie) and the VDEh (Stahlinstitut Verein Deutscher Eisenhüttenleute), the methods for the determination of joinability are described [3]. Aim of this teamwork is the establishment of a standardized, generally accepted process for testing the joinability of new steel grades. Thereby not only the introduction of new materials was accelerated but also the exchange of data as well as the comparability of the investigations between material suppliers, car manufacturers and their suppliers is simplified. The joinability of the test material is evaluated by the user based upon the results of the testing and documentation guideline and the specific case of application. The scope of testing is restricted to two sheet joint configurations with similar material combination with an agreed sheet thickness of approximately 1.0 mm or about 1.5 mm for cold-rolled steels. For hot-rolled steels thicknesses of approximately 2.0 mm shall be tested.

2. Structure of SEP1220

The „Stahl- und Eisenprüfblatt (SEP) 1220" is divided in several sections. Part one of the SEP1220 include the general definitions of material characterization, the following parts specifie the execution of tests in terms of the particular joining processes. The application of SEP1220-1 is recommended for the testing procedures described in the following sections of the document. Figure 1 gives a review of the sections and the actual editing status.

Part	Title	Status
SEP 1220-1	General Specifications	Published
SEP 1220-2	Resistance Spot Welding	Published
SEP 1220-3	Laser Beam Welding	Published
SEP 1220-4	Metal Inert Gas Brazing	Published
SEP 1220-5	Gas Metal Arc Welding	In Progress
SEP 1220-6	Bonding	In Progress
SEP 1220-7	Projection Welding of Fasteners	In Progress
SEP 1220-8	Arc Stud Welding	Planned
SEP 1220-9	Mechanical Joining	In Progress
SEP 1220-10	Laser Beam Brazing	Planned

Fig. 1: Sections of SEP1220 with actual editing status

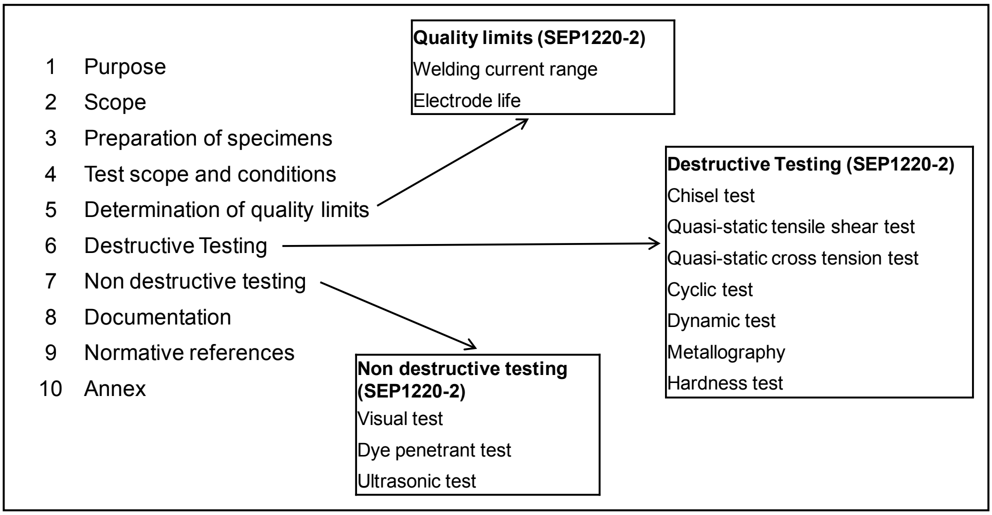

Fig. 2: Structure of guidelines SEP1220-ff

The process specific parts of SEP 1220-ff contain the standards for specimen types and –preparation, applied testing conditions and methods as well as the final documentation of the results. Every section has the same general structure, so that the application for the user and the comparison of results regarding different joining processes is simplified, Figure 2. Chronology of testing and methods of approach of the material release process are described in Stahl-Eisen-Prüfblatt SEP 1245 guideline "Description of the phases in the Material Approval Process" [4]. Here the amount of tests and their repeating is shown in "Joining Matrices" in subject to the phases of the material release process with regard to the joining methods, Figure 3. Beside this, the agreements of SEP 1240, "Testing and Documentation Guideline for the Experimental Determination of Mechanical Properties of Steel Sheets for CAE-Calculations" are valid for description and documentation of the materials.

Tests	Sample coil	Small batch statistics	Pre-series
Welding Current Range 1	X		
Welding Current Range 2	X		
Welding Current Range 3	X		
Welding Current Range 4		X	
Welding Current Range 5			X
Electrode Life 1	X		
Electrode Life 2	X		
Shear Tensile Test	X	X	X
Cross Tensile Test	X	X	X
Cyclic Test		X	
Highspeed Shear Tensile Test			X
Metallography	X	X	X
Hardness Testing	X	X	X
Visual or Penetration Dye Test	X		
Ultrasound Test		X	

Fig. 3: Amount of testing in dependence of approval status (SEP1220-2)

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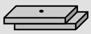
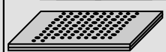
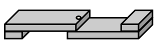
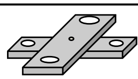
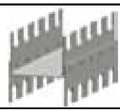
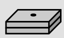
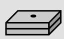
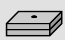
3. Results resistance spot welding

To provide a better understanding of the methods and procedures applied in the guideline, the resistance spot welding process is shown in the following as an example. For this investigation a HCT780XD dualphase steel and, as a comparative material, an HX340LAD microalloyed fine-grained steel in the thickness t = 1.5 mm were available. Both materials are hot-dip galvanized with a weight of 100 g/m². The required investigations are portrayed in Figure 4. They encompass the determination of the quality limits, the microstructure and the load-bearing behaviour of the joint. Welding parameters are chosen in subject to the sheet thickness and the surface conditions. Above that, also methods of non-destructive testing like i.e. visual inspection were applied, which are not especially mentioned.

Tests	Sample geometry	Sample quantity	Welding parameters	Test attribute
Current range		ca. 50 samples	constant: t_V, t_S, t_N, F_E, variable: I_S	- Weld spot diameter - Fracture type - Splashes
Electrode life		max. 20 samples	constant: t_V, t_S, t_N, F_E, variable: I_S	- Weld spot diameter - Fracture type
Shear tensile test		each 5 samples at I_{max}/I_{min}	constant: t_V, t_S, t_N, F_E, variable: I_S (I_{max}/I_{min})	- Weld spot diameter - Fracture type - max. force
Cross tensile test		each 5 samples at I_{max}/I_{min}	constant: t_V, t_S, t_N, F_E, variable: I_S (I_{max}/I_{min})	- Weld spot diameter - Fracture type - Max. force
Cyclic testing		20 samples (min. 12 fine samples)	constant: t_V, t_S, t_N, F_E, variable: I_S (I_{max}/I_{min})	- Weld spot diameter - Load cycles - k-factor (Notch sensitivity)
Optical analysis		*each 3 samples at I_{max}/I_{min}	constant: t_V, t_S, t_N, F_E, variable: I_S (I_{max}/I_{min})	- Defects (cracks, segregations, etc.)
Microstructure analysis		*each 3 samples at I_{max}/I_{min}	constant: t_V, t_S, t_N, F_E, variable: I_S (I_{max}/I_{min})	- Microstructure, base material, HAZ, weld spot
Hardness test		*each 3 samples at I_{max}/I_{min}	constant: t_V, t_S, t_N, F_E, variable: I_S (I_{max}/I_{min})	- Hardness profile over base material, HAZ and weld zone

* Optical analysis, micro structure and hardness tests overall on each with 3 samples at I_{max}/I_{min}

Fig. 4: Testing methods for resistance spot welding

The portrayed investigations were conducted on a "PMS 11 4" pedestal-type spot welding machine from Dalex. This installation works with medium-frequency direct-current technology (1.000 Hz) and can achieve welding currents up to 41 kA and electrode forces up to 6 kN. The same welding facilities and welding electrodes as for the welding of soft deep-drawing steels were used for the spot welding of the HCT780XD. However, it must be taken into consideration that higher electrode forces than those for the spot welding mild steels with the same sheet thickness are required.

4.1 Welding range and electrode lifetime

The welding current ranges of the test materials were determined in order to establish the quality limits. Welding range is defined as the current range between the minimum current value I_{min} for a spot diameter of $d_{min} = 4\sqrt{t}$ and maximum value I_{max} where just welds without spatter can be produced. On Figure 5, the welding range of the HCT780XD with is portrayed in comparison with the HX340LAD. When the parameter values stipulated in SEP1220-2 are set, the HCT780XD exhibits a welding range of 1.8 kA. The failure behaviour is characterised by interfacial or partial interfacial fractures at the lower quality limit (I_{min}) and by plug fractures at the upper quality limit (I_{max}). In comparison with this, the HX340LAD exhibits a welding range with a similar width, i. e. 1.8 kA. Across the entire welding range, the specimens fail as plug fractures. Testing of electrode life shows results of 1800 welds for HCT780XD and 1400 welds for HX340LAD before the minimum spot diameter was undercut.

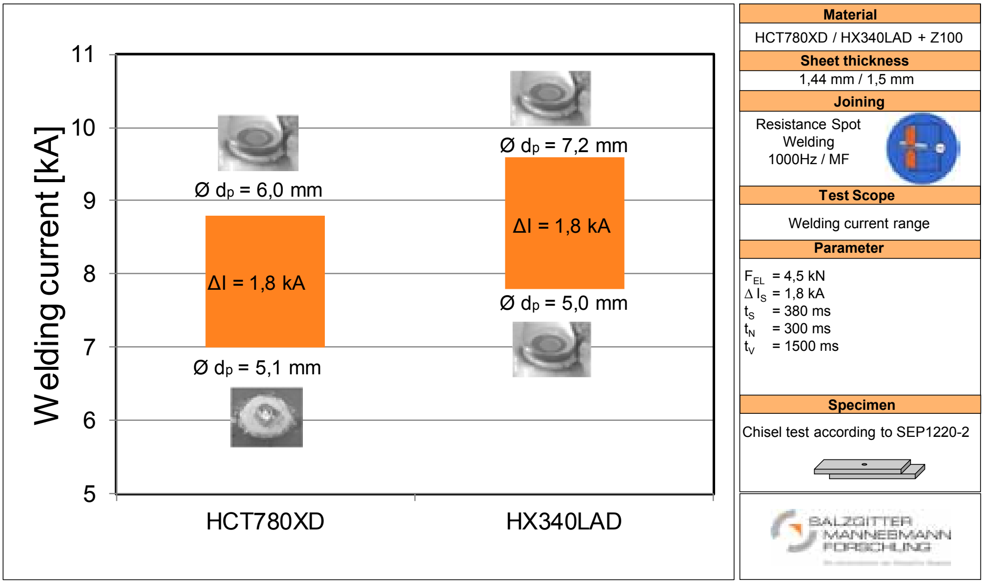


Fig. 5: Comparison of welding range HCT780XD – HX340LAD

4.2 Load bearing behaviour of joints

With the HCT780XD, the highest force level by quasi-static shear tension testing is achieved at 20.9 kN for I_{max} while the HX340LAD exhibits force values of 14.8 kN, Figure 6. In comparison to shear tension testing, with 12.7 kN (I_{max}) and approx. 8.5 kN (I_{min}), comparable forces are achieved for both materials subjected to cross-tension loads but, as expected, these are lower than the forces in the case of the shear tension, Figure 7. A transformation of material strength into increased cross tensile strength was not even attainable due to the notch sensivity of high strength dual phase steel. Fracture behaviour of all specimens was plug failure.

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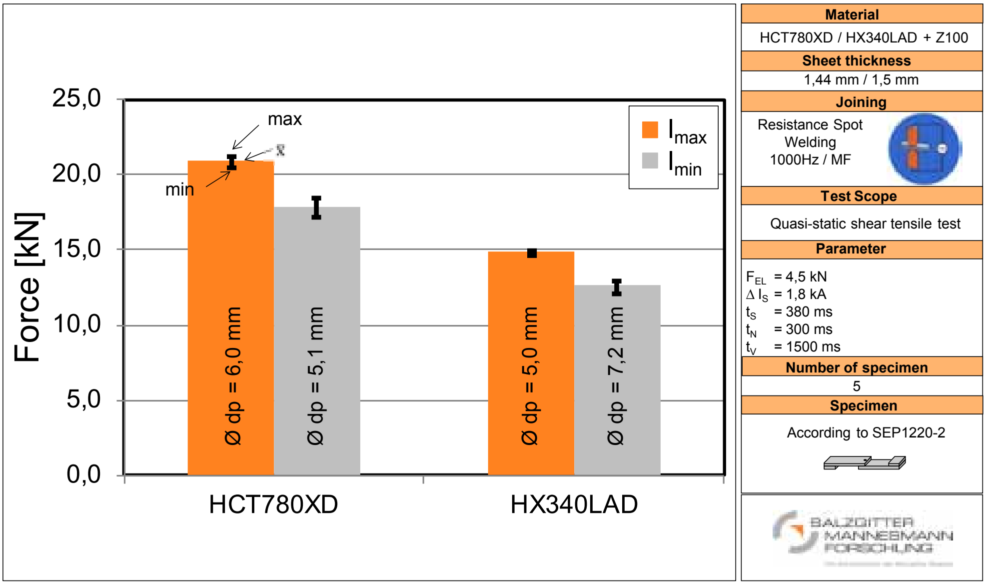

Fig. 6: Comparison of tensile shear testing HCT780XD – HX340LAD

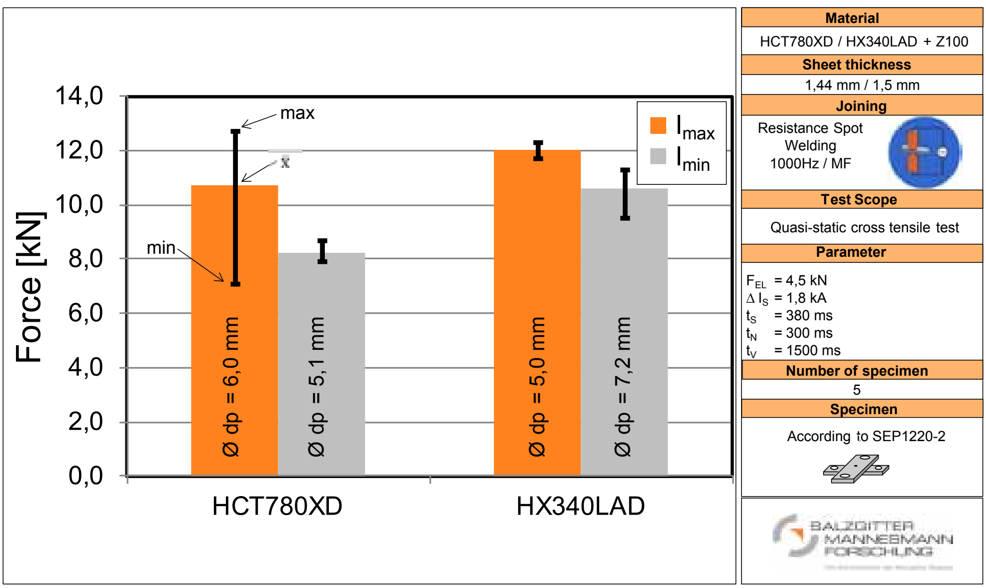

Fig. 7: Comparison of cross tensile testing HCT780XD – HX340LAD

5. Conclusions

Before a new material is applied, the processibility along the automotive processing chain has to be tested. Beside the base material characterization, another major task is the investigation of the joinability of the new material. These tests are currently defined in the teamwork of the VDA (Verband der Automobilindustrie) and the VDEh (Stahlinstitut Verein Deutscher Eisenhüttenleute) as SEP1220-ff "Testing and Documentation Guideline Joining", in which the methods for the determination of all relevant joining processes for automotive production are described. This will allow the customers to select materials in early stage of BIW development and limit the amount of OEM-specific testing to special combinations at steel supplier side. The application of this guideline ensures target-oriented development of a new material at the steel supplier as well as a fast internal material release at the automotive manufacturer.

6. References

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