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Test procedures for the quality assurance of electron and laser beam welds

Technical Bulletin
DVS 3210

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Contents:

1 Introduction

The technical bulletin was elaborated in cooperation with experts from industry, research and acceptance organisations in the field of electron and laser beam welding.

2 Scope of application

Welding technology personnel should apply the technical bulletin to fabrication, supervision, testing and quality assurance tasks. It is based on the currently applicable national and European standards for the destructive and non-destructive testing of welded joints between metallic materials and describes the peculiarities when these procedures are applied to the testing of joints executed by means of electron and laser beam welding.

3 Non-destructive test procedures

3.1 Visual testing

In nearly all cases, the visual examination without any aids is the first testing of a weld. Any external irregularities can be established and assessed by the visual testing according to DIN EN 970 [1]. In the case of beam welds, it is recommended to use magnifying glasses (magnifying power: approx. five times) for the visual inspection because of the well-known low weld width and the associated small dimensions of irregularities. Figs. 1 and 2 show typical top and bottom sides of joints executed by means of electron and laser beam welding.

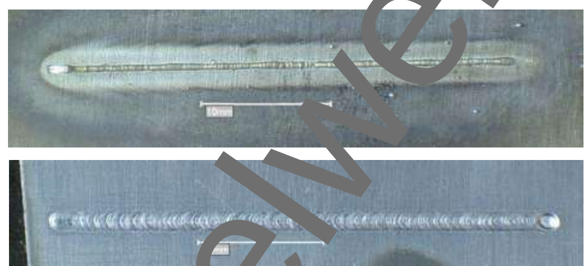

Figure 1. Electron beam weld on DC 04 (1.0338), 2 mm, top: bottom side of the weld, bottom: top side of the weld.

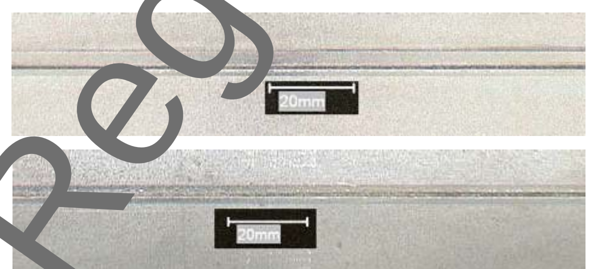

Figure 2. Laser beam weld on DX53D+Z100MB (1.0355), 1.2 mm, top: top side of the weld, bottom: bottom side of the weld.

With a simple additional measure, any deviations of the beam position from the weld groove and thus certain internal irregularities (lack of fusion) can also be checked during the visual inspection (Fig. 3). For this purpose, the weld is executed with periodic interruptions (Fig. 4). Differences between the nominal and actual beam positions can be established by measuring the distance from the weld centre position (can be recognised easily in the end crater of the intermittent weld) to the weld groove. The number and length of the interruptions depend on the weld length and the geometry of the weld course in the weld direction.

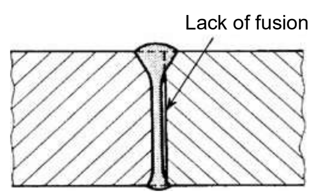

Figure 3. Beam weld with lack of fusion.

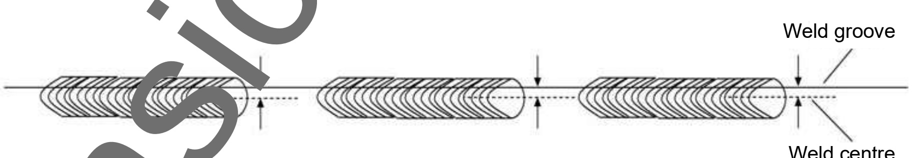

Figure 4. Checking of the laser beam position in relation to the weld groove with the aid of an intermittent weld.

DVS, Technical Committee, Working Group "Beam Welding"

3.2 Penetrant testing

During the penetrant testing according to DIN EN 571-1 [2], it must be borne in mind in the case of beam welds that extreme weld ripples and sharp undercuts may feign cracks. In cases of doubt, a radiographic test must be performed in addition.

3.3 Magnetic particle test

The procedure of the magnetic particle test for ferritic steels according to DIN EN 1290 [8] can be applied to laser beam welds without any particular restrictions. In the case of electron beam welds, it is imperative to carry out a demagnetisation operation after the magnetic particle test in the event of repair welds.

3.4 Eddy current testing

As in the case of other fusion welds, the eddy current test according to DIN EN 12084 [3] can also be applied, i.e. preference should be given to the multifrequency procedure. The machining-off of the top and bottom sides of the weld and the execution of a cosmetic weld are obligatory for the eddy current testing of beam welds.

3.5 Ultrasonic testing

As in the customary way, beam welds can be tested using conventional ultrasound according to DIN EN 1714 [4]. Difficulties are caused merely by low wall thicknesses (< 3 mm) since, in these cases, the ultrasonic waves are predominantly propagated only on the workpiece surface. To a particular extent, the ultrasonic procedure is also suitable for electron beam welds between different materials if thermoelectric voltages lead to the danger of inadvertent beam deflections and thus of lack of fusion (Fig. 5).

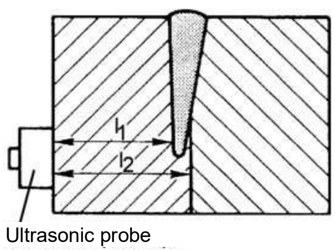

Figure 5.
Schematic representation of the ultrasonic test in order to find lack of fusion.

By utilising ultrasound generated electromagnetically and without any probe-to-specimen contact media (so-called EMUS technique), it is now also possible to evaluate beam welds in thin-walled sheets (e.g. tailored blanks). In the case of this procedure, an ultrasonic plate wave penetrates the volume of the weld across the entire sheet thickness. Any imperfections in the weld are detected with the aid of the ultrasonic wave reflected or diffracted at the defect (Fig. 6).

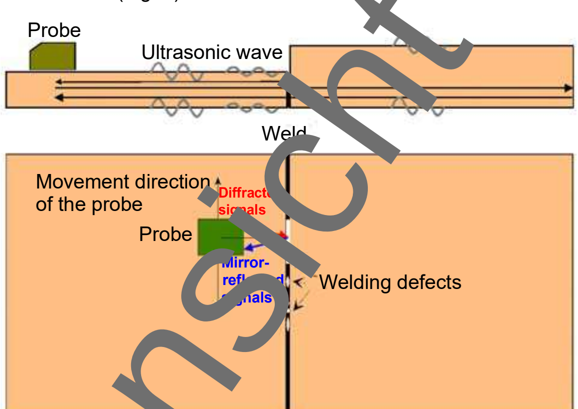

Figure 6. Ultrasonic plate waves generated without any probe-to-specimen contact media in order to prove imperfections in welds with low wall thicknesses.

3.6 Radiographic testing

In the case of radiographic tests according to DIN EN 462-1, DIN EN 462-4 and DIN EN 1435 [5 ... 7], it is necessary to machine off the top and bottom sides of beam welds in order to avoid the overlapping of indications of external and internal irregularities in the region of the narrow fusion zones on the film or on the screen. Otherwise, the radiographic test must be carried out diagonally through the welds. Preference is given to the utilisation of micro-focus tubes for the testing of beam welds in order to increase the recognition of characteristics.

4 Destructive test procedures

4.1 Transverse tensile test

DIN EN 895 [9] includes information about the dimensions of transverse tensile test specimens made of steel particularly for beam welds too. [9] is also valid for transverse tensile test specimens made of non-ferrous metals. This standard must be applied to the determination of the tensile strength and the fracture position of a butt-welded joint subjected to tensile stresses. If the elongation, the offset yield strength, the area reduction at fracture and the tensile yield strength must be determined on the welded joint, it is necessary to reach separate agreements about the specimen dimensions and miscellaneous details. In this respect, it must be borne in mind that, because of the extremely low width of beam welds, a substantial scope of measuring technology is needed, for example, for the exclusive determination of the weld elongation (laser measuring devices). If beam welding is carried out with filler material, there is the possibility, according to DIN EN 876 [10], of preparing tensile test specimens which are made of pure weld metal and are suitable for the relatively simple determination of the elongation values.

4.2 Fracture tests

Furthermore, notched tensile test specimens are also standardised if the fracture position is to be situated in the fusion zone region, e.g. on transformation-hardening materials, Fig. 7 [11 ... 13]. However, within the framework of welder qualification tests, these tests have the purposes of highlighting internal irregularities such as pores, shrinkage cavities, lack of fusion and slag inclusions in the fusion zone region and of drawing conclusions about the manual skills of the welder. In these cases, it is a question exclusively of fracture tests which, although they can be used for beam-welded joints too, are in no way suitable for the determination of the tensile strength.

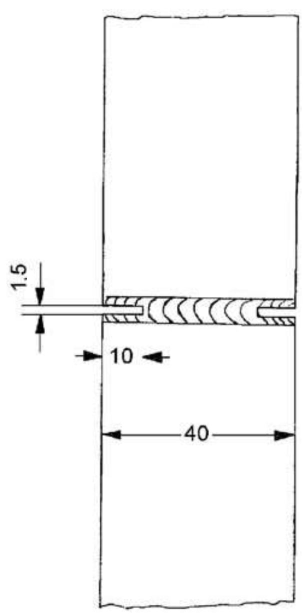

Figure 7.
Notched tensile test specimen [9].