MECHANICAL DAMAGE

Definition

In the context of this study, mechanical damage is defined as 'Localized damage resulting from contact between the pipe and an object'.

Localized means confined to some portion of the cross section or having limited extent along the pipe itself (typically less that five pipe diameters).

Damage means any of a variety of changes to the pipe, its coating, or a related pipeline component that may degrade or reduce serviceability (ability to function as intended), including but not limited to

- Change of pipe shape
- Change in axial alignment
- Change of pipe material properties
- Change to the local distribution of stresses strains, and/or local loading
- The introduction of other anomalies or defects.

(damage features, activities and objects causing damage are described in more detail below)

Contact results in a load or stress experienced by the pipe, its coating, or a related component and not normally considered during the design of the pipeline. Such loads and stresses can be of short or long duration.

Damage Features.

Change in Shape

Cross-sectional changes, such as ovalization, flattening*, buckling, wrinkling, or denting of the normal cross section of the pipe, and wall thinning due to the associated radial and/or axial extension. Cross sectional changes could be a direct result of the loading (e.g., a dent) or a secondary effect (ovalization due to bending along the pipe).

Change in Axial Alignment

Introduction of a sharp change in alignment due to enforced movement perpendicular to the pipeline route. Onshore pipe movement may result, for example, from hooking and dragging by an excavator bucket. Offshore pipe movement includes movement due to snagging or pulling by, for example, an anchor or fishing gear.

* There may be forms of more widespread ovalization or flattening that would not be considered within this definition of mechanical damage.
Change in Material Properties

These include changes in yield strength, ductility, toughness, magnetic properties, etc. in the pipe steel. Steel property changes include the effects of cold working and other changes to the microstructure due to rapid heating/cooling.

Also included are changes in adhesion, puncture resistance, flexibility, etc. for the coating. Coating property changes may include the effects of heating or changes in chemistry resulting from damage (e.g., “drying out” of a coating).

Change in Local Distributions of Stress and Strain, and/or Local Loading

These include residual stress and strain fields in the damaged region, secondary loadings (e.g., bending loads in a dent due to hoop stresses). They also include stress concentrations due to the shape of dents and local anomalies or defects (see also below).

Large-scale changes in axial forces and bending moments due to, for example, landslide, thaw settlement, frost heave, changes in overburden or lack of support due to wash out, are not considered within this definition of mechanical damage.

The Introduction of Other Anomalies or Defects

Anomalies and defects include localized shape changes, such as metal movement and removal, thinning, ploughing, gouging, scratching, deformation, or perforation of the pipe and its coating, or a related component. In the pipe steel, localized shape changes typically result in a stress concentration.

Anomalies and defects also include surface and subsurface cracking, and the development of voids or micro-voids. Cracking could result from the damage process itself (e.g., during sliding contact and heavy deformation of the surface, or as the pipe re-rounds when the indenter is removed) or subsequently as a result of continued operation of the pipeline (e.g. stable crack growth, fatigue, SCC).

Anomalies or defects may extend through the pipe wall. Defects may be comparatively small and circular, for example those caused by an excavator tooth or drilling equipment. Alternatively, defects may extend axially or circumferentially, up to or beyond the extent of the localized damage.

Damage Categories

Damage has often been categorized according to the predominant features present, for example as follows:

Plain (or smooth) dent: A dent with a simple geometric shape, which no other associated anomalies or defects

Kinked dent: A dent with a sharply-changing profile (locally low radius of curvature), but no other associated anomalies or defects

Dent with secondary features: A dent with associated cracking (due directly to the damage, or developing subsequently by fatigue or
stress corrosion cracking), or a dent associated with corrosion, or a dent associated with a girth or seam weld

Constrained dent: A dent that is prevented from re-rounding by the continued presence of the indenter (e.g., a rock dent)

Unconstrained dent: A dent where the indenter has been removed and re-rounding can take place (due to internal pressure or due to removal of surrounding soil)

Gouge: Metal removal, with little or no associated denting

Combined dent/gouge: A combination of a plain dent with a gouge

Pinhole: A small circular through-wall hole (specified dimensions vary)

Leak: A through-wall defect (crack or tear) that does not extend significantly beyond the region of localized deformation

Rupture: A through-wall defect (crack or tear) that extends substantially beyond the region of localized damage

Immediate failure: Through-wall defects that occur at the time of contact or very soon thereafter

Delayed failure: Mechanical damage that is initially non-penetrating, but subsequently becomes a through-wall defect (typically two weeks to ten years after the damage event)

However, as can be seen from the damage features described above, it is often difficult to use these categories in a precise way and they should be considered as descriptive rather than specific

**Activities and Objects associated with Mechanical Damage**

Mechanical damage may occur during the manufacture, transportation, on-site handling and laying of pipelines. Usually such damage is found and remedied prior to service. However some damage, particularly that due to contact with rocks and buried objects during pipe-laying, may not be detected until the pipeline has seen service. Such damage is included within this definition of mechanical damage.

In general, mechanical damage occurs after the pipeline has commenced service, and results from activities in the pipeline right-of-way. Activities associated with mechanical damage occurrences typically include:

- Excavation, drilling, fencing
- Horizontal drilling and trenching
- Drainage, agricultural activity
Infrastructure engineering (building, road-making)

Pipe inspection by ILI devices (internal damage)

Fishing, anchorage, rock dumping, dropped objects (offshore)

Exposure to missiles and projectiles: rocks, shrapnel, bullets (exposed pipelines)

Unauthorized hot tapping and grinding

It can be seen from the above that mechanical damage may occur slowly (e.g., rocks) or quickly (e.g., excavation equipment); it may be accidentally or deliberately caused; and it may originate at the outside or the inside of the pipe.

It can also be seen that mechanical damage may result for example from the activities of pipeline operators or their sub-contractors, other utility operators, landowners, civil engineering contractors or the general public; these are often categorized as ‘first party’, ‘second party’ or ‘third party’ activities.

For clarification, it is pertinent to highlight activities and situations that are not considered to result in mechanical damage. These include:

- Authorized O&M activities; hot tapping, grinding to remove manufacturing defects or corrosion, etc
- Direct Assessment excavations during which the coating is removed
- Propagation of manufacturing and construction defects, stress corrosion cracking.