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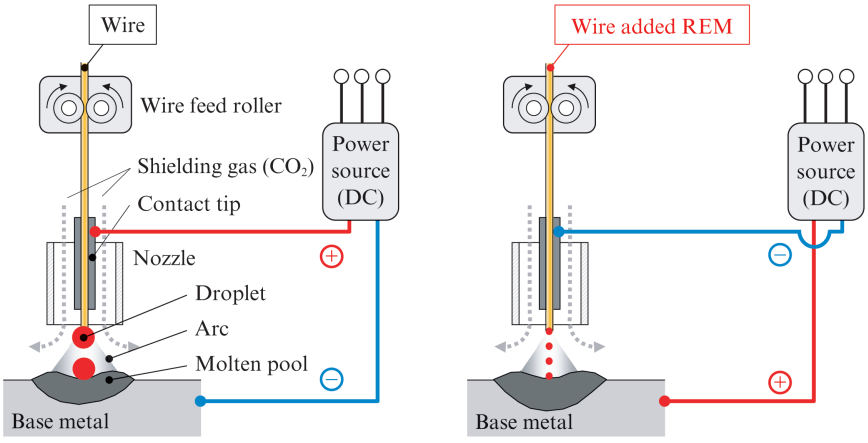
Development and Application of High-Efficiency Narrow-Groove Welding Process for Building Steel Frames

1. Introduction

In recent years, construction of large-scale and high-rise building structures has progressed accompanying the redevelopment of urban areas, and the steel plates applied in these structures also tend to be high strength and heavy thickness products. Because larger plate thickness frequently requires an increase in the number of welding passes in multilayer welding, narrow-groove welding has been studied as a means of reducing welding man-hours by reducing the number of passes. In the conventional narrow-gap gas shielded arc welding proposed in the past, the shield gas was not 100% CO_2 gas, which is normally used in welding of building steel frames, but was generally a mixed gas such as Ar-20% CO_2. Although CO_2 arc welding using 100% CO_2 as the shield gas has the advantage that deep penetration can be obtained, a large amount of spatter is generated during welding, and the generated spatter is deposited or accumulates on the weld groove sidewalls and welding nozzle, causing a remarkable reduction in weldability. To solve these problems, JFE Steel developed a DCEN (direct current electrode negative) CO_2 arc welding method (hereinafter referred to a J-STAR™ welding) using a welding wire containing a small amount of added REM (rare earth metals) as an arc stabilizer for DCEN welding, in which the welding wire functions as the negative electrode [1–2]. Up to the present, JFE Steel has promoted the application of J-STAR™ welding to 25° single-bevel grooves and square grooves in welded joints of building structures, and has obtained Building Technology Performance Evaluation Certification from the General Building Research Corporation of Japan (GBRC) [3–4]. This article introduces an example of practical application of J-STAR™ welding to box column joints of a building structure in order to improve welding efficiency by using an ultra-narrow groove gap, taking advantage of the strong points of J-STAR™ welding.

2. Features of J-STAR™ Welding

Figure 1 shows the technical features of J-STAR™ welding. In the conventional CO_2 arc welding, the welding wire is used as the positive electrode (DCEP: direct current electrode positive). In contrast, J-STAR™ welding is a CO_2 arc welding method in which the welding wire is used as the negative electrode,



(a) Conventional CO_2 arc welding (b) J-STAR welding

Fig. 1 Comparison between conventional CO_2 arc welding and "J-STAR™ welding"

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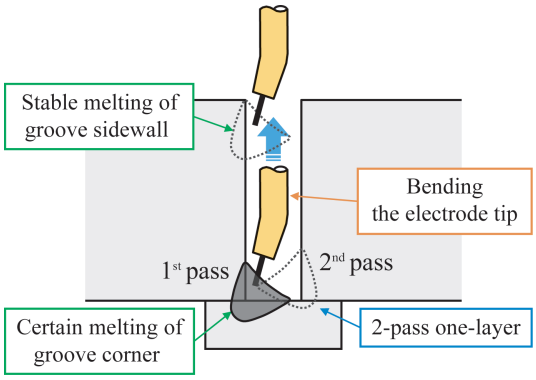

Fig. 2 Schematic illustration of ultra-narrow-gap J-STAR™ welding

Photo 1 Steel frame of Kumamoto Castle's large keep (Arrow points to box column made with ultra-narrow-gap J-STAR™ welding technology)

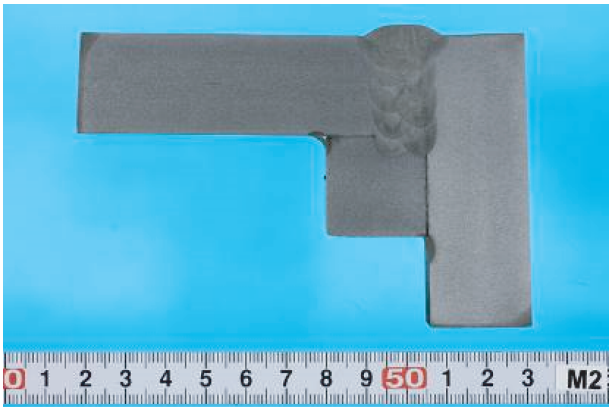

Photo 2 Cross section of corner weld made with ultra-narrow-gap J-STAR™ welding

that is, the opposite polarity of conventional method, and a small amount of REM is added to the welding wire as a welding stabilizer. This welding method realized formation of a stable conical arc and fine and continuous spray transfer, which had been considered impossible in general CO_2 arc welding. As a result, the following effects could be obtained:

① Welding spatter is fine, and the amount of spatter generation is remarkably small.
② The welding arc is easily concentrated, so deep penetration can be obtained.
③ Slag detachability on the surface of the weld metal is good.

Owing to these features, J-STAR™ welding has various advantages when applied to narrow-groove welding, and reduction in welding man-hours in multi-layer welding of heavy thickness steel plates can be expected.

3. Ultra-Narrow-Gap J-STAR™ Welding

Ultra-narrow-gap J-STAR™ welding was developed to further improve welding efficiency by J-STAR™ welding. In ultra-narrow-gap welding, reliable melting of the groove corners and stable melting of the groove sidewalls are necessary in order to prevent weld defects such as lack of penetration and lack of fusion. To achieve these requirements, a high weldability CO_2 arc welding technology called "ultra-narrow-gap J-STAR™ welding" was developed by combining J-STAR™ welding, which has the strength mentioned above, and two passes in one layer welding using an electrode with a bent electrode tip. A schematic illustration of this technology is shown in **Fig. 2**. As an innovation to expand the melting of the groove sidewall, an electrode with a slightly bent tip is inserted in the narrow groove so that the arc strikes directly on the groove bottom corners and sidewalls on the two sides of the groove in two passes. Due to the strong arc orientation in J-STAR™ welding, arc climb-up does not occur and stable melting of the groove sidewalls is achieved. In this welding technology, the cross-sectional area of the groove can be reduced to approximately one-half of the conventional size by the above-mentioned innovations, and as a result, it is possible to minimize weld distortion and shorten welding man-hours.

4. Application to Box Columns of Building Steel Frame

Ultra-narrow-gap J-STAR™ welding was applied to welding of box columns joints of assembly-welded box columns (four-sided box columns), which formed the main structure of the steel frame of 6th floor of the large keep at Kumamoto Castle, during the major reconstruction of the castle following the Kumamoto Earthquakes of 2016 (**Photo 1**, **Photo 2**). Although submerged-arc welding (SAW) had been used in convention box column joint welding, excessive weld dis-

tortion due to the large welding heat input is a problem, particularly in the case of column materials with a small-size square cross section. JFE Steel proposed ultra-narrow-gap J-STAR™ welding as a solution technology for this problem, and Nagai Steel Works Corporation fabricated the box columns utilizing this technology, which received a high evaluation for suppressing weld distortion and greatly reducing welding man-hours.

5. Conclusion

In the future, JFE Steel will continue to respond to a wide range of customer requests, positioning the J-STAR welding technology, which is one of the company's "Only One" technologies, as a welding technology that can contribute to higher performance in building steel structures in which high steel materials are used.

References

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