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).

Table 1 Main product items.

Corrugated cable for power use	Stainless steel pipe for automotive exhaust gas
Corrugated cable for communications use	Magnet cover for motors in home appliances
Stainless steel corrugated cable	Corrugated metal tube (flexible tube)
Aluminum corrugated cable	Various special pipes (perforated pipe, deformed pipe)

Figure 1 Thin-wall metal pipe products.

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In out 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

Figure 2 Automatic continuous manufacturing machine for thin-wall metal pipes.

their mother material. While the weld bead portion achieves the equivalent mechanical strength as for the mother material, the strength and shape of the weld beads can be controlled in accordance with the intended use. The integrity of the pipes that has been achieved is such that its circularity, one of the measures representing the pipe precision, is ±0.3 mm or better; the straightness is 1 mm/m or better; and the pipe ends are cut using a clear-cut technique with circumferential uniformity, realizing a burr- and dust-less cut ends. Moreover, special products and processing are available including flaring work for the pipe ends and piercing work for the double pipes, in addition to manufacturing deformed pipes such as thin-wall rectangular pipes and semi-circular pipes, which were difficult to manufacture conventionally.

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-

Table 2 Specifications for standard thin-wall metal pipes.

Material	Wall thickness (mm)	Outer diameter (mm)	Length (m)
Titan	0.1~2.0	5~130	0.01~6.0
Stainless steel			
Copper			
Aluminum			

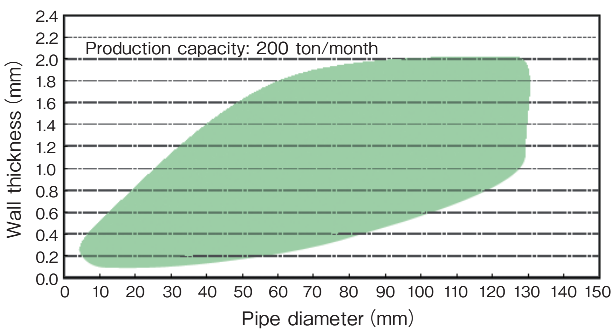


Figure 3 Manufacturable range by wall thickness and pipe diameter.

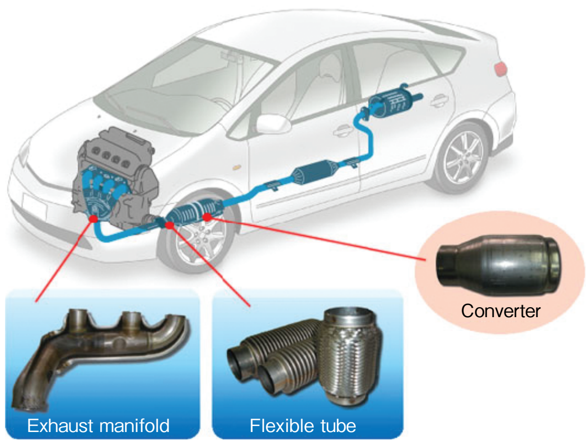


Figure 4 Schematic of automotive gas exhaust pipe system.

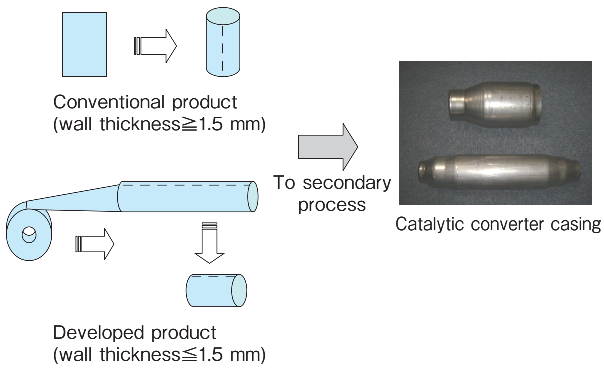


Figure 5 Manufacturing process for catalytic converter casing, comparing the conventional and developed methods.

mum wall thickness is generally 1.5 mm or more. In contrast, 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 continuous corrugating.

4. DEVELOPMENT OF SPECIAL PERFORATED ALUMINUM PIPES

We have been successful in developing a pipe manufacturing 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 applications to commodities related with the housing industry, such as watering pipes and the like.

Figure 6 Perforated aluminum pipe.

5. CORRUGATED CABLES AND APPLICATION OF THEIR MANUFACTURING TECHNOLOGY

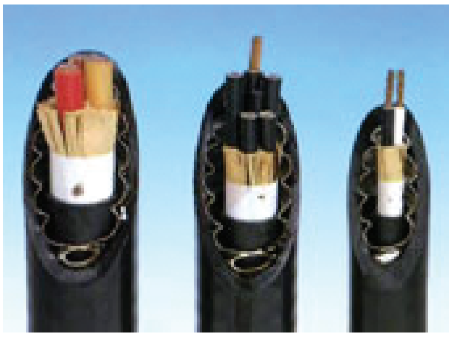
5.1 Features of Corrugated Cable

Figure 7 shows the structure and the cross section of typical 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 polyethylene is applied as a corrosion protection layer. The features of corrugated cable include: 1) direct underground embedding is allowed for, 2) provided with superior mechanical characteristics, together with high compression strength and high inner pressure strength, 3) provided with light weight and high bendability, permitting ease of laying work, 4) complete anti-ant and anti-rodent 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 flexibility is of much importance. Moreover, partially corrugated pipes combining straight sections and corrugated sections can also be manufactured.

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



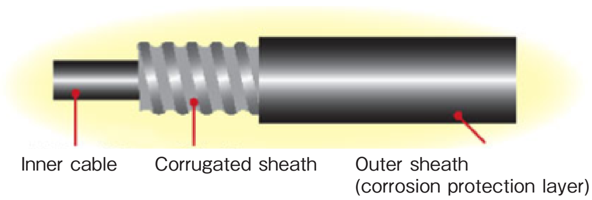


Figure 7 Structure of typical corrugated cable.

Table 3 Available corrugation forms.

Form of corrugation	Spiral corrugation
	Bellows-type corrugation
	Partial corrugation

Table 4 Standard specifications of corrugated pipes.

Material	Wall thickness (mm)	Inner diameter (mm)	Outer diameter (mm)
Steel	0.3~0.6	10.0~47.4	13.5~53.0
Stainless steel			
Copper			
Aluminum	0.5~1.5	10.0~37.4	14.7~42.9

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

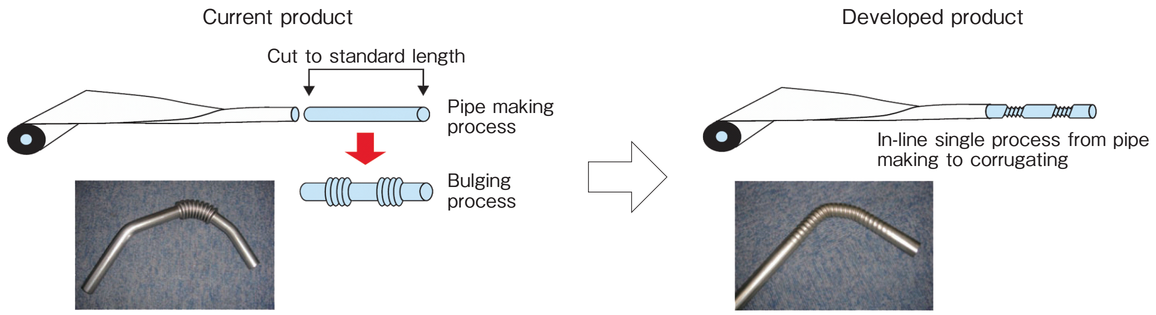


Figure 8 Comparison of manufacturing processes of partially corrugated pipes for the current and developed products.

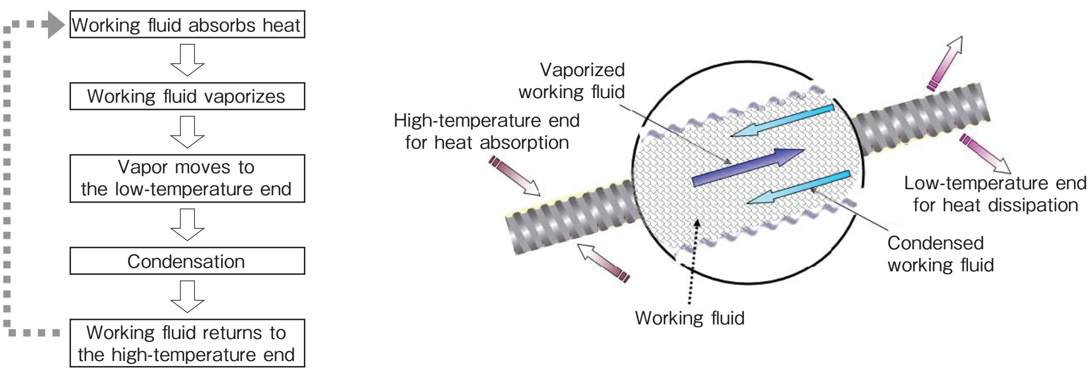


Figure 9 Operating principle of heatpipe.

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.

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