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## Effect of heat treatment conditions on the tube hydroformability

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**Key Words:** Axial Feeding Amount( ), Hydro-formability( )  
 As welded( ), PSA(Post seam annealing : Seam ),  
 BA(Bright annealing : Full body annealing )

### Abstract

Tube hydroforming provides a number of advantages over conventional stamping process, including fewer secondary operation, weight reduction, assembly simplification, adaptability to forming of complex structural components and improved structural strength and stiffness. In this study, the effect of the heat treatment on the hydro-formability has been investigated. By using the mild steel tube bulging test is performed at various heat treatment conditions to evaluate the hydro-formability.

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SAPH

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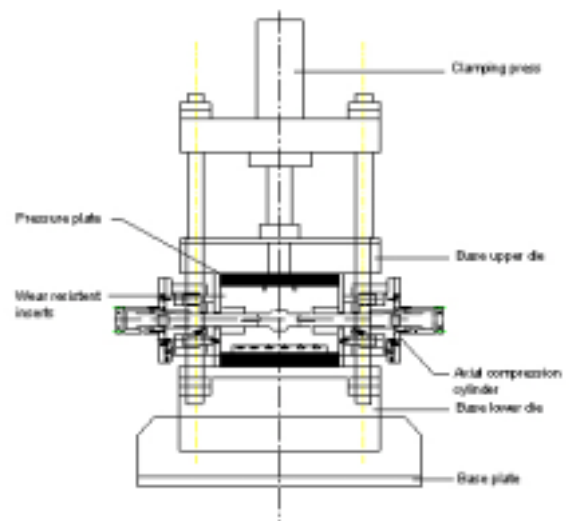


Fig. 1 Schematic drawing of tube hydroforming machine.

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Fig. 5

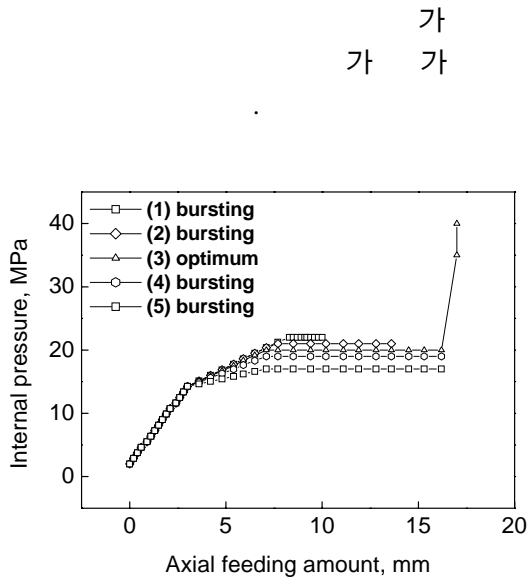


Fig. 6 The loading curves at SAPH 400 As welded.

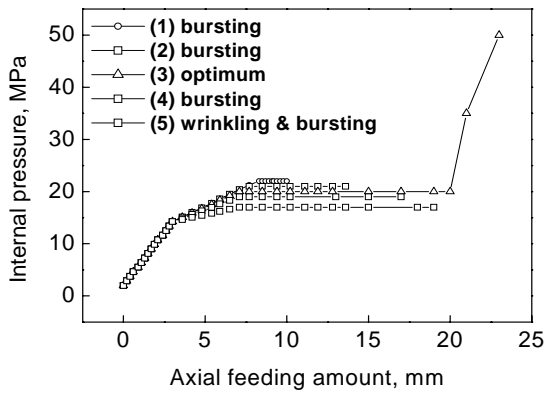
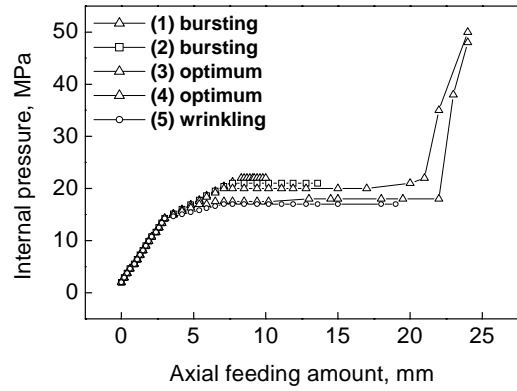


Fig. 7 The loading curves at SAPH 400 PSA.

Fig. 6~8 SAPH400  
BA 가  
PSA BA

Fig. 8 The loading curves at SAPH 400 BA.



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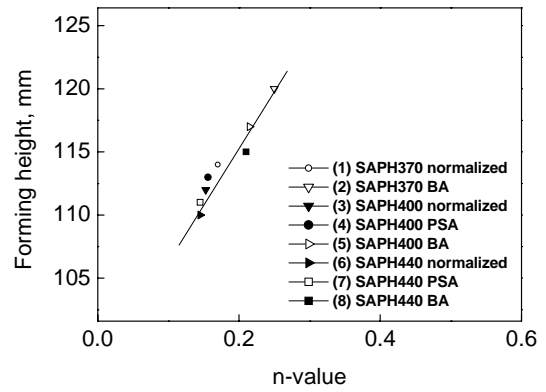


Fig. 9 Relationship between the n-value and the forming height in the T-fitting forming experiments

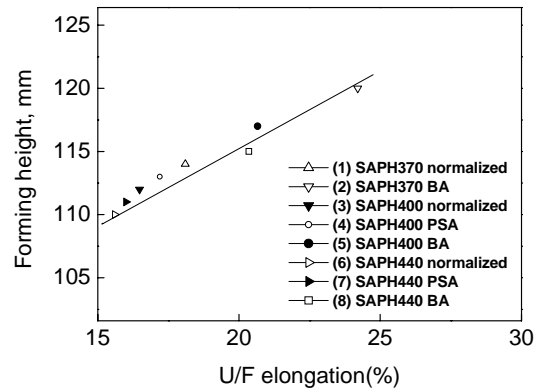
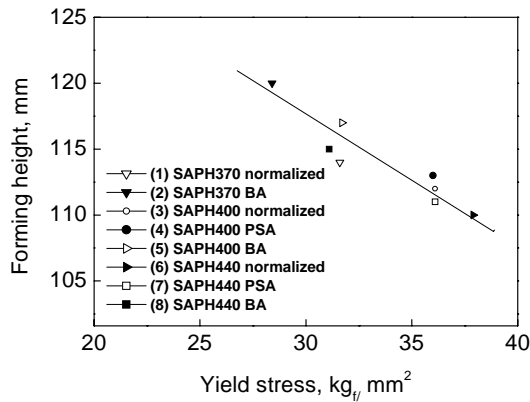
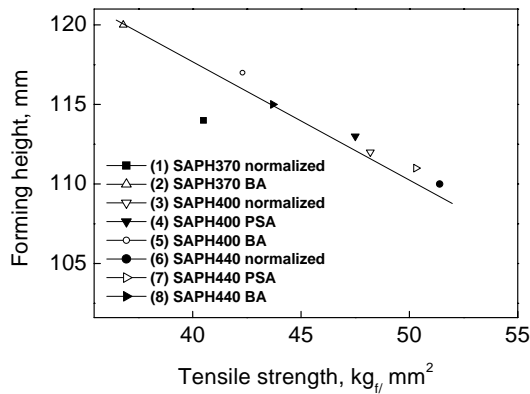


Fig. 10 Relationship between the Uniform elongation and the forming height in the T-fitting forming experiments



**Fig. 11** Relationship between the yield stress and the forming height in the T-fitting forming experiments



**Fig. 12** Relationship between the tensile strength and the forming height in the T-fitting forming experiments

**Fig. 9~12** 가 n, elongation, T-fitting forming forming height 가 H/F forming height 가 PSA 가 As welded 가 forming height가 , BA PSA forming height 가 PSA BA 가 가

SAPH 400 As welded forming height가  
SAPH 440 PSA  
SAPH 400 As welded 가  
가 hydroforming  
hydroformability가 SAPH 440 PSA  
Full body  
SAPH 400 SAPH 440 가  
weld line base metal  
weld line  
SAPH 400 BA SAPH 370 As  
welded T-fitting  
forming height가  
SAPH 400  
PSA

**Table 1** Hardness test(Hv)

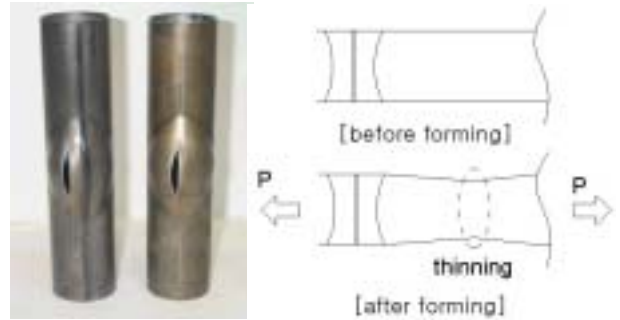
| POSITION | SAPH 400 As welded |       |       |       |       |       |       |       |       |
|----------|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|
|          | CHECKING POINT     |       |       |       |       |       |       |       |       |
|          | B.M                | B.M   | HAZ   | HAZ   | W.S   | HAZ   | HAZ   | B.M   | B.M   |
| TOP      | 167.1              | 171.5 | 210.0 | 211.5 | 208.1 | 210.2 | 211.4 | 175.9 | 167.8 |
| CENTER   | 174.5              | 176.8 | 211.4 | 210.6 | 209.5 | 210.9 | 213.5 | 178.3 | 165.0 |
| END      | 172.2              | 175.7 | 213.5 | 209.4 | 209.3 | 211.8 | 210.6 | 173.7 | 167.8 |

| POSITION | SAPH 400 PSA   |       |       |       |       |       |       |       |       |
|----------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|
|          | CHECKING POINT |       |       |       |       |       |       |       |       |
|          | B.M            | B.M   | HAZ   | HAZ   | W.S   | HAZ   | HAZ   | B.M   | B.M   |
| TOP      | 175.2          | 173.0 | 191.7 | 192.7 | 184.3 | 192.1 | 176.8 | 171.5 | 168.6 |
| CENTER   | 172.3          | 174.8 | 194.3 | 193.1 | 187.8 | 193.2 | 173.7 | 170.7 | 175.2 |
| END      | 172.2          | 167.0 | 193.2 | 194.5 | 185.1 | 193.3 | 170.7 | 167.8 | 165.1 |

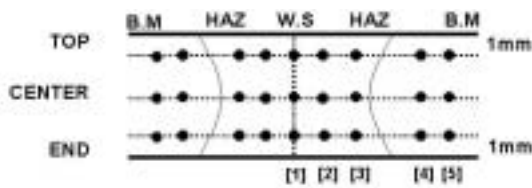
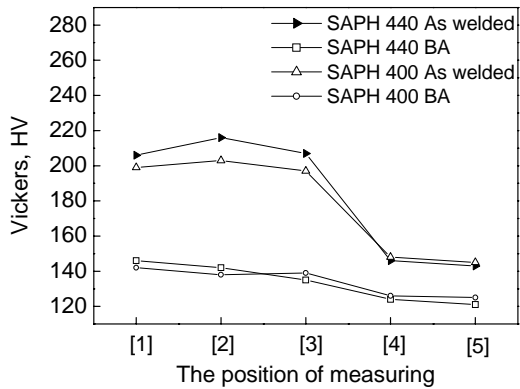
| POSITION | SAPH 400 BA    |       |       |       |       |       |       |       |       |
|----------|----------------|-------|-------|-------|-------|-------|-------|-------|-------|
|          | CHECKING POINT |       |       |       |       |       |       |       |       |
|          | B.M            | B.M   | HAZ   | HAZ   | W.S   | HAZ   | HAZ   | B.M   | B.M   |
| TOP      | 126.7          | 129.5 | 118.1 | 117.0 | 111.3 | 116.5 | 120.1 | 127.1 | 127.7 |
| CENTER   | 124.2          | 129.5 | 120.0 | 120.7 | 118.6 | 125.7 | 124.8 | 128.3 | 122.0 |
| END      | 128.9          | 132.5 | 121.6 | 122.0 | 112.2 | 121.5 | 117.6 | 122.5 | 129.2 |

**Table 2** The material properties of the tubes.

| material | heat treatment | position | tensile test                |                            |       |               |         |
|----------|----------------|----------|-----------------------------|----------------------------|-------|---------------|---------|
|          |                |          | TS<br>(kg/mm <sup>2</sup> ) | YS<br>(kg/m <sup>2</sup> ) | T-EL  | U/F-EL<br>(%) | n-Value |
| SAPH 370 | none           | weld     | 47.3                        | 42.0                       | 27.06 | 8.4           | 0.094   |
|          |                | base     | 40.3                        | 33.2                       | 34.2  | 18.6          | 0.166   |
|          | EA             | weld     | 37.5                        | 29.0                       | 38.6  | 23.0          | 0.235   |
|          |                | base     | 37.0                        | 27.8                       | 40.7  | 24.1          | 0.244   |
| SAPH 400 | none           | weld     | 50.2                        | 42.1                       | 27.0  | 11.53         | 0.106   |
|          |                | base     | 48.4                        | 41.0                       | 28.97 | 14.50         | 0.132   |
|          | PSA            | weld     | 51.6                        | 42.3                       | 26.70 | 12.86         | 0.115   |
|          |                | base     | 47.5                        | 36.0                       | 30.70 | 17.2          | 0.156   |
|          | EA             | weld     | 40.2                        | 29.4                       | 32.65 | 20.58         | 0.206   |
|          |                | base     | 42.1                        | 31.1                       | 35.95 | 20.50         | 0.213   |
| SAPH 440 | none           | weld     | 55.4                        | 45.0                       | 25.22 | 9.90          | 0.089   |
|          |                | base     | 51.2                        | 40.1                       | 28.15 | 14.43         | 0.132   |
|          | PSA            | weld     | 53.8                        | 41.8                       | 25.1  | 11.66         | 0.088   |
|          |                | base     | 50.9                        | 39.8                       | 29.1  | 14.21         | 0.132   |
|          | EA             | weld     | 42.2                        | 29.4                       | 34.2  | 20.50         | 0.209   |
|          |                | base     | 43.7                        | 31.1                       | 33.6  | 20.35         | 0.209   |



**Fig. 14** The thinning position of the tube under the hydroforming



**Fig. 13** The measuring position of the hardness test

Table 1  
Seam (PSA)  
가  
가  
가  
가  
SAPH 400  
mild steel  
가  
가  
가  
가  
가  
가  
4.

- (1) forming height  
BA 가 가 , PSA
- (2) PSA  
가 . , ,  
, ,  
PSA 가
- (3) 가  
가 .

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