DYNAMIC ARREST OF PROPAGATING BUCKLES IN OFFSHORE PIPELINES

Theodoro A. Netto*, Stelios Kyriakides**
*Universidade Federal do Rio de Janeiro, Prog. de Engenharia Oceânica, Caixa Postal 68508, Rio de Janeiro RJ 21945-970, Brazil
**Center for Mechanics of Solids, Structures & Materials, The University of Texas at Austin, WRW 110 Austin, TX 78712, USA

Summary Buckle arrestors are devices which locally strengthen an offshore pipeline and safeguard it against the catastrophic effects of a potential propagating buckle. They are usually designed based on quasi-static experiments and analyses. This paper discusses how such devices perform under the more realistic dynamic propagation conditions encountered in the sea. It will be shown that dynamics enhance the arresting performance of all arrestors considered.

Offshore pipelines are susceptible to local damage and collapse. Because of the ambient external pressure, such a weakened section can initiate propagation of collapse up and down the line. Buckle propagation usually occurs at high velocity and can quickly catastrophically collapse large sections of the pipeline. An effective way to ensure that collapse, should it occur, affects only a small length of the pipeline, is the periodic placement of buckle arrestors along the line. Buckle arrestors are devices which locally increase the circumferential bending rigidity of the pipe and thus provide an obstacle in the path of a propagating buckle. They are usually thick-walled rings that are grouted onto the pipe (*slip-on* arrestors), welded between two sections of pipe (*integral* arrestors) or slip-fit into the outer pipe in pipe-in-pipe systems (*internal ring* arrestors). The design of such devices has been traditionally based on quasi-static buckle propagation and arrest experiments and analyses, primarily because dynamic experiments are much more difficult and costly to conduct.

The effectiveness of each of these three types of arrestors has been studied first under quasi-static and subsequently under dynamic buckle propagation conditions using combinations of experiments and analyses. In all cases, inertial effects were found to enhance the arrestor performance; in other words, the pressure at which a given arrestor is crossed dynamically is higher than the quasi-static crossover pressure. This presentation will outline the reasons for this dynamic enhancement in performance for each arrestor.

An extensive parametric study of the quasi-static arresting efficiency has been conducted experimentally for each of the arrestors. Each process was also modeled numerically using large scale FE models. The experimental crossover pressure values enriched with numerical ones were used to develop empirical design formulae (e.g., [1,2]). Arrestors designed in accordance with these quasi-static criteria were then tested under the more realistic dynamic buckle propagation conditions. This was achieved by initiating a buckle in a pipe with an arrestor under (nearly) constant pressure conditions. The buckle then propagates and engages the arrestor at velocities ranging from 60-300 m/s. For all arrestors considered, the dynamic crossover pressure was found to exceed the corresponding quasi-static value.

To better understand the reasons behind the dynamic enhancement in the performance of buckle arrestors, the dynamic initiation, propagation and crossing/arrest of buckles were simulated with FEs for both single pipe and pipe-in-pipe systems. The models account for the inertia of the pipe and the nonlinearity introduced by contact between its collapsing walls, while the material is modeled as a finitely deforming elastic-viscoplastic solid (a sequence of deformed configurations from a propagating buckle engaging and crossing an internal ring arrestor in pipe-in-pipe system is shown in Fig. 1). The simulations confirmed the dynamic enhancement of arrestor performance seen in the experiments. They also provided details of the engagement of a running buckle with the arrestor [3-5]. For example, the profile of dynamic buckles is considerably sharper than the quasi-static profile. This produces a zone of reverse ovality downstream of the buckle [6]. In the case of integral and internal ring arrestors, reverse ovality interacts with the arrestor and the pipe downstream of it, and increases its local collapse pressure and, as a consequence, the crossover pressure. For the slip-on arrestor, the prevalent mode of crossover is penetration of the ring by the pipe folding up into a U-shape as shown in Fig. 2a [1]. A running buckle engages the arrestor with a doubly symmetric dogbone-like cross section and penetrates it to some degree as shown in Fig. 2b. It thus takes a higher pressure to switch it to the singly symmetric U-mode than in the quasi-static case where no symmetric mode penetration of the arrestor takes place [7].

References

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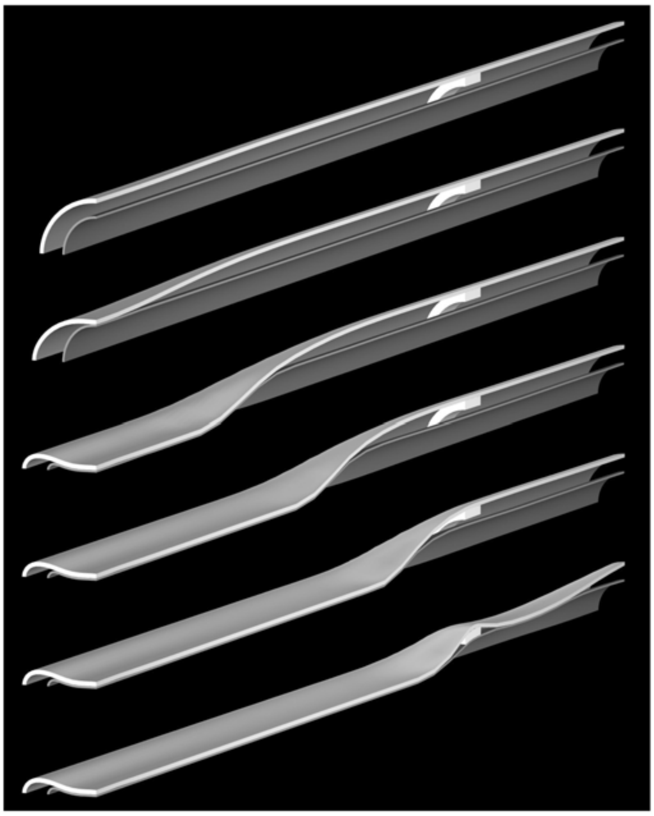

Fig. 1 Sequence of calculated pipe-in-pipe deformed configurations showing dynamic buckle propagation and crossing of internal ring arrestor

(a)

(b)

Fig. 2 Slip-on arrestor crossover modes. (a) Quasi-static case (b) dynamic case