UNHARDENING CENTRIFUGAL FORMING OF BEND PIPE

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ABSTRACT

We present here a method of forming FRPM bend pipe as an application of centrifugal forming pipe, which is based on the secondary treatment of forming bend pipe from straight pipe. Examining from various view points, we have developed an unhardened pregel bend pipe forming method.

KEY WORDS: Bend pipe, FRPM, Unhardened forming, Pregel

1. INTRODUCTION

FRPM (glass Fiber Reinforced Plastic resin Mortar) pipe has been developed with an aim to increase the rigidity and to reduce the cost of FRP by mixing sand in the glass fiber reinforced plastic. Applications are for water supply and drainage, agricultural electric wire cable, and other buried-in pipes. The forming methods of straight FRP pipes are the filament winding (FW) method to wind the resin-contained robing and sand on the mandrel from the outer surface of the mandrel, the continuous forming method to form the filament winding continuously on the mandrel [1, 2], and the casting forming method utilizing centrifugal force (**CW**; Centrifugal Winding) [3, 4]. However, in the FRPM bent pipe forming method, there have been no other effective methods than the FW-applied forming method with the bent type mandrel, there existed problems of mass-productivity and equality as compared with the straight pipe forming. Because of this reason, development of the forming technology for high quality and low cost bent pipe production has been looked for. With this background, the authors have been developing the technology already for over a dozen years.

In this paper, the authors report the results of technical development on the unhardened bent pipe forming method in which firstly the straight pipe is formed by the centrifugal forming method and then the bent pipe is formed by the secondary processing. Features of this method are better quality and productivity than the bent pipes by conventional methods.

2. VARIOUS BENT PIPE FORMING METHODS BY CW

By the centrifugal forming method (CW), it is impossible to form other pipes than the symmetrical-to-axis cylindrical bodies (straight pipes and pipes with joints). Therefore, the bent pipe forming method utilizing the centrifugal forming method is to form the straight pipe in the unhardened state, and process the straight pipe having plasticity after removal from the mould into the bent pipe, and harden it. There are following three methods in this bent pipe forming.

2.1 Pregel bent pipe forming method

As shown in Fig.1, in the pregel bent pipe forming method, the straight pipe, centrifugally formed in the state of pregel (semi-hardened) where the shape is kept but still can be bent, is removed from the mould and plastically bent by heating or at normal temperature, and hardened at a high temperature. As the pregel method, there are (1) method to use metal bridging, (2) method to use chelate combination, and (3) the method to use partial bridging, etc, are available as shown in Table 1. The state of pregel can be kept by these methods.

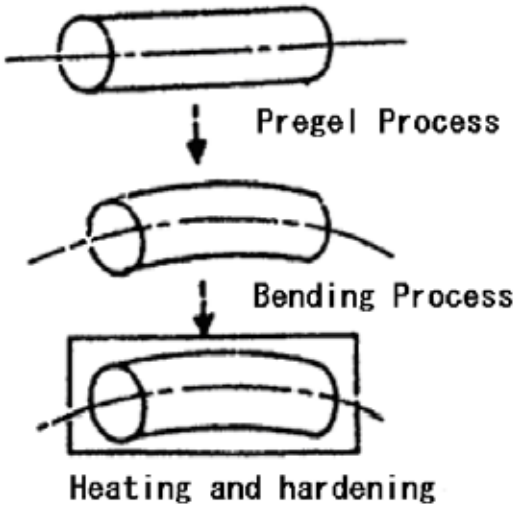


Fig.1: Pregel bent pipe forming method.

Table 1 Features of Pregal Bent Pipe Forming Method

Name	Outline	Pregel time	State of Pregel	Straight pipe forming method	Remarks
Metal bridging method	Carboxyl group Ion coupling	4～	Clay-like, not pasty	Film sandwich forming	Practical application
Chelate coupling method	Chelate coupling of ammonium salt, mercaptan and metal soap	1～	ditto	ditto	Only few application examples
Partial bridging method	Partial hardening with high temperature oriented catalyst, accelerating agent and inhibitor	0.05～	Semi-hardened, slightly pasty	Oridinary forming	Some application examples in electrical field

2.2 Unhardened bent pipe forming method

As shown in Fig.2 in the unhardened forming method, the film tube is inserted to the inside of centrifugally formed pipe to maintain the pipe shape by the inner pressure of the inserted tube; after removing the mould, the pipe is bent and hardened. Therefore, there are three methods for unhardened forming as shown in Table 2. From Table 2 it is clear that the method to sandwich the unhardened layers with film such fluid substances as paraffin. etc. and fix by cooling, the method to keep the shape by sandwiching with mechanical spring bag, etc. are available to maintain the pipe form.

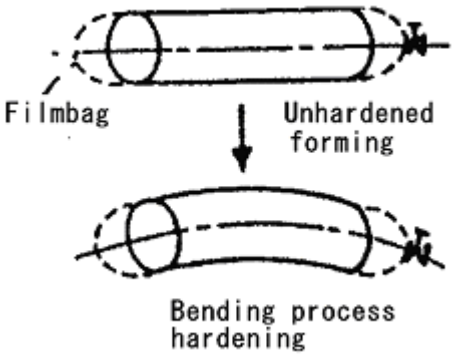


Fig.2: Unhardened bent pipe forming method.

Table 2 Features of unhardened Bent Pipe Forming Method

Name	Outline	Workability	Product	Remarks
Film sandwiching method	Make sandwich of unhardened product with film on both inner and outer surface and maintain shape by adding pressure	Amount of deformation by processing····Large Shape-maintaining force·····Small	Smooth surface	Many application examples in conventional vacuum bag forming
Paraffin sandwiching method	Maintain shape by pouring paraffin on both inner and outer surface or inner surface only	ditto·····Small ditto·····Small	Uneven surface on the inner surface	No practical example Many unstable elements
Spring backing method	Maintain shape by applying coil springs to the inside	ditto·····Small ditto·····Small	High accuracy in roundness degree	Practical examples in centrifugal forming of tapered hole

2.3 Unhardened prepleg forming method

As shown in Fig.3, the forming method to combine the unhardened forming method and the pregel forming is called the unhardened prepleg forming method. In this method, the pipe is formed in the unhardened stage and kept in the form of pipe with film, etc., then prepleged. Later the pipe is bent and hardened by heating. Two methods shown in Table 3 are considered for this method. Now the authors like to carry on fundamental experiment on the representative unhardened pregel forming method.

Table 3 Features of Unhardened Prepleg Forming

Name	Outline	Workability	Product	Remarks
Unhardened prepleg method	Metal bridging pregelation and pregel forming after unhardened forming	Amount of deformation by processing···Large Shape-maintaining force·····Large	Can be stored for a long period as an interim product	No example
Outer & inner layers pregel method	Pregelative the inner and outer layers to each a degree that the shape can be maintained in the unhardened state	ditto·····Large ditto·····Large	Such auxiliary materials as film etc. not needed	No example

3. UNHARDENED PREGEL BENT PIPE FORMING EXPERIMENT

3.1 Fundamental experiment on pregel

For the pregel bent pipe forming method, experiment is made on the partial bridging method which is considered to be the most practical. "Pregel" in the partial bridging method means to harden the resin and catalyst (which harden by heating) in the state of jelly by cooling in the state of incomplete hardening. Therefore, the catalyst giving long stability in the state of pregel in the centrifugal forming region such as Park-Mill P and Par-hexa 3M from the hardening catalyst conditions were selected.

Since the minimum bent radius of general bending ratio of FRPM bent pipe is considered as 5m, the plasticity elongation

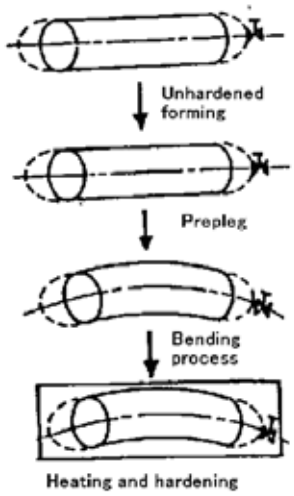


Fig.3: Unhardened prepleg forming method.

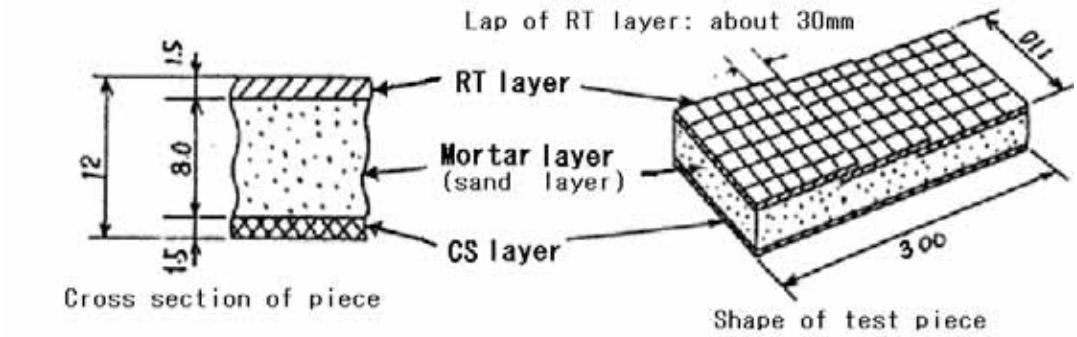


Fig.4 Fundamental experiment of layer material

degree necessary for formation of si
"elongation degree") can be said as
tolerable elongation degree of the
pregel is obtain as Fig.5.

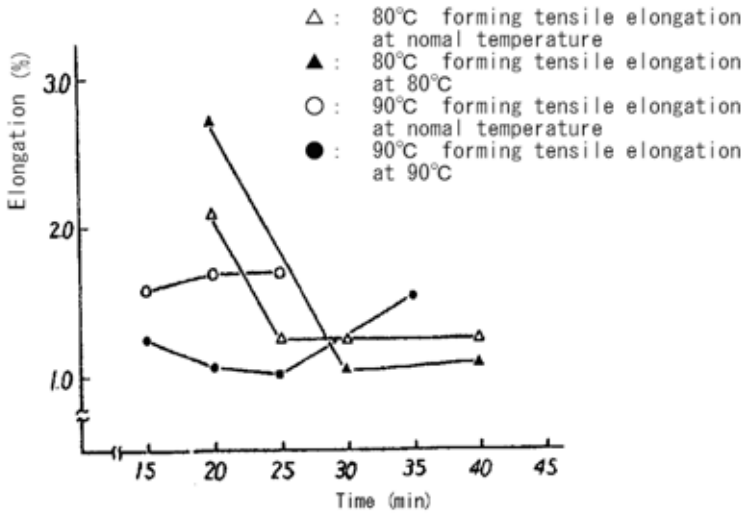


Fig.5 Pregel elongation

Though the ordinary elongation rate of pregel test piece was maximum 2.5 %, by adding about 3kPa press along the thickness direction it became 6.67 %. Thus, it was suggested that the forming bend pipe from straight pipe is possible.

3.2 Unhardened prepleg forming experiment

"Unhardened prepleg bend pipe forming method" is a combination of unhardened forming method and pregel forming method. This method is such that after keeping the shape of unhardened pipe with film etc. make it preplegnize, and then treat it bended and hardened with heating as shown in Fig.3.

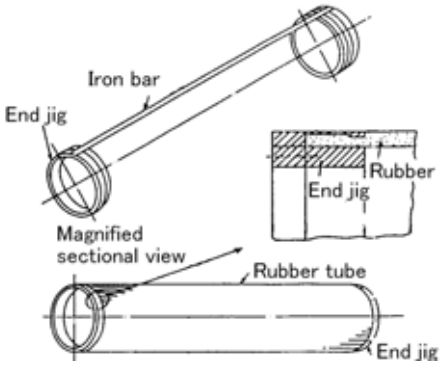


Fig.6: rubber mould.

We found that rubber tube is fitted as the outer film (Fig.6) and film pushing-in method by air pressure is fitted as the inner film (Fig.7). The iron bar in Fig.6 gives a pulling force to make the bent shape of the pipe when the inner film is inflated by air. By this method, we can avoid problems of wrinkles of the film, bad seal of the film, un-uniform extension of the film, remained air bubble in the product, and cracks of the product.

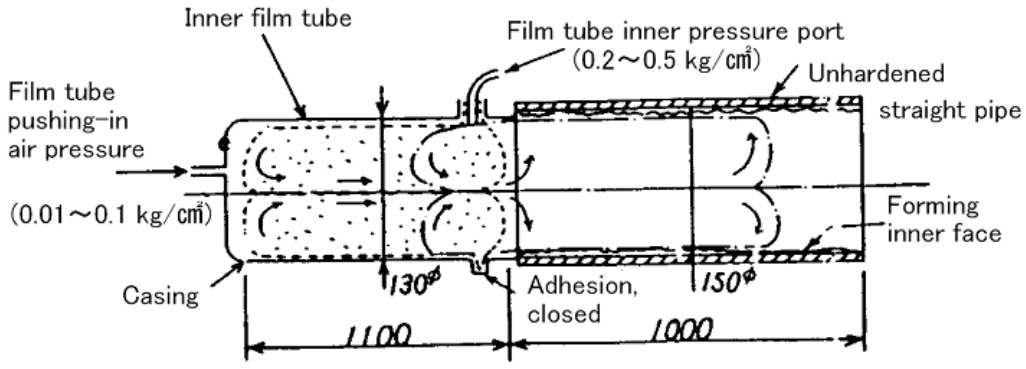
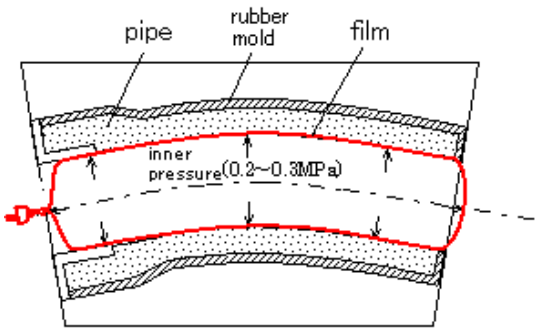


Fig.7: Film pushing-in method by air pressure.

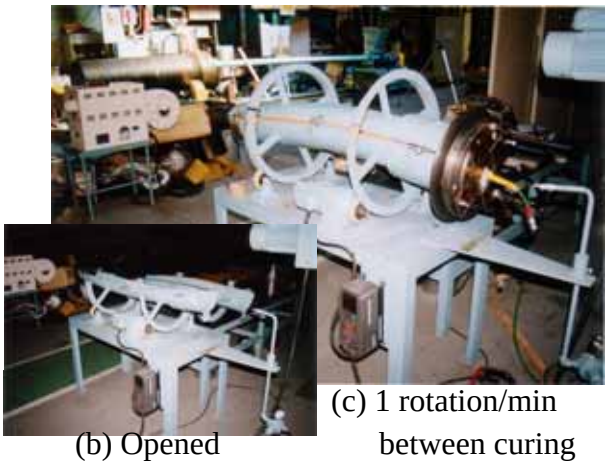
Fig.8 shows the rubber mould embedded in the halfly dividable outer metal mould. Fig.9 shows the production machine at the stage of inserting film bag role. Fig.5 shows a cast of bend pipe.

Fig.8: Inner rubber mould and separable outer metal mould.

Fig.9: Inserting film bag role to centrifugal forming machine.



(a) Cross section



(b) Opened (c) 1 rotation/min between curing

Fig.10: Cast of bent pipe.

4. MATERIALS

Glass fiber: Chopped strand mat REM450-G5 (450g/m**2) and REM600-G5 (600g/m**2) made by NSG Vetrotex are used.

Resin: The following three resins are mixed with 50/40/10 wt%.

(1) General; Japan Composite Polymar RZZ-431

(2) High elongation; Japan Composite Polymar 6330F

(3) Low shrinkage; Japan Composite Prominate M501

Aggregate: Small aggregate (<0.5mmϕ)/ large aggregate (1.5-2.5mmϕ) =65/35wt% treated with silan coupling agent Nippon Unicar A-174

5. PROCESS

Bent pipe is produced by the order of (1) mould set, (2) forming receiving end (socket part), (3) forming straight part (main body of the pipe), (4) bending process, (5) curing, (6) demoulding.

The main process (3) of forming the straight part of the pipe is composed of

[outer layer forming] 1) supplying resin, 2) supplying glass, 3) pressing by roller, 4) impregnation by speed up

[mortar layer forming] 5) supplying resin, 6) preparing aggregate, 7) supplying ggregate, 8) smoothing surface of aggregate, 9) pressing by roller, 10) impregnation by speed up

[inner layer forming] 11) supplying resin, 12) supplying glass, 13) pressing by roller, 14) impregnation by speed up, 15) supplying resin, 16) pressing by roller, 17) finish of forming, 18) film bag

The core technique of centrifugal winding method is illustrated in Fig.11, where glass fiber mat initially winded at the central fiber roll is thrown to the inside wall of cylindrical mould by setting the speed V2>V1 for initial several second and V2<V1 afterward. The produced pipe is shown in Fig.12. The layers composing the pipe is shown in Fig.13.

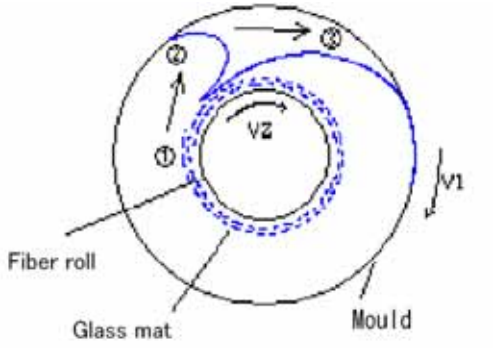


Fig.11 Centrifugal method winding glass fiber mat from role to mould. V2>V1 for initial several second.

Fig.12 FRPM bent pipe formed unifiedly with socket.

6. PRODUCT QUALITY

Precision and strength of the product was enough for practical use. Though the precision of the inner diameter and thickness of the produced pipe depend on the film pressure and shape, and therefore not expected so much compared with that of outer diameter and curvature, they were less than 0.5%. The bending test machine for 3 point method and obtained characteristic of the pipe is shown in Fig.14 and 15, respectively. The strength is at least almost similar to that of the conventional FW pipe. The destruction stress was 58.26 kN and 56.67 kN to concave direction and convex direction, respectively of 1000mm length pipe, which are larger than 40kN of the rule. That is the merit of our method based on CW method is its productivity which is, e.g., 1 piece/minute, hundred times of FW.

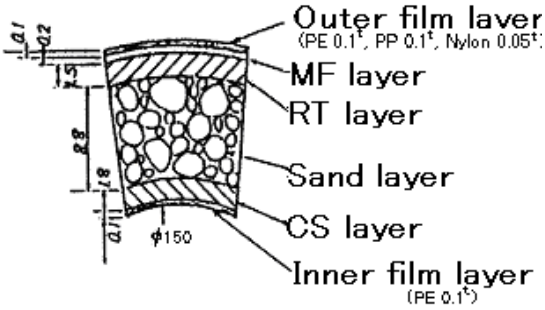


Fig.13: Diagram of layers

Fig.14 Bending test

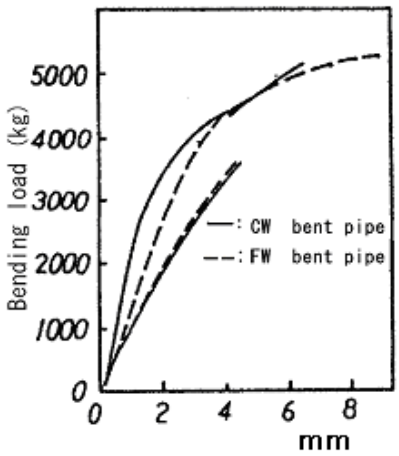


Fig.15 Bending characteristic. Length 1000mm.

7. CONCLUSIONS

We have developed unhardened prepleg bend pipe forming method which is the secondary processing method from the straight pipe produced by our unique centrifugal winding (CW) method. Produced pipe was shown to have enough precision and strength for practical use. The merit of the CW method is its productivity of, e.g., hundred times of conventional FW method. The products have been widely used for underground electrical power lines.

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