Local Buckling Strength and Deformation Capacity of Pipes

A.M. (Nol) Gresnigt
Delft University of Technology, Civil Engineering and Geotechnical Sciences
The Netherlands

S.A. (Spyros) Karamanos
University of Thessaly, Department of Mechanical Engineering
Volos, Greece

ABSTRACT

Local buckling in cylindrical shells may occur elastically or plastically, mainly depending on the diameter to wall thickness ratio. In offshore structures plastic local buckling is mostly the governing criterion. In thin walled shells such as silos and tanks, local buckling may occur at stresses below the yield stress (elastic buckling). In this paper, the focus is on local buckling limits in both elastic and plastic local buckling. A survey of available test results and differences in various design standards is given. Reasons for the scatter found in experiments are identified. There is a need for more harmonization in design standards, focusing on the practical needs for each application.

KEY WORDS: local buckling, Eurocode 3, EN1993-1-6, shell, pipe, pipeline.

INTRODUCTION

Tubes in structural applications not only need sufficient strength, but also sufficient deformation capacity to allow for redistribution of stresses and loads. Such redistribution is important because in structural applications such as trusses and frames, the stresses are not only the result of the design loads, but often are also caused by loads that are usually not taken into account in the design. Examples are temperature differences, uneven settlements of supports and stresses due to welding.

Also the type of analysis has an influence on the requirements for the deformation capacity. Plastic design methods are based on the possibility of local plastic deformations to obtain an optimal distribution of forces in the structure (normal forces, bending moments and shear forces).

To obtain optimal stiffness and strength in bending and in axial compression (column buckling), the diameter to wall thickness ratio (D/t) is chosen as high as possible. The limiting factor is local buckling and the limitations in load carrying capacity and deformation capacity that comes with local buckling. The higher the D/t ratio is chosen, the lower the strain at which local buckling will occur. In other words, the lower the deformation capacity is.

In this paper, the focus is on local buckling limits after yielding of a part of the cross section (plastic buckling). This is in contrast to thin cylindrical shells where local buckling usually occurs at stresses below the yield stress (elastic buckling). In structural design for trusses and frames, the D/t ratio usually is less than 120.

Attention is paid to the research that is carried out into local buckling in tubes loaded in bending and normal force. The factors that are responsible for the large scatter in the critical strain are discussed. An overview is given of the design rules in various standards for structures such as the Eurocode 3 (EN 1993) and other standards.

It appears that the various standards show different types of analysis, different design strength (resistance) and deformation capacity. Obviously, there is a need to harmonize and develop design rules which take into account the various influences on the structural behaviour, in particular the bending moment capacity, the normal force capacity and the local buckling behaviour. Also the design rules should take account of the differences in safety requirements in various applications.

Summary on research into bending behaviour of cylinders

In elongated cylinders, loading is a combination of bending moment and axial force (tensile or compressive). Under this combined loading situation, the tubular member may buckle when stressed or strained above a certain level. This instability is crucial for the structural integrity of the cylinder, resulting in failure and collapse. This may be in the form of global buckling (Euler-type instability) when significant axial loading is applied or local buckling due to bending and/or axial compression, at the compressive side of the cylinder wall.

The present paper focuses on the second form of instability, i.e. local buckling instability. In particular, it is aimed at reliable buckling limits for the safe design of cylinders within the design framework for structural Eurocodes.

When subjected to bending, the cylinder cross-section distorts in an oval shape. This ovalisation phenomenon has been first studied by