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Ultra Heavy Gauged Square Tube "JFE Kakuhot" for Excellent Designing†

1. Introduction

Steel columns with square cross section used for steel frames of buildings are roughly classified into: those fabricated by welding heavy gauge steel plates; those fabricated by forming heavy gauge steel sheets into a U-shape or square shape by pressing, which are then welded; and those fabricated by forming hot-rolled steel strips into a cylindrical shape, which are then welded by electric resistance welding, followed by forming them into a square cross sectional shape. These are respectively called the welded square box, the pressed column, and the rolled column, and their general dimensional ranges are given in **Fig. 1**.

Modern architecture emphasizes the design, and so buildings with larger areas of glass in the walls, or columns buried in thin walls are on the rise. Such buildings require a column material of small cross section. Meanwhile, for the joints of beams and columns, reinforcement of the joint is often eliminated by using heavy gauge square steel tubes.

To fabricate ultra heavy gauge square steel tubes of small cross section that satisfy these requirements, the above-described method of using the welded square box has been tried. A small cross sectional area, however, decreases the inside space and so hand-welding is needed, but this increases the cost.

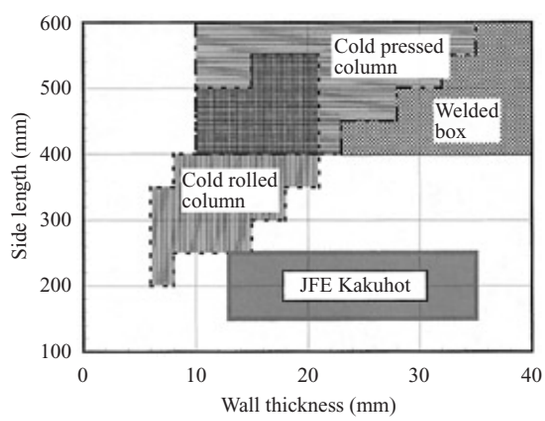

Fig. 1 Size range and kinds of square steel tubes

JFE Steel has therefore developed "JFE Kakuhot" which is an ultra heavy gauge square steel tube of small cross section fabricated using the seamless steel tube manufacturing process.

2. Characteristics of JFE Kakuhot

2.1 Manufacturing Method

JFE Kakuhot is manufactured using a seamless steel tube manufacturing line. That is, the hot sizing mill (**Fig. 2**) which is the final step of the manufacturing process, reshapes the mother pipe of circular cross section into a square one.

The hot sizing mill has a tandem arrangement of mill stands with grooved rolls, thereby forming a mother pipe and its large outside diameter is reduced to a small specified outside diameter. The product is manufactured by applying an existing 8-stand sizing mill of 2-roll type. A circular cross section of the mother pipe is formed into a square cross section by the last four stands in the sizing mill.

2.2 Dimensional Characteristics

Figure 3 shows an example of the product, which has a cross section of 250 mm in side length and 35 mm in wall thickness.

It is generally considered that when manufacturing a square steel tube by roll forming or press forming, it is difficult to satisfy both corner sharpness and side flatness. However, JFE Steel has achieved both requirements simultaneously by making full use of the hot-

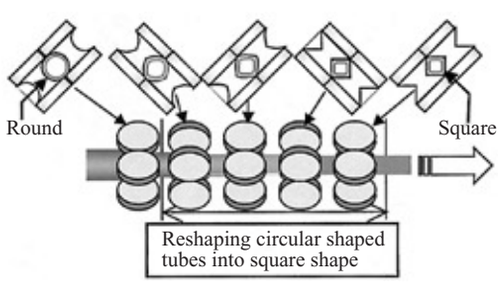

Fig. 2 Schematic drawing of forming JFE Kakuhot using hot sizing mill

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Fig. 3 Cross-sectional shape of JFE Kakuhot (Side length: 250 mm, Wall thickness: 36 mm)

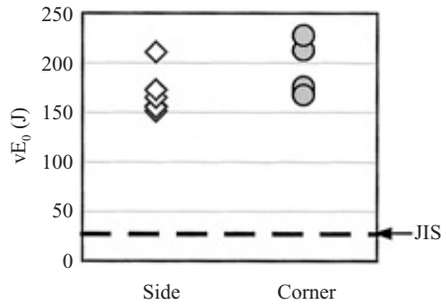

Fig. 4 Absorbed energy at corners and sides of JFE Kakuhot

Table 1 Corner radius and side flatness of JFE Kakuhot

	Produced cross section	Request for joint	Cold rolled column (Torelance)
Corner radius (× Wall thickness)	1.0	≦1.5	≦3.0
Side flatness (%)	0.2	≦0.5	≦0.5

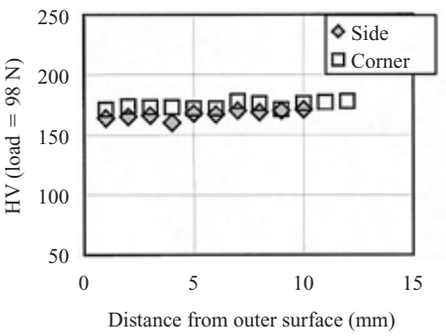

Fig. 5 Distribution of hardness in thickness direction of JFE Kakuhot

forming process for the seamless steel tubes and optimizing the forming conditions through an experiment[1] using a high strength production facility and a calculation using the rigid plastic finite element method[2]. The corner radius *R* and the side flatness on the cross section of the product manufactured by the technology are given in **Table 1**. For the joint of a beam and column, the dimensional requirements may become severe in some cases, requiring a corner radius *R* of not larger than ((wall thickness) × 1.5), and a side flatness of not larger than 0.5%. The product of JFE Steel satisfies these requirements. Furthermore, as a small cross sectional column material that facilitates designing the building, the cross sectional shape of the product has been highly reputed in practical applications by users.

2.3 Material Properties

The mechanical properties of products of 250 mm in side length and 16 mm and 35 mm in wall thickness are shown in **Table 2**. With the product of 16 mm in wall thickness, the yield strength (YS) at the corner is somewhat larger than that at the side. For the product having a large wall thickness of 35 mm, the difference in YS between the corner and side is small.

Table 2 Mechanical properties of JFE Kakuhot

Side length (mm)	Wall thickness (mm)	Part	YS (N/mm^2)	TS (N/mm^2)	El (%)	YR (%)
250	16	Side	346	518	47	66.8
		Corner 1/2*t*	385	523	36	73.6
	35	Side	331	502	60	65.9
		Corner 1/2*t*	341	494	38	68.9

YS: Yield strength, TS: Tensile strength, El: Elongation, YR: Yield ratio

The Charpy absorbed energy at 0°C at the side and at the corner of the products is shown in **Fig. 4**. The toughness at the side ranges from 150 to 220 J, while that at the corner ranges from 160 to 230 J. Since the product is integrally formed, without using welding, by rolling the material at temperatures slightly above the Ar_3 transformation point, it has sufficient toughness and the difference in toughness between the corner and side is small.

Figure 5 shows the hardness distribution in the wall thickness direction at the side and the corner of the product. As shown, the hardness is almost uniform for both the side and the corner. Since the product is formed by hot-forming, no work hardening induced by the strain caused by bending during square-section forming occurs, hardness is uniform for both the side and the corner.

3. Conclusion

As described above, “JFE Kakuhot” is manufactured by forming a steel tube of circular cross section into a tube of square cross section using the seamless steel tube manufacturing process. As a result, the product has a cross section with a steep corner and flat side, yet it has a small cross sectional area and very large wall thickness. Owing to these characteristics, the product takes up less space in columns and increases the flexibility in design of buildings. Furthermore, elimination of cold

Photo 1 Exterior appearance of an arcade[3], as an example where JFE Kakuhots are used as columns (white arrow)

working and welding ensures that the column material has sufficient toughness, and achieves uniform hardness over the whole cross sectional area.

“JFE Kakuhot” has been applied to various buildings as a material for designing columns effectively. **Photo 1** is an example of these applications, showing a crowded shopping street which is designed to facilitate access for shoppers and allow attractive displays of articles, by applying the developed small cross section material for columns to the arcade[3]. Other examples include: a research and development facility[4] which adopts “JFE Kakuhot” to increase the glass panel area on external walls, thereby significantly improving the beautiful appearance of the building; and a celebrated apparel shop[5] which has columns buried in the interior walls, thus allowing all-glass exterior walls. As these examples show, the product is used as the material of columns for well-designed buildings, and has acquired a solid reputation. In addition to these applications, the product is expected to be used further for curtain walls of department stores, columns for condominiums and sports stadiums, and for structural members called brace and truss, and for parts of construction machines.

References

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