Cold End Forming Of Welded Steel Tubes

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ABSTRACT

The production of custom and specific tube end shapes by cold end forming using a die is generally limited to seamless tubular parts. Current research work in the field follows the same trend as that of industry and, therefore, there is no accumulated experience, no practical design rules, and no information available in the specialized literature concerning the utilization of tube end forming for shaping the end of thin-walled welded tubes. This paper is concerned with the lack of knowledge and is a contribution towards the understanding of the mechanics of deformation of tube end forming applied to welded tubes. The presentation addresses the influence of major operating parameters on the formability limits of the process with the purpose of understanding feasibility and establishing design rules for the benefit of those who design tubular parts in daily practice. The authors effectively contribute to transferable technological knowledge opening new market opportunities that stimulate innovations among carbon and stainless steel tubular products.

Keywords: Design Rules, Experimentation, Finite Element Method, Tube End Forming, Welded Thin-Walled Tubes

INTRODUCTION

Tube end forming processes are commonly utilized for producing of a wide variety of shapes and profiles such as inversions, flares, expansions, reductions, beads and noses by means of single or multiple forming operations (Figure 1).

The historical review of research on tube end forming can be organized in three different periods. The first period (1960-1990) draws from pioneer studies on axial loading (Alexander, 1960; Allan, 1968) to the external and internal inversion (Guist & Marble, 1966; Al-Hassani et al., 1972; Al-Qureshi & Morais, 1976; Reddy, 1989). In this period most attention was given to the identification of the main operative parameters, development of theoretical models to explain the mechanics of the processes (Avitzur, 1980) and correlation between theory and experimentation (Kinkead, 1983).

The second period (1990-2000) kept research focus on tube inversion and refined existing knowledge on the mechanics of deformation. The investigation on forming load and formability limits by means of analytical meth-
ods (Reddy, 1992; Tomesani, 1997; El-Domiaty, 1997) was progressively replaced by numerical simulation based on the finite element method (Yang, 1995) in an effort to better understand the typical modes of deformation. In contrast to tube inversion, published research work in other tube end forming processes during this period, was practically inexistent. At the end of the second period basic design rules were mainly derived from the accumulated experience of both manufacturers of tubular parts and suppliers of machine tools (Miller, 2003).

The third period (2000-until now) has been the most active in research and is being driven by the objective of consolidating existing knowledge and extending research for other tube end forming processes and materials. Recent published work provides a better insight into the deformation mechanics and formability limits of tube end forming (Yang, 2001; Sun & Yang, 2002; Sekhon et al., 2003; Rosa et al., 2003; Rosa et al., 2004) and extends investigation to nosing (Lu, 2005), reduction, expansion and flaring (Almeida et al., 2006) and compression beading (Gouveia et al., 2006). The utilization of tubes other than seamless metal tubes was only recently accomplished by Alves and Martins (2009a, 2009b) who successfully shaped the end of thin-walled polymer tubes.

From an industrial point of view there is a contribution to knowledge need to be given on the feasibility of applying conventional tube end forming processes to welded tubes made from carbon and stainless steel. This is important because the prospect of extending the actual offer of custom and specific end shapes to welded tubes will open new market opportunities and stimulate innovations among tubular based products. Under these circumstances, the main objective of this paper is to present recent developments in the experimental and numerical modelling of tube end forming applied to carbon and stainless steel welded thin-walled tubes.

Figure 1. Tube end forming processes; a) Expansion, b) Reduction, c) Internal inversion, d) External inversion, e) Nosing, f) Compression beading and g) Flaring
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