Development of Ultra-Thin Wall Welded Metal Pipe and Its Applications

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ABSTRACT

Recently, there has been a year-by-year growing need for weight reduction in metal pipes aimed at cost reduction and energy saving, centering on the automotive industry. It has been difficult for the conventional welded pipe manufacturing technology to manufacture ultra-thin wall metal pipes having a thickness to diameter (t/D) ratio of not more than 1%, so that such pipes have normally been manufactured using handicraft means. On the other hand, utilizing a special forming technology of our development and our proprietary manufacturing technology, we have established a continuous, high-speed manufacturing technology for ultra-thin wall metal pipes having a t/D ratio of not more than 1%. The development of ultra-thin wall metal pipes will be described in this paper, including those for the automotive industry.

1. INTRODUCTION

The Kanagawa Plant of Kyowa Electric Wire has been developing, since it was established in 1972 as a plant specialized in corrugated metal sheath, various products such as thin-wall welded metal pipes for automotive exhaust gas and home appliance applications, as well as corrugated cables (see Table 1 and Figure 1).

In our plant, an automatic continuous manufacturing machine (see Figure 2) is employed to manufacture the thin-wall welded metal pipes from metal strips in a complete inert gas atmosphere, using special welding techniques such as tungsten inert gas (TIG) arc welding or plasma welding. This manufacturing process provides the metal pipes with flat and smooth weld beads on the inner surface as well as complete air- and water-tightness, making it possible to apply these pipes for use in corrosive atmospheres and complicated secondary machining processes.

2. FEATURES AND SPECIFICATIONS OF THIN-WALL WELDED METAL PIPES

2.1 Features

The metal pipes have a uniform wall thickness except for the weld bead portion, because strip stock is used as...
steel pipes have been employed by many automobile manufacturers as a mother material for components of automotive exhaust gas pipe systems comprising exhaust manifold, flexible tube and catalytic converter casing (see Figure 4). We succeeded in developing in-house a manufacturing machine for stainless steel mufflers in 1979, and we have delivered a sum total of approximately 10,000 tons of these products since then. In particular, manufacturing of double tubes consisting of two thin-wall metal pipes was made possible for the first time, by using this metal pipe with superior circularity and straightness to realize a small clearance between the inner and outer pipes. And the bulge processed products using this double tube as a mother material have acquired a high reputation for their heat-insulating effects together with the damping and vibration absorption effects due to flexibility.

2.2 Specifications
In response to diversified customers’ needs, a variety of products are available as shown in Table 2 and Figure 3. They are: in terms of material, stainless steel which is a multipurpose material for automobiles as well as titan, copper and aluminum; as for wall thickness, 0.1~2.0 mm; and as for pipe diameter, 5~130 mm.

3. DEVELOPMENT OF STAINLESS STEEL THIN-WALL WELDED PIPES FOR AUTOMOBILES

3.1 Development History and Track Record
Automotive exhaust gas pipes are required to be thin-walled from the standpoint of energy saving and weight reduction, and yet they have to satisfy stringent requirements such as endurance, corrosion resistance and heat resistance. Our products of thin-wall welded stainless steel pipes have been employed by many automobile manufacturers as a mother material for components of automotive exhaust gas pipe systems comprising exhaust manifold, flexible tube and catalytic converter casing (see Figure 4). We succeeded in developing in-house a manufacturing machine for stainless steel mufflers in 1979, and we have delivered a sum total of approximately 10,000 tons of these products since then. In particular, manufacturing of double tubes consisting of two thin-wall metal pipes was made possible for the first time, by using this metal pipe with superior circularity and straightness to realize a small clearance between the inner and outer pipes. And the bulge processed products using this double tube as a mother material have acquired a high reputation for their heat-insulating effects together with the damping and vibration absorption effects due to flexibility.

3.2 Advantages of Wall Thickness Reduction
Figure 5 illustrates the advantages of wall thickness reduction, taking different manufacturing processes for catalytic converter casing for example. Conventionally, bent sheet pipes were manufactured by a method such that a metal strip having the specified length for the final product is bent to form a circular tube, and the mating edge is seam welded, and in this case, the required mini-

![Figure 4 Schematic of automotive gas exhaust pipe system.](image)

![Figure 5 Manufacturing process for catalytic converter casing, comparing the conventional and developed methods.](image)
mum wall thickness is generally 1.5 mm or more. In con- 
trast, in our manufacturing process a coiled strip is formed 
into a tubular shape through our proprietary forming 
method, continuously welded, and cut into the specified 
lengths for the final product, and in this case, sufficient 
weld strength can be obtained even for a wall thickness of 
not more than 1.5 mm.

The advantages of wall thickness reduction include a 
weight reduction of 20~40 % and a cost reduction due to 
material costs of 10~20 %. Based on our proprietary 
forming method, the thin-wall metal pipes allow a free 
choice of the weld bead shapes without impairing the 
mechanical characteristics of the mother material, so that 
the pipes are suitable for severe-conditioned secondary 
processing such as bending, bulging, drawing and con-
tinuous corrugating.

4. DEVELOPMENT OF SPECIAL 
PERFORATED ALUMINUM PIPES

We have been successful in developing a pipe manufac-
turing technology using TIG welding for thin perforated 
Al-Mg-based aluminum strips, thereby releasing the 
products (see Figure 6). Since the product allows for 
customizing the hole diameter, hole number and pattern of 
the perforation, in addition to a free choice of materials 
including stainless steel, copper and copper alloys as 
well as aluminum, we are planning to expand its applica-
tions to commodities related with the housing industry, 
such as watering pipes and the like.

5. CORRUGATED CABLES AND 
APPLICATION OF THEIR 
MANUFACTURING TECHNOLOGY

5.1 Features of Corrugated Cable

Figure 7 shows the structure and the cross section of typi-
cal corrugated cables. The structure of corrugated cables 
is such that an inner cable is covered with a corrugated 
metal pipe, over which an outer sheath of PVC or polyeth-
ylene is applied as a corrosion protection layer. The fea-
tures of corrugated cable include: 1) direct underground 
embedding is allowed for, 2) provided with superior 
mechanical characteristics, together with high compres-
sion strength and high inner pressure strength, 3) provid-
ed with light weight and high bendability, permitting ease 
of laying work, 4) complete anti-ant and anti-rodsen 
effects are offered, and 5) large electromagnetic shielding 
effect is offered.

5.2 Specifications of Corrugated Cables

Table 3 shows available forms of corrugation. Depending 
on applications, corrugated pipes having spiral grooves 
are used in applications where strength is emphasized, 
while corrugated pipes having independent bellows-type 
grooves in such applications as various piping where flex-
ibility is of much importance. Moreover, partially corrugat-
ed pipes combining straight sections and corrugated sec-
tions can also be manufactured.

In terms of material and wall thickness, various custom-
ized specifications are available as shown in Table 4, and

![Figure 6 Perforated aluminum pipe.](image1)

![Figure 7 Structure of typical corrugated cable.](image2)

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Available corrugation forms.</th>
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<td>Form of corrugation</td>
<td>Spiral corrugation</td>
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<td></td>
<td>Bellows-type corrugation</td>
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<td></td>
<td>Partial corrugation</td>
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<th>Table 4</th>
<th>Standard specifications of corrugated pipes.</th>
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<tr>
<td>Material</td>
<td>Wall thickness (mm)</td>
</tr>
<tr>
<td>Steel</td>
<td>0.3~0.6</td>
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<tr>
<td>Stainless steel</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>0.5~1.5</td>
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<td>Aluminum</td>
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with respect to the depth of corrugations that constitutes an important factor for determining the bendability and mechanical strength, the deep groove-type corrugation (corrugation height/pitch > 0.25) is also available besides the standard-type corrugation (corrugation height/pitch ≤ 0.25).

5.3 Company’s Share in the Corrugated Cable Market
As of March 2007, we have produced 30,000 km of corrugated cables since the start of production in 1972, equivalent to three quarters of the circumference of the earth. Such being the case, thanks to the long-cultivated technology for corrugated cables, our performance is highly appreciated in terms of quality, delivery time and cost effectiveness, and we enjoy the highest domestic market share of corrugated cable production (i.e., as of January 2007, according to our study). We are developing new technology innovations targeted at achieving a 100% share in manufacturing corrugated cable sheathing domestically.

6. APPLICATION DEVELOPMENT OF CORRUGATION TECHNOLOGY
6.1 Application to Automotive Fields
Figure 8 shows the schematics of the current and developed manufacturing processes for partially corrugated pipes, which are used as flexible tube and EGR piping in automotive exhaust gas piping. In the current manufacturing process, mother material is made into a pipe, cut to a standard length, and bulging in applied, in a separate process using an inner pressure, to the corrugation portion to swell the pipe outside. This method results in two separate manufacturing processes, leading to a high process cost. In contrast, the corrugating technique is applied to manufacture the developed product, where the corrugation portion is formed by mechanically grooving the raw pipe from the outside. This method allows for corrugating in-line with the pipe making process, resulting in a significant processing costs reduction. The number of spiral corrugations can be changed as desired, and production lengths up to 2000 m are possible. Moreover, aluminum corrugated cables, which use aluminum of high shielding effect and light weight are drawing attention as protection piping for harness cables used in hybrid cars, where high-voltage power transmission is needed, whereby it is expected that the cables are particularly effective not only for their shielding effect but also for their resistance against external damage and corrosion.

6.2 Application to Heatpipe Technology
Recently, heatpipe technology is drawing attention, from the standpoint of environmental issues and energy conservation, since heatpipes allow for maintenance-free operation without using driving power. Figure 9 illustrates the operating principle of heatpipe, which is a thermal device taking advantage of the latent heat of a liquid at
the time of evaporation and condensation. When one end (high-temperature end) of a heatpipe containing a working fluid is heated, the working fluid vaporizes absorbing heat. The vaporized working fluid diffuses in the pipe to reach the other end (low-temperature end) to condense emitting latent heat there. In this way, heat is efficiently transferred from the high-temperature end to the low-temperature end.

At present heatpipes are extensively used in such applications as snow melting system using geothermal heat, temperature control in spacecraft, heat dissipation in electrical equipment, and home appliances. Because our corrugated pipes of stainless steel and copper possess, taking advantage of the manufacturing process in a completely inert gas environment in addition to continuous long-length welding, perfect air- and water-tightness as well as flexibility that make the pipes suitable for long-distance piping, it is expected that the pipes find wide applications in the next-generation heatpipe systems.

7. CONCLUSION

In response to the weight reduction requirements including those from the automotive industry, we have developed the manufacturing technology for ultra-thin wall welded metal pipes that can endure, in spite of their reduced thickness, in severe secondary processes and application environments. By combining it with corrugation technology, the pipe manufacturing technology allows for making proposals for, and manufacturing of, next-generation commodities that can cope with environmental issues and energy conservation.

REFERENCES