Title: TUBE BLANKS FOR HYDROFORMING

Abstract: A monolithic tube blank (100) for forming a hydroformed product, the tube blank having at least one first section (102) having a first wall thickness and at least one second section (104) having a second wall thickness being greater than the first wall thickness. The wall thickness variation (106) along the axis (101) of the tube may be designed to be axially asymmetrical at any segment of the axis in order to facilitate differential stretching when bending or otherwise deforming the tube at that segment or at points proximate to the segment parallel to the axis of the tube. The tube blank is adapted to accept hydroforming stresses during a hydroforming process while precluding a reduction in wall thickness sufficient for stressing material of the tube blank to failure. Also contemplated is a method for forming a hydroformed product with such a tube blank.
TITLE

TUBE BLANKS FOR HYDROFORMING

FIELD OF THE INVENTION

The present invention generally relates to tube blanks utilized in hydroforming processes.

BACKGROUND OF THE INVENTION

Hydroforming involves the use of fluid pressure, applied from inside the cavity of a tube or tube blank, to expand the tube or tube blank in order to comply with the shape of a surrounding die. The cross-sectional shape of the resultant structural member is often considerably different from the cross-sectional shape of the tube blank. For instance, box-shaped cross sections are commonly formed from cylindrical tube blanks.

The degree of stretching that results at various points along the longitudinal axis of the tube is different, and there is also a difference between the degree of stretching at the outer and inner arcs of a straight tube that is bent on a curve in a hydroforming operation. One can also visualize similar differences in degrees of stretching in various other forms of shape deformation that may be imposed on a tube using a hydroforming or other shaping process. (For example, making a rectilinear section as shown in Figure 5 out of a round section as shown in Figure 4, would cause excessive thinning along the contours of the edge in Figure 5.) It has thus been found that a tube which has
wall thicknesses that are tailored to the bending and other deformation requirements along the axis lends itself to efficient formation into the final shape desired in connection with the subsequent hydroforming process.

U.S. Patent No. 4,759,111 (TI Canada, Inc.) embraces the concept of welding sleeves on a tube at specific points and using the enhanced thickness to facilitate the hydroforming of certain shapes.

U.S. Patent No. 5,333,775 (General Motors) discusses several known processes for producing tubular parts of variable wall thickness via hydroforming and proposes a solution involving, initially, the fabrication of a tube blank of the desired longitudinal combination of wall thickness, perimeter and material by welding together portions of tubing having the desired characteristics and then hydroforming the resulting blank. Thus, similarly to the TI Canada patent discussed above, in the GM patent the thickness variation is obtained by welding segments of the tube with different wall thicknesses (and possibly even different material) in the segments themselves. This achieves substantially the same effect, as the sleeved tubes in the TI Canada patent, in hydroforming.

However, it has been found that the processes discussed in both of the above-cited patents can tend to be cumbersome to set up and carry out. In the case of the GM patent, the fact that the various longitudinal sections are welded together will often result in the production of excessive stresses at the weld points, which may lead to premature failure.
A need has thus been recognized in conjunction with providing a type of hydroforming tube blank that overcomes the disadvantages and shortcomings of the conventional arrangements discussed heretofore.

**SUMMARY OF THE INVENTION**

Broadly contemplated herein is a one-piece integral hollow metal part of any essentially cross sectional shape (e.g., circular, hexagonal, square, oval, etc. etc.) made by essentially any of several different possible methods of formation. This part, or tube blank, is then used as the starting piece for a subsequent hydroforming process.

In this connection, also broadly contemplated herein is an integral, monolithic hollow tube blank with different desired wall thicknesses at different positions along the length of the hollow.

Primarily, a monolithic tube is contemplated, which thus has no welding joints or other discontinuities that lie in a direction that is transverse to the longitudinal axis of the tube. (It will be understood that a "monolithic" tube, as the term is employed herein, does not rule out the inclusion of a seam and/or weld that is essentially parallel to the longitudinal axis of the tube, as is known in the tube-making arts. A "monolithic" tube could thus be a seamless tube, an electric resistance welded [ERW] tube with a weld line along the length or axis of the tube, or a drawn over mandrel [DOM] tube. All or any of these are essentially characterized by an absence of any weld-line or seam transverse to the axis of a tube or without any weld-line
or seam around the circumference of the tube.) Since welding joints and other discontinuities tend to be susceptible to cracks, imperfect bonding and other potentially debilitating imperfections, it is believed that the inventive monolithic tube blank will ultimately result in a final hydroformed product of enhanced structural integrity.

Generally, at least one presently preferred embodiment of the present invention broadly embraces a monolithic tube blank for forming a hydroformed product, the tube blank comprising: a monolithic main body portion; the monolithic main body portion comprising at least one first section having a first wall thickness and at least one second section having a second wall thickness; the second wall thickness being greater than the first wall thickness; whereby the monolithic main body portion is adapted to accept hydroforming stresses during a hydroforming process while precluding a reduction in wall thickness sufficient for stressing material of the tube blank to failure.

Further, at least one presently preferred embodiment of the present invention broadly embraces a method of making a hydroformed product, the method comprising: forming a monolithic main body portion; the forming of the monolithic main body portion comprising providing at least one first section having a first wall thickness and providing at least one second section having a second wall thickness, the second wall thickness being greater than the first wall thickness; adapting said monolithic main body portion to accept hydroforming stresses while precluding a reduction in wall thickness sufficient for stressing material of the tube blank to
failure; and hydroforming the monolithic main body portion to produce a hydroformed product.

Finally, but not necessarily exclusively, at least one presently preferred embodiment of the present invention broadly embraces a monolithic tubular product comprising: at least one section having a first wall thickness profile; and at least one other section having a second wall thickness profile, the second wall thickness profile being different from the first wall thickness profile.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The present invention and its presently preferred embodiments will be better understood by way of reference to the detailed disclosure here below and to the accompanying drawings, wherein:

Figure 1 is a cross-sectional side view of a portion of a tube blank showing two primary sections of varying wall thickness and associated transition section;

Figure 2 is a cross-sectional side view of a tube blank showing five primary sections of varying wall thickness and associated transition sections;

Figure 3 is a schematic diagram of the steps of a hydroforming process;

Figure 4 is a perspective view of an intermediate blank; and
Figure 5 is a perspective view of a final hydroformed product formed from the intermediate blank of Figure 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 illustrates a portion of a tube blank 100, with central longitudinal axis 101, that may be used for subsequent hydroforming, in accordance with an embodiment of the present invention.

As shown, blank 100 may have at least three sections, namely, a first section 102 having wall thickness \( t \), a second section 104 having a greater wall thickness \( T \) and a third transition section 106. The longitudinal extent of each section 102, 104, 106, will preferably be chosen in a manner appropriate for the hydroforming application at hand. Although steel is primarily contemplated as a material for tube 100, other metals are also conceivable for this purpose, such as aluminum, copper, titanium, alloys that include one or more of the above (including possibly steel) or alloys including other metals. Also possible for use as a material for tube 100 are non-metal materials such as plastics, fiberglass-reinforced plastics, or plastic composites.

The tube 100 will preferably have a constant outer diameter \( D \). Thus, varying wall thickness will result in varying inner diameters. Also, there is preferably radial symmetry about central longitudinal axis 101.
Figure 2 illustrates a view of a tube blank 200, with a central longitudinal axis 201, having five distinct primary sections. Particularly, the main tube blank body 200 may have three types of primary sections, namely, three first sections 202 a/b/c having wall thickness t and two second sections 204 a/b having a greater wall thickness T. (Although a common thickness T is shown for sections 204a and 204b, it is to be understood that the thickness of section 204a may conceivably be different from thickness of section 204b.) As shown, the second sections 204 a/b are disposed between pairs of first sections 202 a/b/c. Similarly to the embodiment shown in Figure 1, there may be transition zones 206 a/b/c/d, respectively, between adjacent pairs of sections 202a/b/c and 204 a/b. Transition zones 206 a/b/c/d are preferably configured in a similar manner as the transition zone 106 discussed with respect to Figure 1. In each case, although a strictly linear transition between the two thicknesses is shown, it is to be understood that in reality an essentially non-linear transition will likely exist. As in the embodiment of Figure 1, D represents the overall outer diameter of blank 200 and there is preferably radial symmetry about central longitudinal axis 201.

It is to be understood that the tube blanks 100, 200 illustrated in Figures 1 and 2 are provided merely for purposes of illustration. It is conceivable, within the scope of the present invention, to provide a tube blank having even more than five distinct main sections. Preferably, the number of distinct sections, with differing wall thicknesses, will be chosen in a manner appropriate for the eventual hydroforming operation at hand. It is to be understood, as well, that
a significantly long tube blank, perhaps having a length on the order of 30 or 40 feet, may be produced with the understanding that it can be cut into smaller lengths in accordance with different ultimate uses.

It will be appreciated that a tube blank formed in accordance with the embodiments of the present invention, since it is monolithic, will present distinct advantages when engaged in a subsequent hydroforming operation. Particularly, since there are no transverse seams or other transverse deliberate discontinuities along which significant hydroforming stresses could develop that might otherwise lead to excessive reduction of wall thickness that would stress the material to failure, the subsequent hydroforming process will in all manner of likelihood be relatively smooth and uneventful, thus leading to the creation of optimized cross-sectional shapes and avoiding the waste that might otherwise be associated with rejecting defective final product.

Broadly contemplated, in accordance with at least one embodiment of the present invention, is a beginning-to-end hydroforming process that involves careful selection of the method or methods used to form the initial tube blank as well as the physical parameters to be imparted to the tube blank. It will be appreciated that the desired end product will inform such choices. It has been found that a monolithic tube blank formed in accordance with at least one embodiment of the present invention lends itself to successful hydroforming operations and, as such, can be subjected to a versatile degree of initial tailoring that will reliably result in any of a very wide variety of final hydroformed products having exemplary structural integrity.
In this connection, Figure 3 illustrates, in schematic form, an overall process 305 of forming a hydroformed product. It is to be appreciated that the desired end product, and its physical dimensions and characteristics, will inform the manner in which each stage of the process is carried out.

Preferably, a tube blank is formed (311) after having selected one or more methods (307) for forming the blank as well as the ultimate parameters (309) for the blank. The dotted line with two-way arrows interconnecting method selection (307) and parameter selection (309) implies that these two steps also inform one another to a degree.

In selecting a method of forming a tube blank (307), essentially any suitable method may be used. It has been found, in particular, that drawing (308a), extrusion (308b) and upsetting (308c) are particularly suitable methods, either alone or in any reasonable combination (308d) for forming a monolithic tube blank in accordance with at least one embodiment of the present invention. Of course, any other method (308e) that achieves substantially equivalent results is also contemplated in accordance with the present invention, such as forging.

In drawing (308a), the cross-sectional shape of a metal hollow will be changed by deforming the hollow using tensile force, resulting in an increase in the length of the hollow. The tube blank cross-section preferably assumes its ultimate desired shape by forcing the wall of the hollow to pass between a die and a mandrel. The cross-sectional area of the metal in the
finished product will be smaller than that of the starting hollow.

An extrusion method (308b), on the other hand, will preferably involve imparting a cross-sectional shape to a material by pushing the material through an orifice. The orifice is preferably defined either by a die or by a combination of a die and a mandrel. For this method, the material may be a metal or a non-metallic organic or inorganic substance. The material to be processed may have a shape with a uniform cross-section along its length or axis or it may be a billet. Heating may or may not be involved during extrusion. The final tube blank can have a range of sizes and shapes depending on the design of the orifice through which the material is pushed.

Upsetting (308c) will preferably involve the application of a compressive force to a material so that it deforms in a shape determined by a die-cavity surrounding it. Usually, the material outside of the die cavity is constrained from moving along its longitudinal axis with a type of holding device while it is rammed head-on with considerable force. This causes plastic deformation of the material, which takes the shape of the die cavity.

Depending on the tube blank desired, it may be appropriate to use a combination (308d) of the methods 308a-c, or even another method (308e) entirely. One conceivable "combination" method, for instance, might involve pushing or drawing a shaped mandrel, with a tube disposed thereon, through a die, followed by pulling the tube off of the mandrel.
It will also be necessary to select the ultimate parameters of the tube blank (309). Part of this selection process will involve choosing the number of distinct sections desired (310a), such as, sections with greater wall thickness, sections with lesser wall thickness and transition sections. The length of each section (310b) and wall thickness within each section (310c) will also preferably be chosen with a view to the ultimate provision of an optimally hydroformed product.

Subsequent to carrying out the formation of the tube blank (311) in accordance with the selected method(s) (307) and parameters (309), a hydroforming operation (313) will take place. The hydroforming operation may include the formation of an intermediate blank (for example, see Figure 4) prior to actually hydroforming the same into an end product (for example, see Figure 5). Although the present invention, in accordance with the embodiments disclosed and contemplated herein, is not restricted to a particular type of subsequent hydroforming process or hydroformed product to be formed, a discussion of general hydroforming operations, and of typical hydroformed products that may be produced, is to be found in U.S. Patent No. 5,333,775.

Figure 4 illustrates an intermediate blank 452 that may be encountered in accordance with the embodiments of the present invention. The intermediate blank 452 may include a tubular central section 454 of larger diameter and two tubular end sections 456 of smaller diameter. Further, there may be frustoconical transition sections 458 between the central section 454 and end sections 456. If a starting blank in accordance
with at least one embodiment of the present invention is employed, thicker regions (such as section 104 illustrated in Figure 1) may preferably be utilized in the vicinity of the interfaces between the different sections that will ultimately ensue in the intermediate blank 452 shown in Figure 4 (i.e., the interfaces between a section 456 and a section 458, between a section 458 and section 452, etc.). Thus, regions of reduced thickness (such as section 102 shown in Figure 1) may preferably be utilized between the aforementioned thicker regions. To actually transform a starting blank into an intermediate blank such as that (452) shown in Figure 4, any of a variety of methods may be used that are well-known to those of ordinary skill in the art, such as pointing (e.g. to form the central section 454 of greater diameter from a tube generally having an overall outer diameter corresponding to the end sections 456).

Figure 5, on the other hand, illustrates a finished product 550 subsequent to hydroforming. The product 550 may be essentially straight, as shown, or could even be further processed by bending, in which case a distinctly different end product may ensue. An example of such a bent end product is shown in Fig. 5 of U.S. Patent No. 5,333,775.

As an example of a monolithic tube blank in accordance with the present invention, that may be a very reliable starting material for the subsequent hydroforming of the type of end products contemplated by U.S. Patent No. 5,333,775, there may be five main sections 202 a/b/c and 204 a/b as shown in Figure 2. The smaller thickness t could be, for instance, about .118 inch (or 3 mm), while the larger thickness T could be
about .138 inch (or 3.5 mm). The overall outer diameter D could be about 1.174 inch. Referring to Figure 2, two outer sections 202a and 202c could each have a length of about 3 inches, while section 202b could have a length of about 3 feet. The two thicker sections 204a and 204b, in turn, could each have a length of about 4 inches.

It is to be understood that, although, the foregoing discussion contemplates tube blanks, intermediate blanks and hydroformed products exhibiting radial symmetry with respect to a central longitudinal axis, structural profiles exhibiting radial asymmetry with respect to a central longitudinal axis are also contemplated within the scope of the present invention.

If not otherwise stated herein, it may be assumed that all components and/or processes described heretofore may, if appropriate, be considered to be interchangeable with similar components and/or processes disclosed elsewhere in the specification, unless an express indication is made to the contrary.

If not otherwise stated herein, any and all patents, patent publications, articles and other printed publications discussed or mentioned herein are hereby incorporated by reference as if set forth in their entirety herein.

It should be appreciated that the apparatus and method of the present invention may be configured and conducted as appropriate for any context at hand. The embodiments described above are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is defined by the following claims.
rather than the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.
CLAIMS

What is claimed is:

1. Monolithic tube blank for forming a hydroformed product, said tube blank comprising:

   a monolithic main body portion;

   said monolithic main body portion comprising:

   at least one first section having a first wall thickness; and

   at least one second section having a second wall thickness;

   said second wall thickness being greater than said first wall thickness;

   whereby said monolithic main body portion is adapted to accept hydroforming stresses during a hydroforming process while precluding a reduction in wall thickness sufficient for stressing material of the tube blank to failure.

2. The tube blank according to Claim 1, wherein:

   said at least one first section consists essentially of one first section having said first wall thickness;
said at least one second section consists essentially of two second sections having said second wall thickness; and

said one first section being disposed between said two second sections.

3. The tube blank according to Claim 2, further comprising a transition section between said first section and at least one of said second sections, said transition section having a varying wall thickness with said first wall thickness as a minimum and said second wall thickness as a maximum.

4. The tube blank according to Claim 3, wherein the wall thickness of said transition section increases between said first wall thickness and said second wall thickness.

5. The tube blank according to Claim 2, further comprising a transition section between said first section and each of said second sections, said transition sections each having a varying wall thickness with said first wall thickness as a minimum and said second wall thickness as a maximum.

6. The tube blank according to Claim 5, wherein the wall thickness in both of said transition sections increases between said first wall thickness and said second wall thickness.

7. Method of making a hydroformed product, said method comprising:
forming a monolithic main body portion;

said forming of said monolithic main body portion comprising:

providing at least one first section having a first wall thickness; and

providing at least one second section having a second wall thickness, said second wall thickness being greater than said first wall thickness;

adapting said monolithic main body portion to accept hydroforming stresses while precluding a reduction in wall thickness sufficient for stressing material of the tube blank to failure; and

hydroforming said monolithic main body portion to produce a hydroformed product.

8. The method according to Claim 7, wherein said forming of said monolithic main body portion includes at least one of: drawing, extruding, forging and upsetting.

9. The method according to Claim 7, wherein:

said providing of at least one second section comprises providing two second sections having said second wall thickness; and

said providing of at least one first section comprises providing one first section having said first
wall thickness, said one first section being disposed between said two second sections.

10. The method according to Claim 9, further comprising providing a transition section between said first section and at least one of said second sections, said transition section having a varying wall thickness with said first wall thickness as a minimum and said second wall thickness as a maximum.

11. The method according to Claim 10, wherein the wall thickness of said transition section increases between said first wall thickness and said second wall thickness.

12. The method according to Claim 9, further comprising providing a transition section between said first section and each of said second sections, said transition sections each having a varying wall thickness with said first wall thickness as a minimum and said second wall thickness as a maximum.

13. The method according to Claim 12, wherein the wall thickness in both of said transition sections increases between said first wall thickness and said second wall thickness.

14. A monolithic tubular product comprising:

at least one section having a first wall thickness profile; and
at least one other section having a second wall thickness profile, said second wall thickness profile being different from said first wall thickness profile.

15. The monolithic tubular product according to Claim 14, wherein at least one of said first and second wall thickness profiles exhibits symmetry with respect to a central longitudinal axis of the tubular product.

16. The monolithic tubular product according to Claim 14, wherein at least one of said first and second wall thickness profiles exhibits asymmetry with respect to a central longitudinal axis of the tubular product.
FIG. 3
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : F16D 1/08
US CL : 188/44
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 188/44, 108, 177, 178, DIG 11

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST BRS
search terms: hydroform$, tube, hose, pipe, conduit, thickness

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>US 5,802,899 A (KLAAS et al) 08 September 1998, see entire document.</td>
<td>1-7, 9-16</td>
</tr>
<tr>
<td>Y</td>
<td>US 4,435,972 A (SIMON) 13 March 1984, see entire document.</td>
<td>8</td>
</tr>
<tr>
<td>A</td>
<td>US 5,333,775 A (BRUGGEMANN et al) 02 August 1994, see entire document.</td>
<td>1-16</td>
</tr>
<tr>
<td>A</td>
<td>US 5,491,883 A (MARLINGA) 20 February 1996, see entire document.</td>
<td>1-16</td>
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<td>US 5,918,494 A (KOJIMA et al) 06 July 1999, see entire document.</td>
<td>1-16</td>
</tr>
<tr>
<td>A</td>
<td>US 6,016,603 A (MARANDO et al) 25 January 2000, see entire document.</td>
<td>1-16</td>
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</table>

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered
  to be of particular relevance
  "E" earlier document published on or after the international filing date
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considered novel or cannot be considered to involve an inventive step
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considered novel or cannot be considered to involve an inventive step
when the document is combined with one or more other such documents, each combination being
obvious to a person skilled in the art

Document member of the same patent family

Date of the actual completion of the international search: 20 JULY 2001
Date of mailing of the international search report: 28 AUG 2001

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