

# Oil and Gas Pipeline Design, Maintenance and Repair

Dr. Abdel-Alim Hashem El-Sayed  
Professor of Petroleum Engineering  
Mining, Petroleum & Metallurgical Eng. Dept.  
Faculty of Engineering – Cairo University

[aelsayed@mail.eng.cu.edu.eg](mailto:aelsayed@mail.eng.cu.edu.eg)

[ahshem2000@yahoo.com](mailto:ahshem2000@yahoo.com)

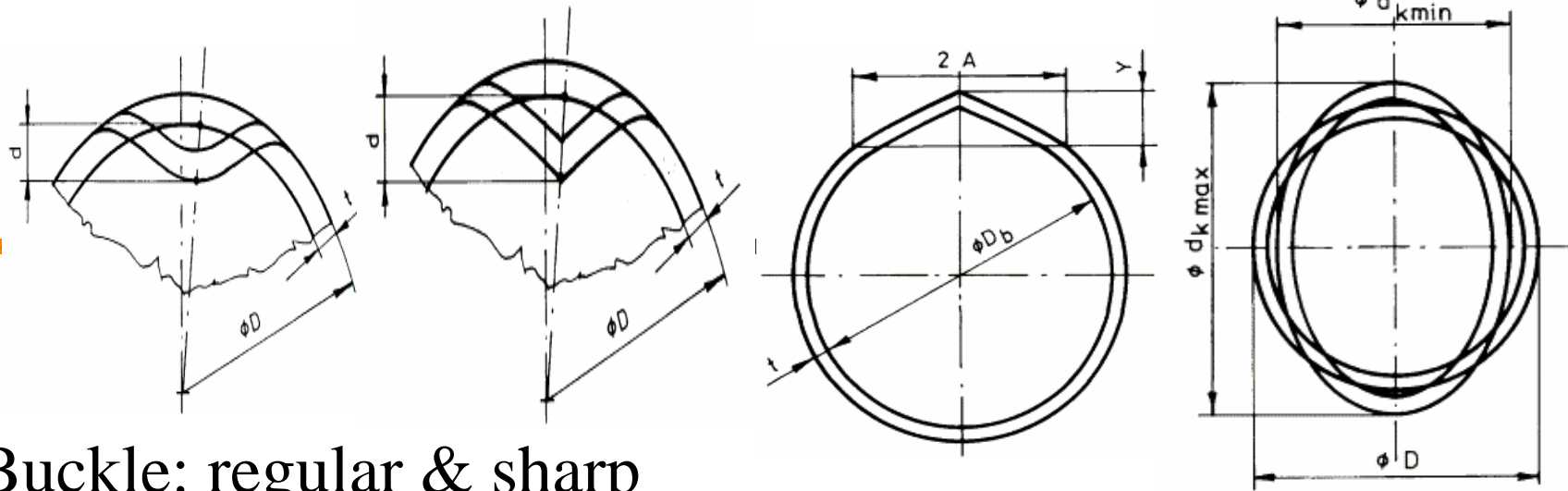
## Part 9: Pipe Defects

# Defect Types

Geometrical Defects	smaller change in wall thickness than the allowable wall thickness tolerance and result in stress accumulation and concentration.
Defects resulting in metal loss	greater change in wall thickness than the allowable wall thickness tolerance and result in stress concentration.
Planner discontinuities	two dimensions are significantly greater than the third one
Change in metal	do not cause change (or the change does not exceed the allowable limit) in dimension or shape of pipe geometry but they result in disadvantageous change in the material structure and by this way in material characteristics.

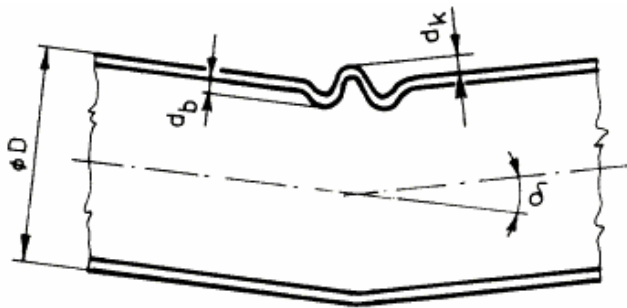
# Geometrical defects

- Buckle: regular buckle and sharp buckle
- Ovality
- Wrinkle
- Ruck
- Knob
- Rolling imperfection or angularity
- Tube expansion
- Joint imperfection: edge displacement & angle error

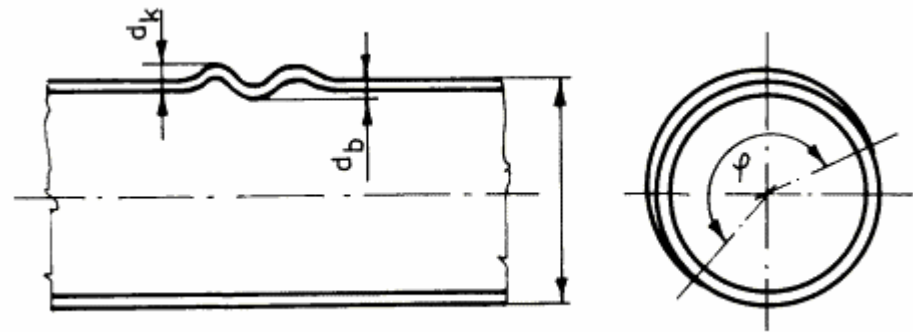


Buckle: regular & sharp

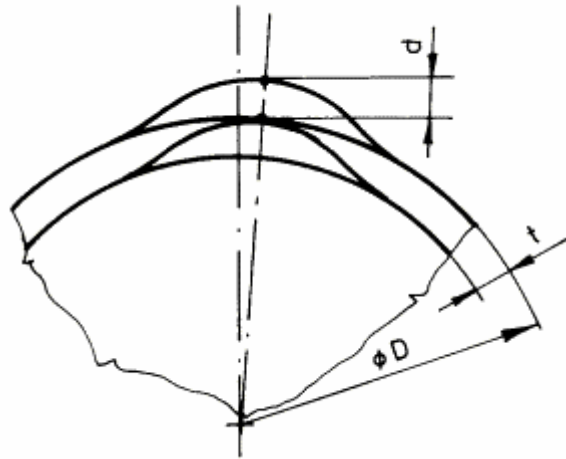
Rolling imperfection Ovality



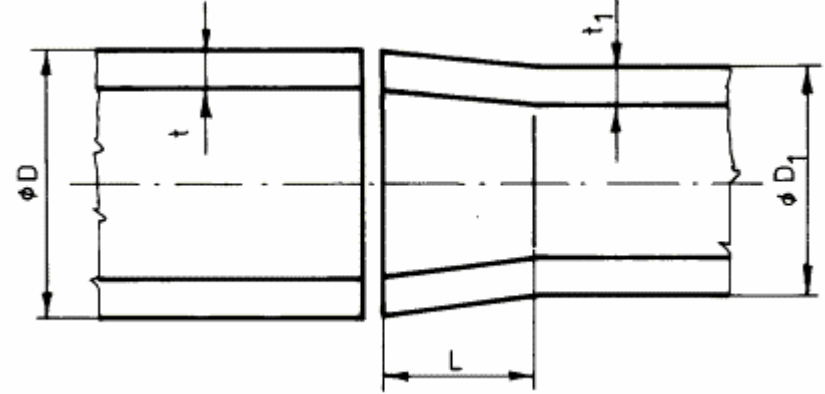
Wrinkle



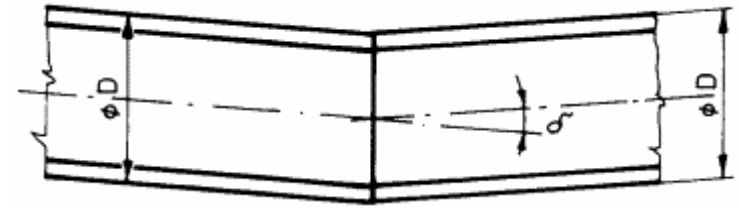
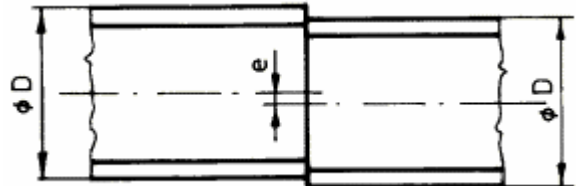
Ruck



knob



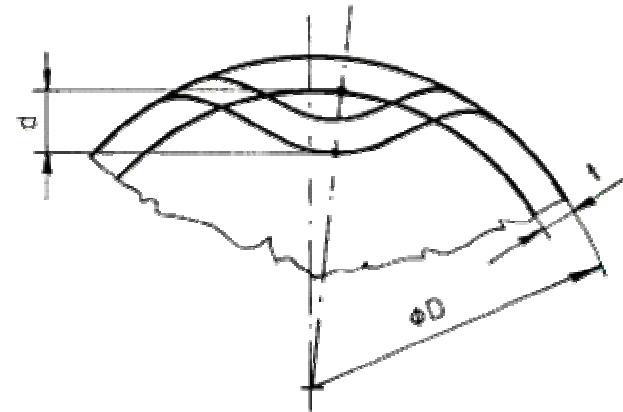
tube expansion



joint imperfection: edge displacement & angle error

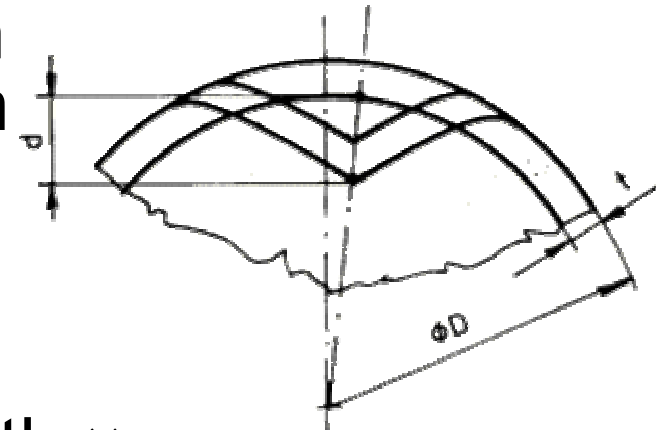
# Regular buckle

- **Definition:** residual deformation of the pipe wall inside the pipe without sharp edge extending over an area.
- **Measures:**
  - maximum depth,  $d$  [mm];
  - overall dimensions (axial length  $\times$  circumferential length),  $l \times k$  [mm  $\times$  mm].
- **Possible cause of origin:** external mechanical impact.



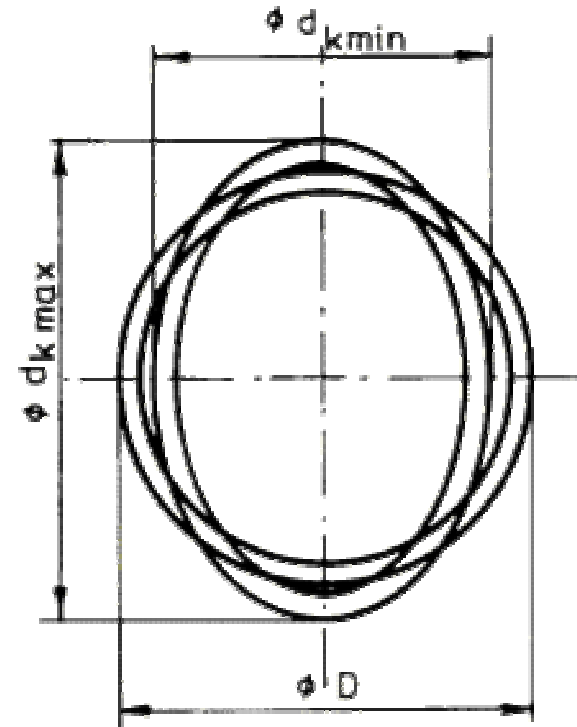
# Sharp buckle

- Definition: residual deformation of the pipe wall inside the pipe with sharp edge(s) extending over an area.
- Measures:
  - maximum depth,  $d$  [mm];
  - overall dimensions (axial length  $\times$  circumferential length),  $l \times k$  [mm  $\times$  mm].
- Possible cause of origin: external mechanical impact.



# Ovality

- Definition: nearly symmetric deviation of the pipe cross-section from the circular shape resulting in ellipse cross-section without sharp breakpoints.
- Measures:
  - minimum outside diameter,  $d_{kmin}$  [mm];
  - maximum outside diameter,  $d_{kmax}$  [mm].
- Possible cause of origin:
  - pipe manufacturing;
  - external mechanical impact.





# Wrinkle

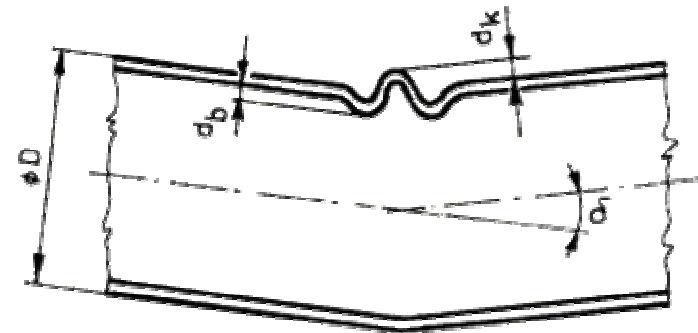
- **Measures:**

- maximum depth of the ripple,  $d_b$  [mm];
- maximum height of the ripple,  $d_k$  [mm];
- angle of curvature,  $d$  [°].

- **Possible cause of origin:**

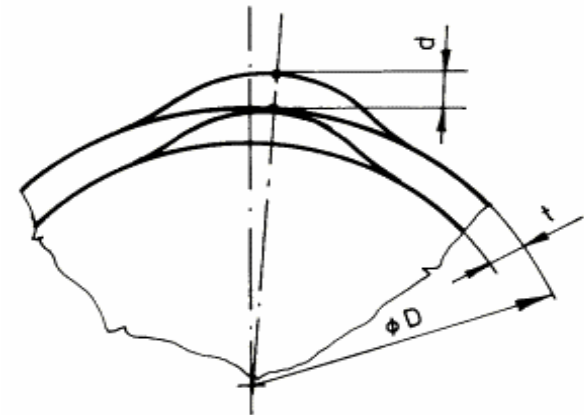
- external mechanical impact;
- soil movement.

- **Remark:** from the characteristics of the rippled side of the pipe (number and shape of ripples) the extent of deformation of the opposite side of the pipe can be concluded



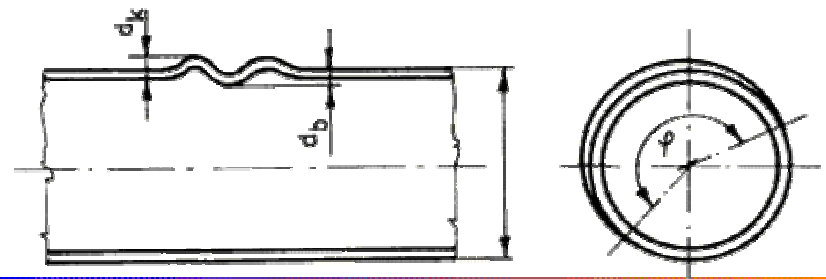
# Knob

- **Definition:** residual deformation of the pipe wall outside the pipe without sharp edge extending over an area.
- **Measures:** maximum height,  $d$  [mm]; overall dimensions (axial length  $\times$  circumferential length),  $l \times k$  [mm  $\times$  mm].
- **Possible cause of origin:** change in internal pressure interacting with another defect.
- **Remark:** the knob can be interpreted as the opposite of the regular buckle.



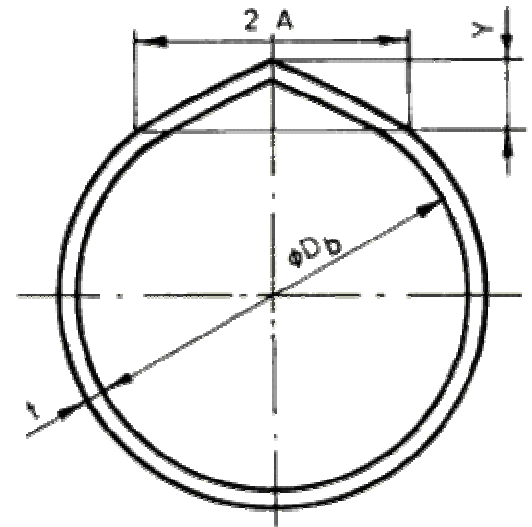
# Ruck

- **Definition:** the pipe wall is rippled along its circumference partly or entirely and the centre line of the pipe remains straight
- **Measures:**
  - maximum depth of the ripple,  $d_b$  [mm];
  - maximum height of the ripple,  $d_k$  [mm];
  - angle subtended by the ruck along the circumference of the pipe,  $j$  [°].
- **Possible cause of origin:**
  - pipe manufacturing;
  - soil movement.



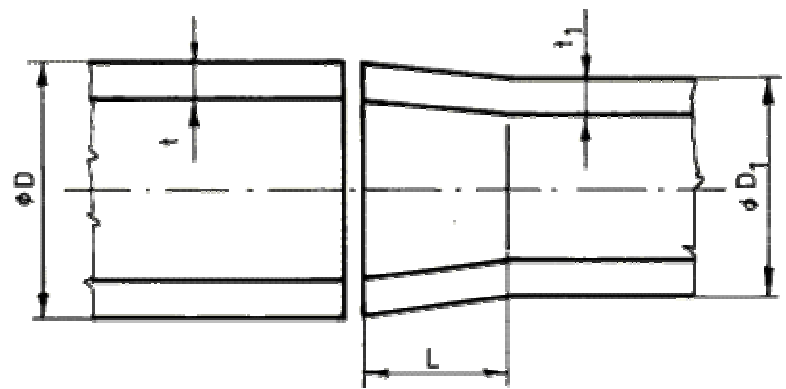
# Rolling imperfection or angularity

- **Definition:** during the pipe manufacturing in the vicinity of the plate edge to be joined by welding (seam) the shape of the pipe deviates from cylindrical forming a sharp edge.
- **Measures:**
  - height of the bevel edge,  $Y$  [mm];
  - chord of the bevel edge,  $2A$  [mm].
- **Possible cause of origin:** pipe manufacturing.



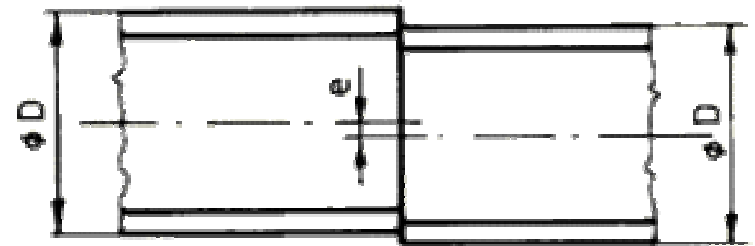
# Tube expansion

- Definition: elimination of diameter difference between the two pipe ends to be joined with welding (girth weld).
- Measures:
  - outside diameter of the pipe to be expanded,  $D_1$  [mm];
  - wall thickness of the pipe to be expanded,  $t_1$  [mm];
  - expansion length,  $L$  [mm].
- Possible cause of origin:
  - pipe installation (laying);
  - repair.



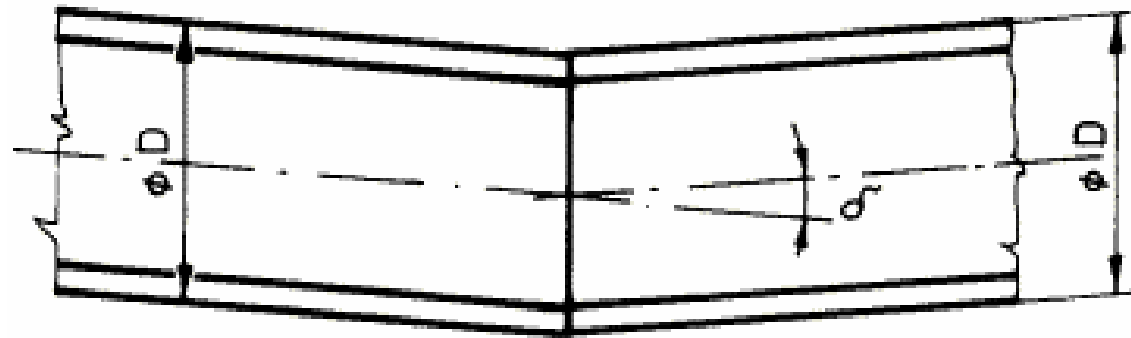
# Edge displacement

- **Definition:** radial displacement of parallel centre lines of pipe sections joined with welding (girth weld).
- **Measures:** eccentricity,  $e$  [mm].
- **Possible cause of origin:**
  - pipe installation (laying);
  - repair;
  - pipe manufacturing.



# Angle error

- **Definition:** deviation of centre lines of pipe sections joined with welding (girth weld).
- **Measures:** angle between the centre lines,  $\delta$  [ $^{\circ}$ ].
- **Possible cause of origin:** pipe installation (laying); repair; pipe manufacturing

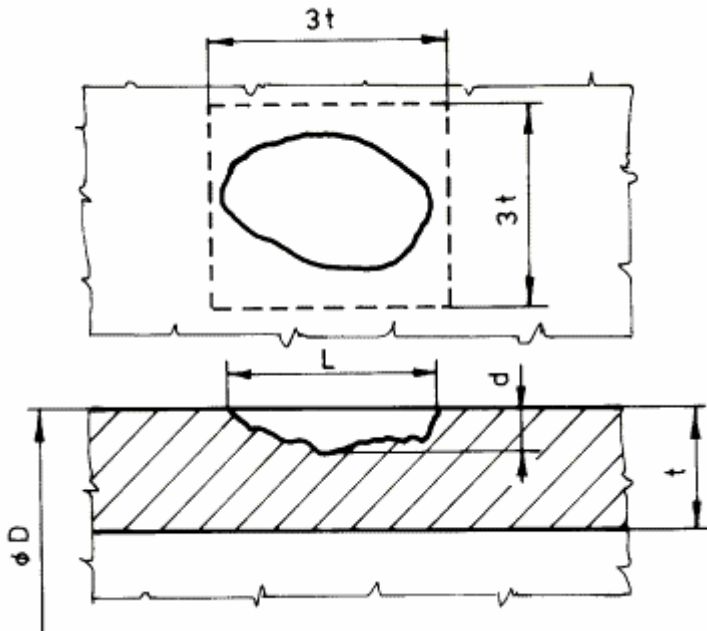


# Defects Resulting Metal Loss

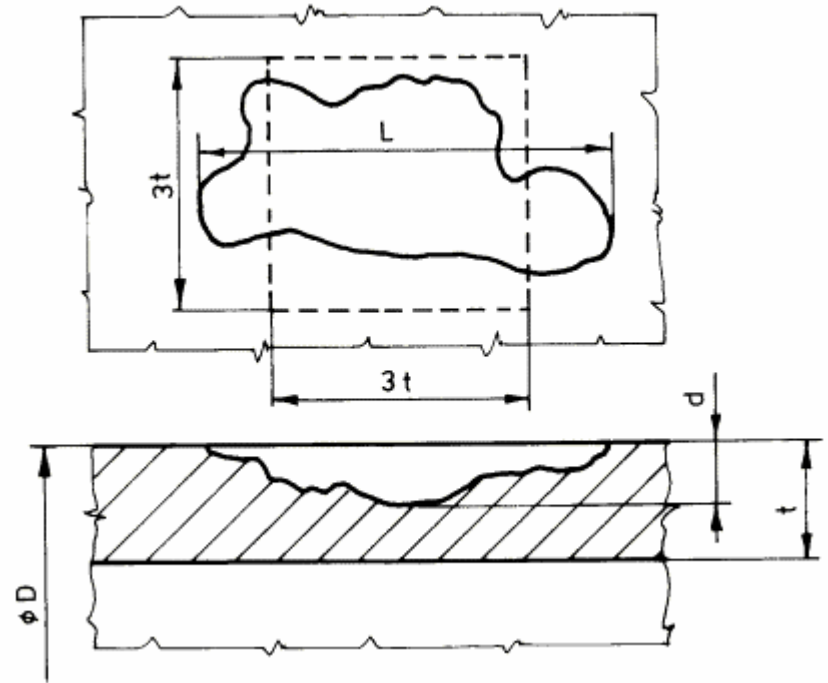
- Scar
  - Longitudinal scar
  - Circumferential scar
  - General location scar
  - Longitudinal corrosion
  - Circumferential corrosion
  - Spiral corrosion
- General corrosion
- Local corrosion
  - Pitting
  - General location local corrosion
- Abrasion
- Grinding off
- Rupture
- Puncture or leak



# Defects Resulting Metal Loss

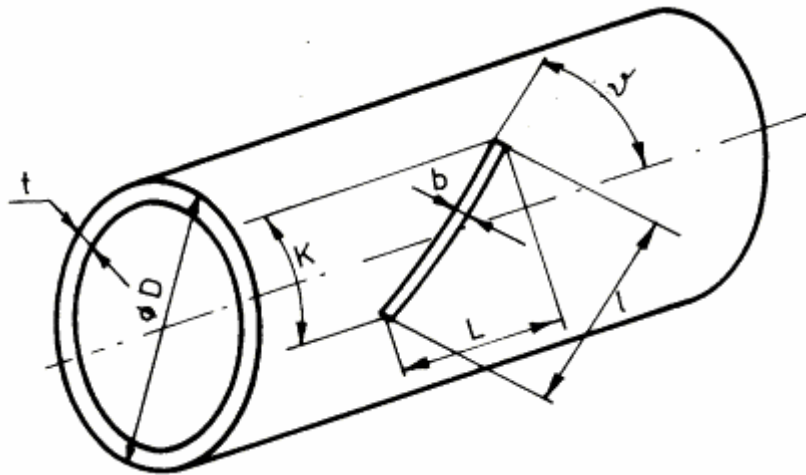


Pitting

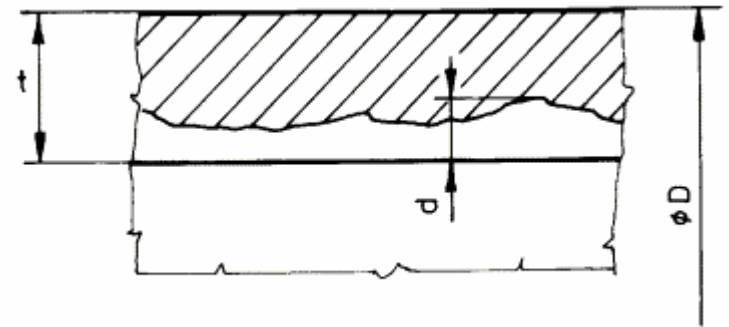


General location local corrosion

# Defects Resulting Metal Loss

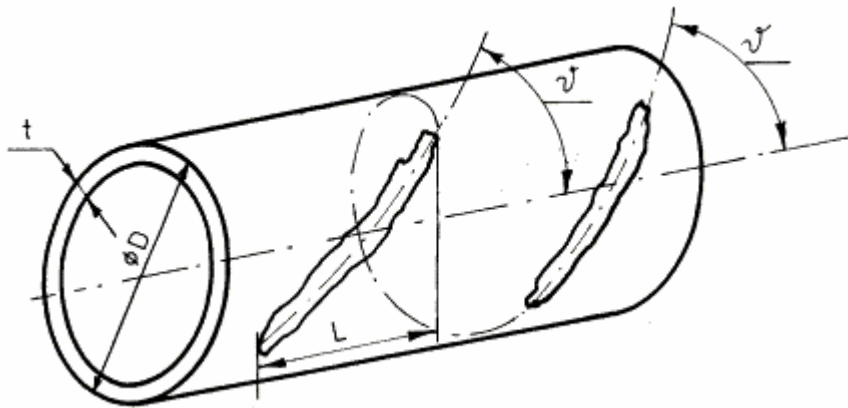


General location scar

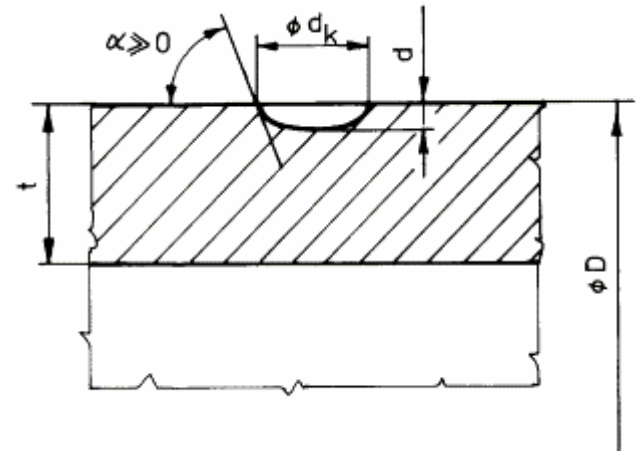


General corrosion

# Defects Resulting Metal Loss

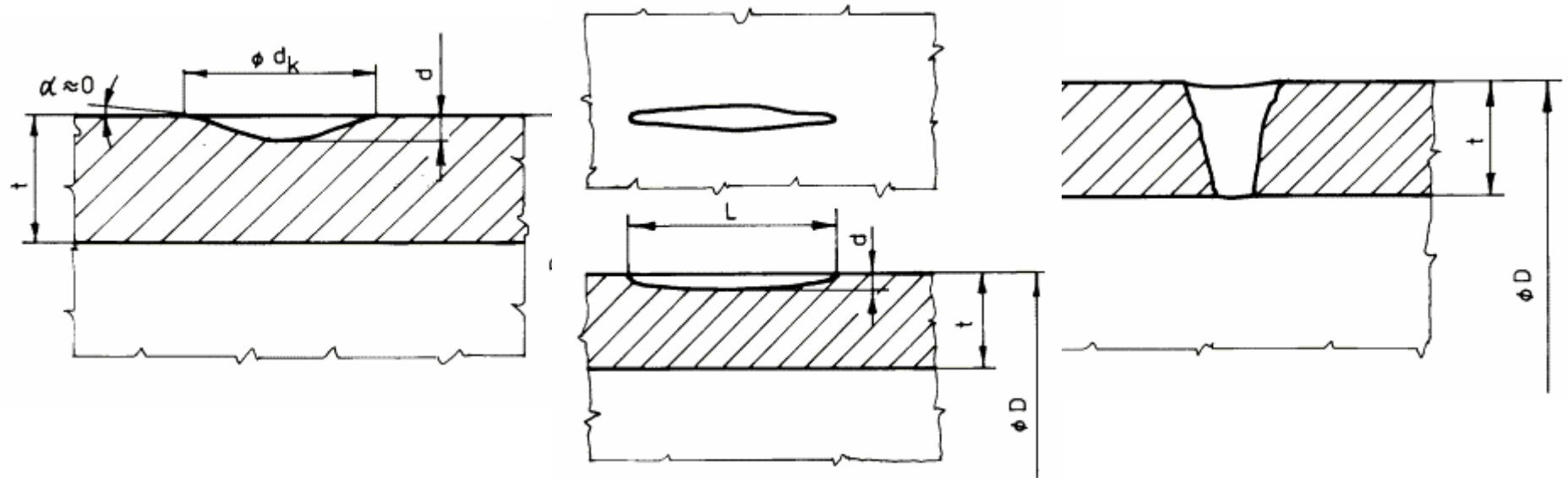


Spiral corrosion



Abrasion

# Defects Resulting Metal Loss



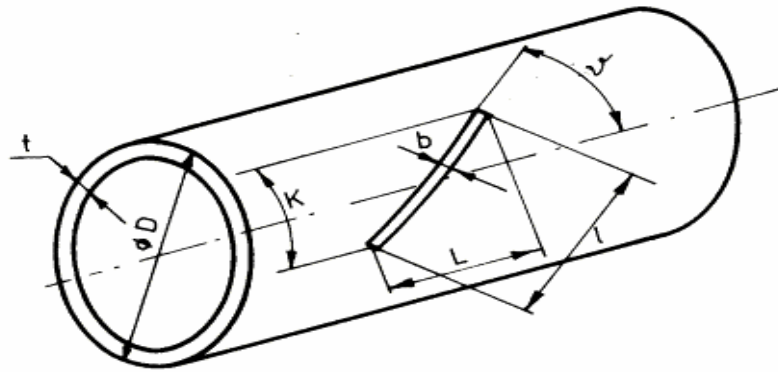
Grinding off

Rupture

Puncture or leak

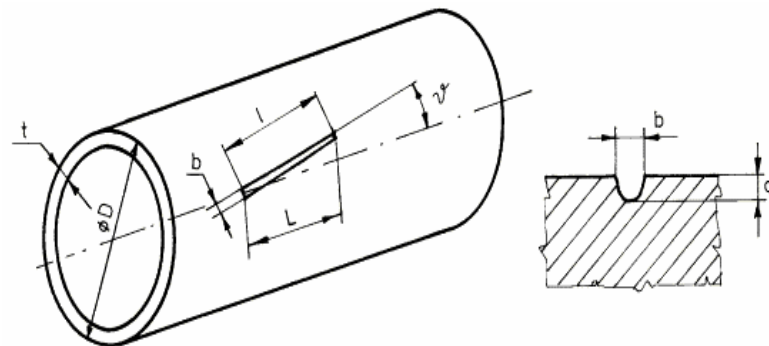
# General Location Scar

- **Definition:** groove like defect having greater projected length in both axial circumferential directions than the triple of the nominal wall thickness and having a width which is less than the 30% of the nominal wall thickness.
- **Measures:** angle between the defect and the centre line of the pipe,  $\psi$  [ $^{\circ}$ ]; length,  $l$  [mm]; projected circumferential length,  $K$  [mm]; maximum width,  $b$  [mm]; maximum or effective depth,  $d$  [mm];
- **Possible cause of origin:** pipe manufacturing; installation (laying); external mechanical impact.



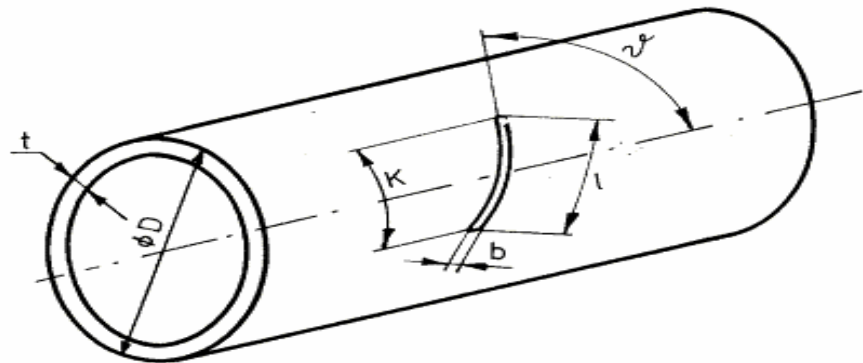
# Longitudinal Scar

- **Definition:** groove like defect which is nearly parallel with the centre line of the pipe having greater projected axial length than the triple of the nominal wall thickness and having a width which is less than the 30% of the nominal wall thickness.
- **Measures:** angle between the defect and the centre line of the pipe,  $\nu$  [ $^{\circ}$ ]; length,  $l$  [mm]; projected axial length,  $L$  [mm];
- maximum width,  $b$  [mm]; maximum or effective depth,  $d$  [mm];
- **Possible cause of origin:** pipe manufacturing; external mechanical impact



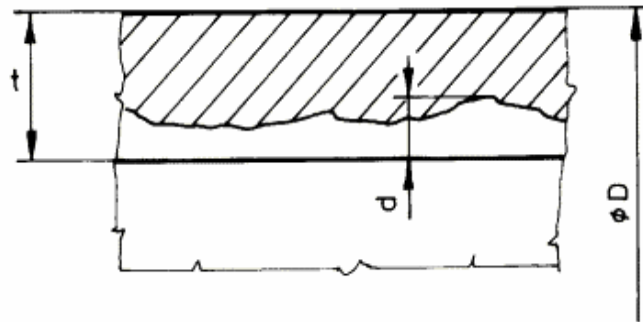
# Circumferential Scar

- **Definition:** groove like defect which is nearly perpendicular to the centre line of the pipe having greater circumferential length than the triple of the nominal wall thickness and having a width which is less than the 30% of the nominal wall thickness.
- **Measures:** angle between the defect and the centre line of the pipe,  $\nu$  [ $^{\circ}$ ]; length,  $l$  [mm]; projected circumferential length,  $K$  [mm]; maximum width,  $b$  [mm]; maximum or effective depth,  $d$  [mm];
- **Possible cause of origin:** pipe manufacturing; installation (laying); external mechanical impact.



# General Corrosion

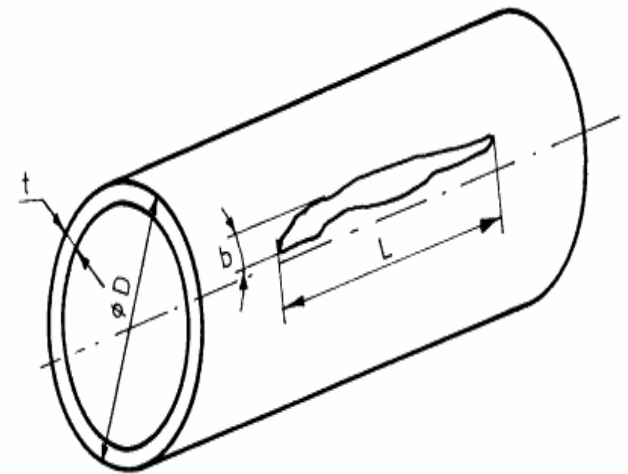
- **Definition:** metal loss extending over a significant area of the pipe resulting in wall thickness decrease.
- **Measures:** maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** effect of the transported medium (internal); inappropriate material selection (internal); imperfect coating (external); damaged coating (external); inadequate cathodic protection (external)





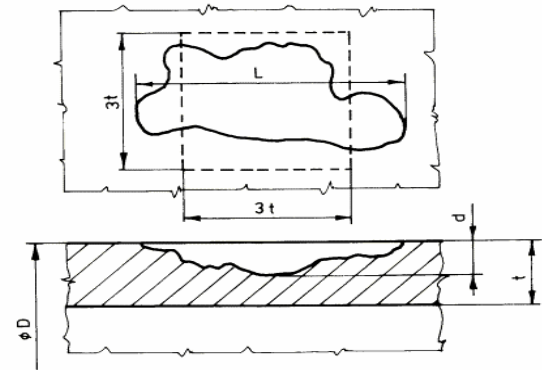
# Longitudinal Corrosion

- **Definition:** metal loss parallel with the centre line of the pipe resulting in wall thickness decrease having an axial length which exceeds the nominal outside diameter of the pipe and its circumferential size is significantly smaller.
- **Measures:** axial length,  $L$  [mm]; maximum width,  $b$  [mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:**
  - improper welding technology (seam);
  - damaged coating (external);
  - installation (pipe laying);
  - short circuited structure.



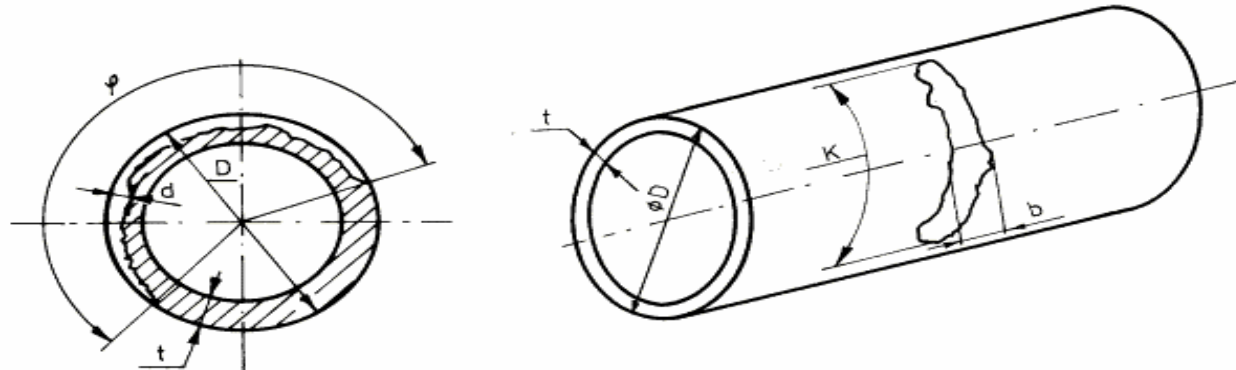
# General Location Local Corrosion

- **Definition:** metal loss resulting in wall thickness decrease, extending over a quadratic area of the pipe having a side which is greater than the triple of the nominal wall thickness but not extending over a significant area.
- **Measures:** projected axial length,  $L$  [mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** effect of the transported medium (internal); imperfect coating (external); damaged coating (external); inadequate cathodic protection (external).



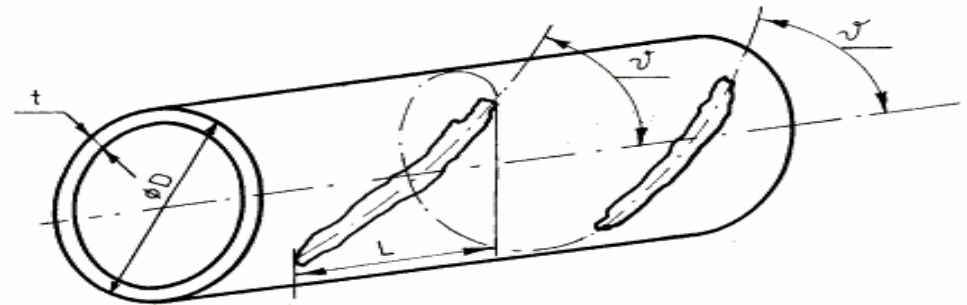
# Circumferential Corrosion

- **Definition:** metal loss perpendicular to the centre line of the pipe resulting in wall thickness decrease having a circumferential length which is significantly greater than its axial width.
- **Measures:** circumferential length,  $K$  [mm]; maximum width,  $b$  [mm]; maximum or effective depth,  $d$  [mm]; angle subtended by the defect,  $\varphi$  [°]; “clock” position of the defect.
- **Possible cause of origin:** improper welding technology (seam); imperfect coating (external); damaged coating (external); installation (pipe laying).



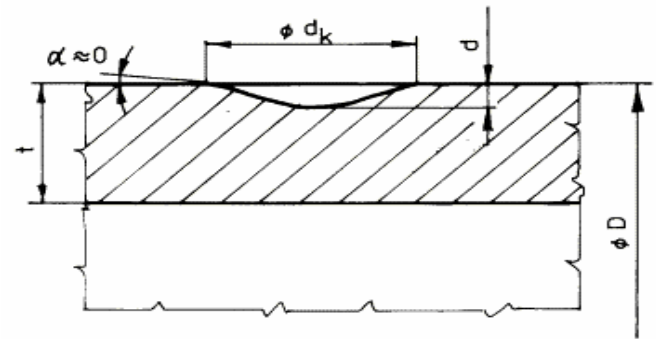
# Spiral Corrosion

- **Definition:** metal loss subtending nearly constant angle with the centre line of the pipe, forming a continuous strip or repeating periodically resulting in wall thickness decrease.
- **Measures:** angle subtended by the defect and the centre line of the pipe,  $\psi$  [ $^{\circ}$ ]; maximum or effective depth,  $d$  [mm]; length,  $l$  [mm]; projected axial length,  $L$  [mm];
- **Possible cause of origin:** imperfect coating (external).
- **Remark:** considering the cause of defect origin, the spiral corrosion is always an external defect.



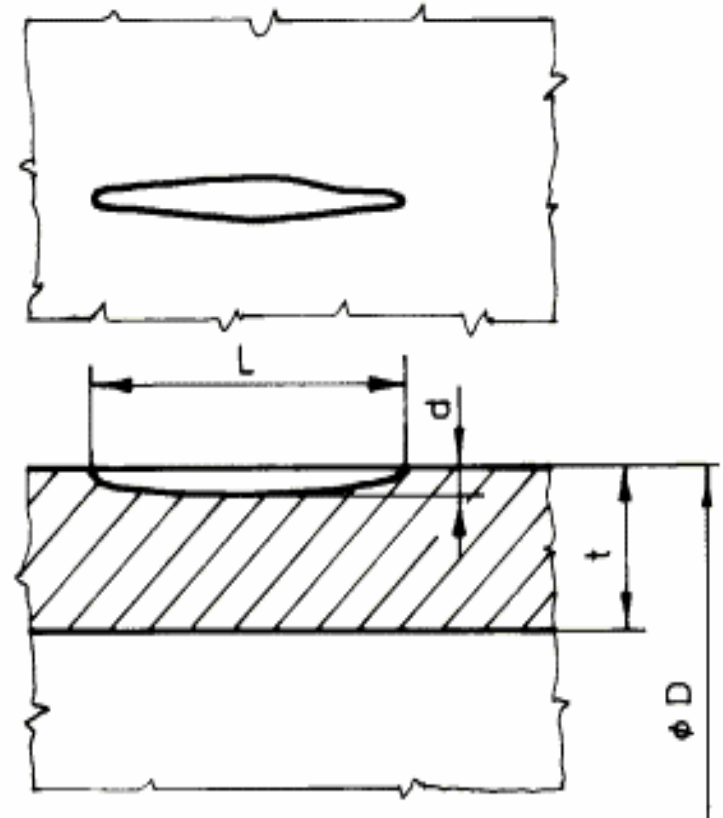
# Grinding Off

- **Definition:** patch like, general location metal loss having a continuous transition resulting in wall thickness decrease caused by human action (machining).
- **Measures:** overall diameter,  $d_k$  [mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** repair.
- **Remark:** definition of the defects and the comparison of  $\alpha$  angles on the relevant figures justifies the difference between the abrasion and the grinding off; considering the cause of defect origin, the spiral corrosion is always an external defect.



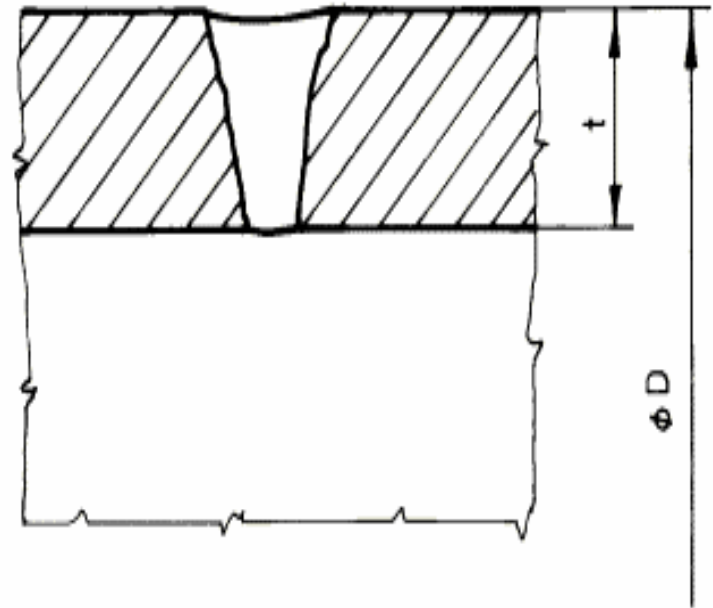
# Rupture

- **Definition:** generally longitudinal discontinuity caused by superficial or near superficial manufacturing defect
- **Measures:**
  - axial length,  $L$  [mm];
  - Max. or eff. depth,  $d$  [mm].
- **Possible cause of origin:**
  - pipe manufacturing.



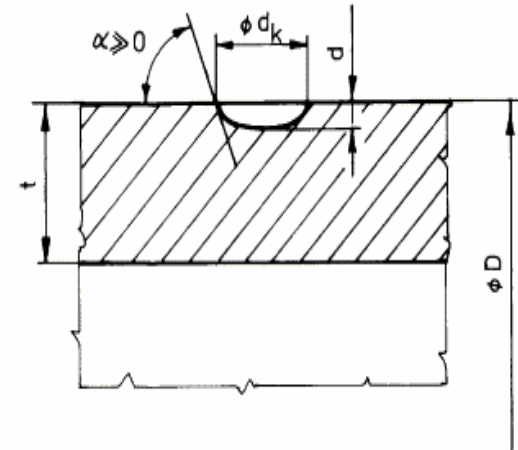
# Puncture or Leak

- **Definition:** total loss of the pipe wall extending over a small area.
- **Measures:** geometrical description of this defect is not necessary.
- **Possible cause of origin:**
  - Material defect;
  - Damaged coating



# Abrasion

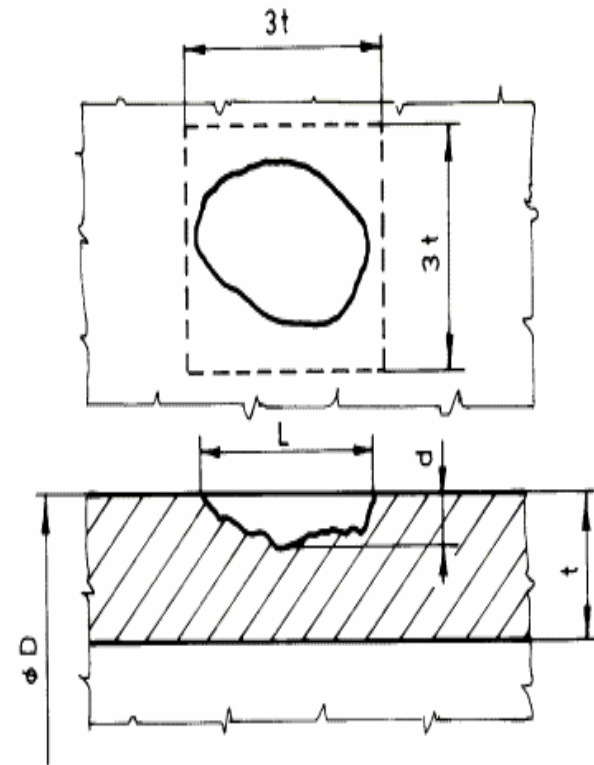
- **Definition:** patch like metal loss resulting in wall thickness decrease caused by friction with a foreign material.
- **Measures:** overall diameter,  $d_k$  [mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** external mechanical impact; soil movement; repair.
- **Remark:** the distinction which was made between the abrasion, scar and especially the general location scar is unambiguous because of their geometry.





# Pitting

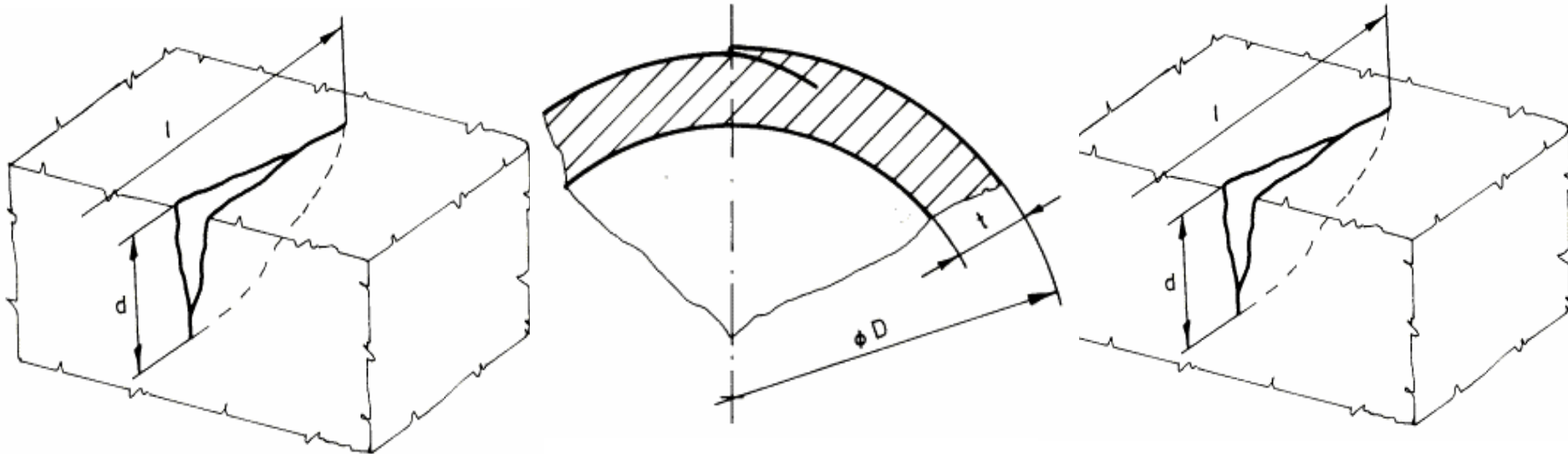
- **Definition:** metal loss resulting in wall thickness decrease, extending over a quadratic area of the pipe having a side which is smaller than the triple of the nominal wall thickness.
- **Measures:**
  - Projected axial length,  $L$  [mm];
  - Max. Or effective depth,  $d$  [mm];
- **Possible cause of origin:**
  - Material defect (internal, external);
  - Damaged coating (external).



# Planner Discontinuities

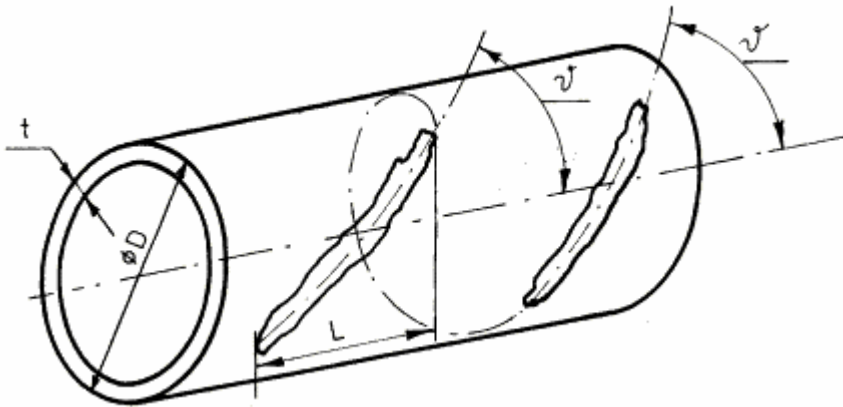
- Crack
  - "ordinary" crack
  - Stress corrosion crack
  - Fatigue crack
- Lapped grinding
- Lamination

# Planner Discontinuities

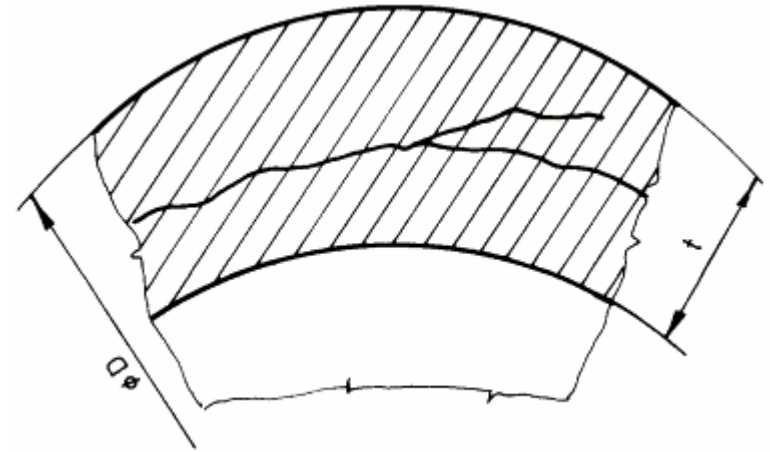


Ordinary crack    Lapped grinding    Fatigue crack

# Planner Discontinuities



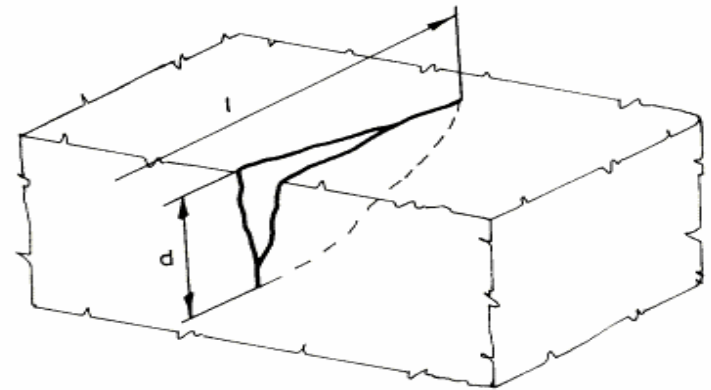
Stress corrosion crack



Lamination

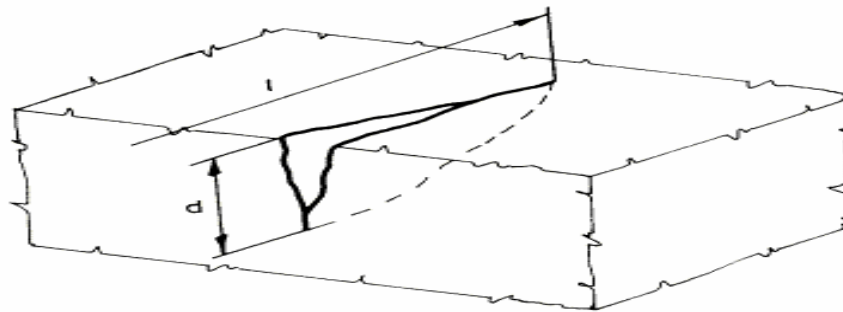
# Ordinary Crack

- **Definition:** material discontinuity of which surfaces located very closely to each other and the surfaces end in sharp tip.
- **Measures:** length,  $l$  [mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** pipe manufacturing; welding (seam, girth weld, repair weld).



# Fatigue Crack

- **Definition:** generally growing crack originated due to constant or variable amplitude cyclic load at a stress level under yield strength
- **Measures:** length,  $l$  [mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** cyclic load caused by operating conditions (low-cycle fatigue, high-cycle fatigue, fatigue crack propagation).



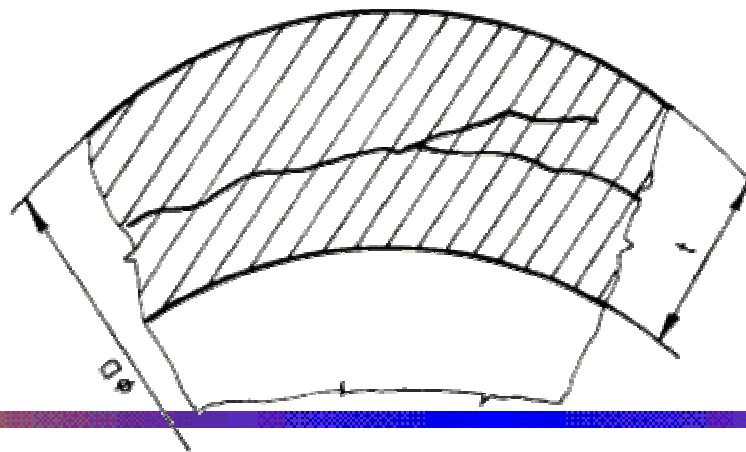
# Stress Corrosion Crack

- **Definition:** crack originated due to common action of sufficient tensile stress and medium having critical electrochemical potential.
- **Measures:** length,  $l$  [mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** it can be concluded from the definition.



# Lapped Grinding

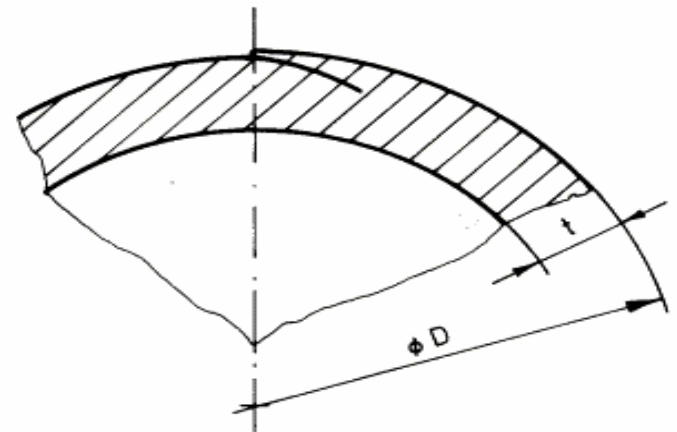
- **Definition:** one or multi-part material discontinuity which makes the pipe wall multi-layer
- **Measures:** overall dimensions (axial length  $\times$  circumferential length),  $l \times k$  [mm  $\times$  mm].
- **Possible cause of origin:** pipe manufacturing.





# Lapped Grinding

- **Definition:** excess material rolled or pressed into the pipe surface which partly forms metallic joint with each other.
- **Measures:** overall dimensions (axial length  $\times$  circumferential length),  $l \times k$  [mm  $\times$  mm]; maximum or effective depth,  $d$  [mm].
- **Possible cause of origin:** pipe manufacturing.



# Defects Resulting Changes in the Material Structure

- Arc drawing: burned surface of the pipe wall extending over a relative small area caused by the any part of the electric circuit of the welding apparatus due to improperly applied welding technology.
- Strain aging: application of such steel which became brittle due to the dislocation blocking effect of its nitrogen content, improperly material selection.

# Arc Drawing

- **Definition:** burned surface of the pipe wall extending over a relative small area caused by the any part of the electric circuit of the welding apparatus.
- **Measures:** overall diameter, dk [mm].
- **Possible cause of origin:** improperly applied welding technology.

# Strain Ageing

- **Definition:** application of such steel which became brittle due to the dislocation blocking effect of its nitrogen content.
- **Measures:** impact strength after normalisation,  $KV$  [mm]; impact strength of pipe after operation,  $KV_{\ddot{u}}$  [mm].
- **Possible cause of origin:** improperly material selection.
- **Remark:** this defect can not be characterised with geometrical dimensions.