Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Advanced methods for the strain limit assessment in pipeline applications subjected to extreme loading

Tommaso Coppola, Giuseppe Demofonti
Centro Sviluppo Materiali S.p.A., Rome, Italy

ABSTRACT

Pipelines for offshore and onshore application may be subjected to severe plastic deformations, eventually reaching the post-necking regime, due to both installation procedures or accidental external overloads. In these cases two main problems have to be solved in the strain limits assessment: the prediction of the stress-strain curve extended beyond the necking point and the determination of the stress state influence on the ductile fracture limit. Several procedures and theories have been proposed in literature to treat the two above aspects. In the present work a review of the main techniques and fundamental theories applicable are presented. A new approach is proposed for the prediction of the ductile fracture strain under complex stress states. A procedure for the identification of the material pressure and Lode angle sensitivity is also proposed, with an example of yielding criterion identification.

KEY WORDS: Damage; Triaxiality; Lode angle; Ductile fracture

INTRODUCTION

Pipelines for offshore and onshore application may be subjected to severe plastic deformations due to both installation procedures (barge deployment, casing expansion, pipeline repair) or accidental external overloads (large displacements due to landslide, earthquake, external damage due to impacts).

In such cases large plastic strains are involved which may reach the post necking regime, the ductile fracture limit prediction becoming so the main issue in assessing the material straining capacity. Due to the elevated plastic strain values, two main problems have to be solved in the strain limits assessment: the prediction of the stress-strain curve extended beyond the necking point and the determination of the stress state influence on the ductile fracture limit. In this latter case in fact it is known that the fracture strain may be strongly sensitive to the stress state and in particular to the stress tensor invariants.

Several procedures and theories have been proposed in literature to treat the two above aspects. In the present work a review of the main techniques and fundamental theories are presented.

As far as the stress-strain curve prediction, the conventional power law extrapolation is compared with two relatively recent approaches: the inverse calibration method by means of finite element calculation and the Digital Image Correlation (DIC).

As far as the ductile fracture strain prediction, the conventional theories based on the stress triaxiality parameter dependence are discussed and compared with some very recent approaches based on the influence of the so called deviatoric parameter, a stress parameter related to the Lode angle or, equivalently, to the third stress tensor deviator invariant.

EXTENDED STRESS-STRAIN CURVE DETERMINATION

The conventional tensile test on specimen is used to obtain the basic information on the material behavior: the yield strenght, the maximum strenght (UTS), the elongation at fracture and the reduction of area after fracture. An instrumented test is performed by continuously acquiring the load and the elongation on a gauge length (by an extensometer). It is so possible to reconstruct the true stress-true strain curve from yielding up to UTS directly from the measurement. The procedure is valid until the geometrical instability, or necking, develops. The subsequent strain concentration is no more measurable and the after necking curve is usually extrapolated from the before necking measured one. The extrapolation is made on the basis of conventional formula, like the power law (Hollomon's relation) or the exponential (Voce relation). The real material behaviour