Integration of finite element analysis and design of experiments to analyse the geometrical factors in bi-layered tube hydroforming

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1. Introduction

Tube hydroforming is one of the unconventional metal forming processes which is widely used to form complex shapes. Tubes are formed into the desired shapes using internal pressure usually obtained by various means using hydraulics, viscous media, elastomers, polyurethane, etc. and axial compressive loads simultaneously to force a tubular blank to conform to the shape of a given die cavity. Compared with conventional metal forming processes, tube hydroforming has the merits of a reduction in work piece cost, tool cost and product weight. Furthermore, it can improve structural stability and increase strength and stiffness of the formed parts. THF also offers many other advantages including fine thickness distribution, the requirement for fewer secondary operations and suitability for complex geometries.

The main application of this method has been found in manufacturing of reflectors, household appliances as well as components in the hygiene, aerospace, automotive and aircraft industries [1,2]. Examples of the use of hydroforming in the automotive industry include exhaust parts, camshafts, radiator frames, front and rear axles, engine cradles, crankshafts, seat frames, body parts and space frame.

When complex working environments mean that copper alloys on their own cannot provide a heat exchange solution it may be possible to use bimetallic tubing [2]. Combined tubes can be produced with copper alloy, aluminium, titanium, carbon or stainless steel combinations. Indeed bimetallic tubing gives combined properties of heat exchange, strength and corrosion resistance that single tubes cannot provide. Industrial applications are found in compressed air supply lines, ship building and aerospace industries. Bi-layered systems are also suitable for chemical use in special environments (sea floor piping). Another important application is the bimetallic corrosion-resistant-alloy (CRA)-lined pipe [3], which has a liner pipe made of CRA and an outer pipe made of low-cost steel. CRA-lined pipes have been utilized in oil production, nuclear power plants and refining industry increasingly. However, bimetals are widely used in many fields as radiators, reservoirs, bearing and gaskets for motor heads in automobile industry [4].

Through the last decades, it has been discovered that it is expensive and time consuming to design for hydroforming processes as well as conventional forming processes using trial and error. The application of numerical simulation for the hydroforming process helped engineers to efficiently improve the process development avoiding the cost and limitations of compiling a database of real world parts. Finite element analysis allows an inexpensive study of arbitrary combinations of input parameters including design parameters and process conditions to be investigated. Explicit finite element codes were proved to have much better capabilities to handle such kind of nonlinear behaviour exhibited by the metal forming process and provide a better understanding of the plastic deformation mechanism over implicit finite element analysis [5].