

Introduction of Product

Development of a Twister Machine for Groove Cutting

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A \sqrt twister model TFPV with a new groove cutting function has been added to the lineup of twister machines (fine plasma cutting machines for medium to thick steel plates) as one of the strategic products of Komatsu Industries Corp. in its fabricating machine business. The TFPV is also expected to play a major role in streamlining the machining of welded grooves, which is one of the bottleneck processes in the manufacture of construction machinery. The aim of the TFPV development and its technical features are described.

Key Words: *plasma arc cutting, gas cutting, laser beam cutting, edge preparation, process integration, image processing*

1. Introduction

In 1983, research on thermally crushing rocks was conducted at the then Research Center (currently Corporate Research Division) in Hiratsuka, Kanagawa Prefecture. Even though this research did not bear fruit, fine plasma cutting machines for cutting steel plates derived from the results of this research have developed into products such as twister machines after several model changes have been made, greatly contributing to the fabricating machine business of Komatsu Industries Corp.

\sqrt twister machine models TFPV6082 and 6084 have been developed featuring edge preparation, which have been an obstacle in streamlining the cutting process, by adding a torch tilting and turning mechanism. The new models are based on Komatsu's twister machines, which have won high evaluation in the cutting industry thanks to their excellent cutting quality and operating cost. The new models are described below.



Photo 1 \sqrt twister machine model TFPV6082

2. Aim of Development - Streamlining of Edge Preparation Process

At present, the production sites of welded structures including not only construction machinery, but also buildings and ships that use steel plates cut regular size steel plates (4' x 8', 5' x 10', 8' x 10', 8' x 20', 10' x 20', 8' x 40', 10' x 40' and so forth, 1' = 304.7 mm) into various dimensions, thicknesses, and shapes by automatic NC cutting machines that use gas, plasma, or laser beam cutting. The gas, plasma arc, and laser beam cutting methods have both advantages and disadvantages in terms of plate thickness range, cutting speed, accuracy, initial cost, and running cost. An optimum cutting method is selected suiting the quality requirements and cost target.

By further enhancing high-speed cutting, which is one of the features of plasma arc cutting, and by applying Komatsu's unique fine plasma technology, the new twister models are capable of cutting mild steel plates of medium thickness from about 4.5 to 36 mm with high efficiency and producing high quality. **Figure 1** compares the cutting speeds of gas cutting, 6-kW laser beam cutting, and cutting by the Twister machine. **Figure 1** shows the high cutting performance of the Twister machine in the plate thickness range widely used in the production of construction machinery, achieving a speed several times that by gas cutting and about 2 to 3 times the speed by a 6-kW laser beam cutting machine, which is the largest output laser currently available on the market. The Twister machine demonstrates superb capability in increasing the productivity of the cutting process, especially in thicknesses of 16 mm and greater, in which laser beam cutting is not very efficient.

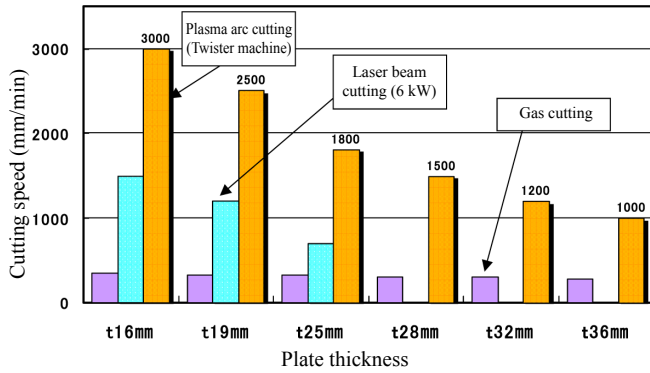


Fig. 1 Comparison of cutting speeds by various thermal cutting methods

Welded structures constituting frames and housings in construction machinery, industrial machines, buildings, and ships are automatically cut from regular-size steel plates into parts and members of various shapes by the Twister machine (plasma arc cutting) or by automatic NC cutting machines that employ gas or laser beam cutting. Following the cutting process, they are machined into welded structures after being bent and welded. During this process, welded groove joints, with which cut surfaces are cut diagonally on the butted surfaces of welding illustrated in Fig. 2a, are widely used in welding of steel plates that are thicker than 6 mm, to provide the needed design strength.

Butted joint				
Groove shape	Type I	V type Both-side V type (X type)	U type Both-side U type (H type)	Tick-mark type Both-side tick-mark type (K type)
Symbol		V X	U H	V K
Shape				

Fig. 2a Butt-welded joints

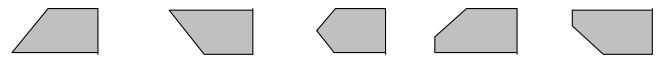


Fig. 2b Shapes of welded grooves

The welded grooves shown in Fig. 2b that will become welded groove joints are not cut by the automatic NC cutting machine in only one process. Welding edge preparation is performed after cutting a shape, whose cut surface is vertical as it is cut by the machine ("I" cutting), and after the cut surfaces are beveled in another process ("V" cutting). The machining flow is shown in Fig. 3.

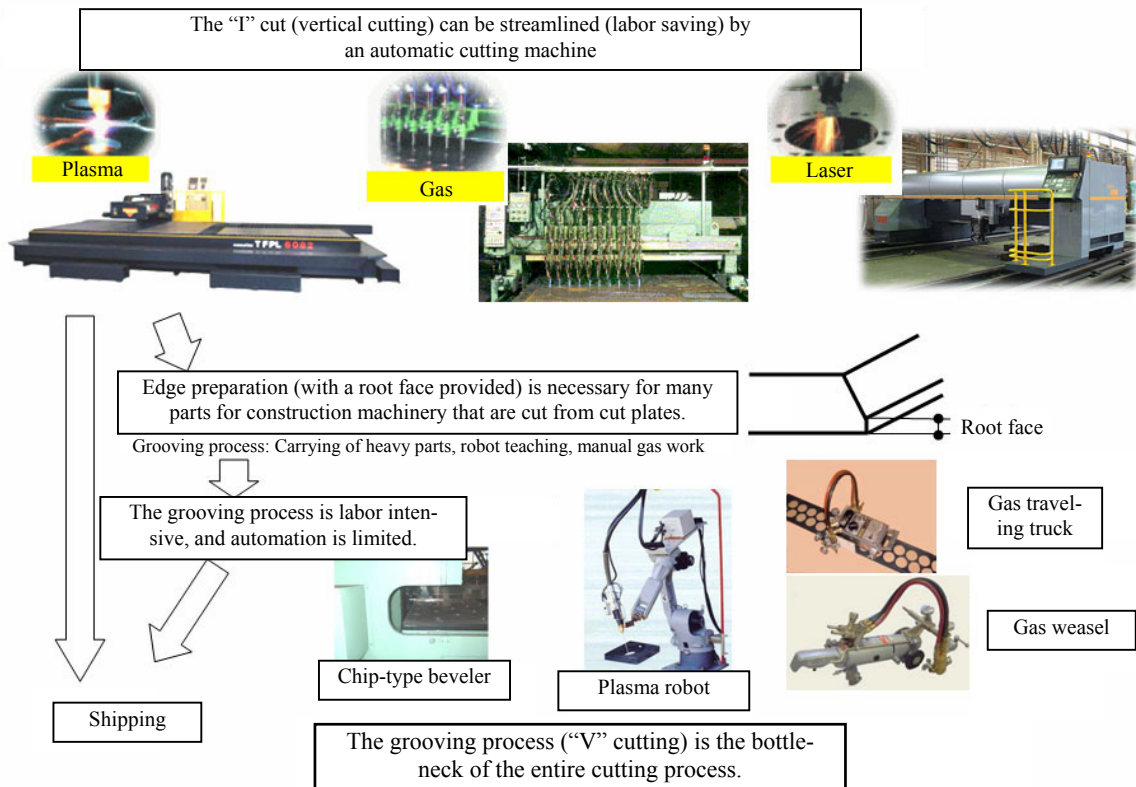


Fig. 3 Flow of edge preparation process

The process for “I” cutting has been streamlined through automation and productivity enhancement by the NC cutting machine including the Twister machine and by laser and gas cutting. However, when it comes to “V” cutting to cut welded grooves, few alternatives are available: the chip-type beveler for straight “V” cutting; gas cutting by the teaching playback method using a robot when the plate thickness becomes thick or curves have to be machined; or semi-automatic or manual gas cutting by the operator using a traveling truck or jig.

Compared with the process involving only simple “I” cutting, automation of the “V” cutting process needed for edge preparation is lagging behind in automation and is a labor-intensive process. Parts for large construction machinery especially are several hundred kg to about one ton in weight even after “I” cutting. They require a large volume of man-hours and attendance during “V” cutting, which is another process sometimes causing much trouble in the entire cutting process.

The Twister machine not only performs “I” cutting efficiently, but also performs “V” cutting, which is a bottleneck process, simultaneously during “I” cutting, aiming at streamlining the cutting process including the welded grooving process. Its nick name, the “√ twister machine,” has been taken from “√” in root face, meaning that “Y” edge preparation can be accomplished.

3. Principal Features

3.1 High-rigidity groove mechanism of simultaneous 5-axis control

The √ twister machine TFPV is a twister machine of simultaneous 5-axis control that adds a torch turning axis (Axis C) and torch tilting axis (Axis B) for “V” cutting to the conventional TFPL machine with 3-axis control (X, Y, and Z axes) for “I” cutting.

To meet the increase in the number of control axes, the TFPV adopts CNC (computerized numerical controller, type 310i series, manufactured by FANUC) with personal computer functions that perform high-speed multi-axis control. The rigidity of the twister machine body is greatly enhanced to ensure high accuracy of the root faces of welded grooves.

3.2 Position misalignment correction function by CCD camera

V grooves (without root faces) are widely used as the shapes of welded grooves in the groove welding of ships. “Y” grooves with a root face on butted surfaces are generally used with welded structures in other industries including the construction machinery industry. As illustrated in Fig. 5, 2-pass cutting (twice cutting) in two steps is necessary for “Y” grooves: a root face cutting step, and a step to cut the groove surfaces.

In 2-pass cutting, position misalignment of products occurs in cut widths after 1-pass cutting for “I” cutting so that the needed root face accuracy cannot be obtained even if 2-pass cutting for “V” cutting is accomplished correctly according to the program. For this reason, plasma arc cutting

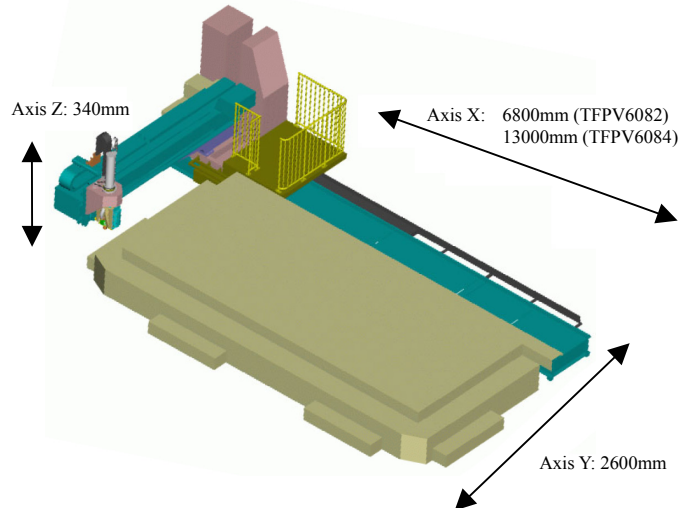


Fig. 4a Full view and strokes of TFPV

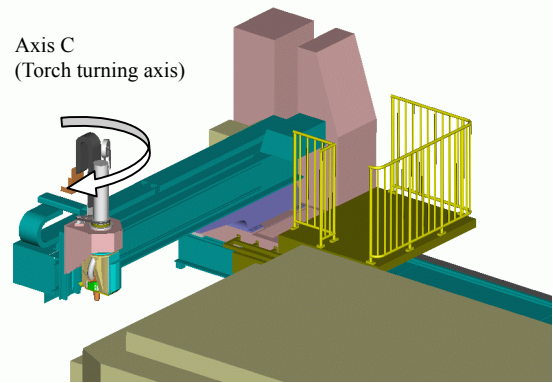


Fig. 4b C Axis (torch turning axis) of TFPV

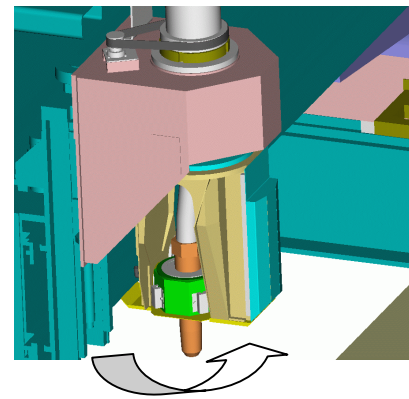


Fig. 4c B Axis (torch tilting axis) of TFPV

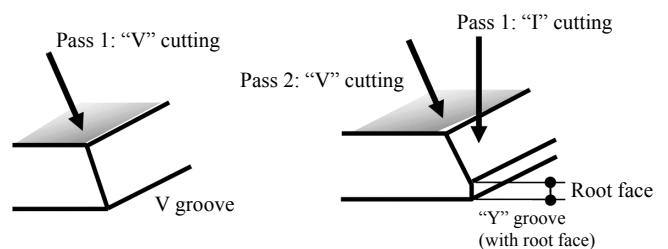


Fig. 5 Types of grooves (V groove and “Y” groove)

machines and laser machines for edge preparation equipped with a torch tilting mechanism have been used. These machines are, however, for cutting of V grooves only in 1-pass cutting, which causes no position misalignment, and they have been limited for use in the shipbuilding industry. Other manufacturers have not put automatic cutting machines that can machine “Y” grooves on the market at a high-volume production level.

The $\sqrt{}$ twister machine TFPV incorporates a system for machining welded grooves by cutting in two passes with high accuracy, to detect position misalignment by a CCD camera located near the torch for automatic correction by a 2-pass cutting program after 1-pass cutting. (Patents are being applied for.)

As shown in Fig. 6, a CCD camera is installed above the plasma torch. The CCD camera photographs two product edge points as shown in Fig. 7b after 1-pass cutting (Fig. 7a). The two edge points to be photographed are designated in advance by the program. The machine automatically moves to the photographing points and photographs after performing cutting in Pass 1 (Fig. 8a). The photographed images are translated into binary values (Fig. 8b), and edge points are extracted by image processing. Position misalignment can be calculated by comparing a position without position misalignment and the actual edge point position. After calculations, the program for 2-pass cutting will be modified according to the position misalignment quantity to perform 2-pass cutting accurately (Fig. 7b). A series of these operations is performed entirely automatically. The processing time until photographing, edge point extraction, and 2-pass cutting after 1-pass cutting is less than 10 second.

Thanks to this position misalignment detection function, the TFPV can now machine “Y” grooves, which cannot be machined by plasma arc or laser beam cutting machines for edge preparation, in addition to the machining of V grooves. This will make a great contribution to streamlining of the edge preparation process.

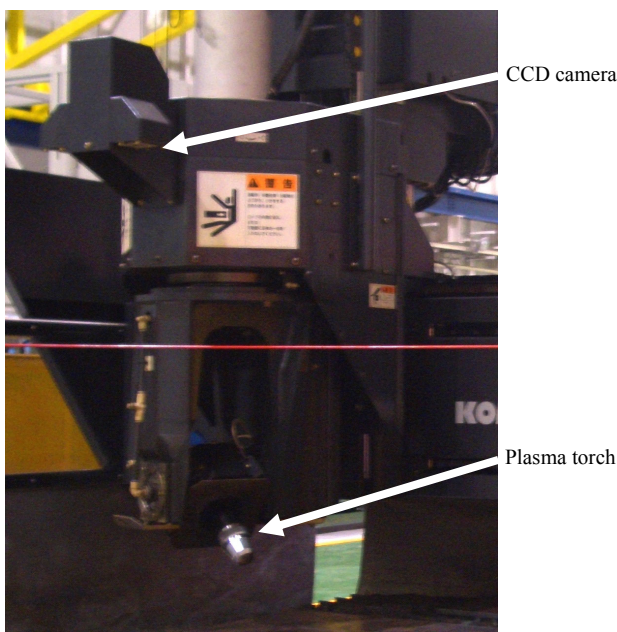


Fig. 6 CCD camera installed above torch

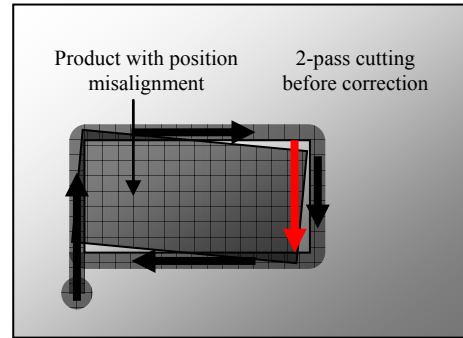


Fig. 7a Product with position misalignment after Pass 1

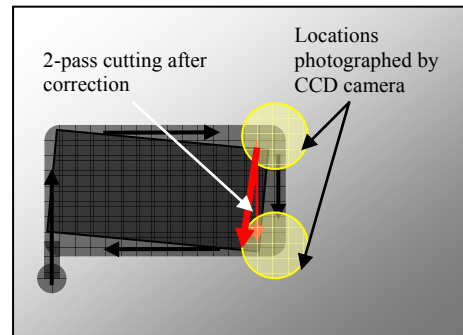


Fig. 7b Detection of position misalignment by CCD camera

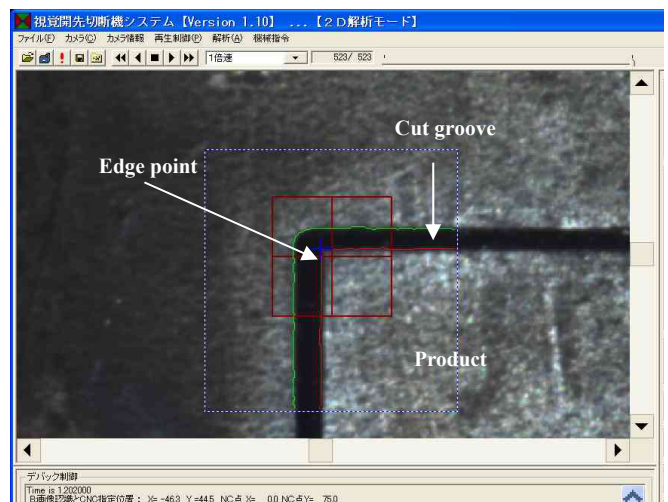


Fig. 8a Image photographed by CCD camera

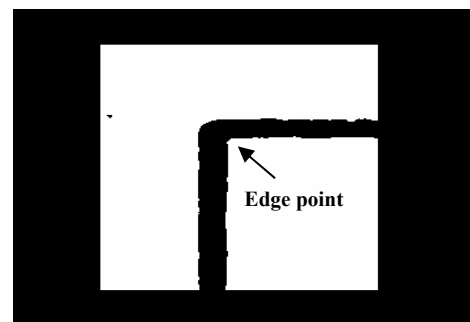


Fig. 8b Binary photograph image

3.3 Basic specification of TFPV and machinable groove shapes

The principle specification of the TFPV is presented in Table 1. The maximum plate thickness that can be cut by the TFPV in one cutting is 36 mm. In “V” cutting, grooves of less than 36 mm in cutting distance can be machined. In 35° total groove, grooves can be cut on plate thicknesses of up to 28 mm. In 45° total groove, grooves can be cut on plate thicknesses of up to 25 mm.

Table 1 Principal specification of TFPV

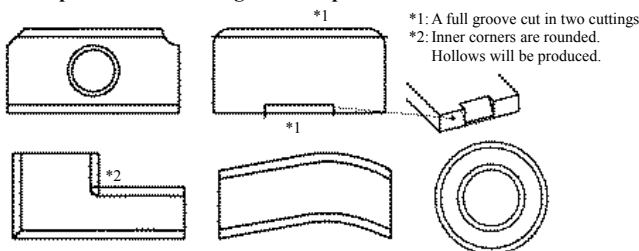
Item	TFPV6082 <6084>
Maximum cutting plate thickness (SS400)	Vertical cutting plate thickness: 36 mm 35° groove: 28 mm 45° groove: 25 mm
Maximum machinable groove angle	45°
Maximum machinable size	2500 x 6200 mm <2500 x 12400>
Rapid feed speed	X axis: 30 m/min Y axis: 50 m/min Z axis: 40 m/min C axis: 60 rpm B axis: 30 rpm
Twister machine power source	60kW
Controller (NC)	FANUC 310i
Cutting speed	22t: 2000mm/min (Example in vertical cutting)
Dust collecting system	Damper change + Push-pull dust collecting system
Crash prevention system	Front and rear of “Y” frame: Supplied as standard provision
Stainless steel cutting	Option

Figures 9a and 9b show the shapes of machinable grooves. At present, grooves of some shapes cannot be machined. The CNC software will be improved in the future to gradually increase the range of machinable groove shapes.



Fig. 9a Groove shapes that can be machined by the TFPV

Examples of machinable groove shapes



Examples of groove shapes that cannot be machined

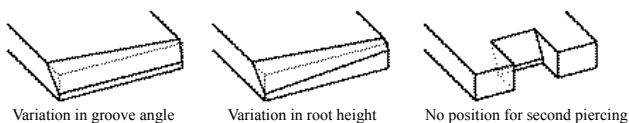


Fig. 9b Groove shapes that can be machined by the TFPV

Figures 10 show photos of samples whose grooves were machined by the TFPV. In the accuracy of the grooves machined by the TFPV, the root height varied by ±1 mm, while the angle varied between 0 and +4°, meeting the quality requirements for welded grooves.

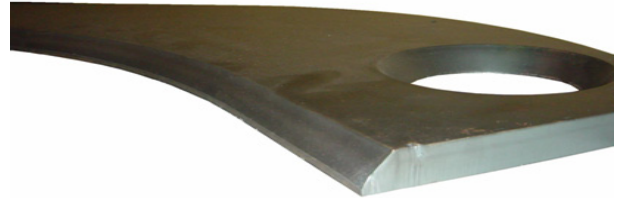


Fig. 10a Sample of machined groove
Plate thickness 25 mm, groove angle 35°, root height 3 mm



Fig. 10b Sample of machined groove
Plate thickness 19 mm, groove angle 35°, root height 5 mm.

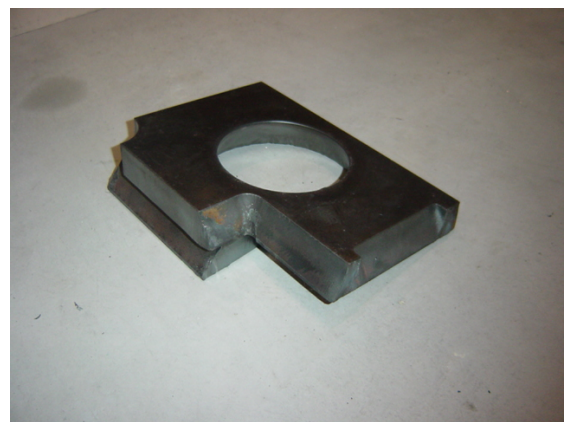


Fig. 10c Sample of machined groove
Plate thickness 19 mm, groove angle 35°, root height 5 mm

3.4 Advantages in streamlining of edge preparation process by TFPV

Figure 11 schematically explains the advantages that can be achieved by streamlining the edge preparation process employing the TFPV. The cost of the conventional method of “I” cutting (vertical cutting) by automatic plasma arc cutting and “V” cutting (edge preparation) by gas cutting in the edge preparation process will be the total cost of the following. Material cost, machining cost for “I” cutting, cost to move cut parts from the automatic cutting machine station to the station for “V” gas cutting by a jig after “I” cutting, and machining cost for “V” cutting. The machining cost con-

sists of the running cost of the cutting machines, operator wages, depreciation of the cutting machines, and other costs.

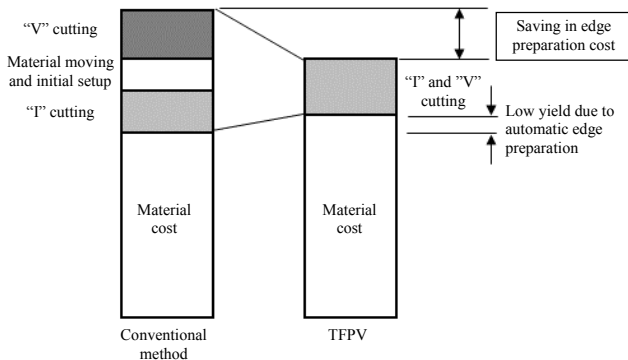


Fig. 11 Advantages achieved by streamlining of edge preparation process by TFPV

On the other hand, edge preparation by the TFPV saves material moving cost through simultaneous “I” and “V” cutting. The TFPV performs “V” cutting faster at lower cost than the conventional gas cutting method, enabling a drastic reduction in the edge preparation cost in total. Nevertheless, the TFPV simultaneously performs “I” and “V” cutting so that loop processing will sometimes be required for a change in the torch attitude depending on the groove shape, slightly lowering the material yield. Cost improvement effects will be affected by the part shape and plate thickness, but will be larger with large parts and with thick steel plates that require much labor in moving. Thus viewed, the cost improvement effects by the TFPV will be greater in the edge preparation of large construction machineries.

4. Conclusion

Full-scale market entry of the $\sqrt{\text{twister}}$ machine TFPV has just started. Automation and streamlining of edge preparation that requires much labor is desired in the construction, shipbuilding, and other industries. As mentioned above, the $\sqrt{\text{twister}}$ machine TFPV cannot machine some shapes of grooves even though the plates are of a cuttable plate thickness. A future challenge is to increase the types of grooves that can be machined by modifying the CAD and CAM system that creates the cutting program.

The substantial cutting plate thickness will increase in “V” cutting of grooves, and the upper limit of plate thickness is 25 mm with 45° V grooves at present. The plasma output has to be increased to widen the machinable plate thickness range. In cooperation with the Corporate Research Division, Komatsu Industries Corp. will develop a large-capacity twister machine that can machine thicker plate thicknesses. Activities will be continued in the future to foster the $\sqrt{\text{twister}}$ Machine as a powerful tool for streamlining of edge preparation streamlining by further modifying the $\sqrt{\text{twister}}$ machine TFPV.

Introduction of the writer



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[A few words from the writers]

Conventional $\sqrt{\text{twister}}$ machines TFPL for “I” cutting are working at Komatsu as tools for streamlining the cutting process of construction machinery parts even at present. Having devoted his energy to the research of rock thermal crushing as an application of construction machines, the author as the developer of the twister machine will be more than happy if the newly developed $\sqrt{\text{twister}}$ machine TFPV makes even a small contribution to streamlining the edge preparation process.