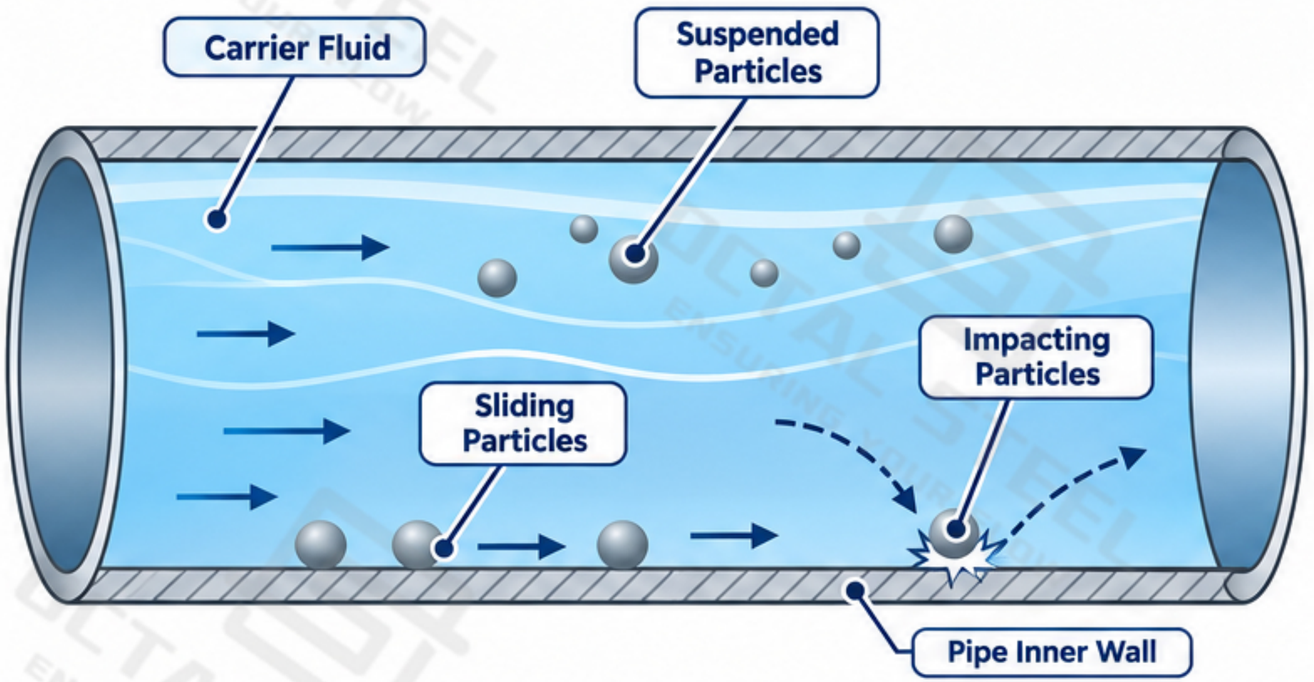
Slurry Pipeline Wear: Mechanisms and Operating Conditions

Understanding Particle Movement, Wear Drivers, and Basic Operating Control

Particle Movement Inside a Slurry Pipeline



During slurry transport, solids may remain suspended, slide along the pipe invert, or repeatedly impact the internal wall. The resulting wear depends on particle characteristics, flow velocity, and pipe geometry.

Primary Wear Mechanisms

Wear Mechanism	Description
Sliding Abrasion	Repeated particle movement along the wall removes material, especially near the pipe invert.
Particle-Impact Erosion	Direction changes and local flow disturbances can increase particle-wall collisions.
Mixed Wear Conditions	Most slurry pipelines experience combined sliding and impact wear rather than one isolated mechanism.

Main Operating Influences

Operating Factor	Effect on Wear
Particle Size and Density	Affect settling tendency and wall interaction.
Solids Concentration	Changes particle loading and collision frequency.
Operating Velocity	Must prevent deposition without creating excessive impact wear.
Flow Distribution	Non-uniform flow can create localized wear zones.
Pressure Conditions	Influence the required structural integrity of the pipeline.

Mechanical Wear Is Not a Single-Parameter Problem

Pipeline wear should not be judged by one material property alone. Slurry characteristics, velocity, concentration, geometry, and operating stability interact to determine the actual wear pattern.

Assessment Focus

- Prevent excessive particle deposition
- Control unnecessary particle impact
- Match pipe dimensions to slurry behavior
- Review fittings and flow transitions carefully
- Maintain stable operating conditions

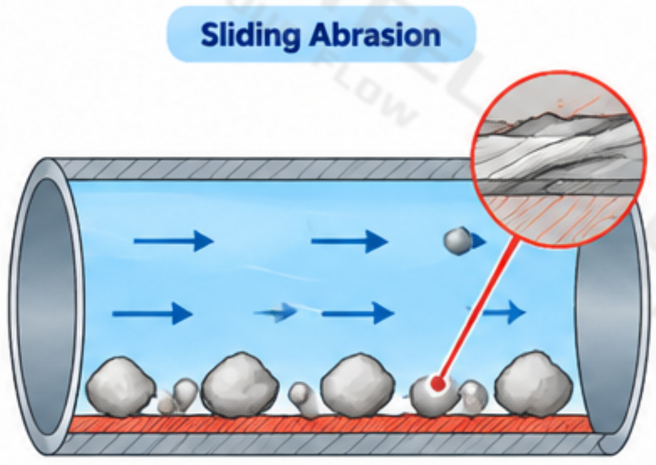
Engineering Takeaway

A reliable wear assessment starts with understanding how particles move inside the pipeline. The key objective is to transport solids efficiently while balancing deposition control, impact reduction, and operating stability.

Abrasive Wear Mechanisms and Slurry Characteristics

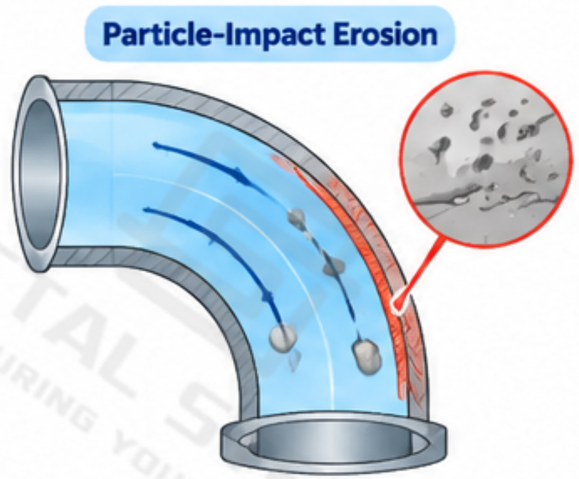
How Slurry Properties Influence Pipeline Wear

Key Wear Mechanisms in Slurry Pipelines



Sliding Abrasion

Coarse particles roll or slide along the pipe wall, producing repeated scratching and material removal, particularly along the lower pipe invert.



Particle-Impact Erosion

Particles collide with the pipe wall when flow direction changes. Elbows and other flow transitions can develop localized impact wear.

Actual wear in a pipeline is the result of multiple mechanisms, including sliding abrasion, particle impact and their combined effects.

Slurry Characteristicns Affecting Wear

Slurry Parameter	Engineering Effect
Particle Size Distribution	Coarse particles increase settling tendency and may intensify local impact.
Particle Shape and Angularity	Angular particles can produce more aggressive scratching and cutting interactions.
Particle Hardness and Density	Hard particles increase abrasive potential, while higher particle density affects suspension and settling behavior.
Solids Concentration	Changes particle loading, collision frequency and slurry flow behavior.
Carrier Fluid Properties	Fluid density and viscosity influence particle transport and pressure loss.
Slurry Rheology	Non-Newtonian behavior and yield stress can affect flow distribution and particle suspension.

Particle size distribution is particularly important. The median particle size (d50), the d85 particle size and the maximum particle size help describe the coarse and fine fractions of thie solids.

Key Takeaway

Pipeline wear depends on both the wear mechanism and slurry characteristics. Evaluating particle size, shape, hardness, concentration and rheology is essential for reliable wear assessment and operating parameter selection.

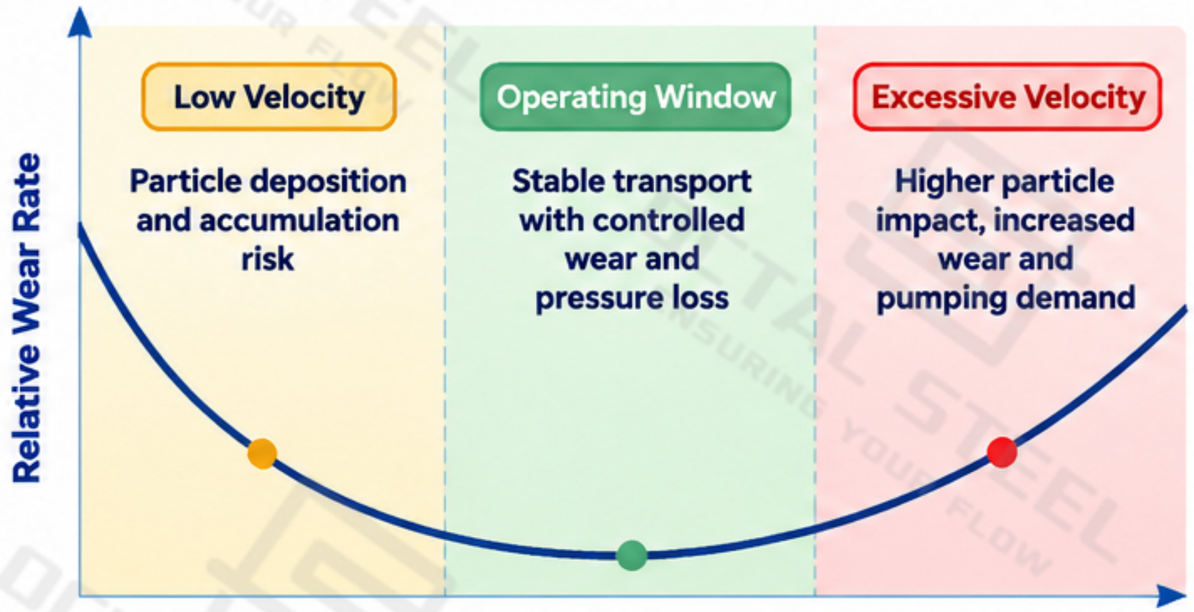
Engineering Implications

- Characterize slurry properties before pipeline design.
- Consider the dominant wear mechanism for key sections.
- Reassess wear risk when slurry characteristics change (e.g., particle size or solids concentration).

Flow Velocity Selection and Operating Conditions

Balancing Solids Transport, Wear Resistance and Hydraulic Efficiency

Slurry Flow Velocity Operating Window



The operating velocity should be high enough to prevent particle settling, but not so high that it significantly increases particle impact, wear and pumping energy. The actual velocity range depends on the slurry and pipeline conditions.

Key Operating Conditions

Operating Condition	Engineering Consideration
Minimum Flow Rate	Check particle deposition risk during low-throughput operation.
Normal Flow Rate	Evaluate stable particle transport and hydraulic efficiency.
Maximum Flow Rate	Assess particle-impact wear, pressure loss and pump capacity.
Solids Concentration Changes	Reassess flow behavior and deposition conditions when concentration varies.
Start-up and Shutdown	Consider particle settling during reduced flow and shutdown periods.

Basic Flow Velocity Calculation

$$V = \frac{Q}{A} = \frac{4Q}{\pi D_i^2}$$

Where:

- V = Average flow velocity (m/s)
- Q = Volumetric flow rate (m³/s)
- D_i = Actual pipe internal diameter (m)
- A = Internal flow area (m²)

Selection Considerations

- Depend on particle size distribution, solids density and concentration.
- Consider slurry rheology, pipe internal diameter and pipeline orientation.
- Balance particle transport, wear resistance and hydraulic efficiency.
- Verify velocity for different operating conditions (normal, minimum and maximum flow rates).

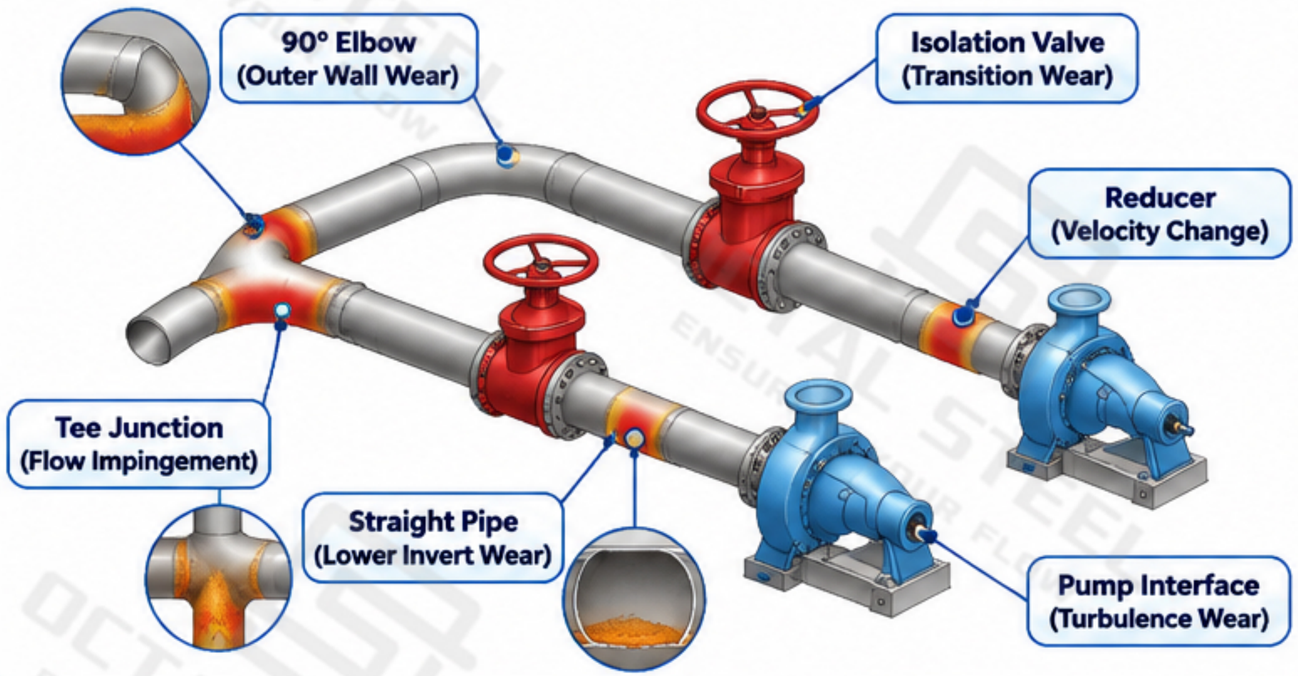
Engineering Takeaway

There is no universal velocity value for all slurry systems. The operating velocity should be determined based on the actual slurry characteristics and pipeline conditions, and verified against deposition risk, wear and pressure loss.

Pipeline Geometry and Localized Wear

Identifying Wear-Prone Locations and Optimizing Pipeline Layout

Pipeline Wear-Prone Locations



Pipeline geometry influences particle trajectories and local flow distribution. Wear is often concentrated at bends, tees, reducers and equipment interfaces, rather than being uniformly distributed along the pipeline.

Wear Characteristics at Different Pipeline Locations

Pipeline Component	Typical Wear Characteristics
Straight Pipe	Sliding abrasion may concentrate along the lower pipe invert when coarse particles settle.
Elbows and Bends	Particle impacts may concentrate around the outer wall and downstream regions.
Tee Junctions	Flow splitting and direction changes can create localized particle impacts.
Reducers	Changes in cross-sectional area alter local velocity and particle distribution.
Pump and Valve Interfaces	Local turbulence and flow restrictions may increase wear around transition sections.

The severity and location of wear depend on slurry characteristics (particle size, concentration, etc.) and operating conditions (flow velocity, flow distribution, and pressure).

Practical Pipeline Layout Considerations

- Avoid unnecessary sharp bends and abrupt diameter changes.
- Select bend geometry according to particle characteristics and flow conditions (e.g., long-radius bends where possible).
- Minimize dead legs and low-velocity areas where solids may accumulate.
- Provide inspection access at bends, tees, reducers and other potential wear locations.

Engineering Takeaway

Local wear is closely related to pipeline geometry and flow behavior. Reasonable layout and appropriate fitting selection can help reduce particle impact, minimize wear risk and extend pipeline service life.

Wear Risk Assessment and Inspection Planning

Building a Practical Framework for Wear Evaluation and Monitoring

Five-Step Wear Assessment Process

1 Characterize the Slurry

Determine particle size distribution, density, hardness, solids concentration and carrier fluid properties.

2 Define Operating Conditions

Establish minimum, normal and maximum flow rates, pressure and temperature.

3 Review Pipeline Geometry

Identify bends, tees, reducers, low points and equipment interfaces.

4 Identify Potential Wear Locations

Prioritize sections according to particle behavior, flow conditions and operating history.

5 Establish an Inspection Plan

Record baseline conditions and monitor changes at defined inspection locations.

Information Required for Wear Assessment

Required Information	Assessment Purpose
Particle Size Distribution	Evaluate particle settling and impact potential.
Particle Density and Hardness	Assess particle transport and abrasive characteristics.
Solids Concentration	Evaluate particle loading and slurry flow behavior.
Flow Rate and Pressure	Establish operating hydraulic conditions.
Pipe Internal Diameter	Calculate average flow velocity and evaluate transport conditions.
Pipeline Layout	Identify potential localized wear areas.

A reliable wear assessment requires slurry properties, operating conditions and pipeline geometry to be evaluated together.

Changes in particle characteristics, solids concentration or flow rate can shift wear patterns and inspection priorities.

Pipeline Inspection and Monitoring

Inspection Method	Main Evaluation
Visual Inspection	Leakage, external damage, deformation and joint condition.
Flow and Pressure Monitoring	Changes in flow rate, pressure drop and abnormal operating behavior.
Dimensional Inspection	Internal diameter, wear-layer condition and dimensional changes using suitable validated methods.
Fitting Inspection	Condition of elbows, tees, reducers and connection areas.

Technical Note: Inspection methods and acceptance criteria must match the actual composite pipe structure and selected pipe configuration.

Engineering Takeaway

Pipeline wear is determined by the combined effects of slurry characteristics, flow velocity and pipeline geometry. A reliable assessment considers these together rather than relying on a single material property or operating parameter.

- Use actual slurry data (e.g., particle size, density, hardness and concentration).
- Focus inspection on elbows, tees, reducers and equipment interfaces.
- Update the inspection plan when operating conditions change (e.g., flow rate, solids concentration or slurry properties).