Fully Machined True Circle Elbow

Masamitsu KIHARA*

*Shimoda Iron Works Co., Ltd.

Abstract

Shimoda Iron works Co., Ltd. has developed a manufacturing procedure for fully machined elbows. Since all the surfaces of the elbow are finished by machining they have high geometric and dimensional accuracy. The fully machined elbow has a true circle section. Moreover this procedure makes it possible to manufacture special elbows, such as, thin wall elbows, thick wall elbows and bifurcated elbows.

1. Introduction

Existing elbows are generally manufactured by bending pipes or welding plates. Their sections usually deviate from true circle and their thickness distributions are not uniform. Such elbows are not able to satisfy the strict requirements for severe applications, such as, high temperature and high stress condition or aerospace usage. On contrast, if it is possible to manufacture an elbow by machining all the surfaces it has high geometric and dimensional accuracy. Moreover the fully machining process makes it possible to manufacture new type elbows which can not be manufactured through existing procedures.

Shimoda Iron Works Co., Ltd. has succeeded in this new process due to developments of special cutting tools, supporting jigs and 3D controlling programs. In this paper several investigation results on the dimensional accuracy of the fully machined elbows are reported.

2. Machining procedure

The fully machined elbow is manufactured by machining the forged solid blank. The schematic diagram of the machining procedure is shown in **Figure 1**. A specially designed cutting tool, "side cutter", is controlled to cut along an elliptical shape at each section (as shown in blue and green in the figure). When a section includes the center of the elbow the orbit of the tool is a true circle (red in the figure)[1].

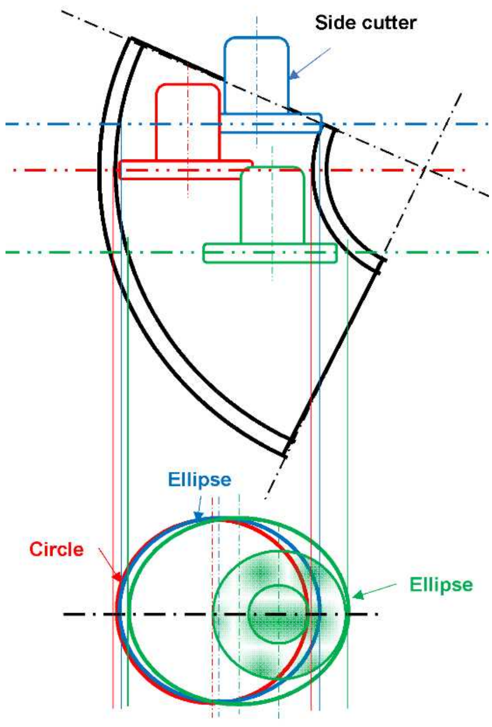


Figure 1 Concept of machining procedure

3. New type elbows

Thanks to the fully machining procedure, the following new elbows can be manufactured.

1) An elbow having the true circle section and the true arc bending curve. (True circle elbow)
2) An elbow having the true circle section but the center of the inside circle is eccentric to the center of the outside circle. This elbow has increased wall thickness at outside. It can give the elbow a longer life against erosion especially when the fluid is including solid materials like sludge. (Eccentric circle elbow: see **Figure 2**)
3) An elbow having very thin wall which can not be manufactured through the existing procedures. (Thin wall elbow: see **Figure 3 a**))
4) An elbow having very thick wall which can not be manufactured through the existing procedures. (Thick wall elbow: see **Figure 3 b**))
5) An elbow made of a special material which is difficult to bend or weld, such as, stainless steel or super alloy.
6) An elbow having a complicated shape which consists of a few parts. When manufacturing through the existing process it is necessary to assemble some pieces to complete the elbow. (Bifurcated elbow: see **Figure 3 c**), solid elbow with flange: see **Figure 3 d**))

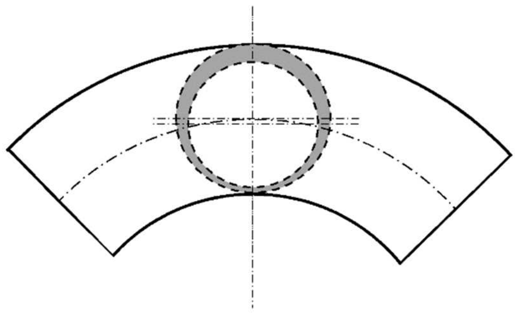


Figure 2 Eccentric circle elbow

a) Thin wall elbow
(Ti-6Al-4V)

b) Large dia. thick wall elbow
(9%Cr steel)

c) Bifurcated elbow
(Al A5083)

d) Solid elbow with flange (Al A5083)

Figure 3 Various fully machined elbows

4. Investigation results on dimensional accuracy

4.1 Sampled elbows

The fully machined true circle elbows made of three materials were manufactured and several measurements were made in order to evaluate their dimensional accuracy. The materials are stainless steel F316L, Titanium and Inconel 718. Their geometries and dimensions are all same. The outside diameter is ϕ128.7mm, the wall thickness is 0.8mm and the bending angle is 90 degrees. As an example of overview of the elbow, F316L elbow is shown in **Figure 4**.
For the purpose of comparison, existing elbows made of mild steel are prepared by pipe bending procedure. The outside diameter is ϕ84mm and the wall thickness is 4mm. **Figure 5** shows the existing elbows.

Figure 4 Fully machined elbow

Figure 5 Existing elbows

4.2 Machinability of three materials

There was no difficulty to finish F316L and Titanium elbows. In the case of Inconel 718 elbow, the amount of cooling water was to be increased because the cutting tool temperature became higher than other two materials. However it can be concluded that there is no serious problem to finish these three materials.

4.3 Roundness measurements

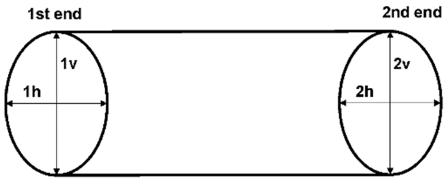
The diameters at each end were measured in both directions of vertical and horizontal. The results of three fully machined elbows and an existing elbow are shown in **Table 1**
In the case of the existing elbow, the ratios of variation divided by nominal diameter are around 2-3%. On contrast, in the case of the fully machined elbows the ratios are approximately 0.2-0.5% which are much more accurate than the existing.

4.4 Thickness uniformity

In the case of the existing elbow, thickness at outside is obviously thinner than inside as shown in **Figure 6**. Thickness measurements were carried out at the points shown in **Figure 7**. The results are shown in **Figure 8** and the summary is shown in **Table 2.**
As shown in Table 2, the variation of the existing elbow is approximately 2.5mm however in the case of the fully machined elbows the variations are less than 0.2mm. Moreover no difference of accuracy is found between three materials.

Figure 6 Longitudinal section of the existing elbow

Table 1 Roundness measurements



Process	Material	O.D (mm)							I.D (mm)						
		Nom.	1st end		2nd end		Variation		Nom.	1st end		2nd end		Variation	
			1v	1h	2v	2h	mm	%		1v	1h	2v	2h	mm	%
Fully machined	SUS316L	128.7	128.67	128.74	128.74	128.95	0.28	0.22%	127.1	127.20	127.10	127.15	127.23	0.13	0.10%
	Ti		128.56	129.19	128.85	129.08	0.63	0.49%		126.93	127.56	127.22	127.45	0.63	0.50%
	Inconel718		128.77	129.40	128.92	129.09	0.63	0.49%		126.97	127.53	127.11	127.33	0.56	0.44%
Pipe bending	Mild steel	84.0	84.83	83.80	84.02	83.30	1.53	1.82%	76.0	76.63	75.20	75.98	74.62	2.01	2.64%

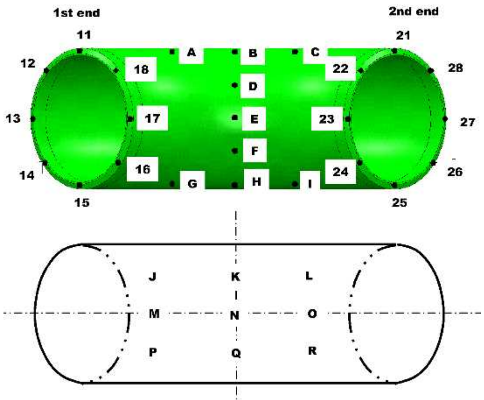


Figure 7 Thickness measuring points

Table 2 Summary of thickness measurements

Process	Material	Thickness (mm)				
		Nom.	Deviation from nominal			
			Ave.	Min.	Max.	Variation
Fully machined	SUS316L	0.8	-0.01	-0.10	0.08	**0.18**
	Ti		0.02	-0.10	0.08	**0.18**
	Inconel718		0.10	0.05	0.17	**0.12**
Pipe bending	Mild steel	4.0	0.05	-0.76	1.70	**2.46**

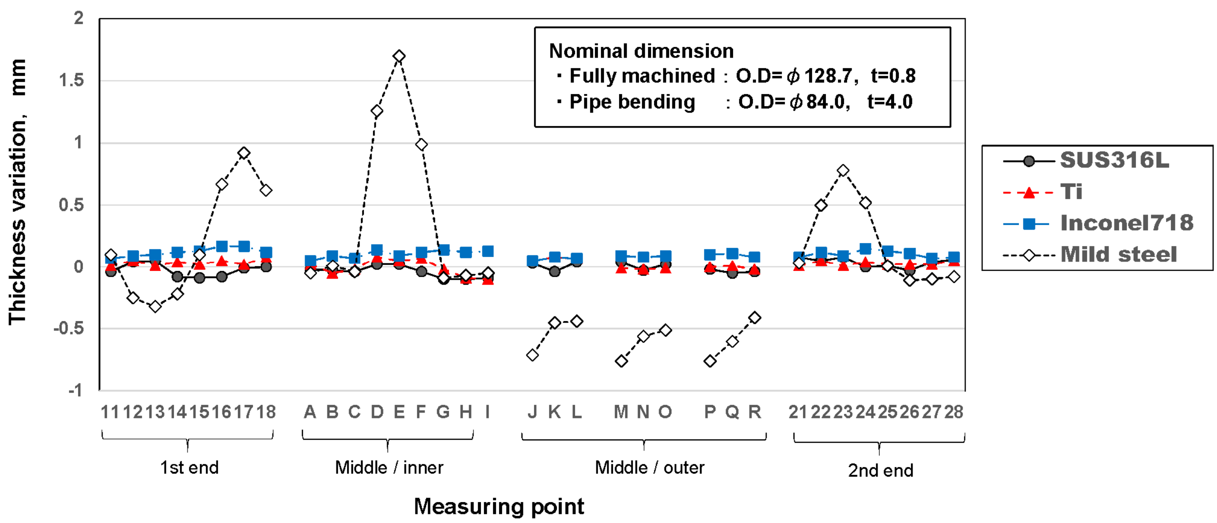


Figure 8 Thickness distribution

5. Conclusions

1) A new manufacturing process of the fully machined elbows has been developed. Its schematic procedure is machining with the side cutter which is controlled to move along ellipse shapes.
2) The thin wall fully machined elbows made of three materials were manufactured. There was no problem when machining every material.
3) The investigations on the roundness and the thickness uniformity were carried out. The results show that the fully machined elbows have much higher geometrical and dimensional accuracies than the existing elbow.

References

1) Manufacturing procedure of fully machined elbows, Japanese patent No.4491538, registered in April, 2010