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Cold hydraulic expansion of oil well tubulars

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ABSTRACT

The cold hydraulic expansion of two concentric tubulars is analysed with emphasis on the applications to oil and gas casings. Theories of elasticity and plasticity are used to develop a model relating the hydraulic pressure, the geometric dimensions of the tubulars and the residual contact pressure between the pipes. Nonlinear finite element analysis is used to validate the theoretical results and to investigate the effects of end support conditions. Hydraulic expansion experiments are conducted on tubulars and the measured evolution of the deformation and residual contact pressure are compared with the corresponding theoretical predictions and finite element solutions. There is a good agreement between the experimental results and predictions from the theoretical analysis and numerical simulations. The implications of the results for the design of casing hangers and patch repairs of oil and gas tubulars are discussed.

1. Introduction

The cold expansion of tubes has been used for many decades in the assembly and leak repair of heat exchangers in power generation, nuclear and process industries, see for example Middlebrooks et al. [1] and Allam et al. [2]. In the assembly of many shell and tube heat exchangers, holes are drilled in the tube-sheet and a tube is placed in each of the holes. The tube is then plastically expanded onto the tube-sheet using either mechanical rolling method or hydraulic pressure. The interference fit that develops between the tube and the tube-sheet upon unloading must provide a leak-proof joint between them. A similar expansion method is also used in the process industry to repair badly corroded tubes in heat exchangers. Here a new thin-walled tube (sometimes referred to as a sleeve) is inserted inside the existing tube bridging across the degraded section. The new tube is then cold expanded onto the existing tube, thereby eliminating the leak path. In these applications, the expansion is usually carried out over a relatively short length of the tube (between 25 mm and 50 mm) with the primary aim of providing a good leak-proof joint. The post-expansion structural and mechanical response is usually not a major concern since the joint is not load bearing in service.

The use of cold expanded tubulars in the oil and gas industry started just over a decade ago, driven mainly by the need to reduce drilling and completion costs and to explore deeper hydrocarbon reserves [3]. Recent applications of expandable technology in the industry include the cold expansion of production tubing, expandable sand screens, cladding or patching systems, expandable liner hangers and multilateral junctions; some of these applications are illustrated in Fig. 1.

In contrast to the application to heat exchangers, the cold expansion of tubulars in the oil and gas industry is subject to many technical and operational challenges. The expansion is carried out *in-situ* downhole in an oil or gas well at a depth of several thousands metres, and the level of expansion can be up to 30% with an expanded length of pipe of up to 600 m (or more). In addition, the expanded tubular must withstand the downhole loading and environmental conditions, e.g. pressure of up to 150 MPa, temperature of up to 200 °C and the presence of a potentially corrosive environment. Consequently, the design of the deployment tools and the assessment of the post-expansion behaviour are technically more challenging. There is therefore an urgent need for detailed understanding of the inter-relationship between the expansion method, material selection, geometric parameters, and post-expansion mechanical response and corrosion characteristics of cold expanded tubulars before the technology can be fully accepted in the high costs and high risk environment as found in the oil and gas industry.

Some of these relationships are beginning to emerge, and recent efforts have focused on the development of expansion tools and means of downhole deployment. Three different methods currently exist for performing the expansion *in-situ* in an oil or gas well.

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