Bend test of dissimilar joints using different methods

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Abstract

Bend test is simple and qualitive test that can be conducted in workshop environment. This paper focuses on the bend test of dissimilar welded joints, which can be problematic using the most commonly used methods.

Introduction

Destructive Testing (DT) is a common way of determining and evaluating different properties of materials such as strength, ductility, toughness or hardness. Usually these properties are determined by analysis of test sample under load/stress until its point of failure. One of the simplest of destructive testing methods is bend test. Bend test can be used to check ductility of tested material, either pure metal or welded joints. The simplest variant of bend test is called free formed and it can be conducted in workshop environment if required. The bend test specimen is called coupon and is bent in three point bent. The outside of the bent is subjected to extensive plastically deformation in a way that any defects in material or welded joint will be revealed by premature failure of coupon. A guided bent test is where coupon is wrapped around mandrel of specified diameter. The diameter may vary depending on used test standard, material ductility [1,2].

In welding industry most of the time guided bend test is used, as it's required by specifications of welding procedure and welder qualification. For example in Europe most common standard for bend test is ISO 5173 [3] which is required by ISO 15614-1 [4]. The ISO 5173 standard proposes 3 bending methods, three point bending, bend test with U-type jig and bend test using roller (wrap-around test). For methods of testing with a former (three point bending and U-type jig bend) the weld shall be at the mid-point between two rollers. The test specimen shall be bend by loading gradually and continuously in the middle of span, on the axis of weld, with a load applied by a former perpendicular to the test specimen surface. The bend test with a roller shall be carried out by clamping one end of the coupon in a device having a roller parallel to a former. The test specimen shall be bend by loading, gradually and continuously, by means of the rotation of the outer roller through an arc centred on the axis of the former. The schemes for the three bend test methods are presented on Figures 1 to 3 [1-3].

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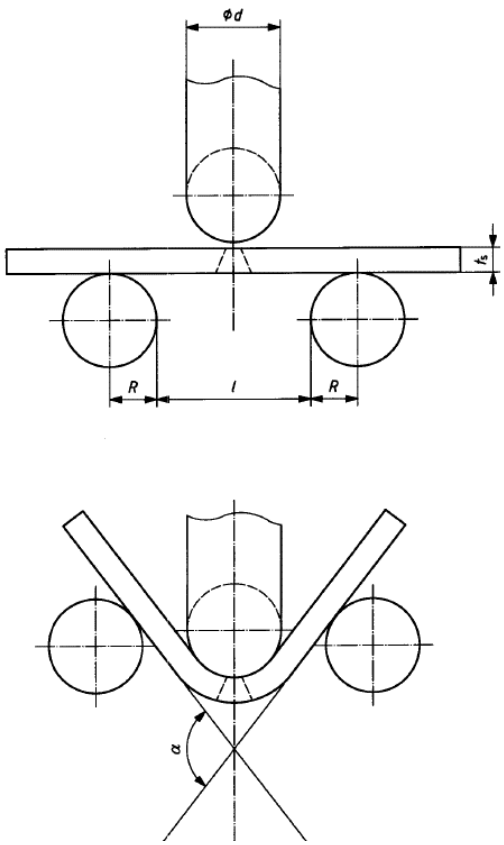
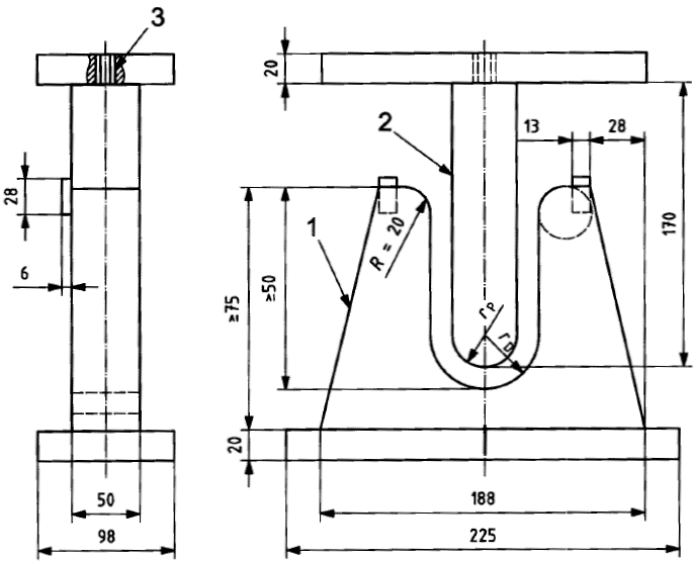


Figure 1 The principle of three point bend test [3].



Key

r_P plunger radius

r_D die radius

1 die

2 plunger

3 tapped hole for attaching plunger to test machine

Figure 2 The principle of bend test with U-type jig [3].

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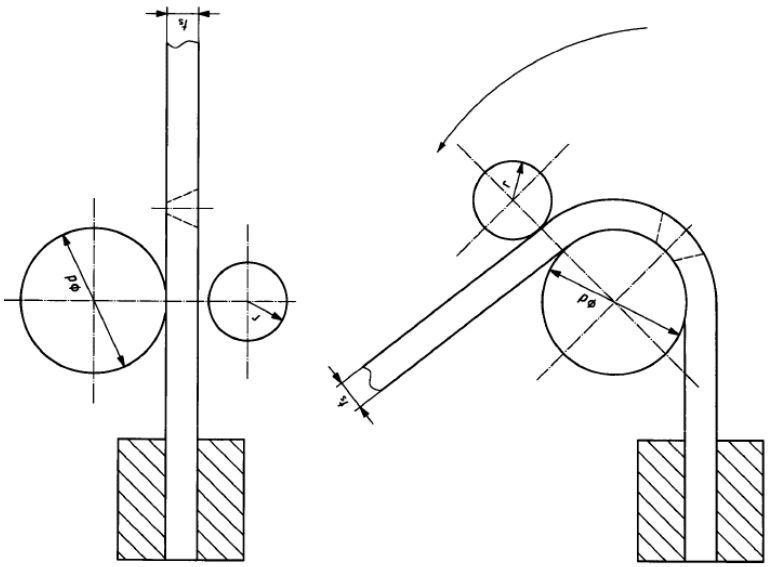

Figure 3 The principle of bend test with a roller [3].

In general, the use of simple three-point bend test is sufficient to test most of the materials and welded joints. However, weld joint with non-uniform properties such as joints where weld and parent metal ductility and strengths are significantly different or dissimilar joints (joint with two different parent materials) can result in so called 'peaking' of test specimen. This is when the majority of the deformation takes place in the weaker material which means excessive localised deformation while almost no deformation occurs in the opposite material. To avoid 'peaking' of bent coupons the use of U-type jig or bend test with a roller is recommended [1].

Experimental procedure

The object of the research was a dissimilar butt welded joint made of steel grades S960QL and S355JR with a thickness of 10 mm. The welded joint was made without use of filler material and the welding groove was square. Welding pad made of S960QL was used. Table 1 shows the properties of the materials being welded, as can be seen the difference in both strength and minimum elongation is significant. The welded joint was fabricated on a CVE EB756 model XW150:30 electron welding machine, shown in the figure 4.

Table 1. Properties of welded materials in accordance to EN 10025-2 [6] and EN 10025-6[7].

	Min. yield strength [MPa]	Min. tensile strength [MPa]	Min. elongation $A_{5,65}$ [%]
S355JR [6]	355	510	20
S960QL [7]	960	980	10

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Figure 4. CVE EB756 model XW150:30 electron welding machine

From the welded joint 8 specimens were taken for bend test. 4 of these specimens were bent using three-point bend test methods and the other 4 were bent using bend test with a roller. Figure 5 shows the specimens taken with removed weld face and pad. The A side of the joint was made from S960QL steel grade and the B side from S355JR. The diameter of former was calculated in accordance to ISO 5173 for the material with lower required elongation and was 90 mm.

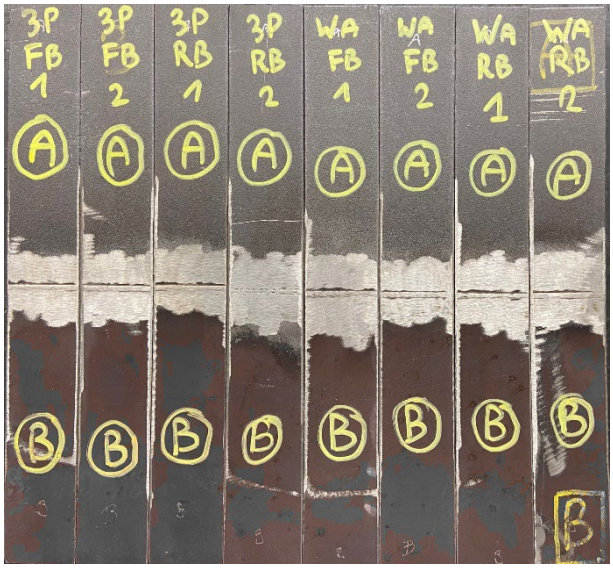

Figure 5. Bend test coupons.

Results and discussion

Testing with both methods did not reveal any defects in joint however, as can be seen in Figure 6a, the three-point bend specimens bent non-uniformly, with a significant part of the deformation occurring in the weaker material B, while the deformation was minimal in material A and the weld. As a result, the diameter of the bending mandrel was not reproduced on the specimens . Figure 6b shows the specimens bent using the method with roller, as can be seen the bending radius is much more similar

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to the bending mandrel radius. Figure 6c and 6d shows bent coupons alongside mandrel of diameter 90 mm.

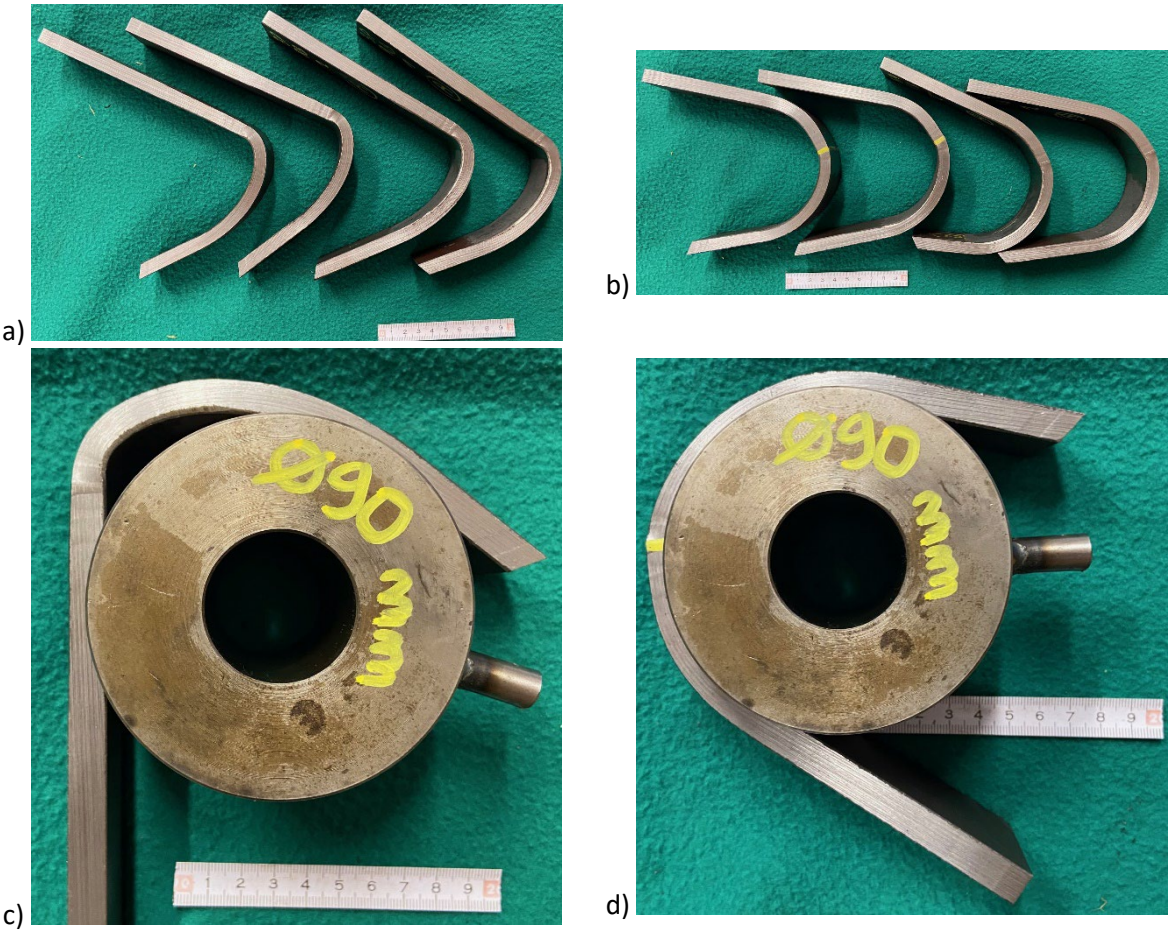

Figure 6. a) specimens after three-point bent test, b) specimens after bent test with roller, c) three point bent test specimen with mandrel, d) specimen bent with roller with mandrel.

Figure 7 shows different stages of bending using three-point bend test method. It can be observed how the axis of the weld (marked with arrow) moves away from the axis of the former. Figure 8 shows the final stage of bend test with roller. A good representation of the bending mandrel on the specimen can be observed.

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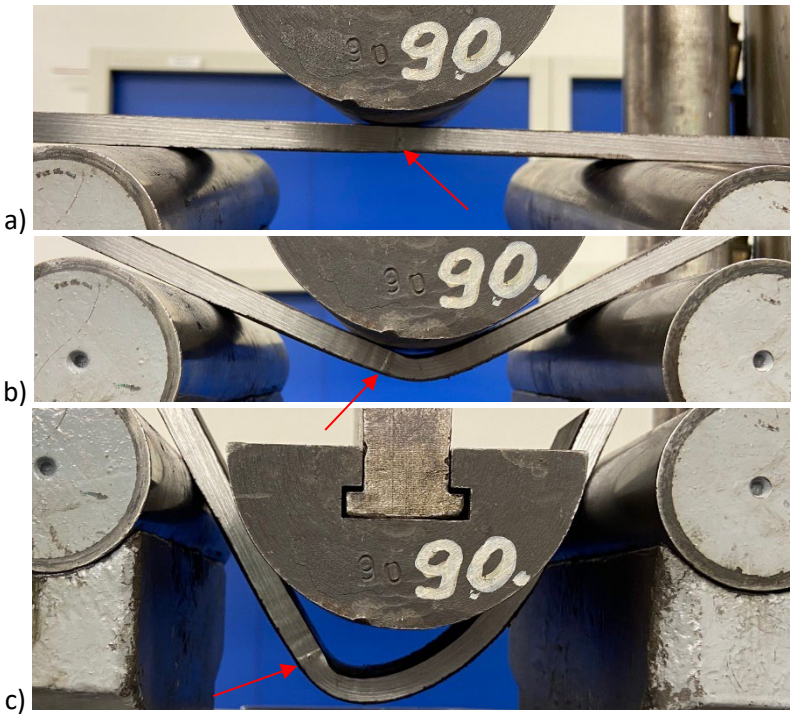

Figure 7. Different stages of three-point bent test: a) initial stage, b) mid-stage c) final stage.

Figure 8. Final stage of bent test with roller.

Conclusion

Three-point bent test method is not suitable for bending dissimilar joints as it is unable to provide good representation of mandrel on the specimen. As result majority of deformation occurs in a single side of welded joint. Using bend test with roller method is advised for such welded joints and results from this paper can confirm this.

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References

[1] TWI (n.d.) Technical Knowledge FAQs, Retrived from https://www.twi-global.com/technical-knowledge/faq/ (accessed on November 2022)

[2] Flyability (n.d.) "Destructive Testing: A Guide". Retrieved from https://www.flyability.com/destructive-testing (accessed on November 2022).

[3] ISO 5173:2009: "Destructive tests on welds in metallic materials. Bend tests" (2009).

[4] ISO 15614-1:2017: "Specification and qualification of welding procedures for metallic materials. Welding procedure test. Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys" (2017).

[5] ISO 4136:2012: "Destructive tests on welds in metallic materials. Transverse tensile test" (2012).

[6] EN 10025-2:2019: "Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels" (2019).

[7] EN 10025-6:2020: "Hot rolled products of structural steels - Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition" (2020).

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