(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 698 410 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.09.2006 Bulletin 2006/36

(21) Application number: **05075534.7**

(22) Date of filing: **04.03.2005**

(51) Int Cl.:
B21D 26/02 *(2006.01)* ***B62D 25/04*** *(2006.01)*
B62D 23/00 *(2006.01)* ***B21D 53/88*** *(2006.01)*

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU MC NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR LV MK YU

(71) Applicant: **Corus Staal BV**
1970 CA Ijmuiden (NL)

(72) Inventor: **Kelder, Maarten Hendrik**
1011 BT Amsterdam (NL)

(74) Representative: **Kruit, Jan**
Corus Technology BV
PO Box 10000
1970 CA IJmuiden (NL)

(54) Tube for hydroforming applications and method for hydroforming a tube

(57) The invention relates to a straight steel tube for hydroforming applications, especially for producing the A-pillar, B-pillar or C-pillar of an automobile.

According to the invention, the steel has a tensile strength of more than 400 MPa, wherein the tube has a wall thickness of 1 - 4 mm, and wherein the tube has been provided with a longitudinal dimple over at least 25 % of the length of the tube, the tube having a mean diameter between 30 mm and 200 mm in the region of the dimple.

The invention also relates to a method for hydroforming a steel tube, especially for hydroforming the A-pillar, B-pillar or C-pillar of an automobile.

EP 1 698 410 A1

Description

[0001] The invention relates to a straight steel tube for hydroforming applications, especially for producing the A- pillar, B-pillar or C-pillar of an automobile. The invention also relates to a method for hydroforming a steel tube, especially for hydroforming the A-pillar, B-pillar or C-pillar of an automobile.

[0002] It is a well-known technology to use straight steel tubes (so without curves) for hydroforming applications. Often the tube is first bent before the tube is inserted in a hydroforming apparatus, where the tube is placed between two or more dies and the diameter of the tube is enlarged and/or the shape of the cross section of the tube is changed over at least part of the length of the tube by inserting a fluid under pressure in the tube while the ends of the tube are kept closed. However, it is not always necessary to bend the tube first.

[0003] A drawback of the hydroforming technology is that the amount of material in the tube is determined beforehand by choosing the diameter of the tube, while the circumference of the tube will often change during hydroforming. The result is that in such cases the thickness of the wall of the tube will be changed during hydroforming, often only locally, resulting in a weakened hydroformed part or a failure of the part during hydroforming.

[0004] Especially the parts of an automobile, notably the A-pillar, B-pillar and C-pillar should not bend easily and have to be strong and stiff. These requirements are a fortiori needed in the A-pillar of an open car, where the A-pillars should be able to withstand the forces during a roll-over of the car. Here also a slim part is required by the users of the car, so as not to hamper the sight.

[0005] It is an object of the invention to provide an improved tube for hydroforming applications, especially for automotive use.

[0006] It is another object of the invention to provide a tube for hydroforming applications with which the change in thickness during hydroforming can be reduced and/or failure of the tube during hydroforming can be prevented.

[0007] It is a further object of the invention to provide a tube for hydroforming applications with an improved strength and stiffness in relation to its circumference, using the same thickness of the wall of the tube.

[0008] According to the invention, one or more of these objects are reached by providing a straight steel tube for hydroforming applications, especially for producing the A-pillar, B-pillar or C-pillar of an automobile, wherein the steel has a tensile strength of more than 400 MPa, wherein the tube has a wall thickness of 1 - 4 mm, and wherein the tube has been provided with a longitudinal dimple over at least 25 % of the length of the tube, the tube having a mean diameter between 30 mm and 200 mm in the region of the dimple.

[0009] For the purpose of this invention a dimple is defined as a part of the circumference of a cross-section of the tube being curved inwardly, for instance approximately one third of the circumference being curved inwardly. Of course the transition between the normal semi-circular circumference of the cross-section and the inwardly curved part is smooth; no sharp angles are present. The mean diameter is the average of all the diameters of the cross section of the tube as if no dimple was present.

[0010] The invention makes it possible during the hydroforming operation to provide more material in that section of the tube where the cross-section of the tube is enlarged by the hydroforming, by supplying part of the material in the dimple to enlarge the cross-section of the tube. This is accomplished by the dimple becoming less deep. For the A-pillar and C-pillar of a car this is especially useful at the part of the pillar where the pillar protrudes above the plane of the bonnet.

[0011] Because the tube has to enlarge over part of its length, the dimple has to be present over at least 25 % of the length of the tube.

[0012] Of course it is known to use dimples in a tube, but those dimples are used to bend the tube, because the dimple gives a lower bending stiffness to the tube. Moreover, those known dimples are short in comparison to the length of the tube, because they are only present where the tube has to be bent.

[0013] It is also known to press dimples into a tube during the hydroforming process, so after the tube has been placed between the dies of a hydroforming apparatus, but in that case the tube is hydroformed in the same process, and a straight tube with a dimple according to the invention is never present as a separate part.

[0014] Preferably the dimple has been provided over at least 50 % of the length of the tube, more preferably over at least 75 % of the length of the tube. The longer the dimple is, the easier it is to provide a tube with such a dimple. The strength and stiffness of the tube will also be improved over a longer portion of the tube when the dimple is longer.

[0015] According to an improved embodiment, the dimple has been provided over the full length of the tube. Such tubes are relatively easy to produce, and usually the dimple is required over the full length, such as for A-, B- and C-pillars.

[0016] However, there are applications where is will be practical when the dimple is only present between the outer ends of the tube. This means that the end parts of the tube are not provided with the dimple, but that the dimple is present between the end parts of the tube. In such cases it will be more easy to connect the end part of the tube provided with the dimple to other parts.

[0017] The tube has preferably been made of high strength steel having a tensile strength of at least 500 MPa, preferably HSLA steel. HSLA steels having a tensile strength of at least 500 MPa are well suited for hydroforming applications are and are often used for automotive parts.

[0018] Preferably the tube has been made of high strength steel having a tensile strength of at least 600 MPa, preferably DP 600 or stronger, TRIP 600 or stronger, complex phase or TWIP steel. Most of these high strength steels are strong, but show a low plastic strain. For such steel types a dimple in the tube is required, because otherwise the circumference cannot be enlarged to more than a small extent without failure of the tube.

[0019] According to a preferred embodiment the tube is a roll formed tube, preferably a roll formed precision tube. Such tubes are easy to produce, and often used in hydroforming.

[0020] According to another preferred embodiment the tube is a tubular blank. Tubular blanks are produced from a planar sheet, and not as a continuous tube as is the case in roll formed tubes. Tubular blanks usually have a laser weld, which is stronger than a high frequency induction weld as in roll formed tubes.

[0021] In an embodiment the tube is a conical tube. Conical tubes without dimple are more expensive to produce than tubes having a constant diameter, because they cannot be produced continuous, but have to be produced as tubular blank.

[0022] Preferably the dimple has a depth that is variable over the length of the dimple. When the depth of the dimple varies over the total length of the tube, it is possible to produce a conical tube starting from a tube having a constant diameter without dimple. The conical tube with dimple is thus less expensive than a standard conical tube, because it can be produced from a tube having a constant diameter.

[0023] According to a preferred embodiment the tube is a tailored tube. The tube thus can for example be formed from two different steel types, or can have two different thicknesses.

[0024] According to another preferred embodiment the tube has been made from a tailor rolled blank. The tube thus has portions having different thicknesses.

[0025] In an embodiment, the tube has been provided with two dimples on opposite sides of the tube. This can be useful to reduce the bending stiffness and strength of the tube at the location of the dimples.

[0026] In another embodiment, the tube has been provided with two or more dimples on the same side of the tube, preferably one dimple having been provided over at least 25 % of the length of the tube. In this way for instance only the ends of the tube are provided with a dimple.

[0027] Preferably, the tube has a mean diameter between 50 mm and 120 mm in the region of the dimple. Tubes to be hydroformed seldom have a diameter outside this range.

[0028] The invention also relates to a method for hydroforming a steel tube, especially for hydroforming the A-pillar, B-pillar or C-pillar of an automobile, wherein the steel has a tensile strength of more than 400 MPa, wherein the tube has a wall thickness of 1 - 4 mm, comprising the steps of:

- in a first step providing a straight steel tube with a longitudinal dimple over at least 25 % of the length of the tube, such that the mean diameter of the tube in the region of the dimple is between 30 mm and 200 mm, in accordance with the invention as described above;
- in a further step that is separate from the first step, hydroforming the tube which has been provided with a dimple.

[0029] This method describes the forming of the straight steel tube as described above and the forming of this tube by using hydroforming. In this way also the use of the tube with a dimple according to the invention is covered.

[0030] According to a preferred embodiment, between the first step and the further step during an intermediate step the straight tube provided with a dimple is bent. Often it will be necessary to bend the straight tube before it is hydroformed, since for instance an A-pillar is not straight.

[0031] According to a more preferred embodiment the intermediate step and the further step are combined into one step. The tube is thus bent in the hydroforming apparatus before the hydroforming itself takes place. In this way it is not necessary to use a separate bending apparatus. Of course this is only possible when the tube remains more or less straight.

[0032] As an example a tube for an A-pillar for an automobile is described. The tube has a length of approximately 2 meter and a wall thickness of 2 mm. Before the dimple is formed, the tube has a diameter of approximately 60 mm. A dimple is formed over the full length of the tube, the dimple having a variable depth such that at one end of the tube the dimple is deeper than at the other end. In this way a conical tube is formed, the tube having a smaller mean diameter at the end where the dimple is deepest. This end will form the top of the A-piller after the tube with dimple has been bent and hydroformed.

Claims

1. Straight steel tube for hydroforming applications, especially for producing the A-pillar, B-pillar or C-pillar of an automobile, wherein the steel has a tensile strength of more than 400 MPa, wherein the tube has a wall thickness of 1 - 4 mm, and wherein the tube has been provided with a longitudinal dimple over at least 25 % of the length of the tube, the tube having a mean diameter between 30 mm and 200 mm in the region of the dimple.

2. Tube according to claim 1, wherein the dimple has been provided over at least 50 % of the length of the tube, preferably over at least 75 % of the length of the tube.

3. Tube according to claim 1 or 2, wherein the dimple has been provided over the full length of the tube.

4. Tube according to claim 1 or 2, wherein the dimple is only present between the outer ends of the tube.

5. Tube according to any one of the preceding claims, wherein the tube has been made of high strength steel having a tensile strength of at least 500 MPa, preferably HSLA steel.

6. Tube according to any one of the preceding claims, wherein the tube has been made of high strength steel having a tensile strength of at least 600 MPa, preferably DP 600 or stronger, TRIP 600 or stronger, complex phase or TWIP steel.

7. Tube according to any one of the claims 1 - 6, wherein the tube is a roll formed tube, preferably a roll formed precision tube.

8. Tube according to any one of the claims 1 - 6, wherein the tube is a tubular blank.

9. Tube according to any one of the preceding claims, wherein the tube is a conical tube.

10. Tube according to any one of the preceding claims, wherein the dimple has a depth that is variable over the length of the dimple.

11. Tube according to any one of the preceding claims, wherein the tube is a tailored tube.

12. Tube according to any one of the preceding claims, wherein the tube has been made from a tailor rolled blank.

13. Tube according to any one of the preceding claims, wherein the tube has been provided with two dimples on opposite sides of the tube.

14. Tube according to any one of the preceding claims, wherein the tube has been provided with two or more dimples on the same side of the tube, preferably one dimple having been provided over at least 25 % of the length of the tube.

15. Tube according to any one of the preceding claims, wherein the tube has a mean diameter between 50 mm and 120 mm in the region of the dimple.

16. Method for hydroforming a steel tube, especially for hydroforming the A-pillar, B-pillar or C-pillar of an automobile, wherein the steel has a tensile strength of more than 400 MPa, wherein the tube has a wall thickness of 1 - 4 mm, comprising the steps of:

    - in a first step providing a straight steel tube with a longitudinal dimple over at least 25 % of the length of the tube, such that the mean diameter of the tube in the region of the dimple is between 30 mm and 200 mm, in accordance with any one of the preceding claims;
    - in a further step that is separate from the first step, hydroforming the tube which has been provided with a dimple.

17. Method according to claim 16, wherein between the first step and the further step during an intermediate step the straight tube provided with a dimple is bent.

18. Method according to claim 17, wherein the intermediate step and the further step are combined into one step.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 07 5534

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	WO 2005/018847 A (THYSSENKRUPP STAHL AG; GRUENEKLEE, AXEL; PATBERG, LOTHAR; WECKENMANN,) 3 March 2005 (2005-03-03) * claim 1; figures 1-5 *	1-18	B21D26/02 B62D25/04 B62D23/00 B21D53/88
A	EP 1 035 994 B (COSMA INTERNATIONAL INC) 19 September 2001 (2001-09-19) * figures 1-4 *	1-18	
A	EP 1 502 840 A (DANA CORPORATION) 2 February 2005 (2005-02-02) * figures 1-3 *	1-18	
A	EP 0 862 956 A (DAIMLER-BENZ AG) 9 September 1998 (1998-09-09) * figures 1,2 *	1-18	
A	US 5 953 945 A (COSMA INTERNATIONAL INC) 21 September 1999 (1999-09-21) * figure 1 *	1-18	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

B21D
B62D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 July 2005	Vinci, V

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 07 5534

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

27-07-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2005018847 A	03-03-2005	DE 10338025 B3	14-04-2005
		WO 2005018847 A1	03-03-2005
EP 1035994 B	20-09-2000	AT 205794 T	15-10-2001
		AU 742844 B2	17-01-2002
		AU 9525398 A	10-05-1999
		BR 9812918 A	08-08-2000
		CA 2306369 A1	29-04-1999
		DE 69801771 D1	25-10-2001
		DE 69801771 T2	04-07-2002
		EA 1477 B1	23-04-2001
		EP 1035994 A1	20-09-2000
		HU 0004299 A2	28-04-2001
		JP 2001520147 T	30-10-2001
		NO 20001916 A	16-06-2000
		NZ 503839 A	28-09-2001
		SK 5492000 A3	07-11-2000
		WO 9920516 A1	29-04-1999
		CN 1093061 C	23-10-2002
		ES 2167944 T3	16-05-2002
		US 2002100746 A1	01-08-2002
		US 2002104830 A1	08-08-2002
		US 2002100747 A1	01-08-2002
		US 2002149189 A1	17-10-2002
		US 6092865 A	25-07-2000
		US 6282790 B1	04-09-2001
		US 6302478 B1	16-10-2001
		US 6346684 B1	12-02-2002
		US 6533348 B1	18-03-2003
		US 2001002760 A1	07-06-2001
		US 2001000119 A1	05-04-2001
		US 2001050497 A1	13-12-2001
EP 1502840 A	02-02-2005	US 2005023865 A1	03-02-2005
		EP 1502840 A1	02-02-2005
EP 0862956 A	09-09-1998	DE 19708905 A1	16-04-1998
		DE 59800058 D1	13-01-2000
		EP 0862956 A1	09-09-1998
		ES 2142174 T3	01-04-2000
US 5953945 A	21-09-1999	US 6065502 A	23-05-2000
		AT 209541 T	15-12-2001
		AU 735003 B2	28-06-2001
		AU 9335398 A	27-04-1999
		BR 9812746 A	29-08-2000

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 05 07 5534

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

27-07-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5953945 A		CA 2304629 A1	15-04-1999
		WO 9917894 A1	15-04-1999
		CN 1274306 A ,C	22-11-2000
		DE 69802712 D1	10-01-2002
		DE 69802712 T2	01-08-2002
		EA 1975 B1	22-10-2001
		EP 1034053 A1	13-09-2000
		ES 2171303 T3	01-09-2002
		HU 0003830 A2	28-03-2001
		JP 2001519238 T	23-10-2001
		MX PA00003264 A	24-04-2002
		NO 20001785 A	05-06-2000
		NZ 503631 A	01-03-2002
		PL 339854 A1	15-01-2001
		PT 1034053 T	31-05-2002
		SK 5162000 A3	07-11-2000

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82