Perspectives for the application of variable thickness aluminium tubes in hydroforming of complex tubes

Bihamta, Reza; Bui, Quand-Hien; Guillot, Michel; D'Amours, Guillaume; Rahem, Ahmed; Fafard, Mario

Publisher's version / Version de l'éditeur:

Light Materials Technology V, 690, pp. 447-450, 2011-07-19

Perspectives for the Application of Variable Thickness Aluminium Tubes in Hydroforming of Complex Tubes

Reza Bihamta[1, a], Quang-Hien Bui[2, a], Michel Guillot[3, a]

Guillaume D'Amours[4, b], Ahmed Rahem[5, b], and Mario Fafard[6, a]

[a]Aluminium Research Centre –REGAL, Laval University, Quebec, Canada

[b]National Research Council Canada, Aluminium Technology Centre, Saguenay, Canada G7H8C3

[1]Reza.Bihamta.1@ulaval.ca, [2]Quang-Hien.Bui.1@ulaval.ca,

[3]Michel.Guillot@gmc.ulaval.ca, [4]Guillaume.DAmours@imi.cnrc-nrc.gc.ca,
[5]Ahmed.Rahem@imi.cnrc-nrc.gc.ca, [6]Mario.Fafard@gci.ulaval.ca

Keywords: Tube Drawing, Tube Hydroforming, Tube Bending, Variable Thickness Tubes, Aluminium.

Abstract

Tubular products have very important applications in various areas especially in the transportation industries. For instance, in the structure of cars there are various tubular products like roof headers, engine cradles, roof rails and frame rails with complex geometries which most of them need multiple steps like tube drawing, tube bending and hydroforming for their production. Based on the recent studies by this group, it was proven that in most of the structural tubular parts in the cars it was not necessary to have constant thickness along the axial direction of tube and it will be considered as overdesign and the overall weight of structures can be reduced considerably by using variable thickness tubes. In this paper, the variable thickness tube drawing and its applications in the tube bending and hydroforming applications were studied. The results showed that this process can have important role in reduction of defective parts in the production of complex tubes by the tube hydroforming method. However especial considerations should be taken into account in the design of thickness distribution along axial direction of these kinds of tubes to avoid problems in the drawing step and as well in the bending and hydroforming steps.

Introduction

Application of tubular aluminium parts in transportation industries like car structure or bicycle frame has found important role because of its higher strength ratio over weight. In the initial designs of these parts because of lack of technology and knowledge about production of variable thickness tube, most of these parts were designed based on the constant thickness variation in the axial and/or radial directions. These days with the development of modern analysis softwares which most of them are based on the numerical methods like finite element the design of most of these parts especially assignment of constant thickness in the axial and/or radial directions are considered to be overdesign and considerable reduction in weight of these parts can be achieved by utilization of variable thickness tubes. As it was estimated by Guillot et. al in [1] an overall reduction of about 25% is expected in weight of car structures by utilization of variable thickness tubes. The production of these kinds of tubes was patented in 2004 by Newport et. al [2]. After registration of this invention, as the best knowledge of authors, up to 2010, there was not any considerable research about various aspects of tubes produced by the method claimed in that invention. The initial researches about variable thickness tube drawing were published by Guillot et. al [1] about experimental studies on the production of variable thickness tubes in the radial and/or axial directions and mechanical properties of tube material after variable thickness drawing. Also Bihamta et al. [3] presented a methodology to have increase and decrease in the same step by this method.

In this paper, application of variable thickness tubes in the production of complex aluminium tubes and their role in reduction of structures weights were evaluated.

Design necessity for the variable thickness tubes

As it is clear in Fig. 1, in some loading conditions, the constant thickness in all over the tubes are not necessary and it will just increase overall weight of the structure. For example, in some products like tubes in bicycles frame, from view point of loading analysis, it is not really necessary to have large thickness along the tube axis and on the other hand, with assigning smaller thickness in the regions with lower loading and assigning larger thickness in the regions with more stress considerable reduction in the weight of structure and consequently on the total weight of the final product can be achieved. Also in some tubular parts it is necessary to weld a part to the other part, therefore the welded zone should have larger thickness than the other regions of the tube.

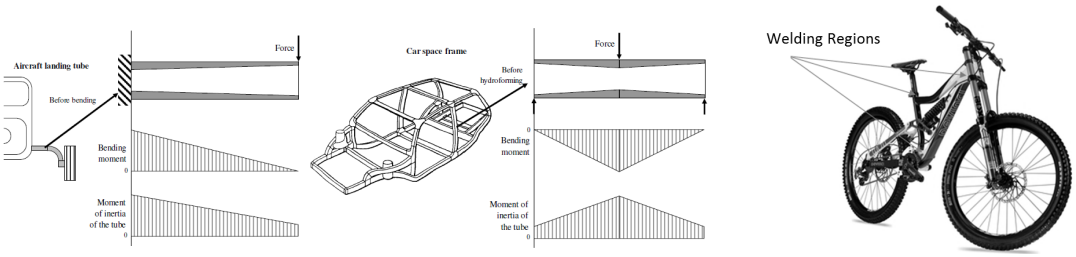


Fig. 1) Application of variable thickness tubes [1]

Manufacturing necessity for variable thickness tubes

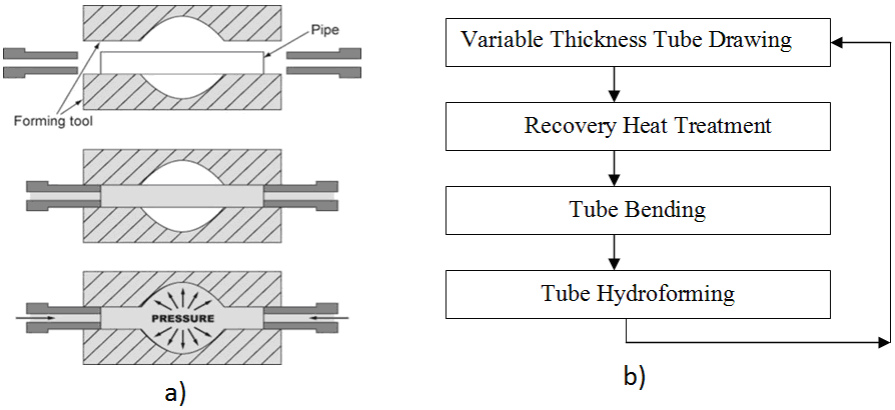


Fig.2. a) Schematics of the THF process [4] b) THF process and preceding processes.

As it is presented schematically in Fig. 2a, in tube hydroforming (THF) process a tube was put in the die cavity and with the application of pressure and axial feeding the tube will take the form of the die. Before development of variable thickness tubes technology, in tube hydroforming (THF) industry there were just three controlling parameters i.e. tube preform, internal pressure and axial feeding for faultless production of complex parts. However, in production of complex geometries, the axial feeding can not have sufficient effect in feeding the material into the zones with more inflation especially if this region is located after the bent region. Therefore in the regions with inflation it is necessary to have an initial tube with larger thickness for compensating the thickness

reduction by the inflation during the hydroforming. On the other hand, the change in the thickness of tube because of bending step can be compensated in the variable thickness tube drawing too. The diagram in Fig.2b shows that the possible optimization for the faultless production in THF should be started from variable thickness tube drawing not only in the hydroforming step.

Mechanism for production of variable thickness tube drawing

Fig. 3, presents the schematics of the methodology for production of variable thickness tube drawing method. In this method the conic mandrel has axial motion during the drawing operation and consequently the distance between the mandrel and die changes and gives variation of thickness to the tube in the axial direction.

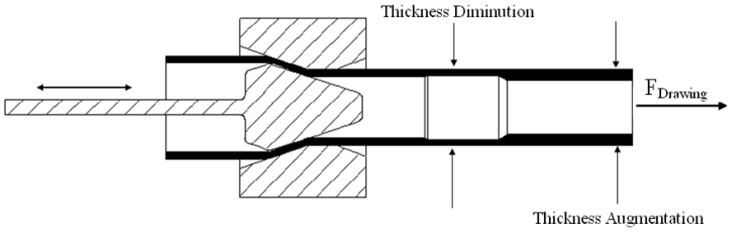
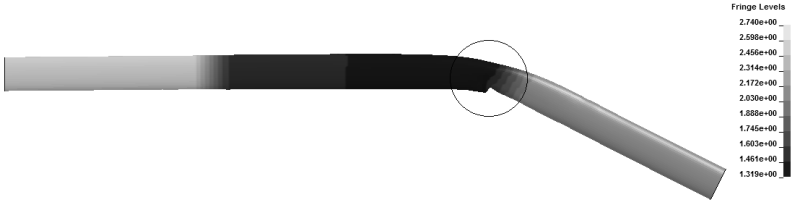


Fig. 3. Schematics of variable thickness tube drawing [3]

Bending of variable thickness tubes

While using the variable thickness tubes, the place of the bent region is very important and if it is located in the zone with both thick and thin zones, the tube will not be bent homogeneously and the geometry of tube will be like Fig. 4a. For solving this problem, the profile of the thickness distribution in the axial direction should be changed. The applied change, relocated the bent region from thick-thin to just thin region consequently the problem of bending of this kind of tubes was solved.



a)

b)

Fig. 4) a) Tube with problem in bending step b) Tube without problem

Experimental study

For production of variable thickness tubes, a prototype variable thickness tube drawing machine was designed and fabricated in REGAL research center in Laval University (Fig. 5a). The attached control system to mandrel made it possible to change the position of mandrel during the experiments. The initial experiments confirmed success of the idea of production of variable thickness tubes (Fig. 5b).

Fig. 5. a)Variable thickness tube drawing machine b) Variable thickness tube.

Conclusion

The variable thickness tube drawing and its applications in the production of complex tubes were concisely introduced. The application of this kind of tubes can have inevitable role in reducing overall weight of the future transportation devices like cars and bicycles. On the other hand, in the production step of complex tubes by THF method, application of these kinds of tubes guarantees reduction of risk of failure. However part designer should make special attention in appropriate selection of the thickness distribution along the tube to avoid the problems during the drawing and other performing steps like tube bending. It seems that with application of this kind of tubes, considerable facilities can be achieved in production of complex tubes.

Acknowledgements

The authors thank the Natural Sciences and Engineering Research Council of Canada, National Research Council Canada-Aluminium Technology Centre, Alfiniti, Aluminerie Alouette, C.R.O.I and Cycles Devinci for the financial support of this research. A part of the research presented in this paper was financed by the Fonds Québécois de la Recherche sur la Nature et les Technologies (FQRNT) by the intermediary of the Aluminium Research Centre – REGAL.

References

[1] M. Guillot, M. Fafard, S. Girard, G. D'Amours, A. Rahem, Experimental exploration of the aluminum tube drawing process for producing variable wall thickness components used in light structural applications, SAE World Congress, Detroit, USA (2010).
[2] C. Newport, S.T. McSwiggan, O.I. Savescu, M.L. Kenaga, Method of manufacturing structural components from tube blanks of variable wall thickness, US patent: US 20040200255A1.
[3] R. Bihamta, Q. H. Bui, M. Guillot, G. D'Amours, A. Rahem, M. Fafard, A new method for production of variable thickness aluminium tubes: numerical and experimental studies, Journal of Materials Processing Technology DOI10.1016/j.jmatprotec.2010.11.012.
[4] www.designlight.se