High-quality geometry module data for pipeline strain analyses

ROSEN Technology & Research Center Germany
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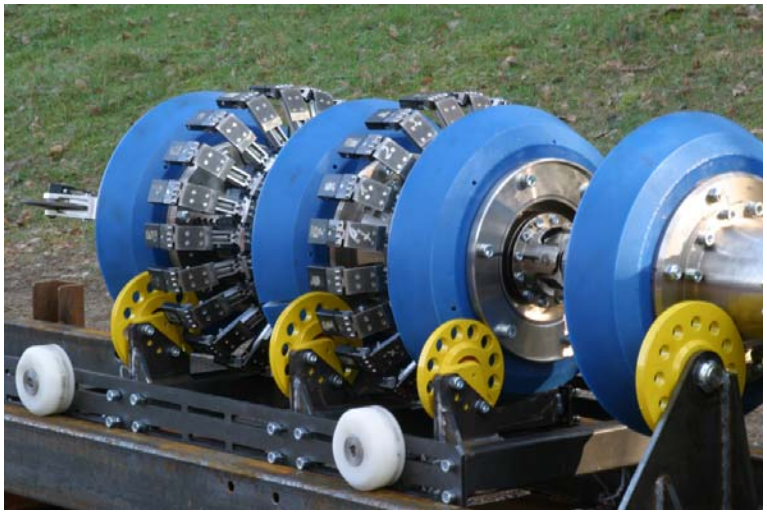
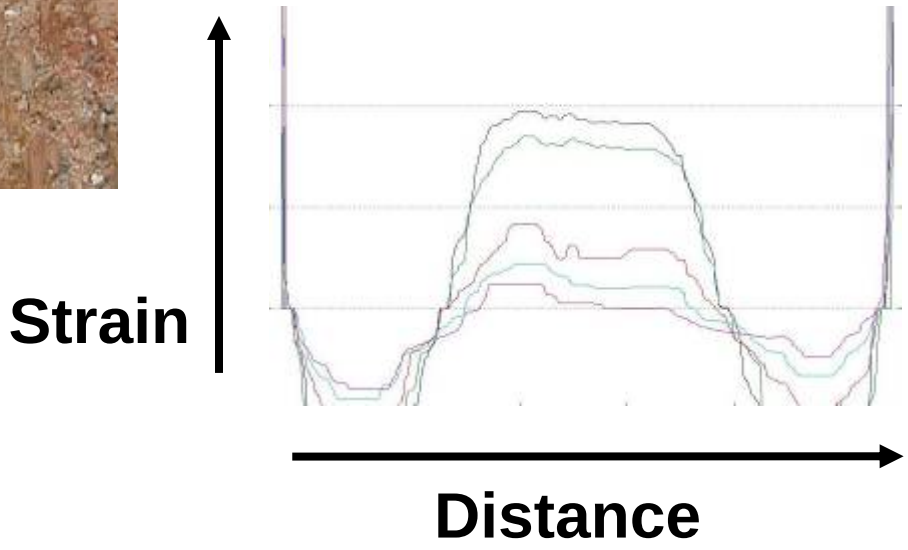
Bending Strain





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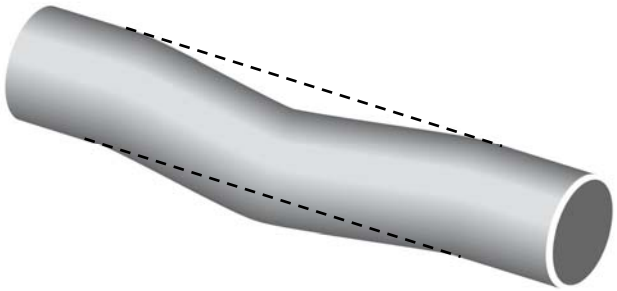
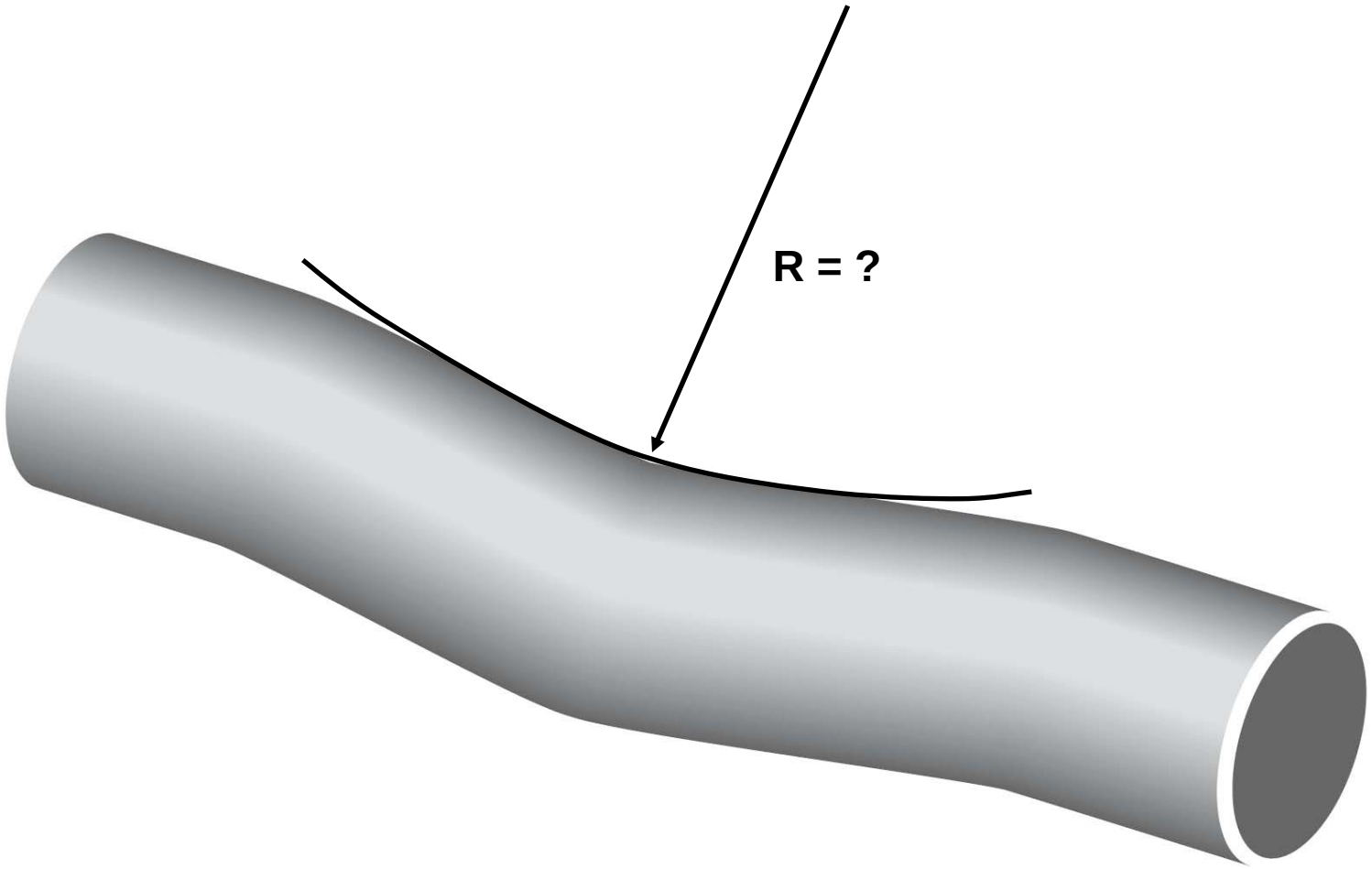
Introduction

Bending the Pipeline can lead to **Strain**



Bending the Pipeline



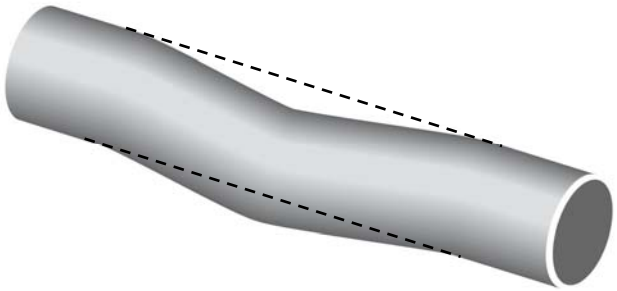
Bending the Pipeline

Bends are a Change in the Curvature κ of a Pipeline

Curvature equivalent Radius in [m]: $R[m] = \frac{1}{\kappa}$

Not-bended Pipeline (straight): Radius is infinite

Bended Pipeline: Radius of 1000 m (e.g.)

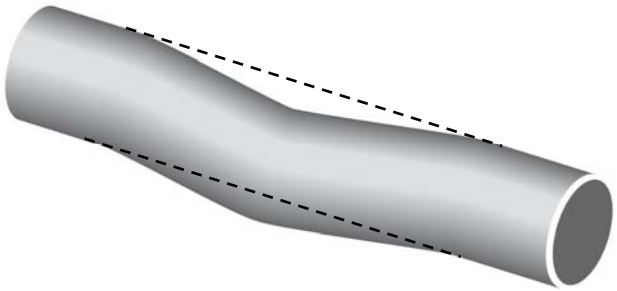


Curvature and Bending Strain

Bends are a Change in the Curvature *κ* of a Pipeline

Strain is equivalent to the Curvature: $\varepsilon = \frac{D}{2}\kappa$

The Bending Strain Radius is: $R[D] = R[m]/D$



Curvature and Bending Strain

1000 m Curvature Radius

	Bending Strain Radius	Percent
 10" Diameter:	3600D →	0.01%
 16" Diameter:	2400D →	0.02%
 24" Diameter:	1600D →	0.025%
 36" Diameter:	1100D →	0.045%
 56" Diameter:	700D →	0.07%

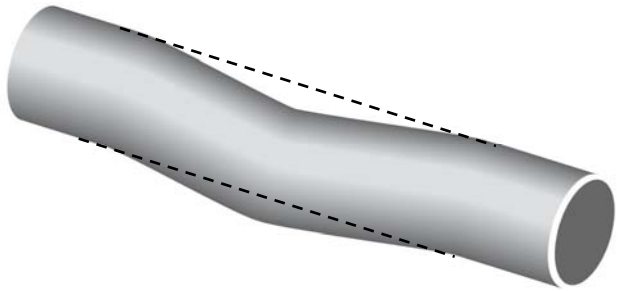
Summary

Bends are a Change in the Curvature κ of a Pipeline

Bending Strain is Curvature related to the Pipe Diameter

e.g. constant Curvature, with differing strain results for different Pipeline Diameters

e.g. the greater the Pipeline Diameter, the more force is needed to bend it



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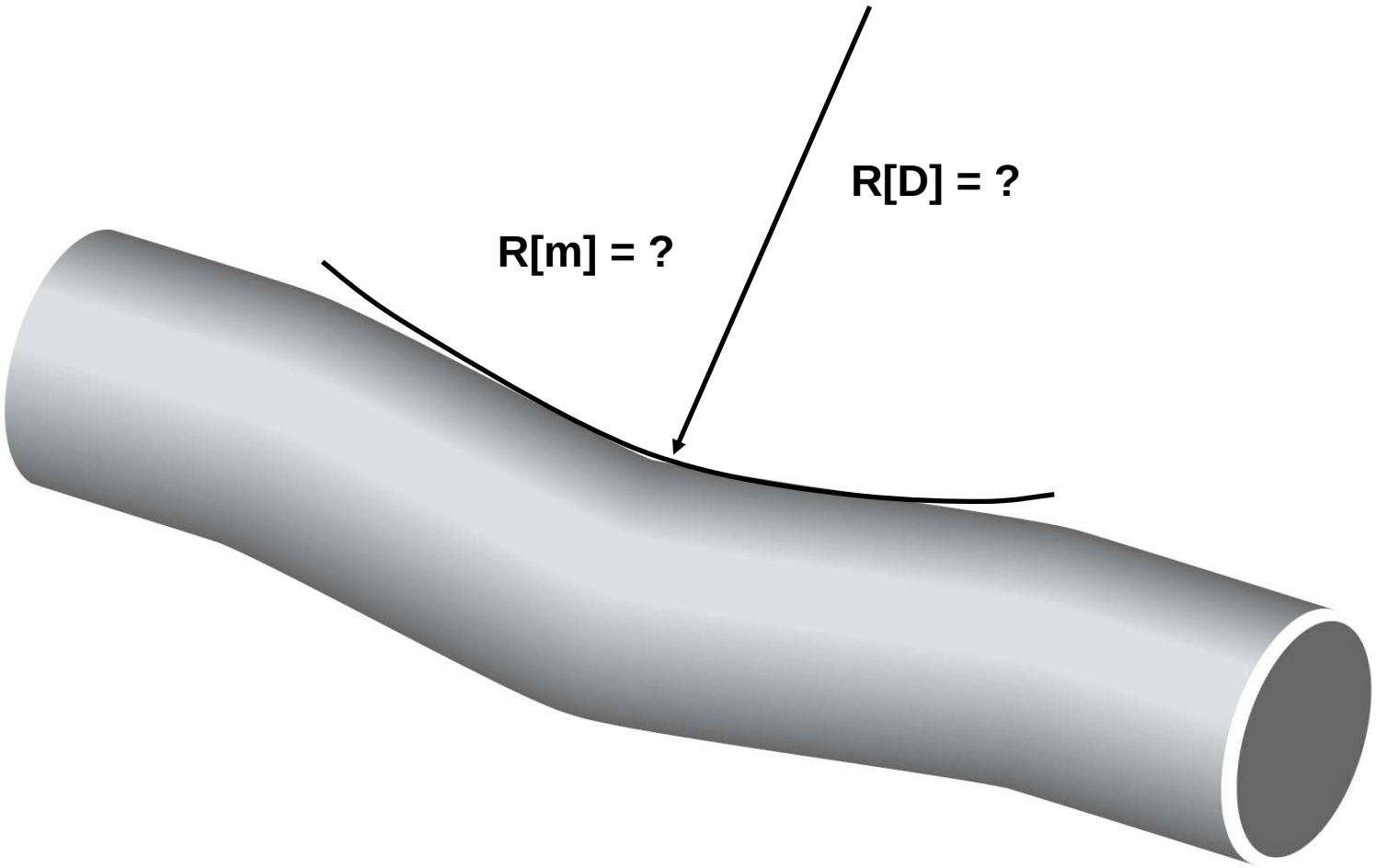
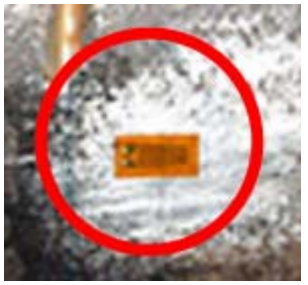
How to Measure Bending Strain?



Direct Strain Measurement

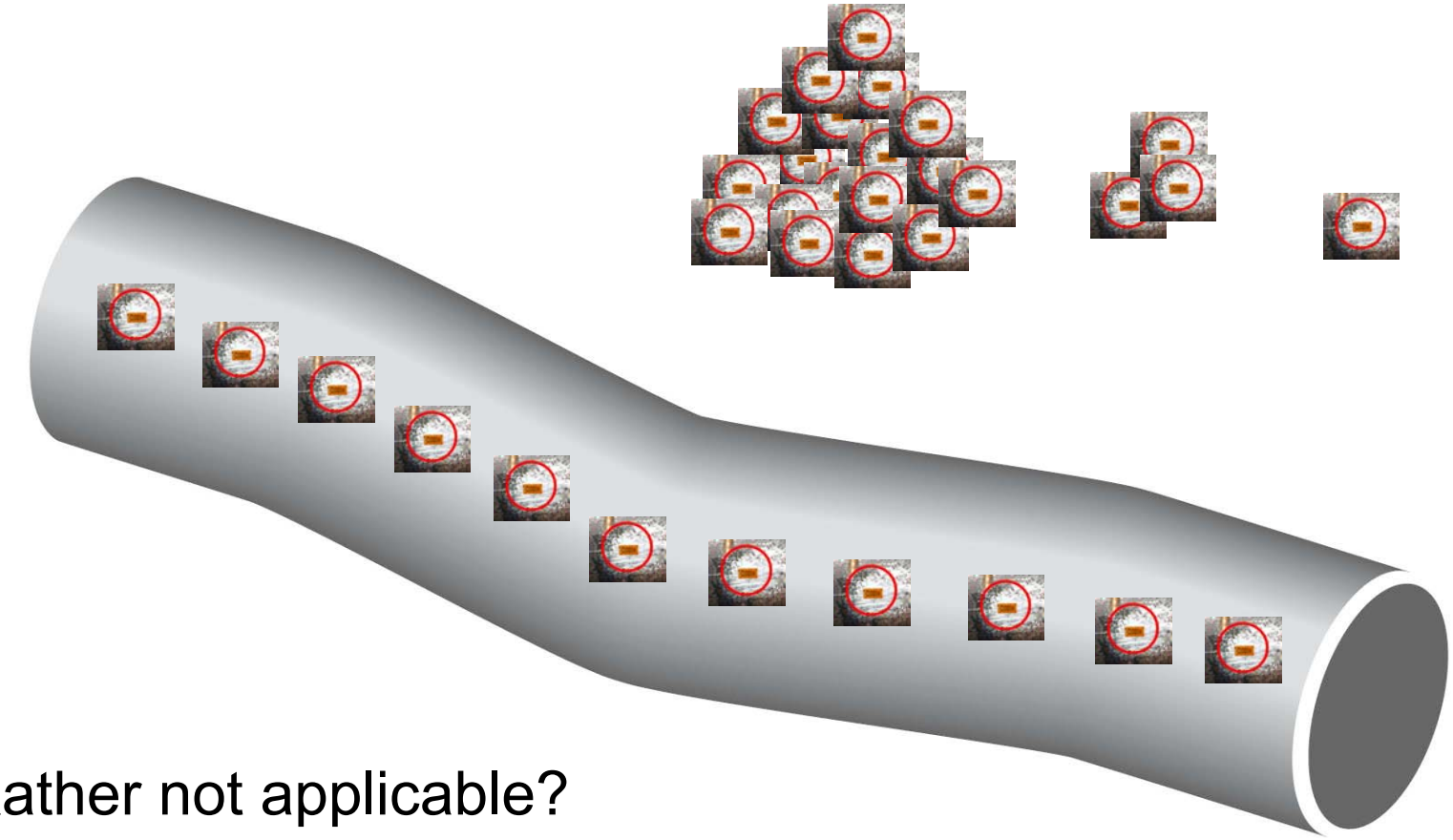
Strain Gauges:



- Sensor in direct contact with the pipeline
- Local Strain Measurement

Direct Strain Measurement

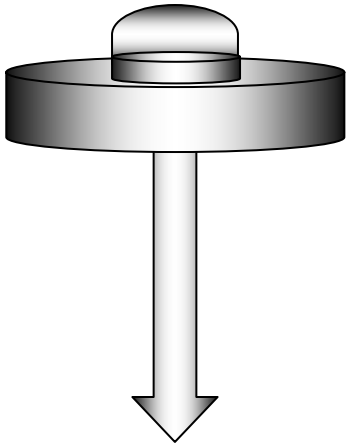
Strain Gauges:

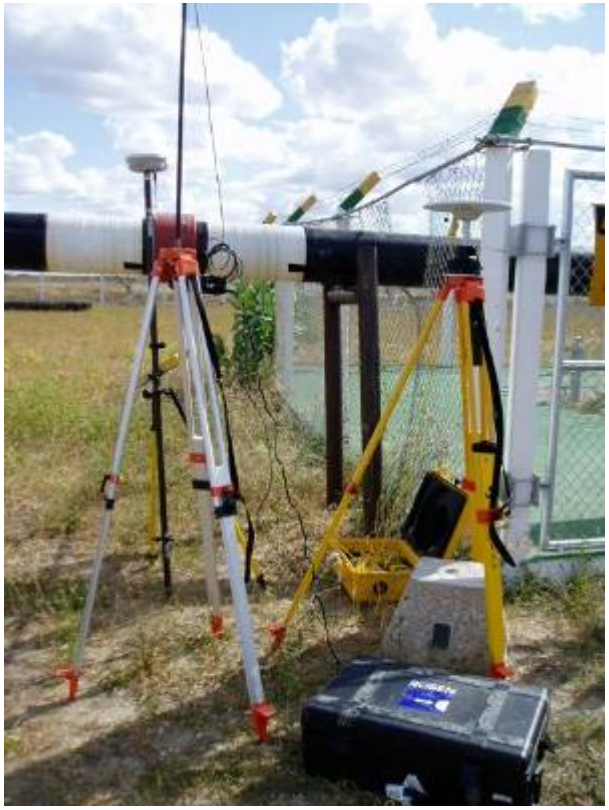


- Rather not applicable?

Direct Curvature Measurement

GPS / Geodetic Measurements:

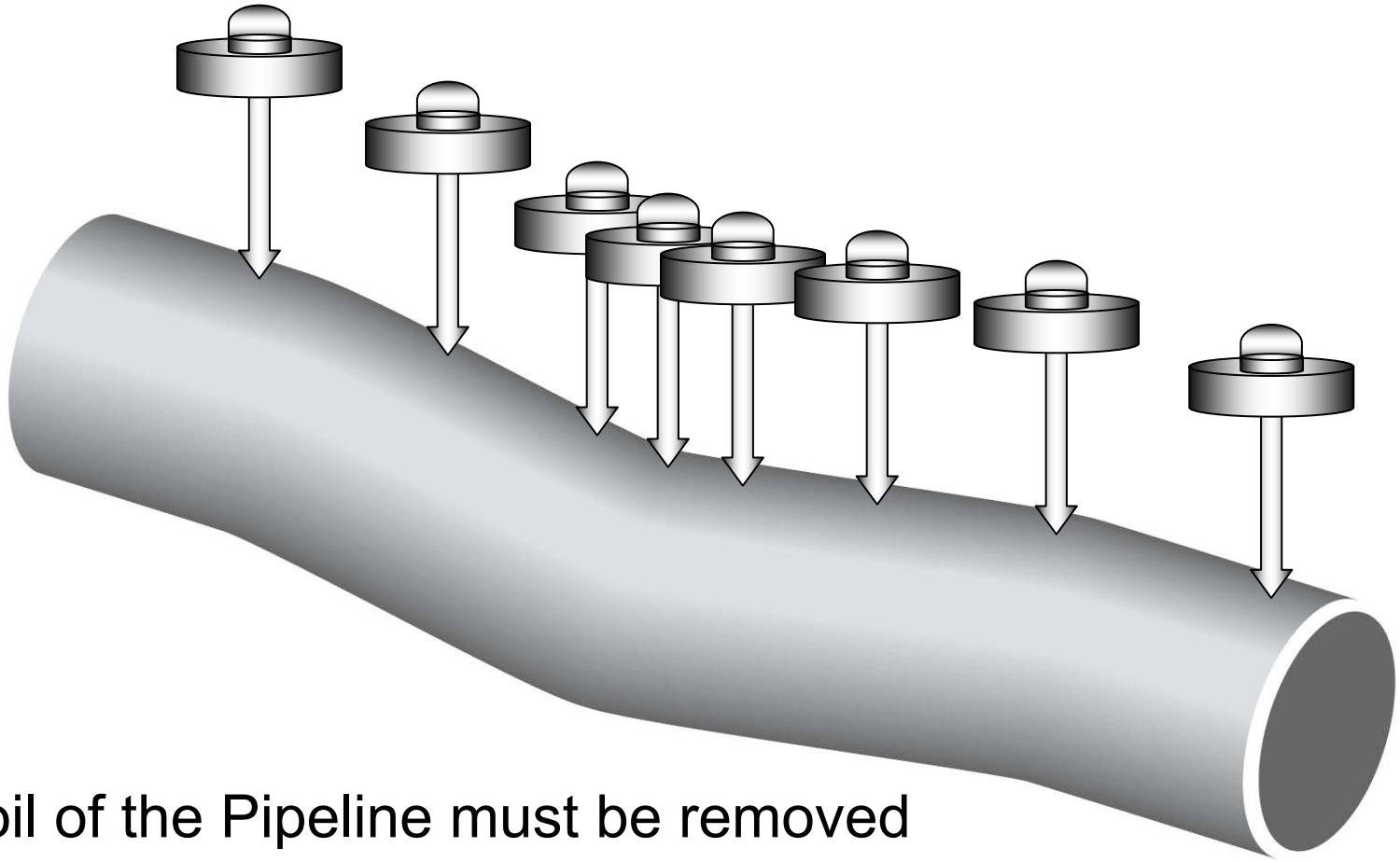




- GPS Points on top of the pipeline
- Local Curvature Measurement

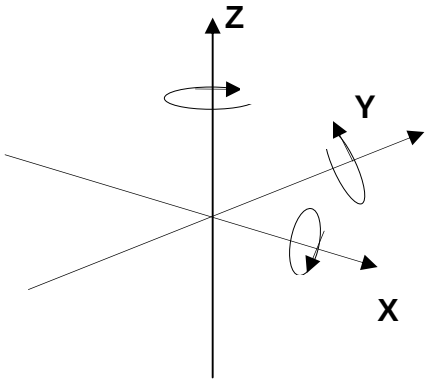
Direct Curvature Measurement

GPS / Geodetic Measurements:

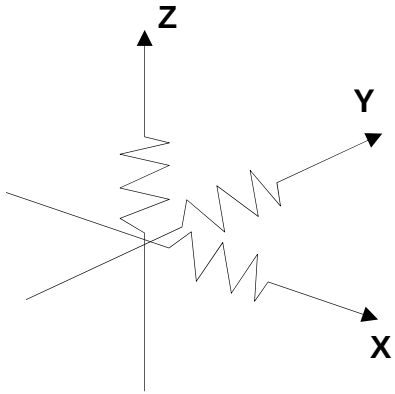


- Soil of the Pipeline must be removed
- Rather not applicable?

In-line Inspection with an XYZ System:



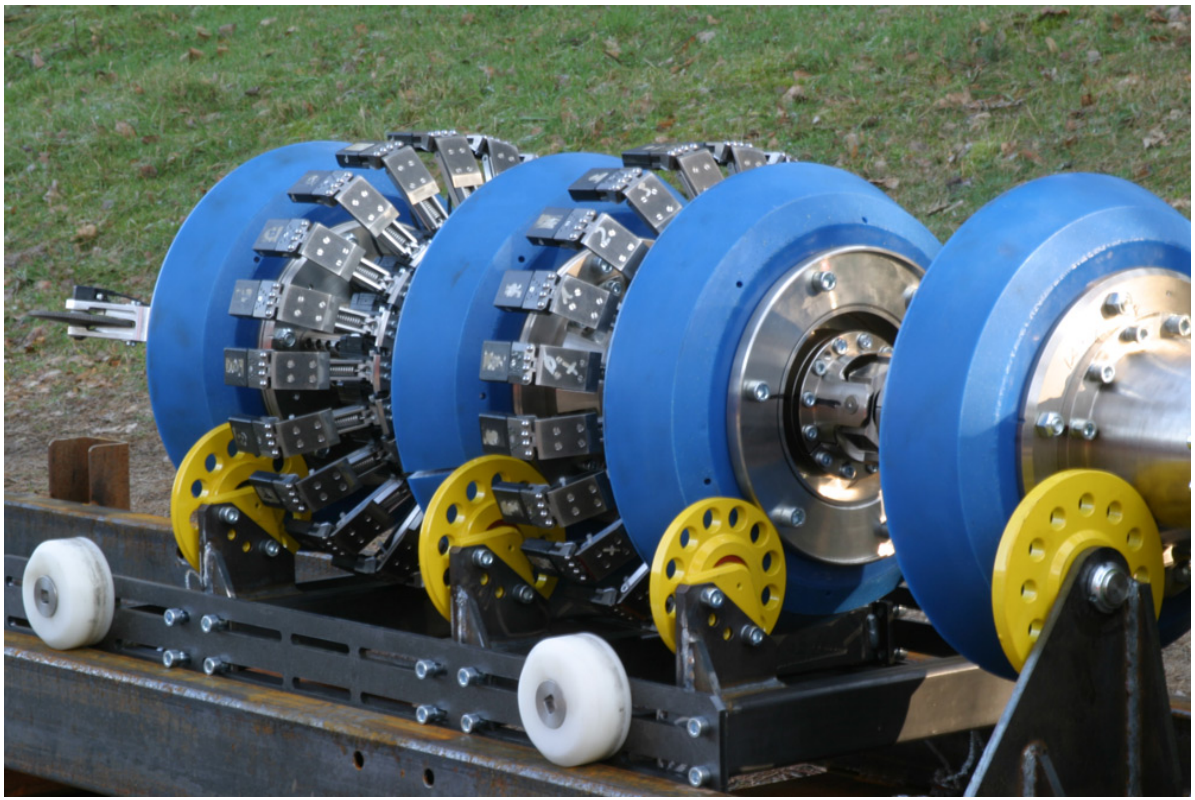
Gyroscopes
[rad/sec]



Accelerometer
[m/sec²]

- Gyroscopes and Accelerometers for Navigation
- XYZ Co-ordinates of the Pipeline Trajectory

In-line Inspection with an XYZ System:



- XYZ System on board of a caliper tool
- High frequent XYZ Co-ordinates of the Pipeline Trajectory
- Known Curvature of the Pipeline

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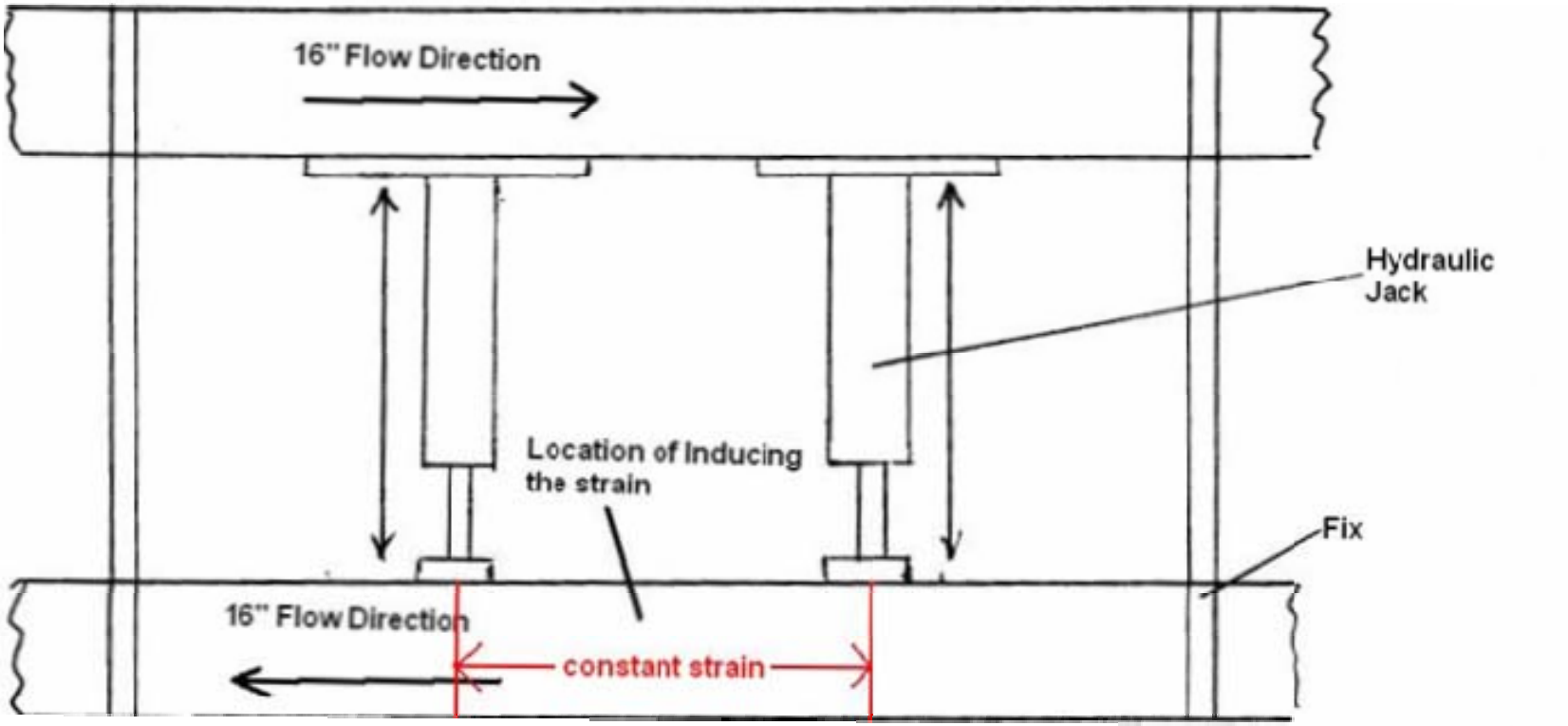
4-Point Bending

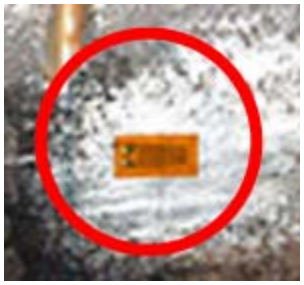
Bending of the Pipe at 4 Points:



- Pipeline fix at 2 Points
- Induced Bending Strain at 2 Points

4-Point Bending

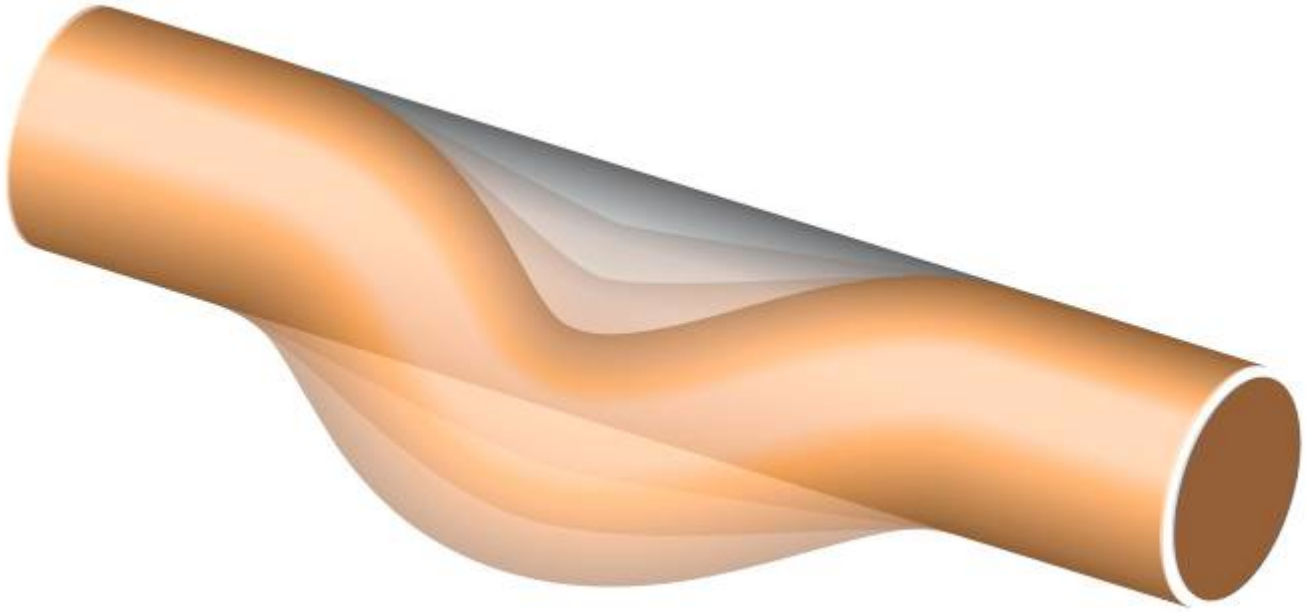
Bending of the Pipe at 4 Points:



- Pipeline fix at 2 Points
- Induced Bending Strain at 2 Points

4-Point Bending

Bending of the Pipe at 4 Points:



- Successively induced Bending Strain
- Different Series of Bending Strain

„Shop“ Bends

Combination of Shop Bends:

- Subsequent 5D-25D-5D Bends
- Simulation of “plastic deformation”

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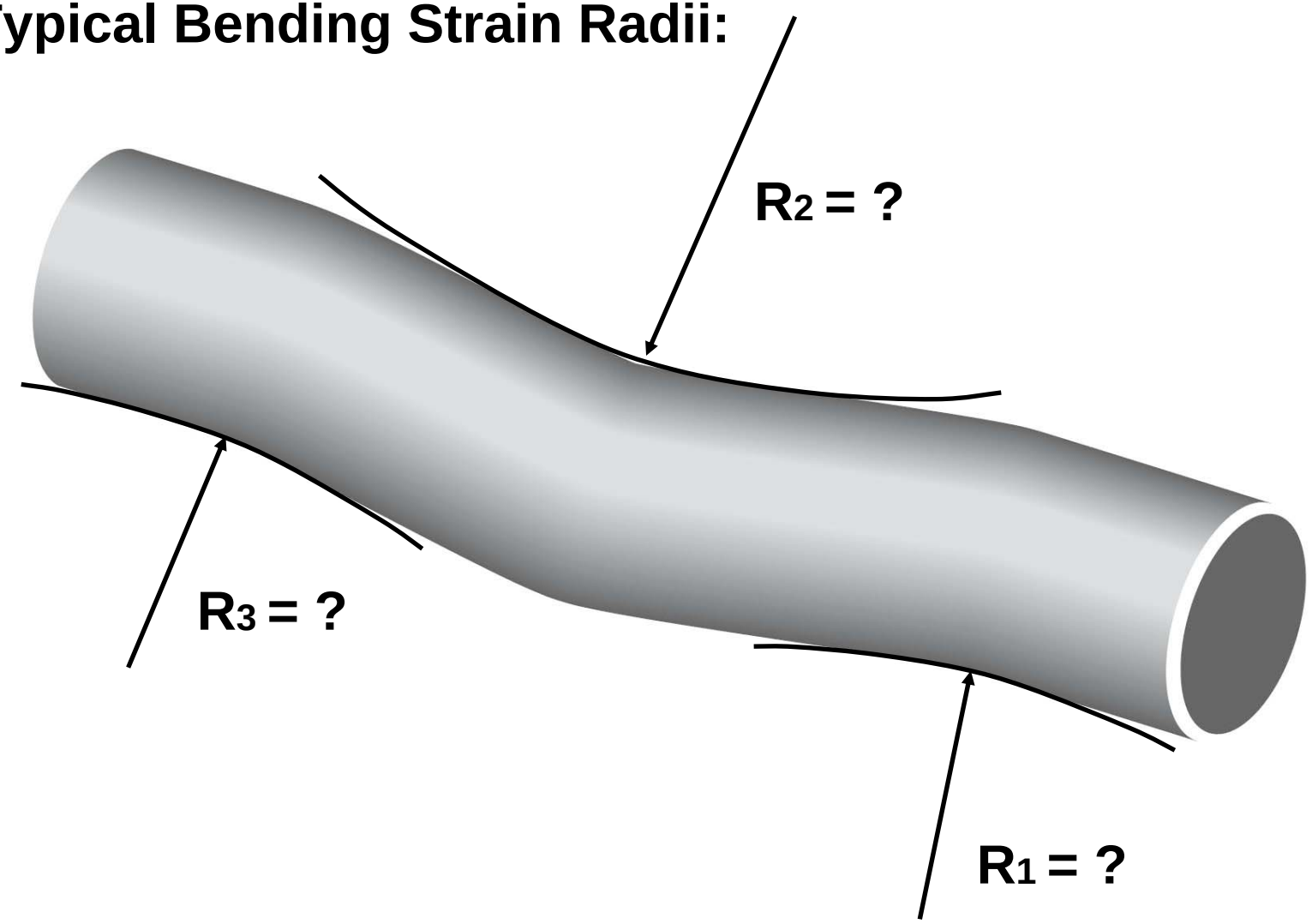
Bending Strain Performance

Performance in order to answer:

- Detection Capabilities
- Repeatability
- Distinction, Accuracy

Detection of Bending Strain

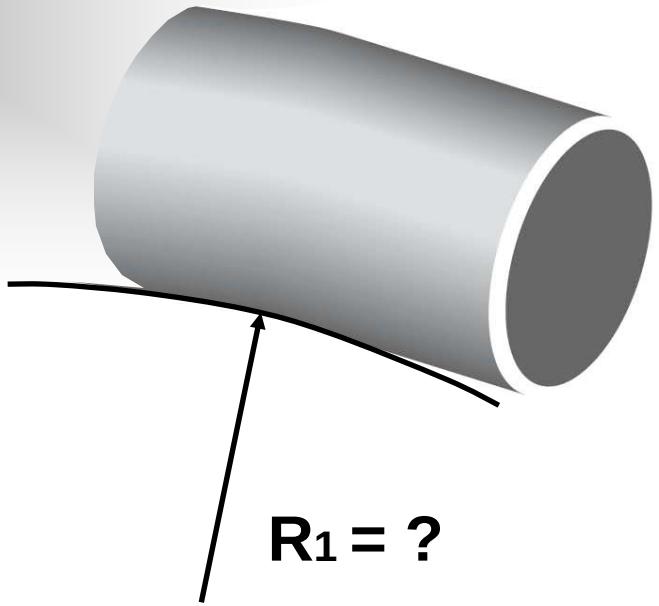
Typical Bending Strain Radii:



- Subsequent Bend Appearance: “3 Circles”

Detection of Bending Strain

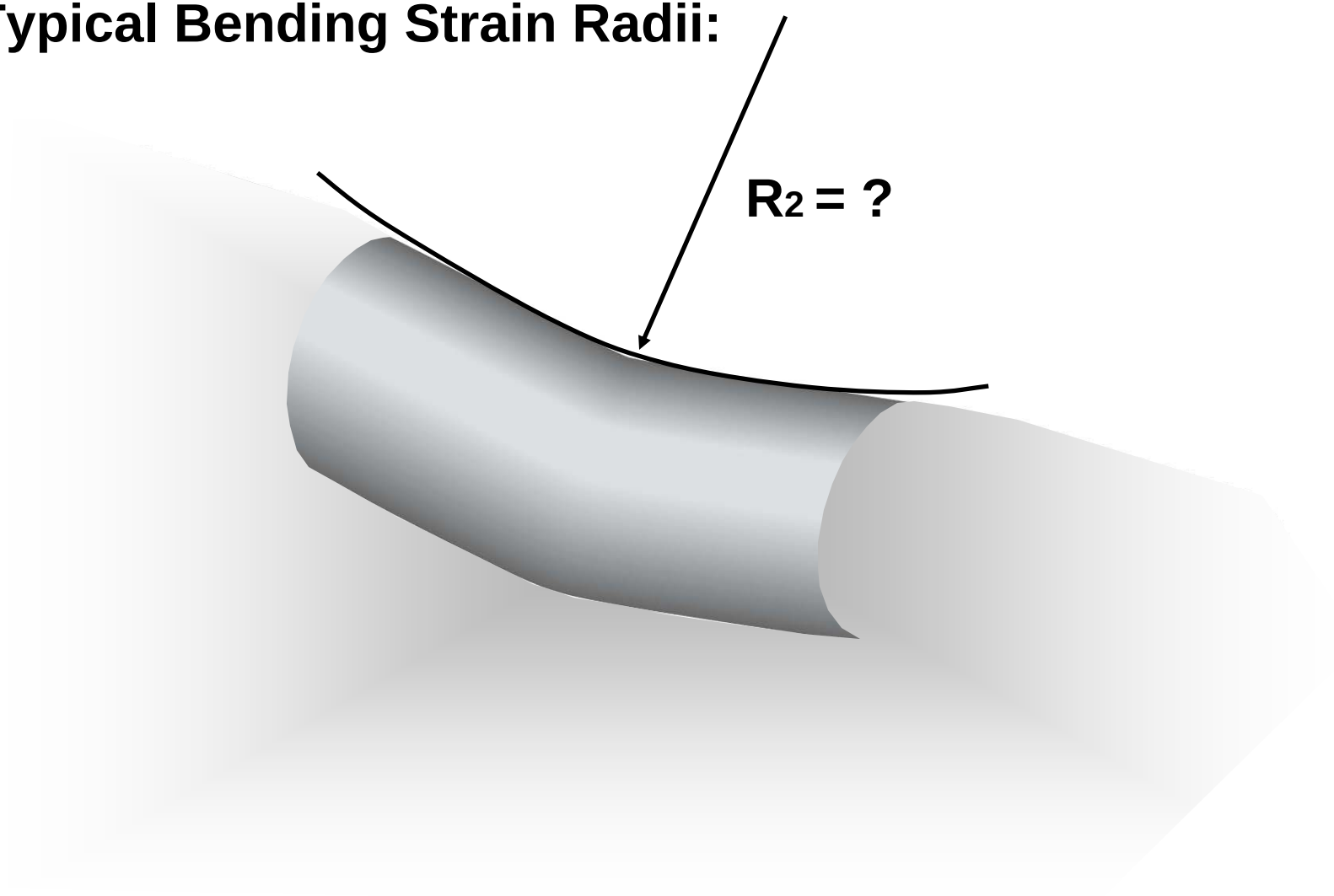
Typical Bending Strain Radii:



- Strain Radius at beginning of Displacement

Detection of Bending Strain

Typical Bending Strain Radii:



- Strain Radius at the maximum of Displacement

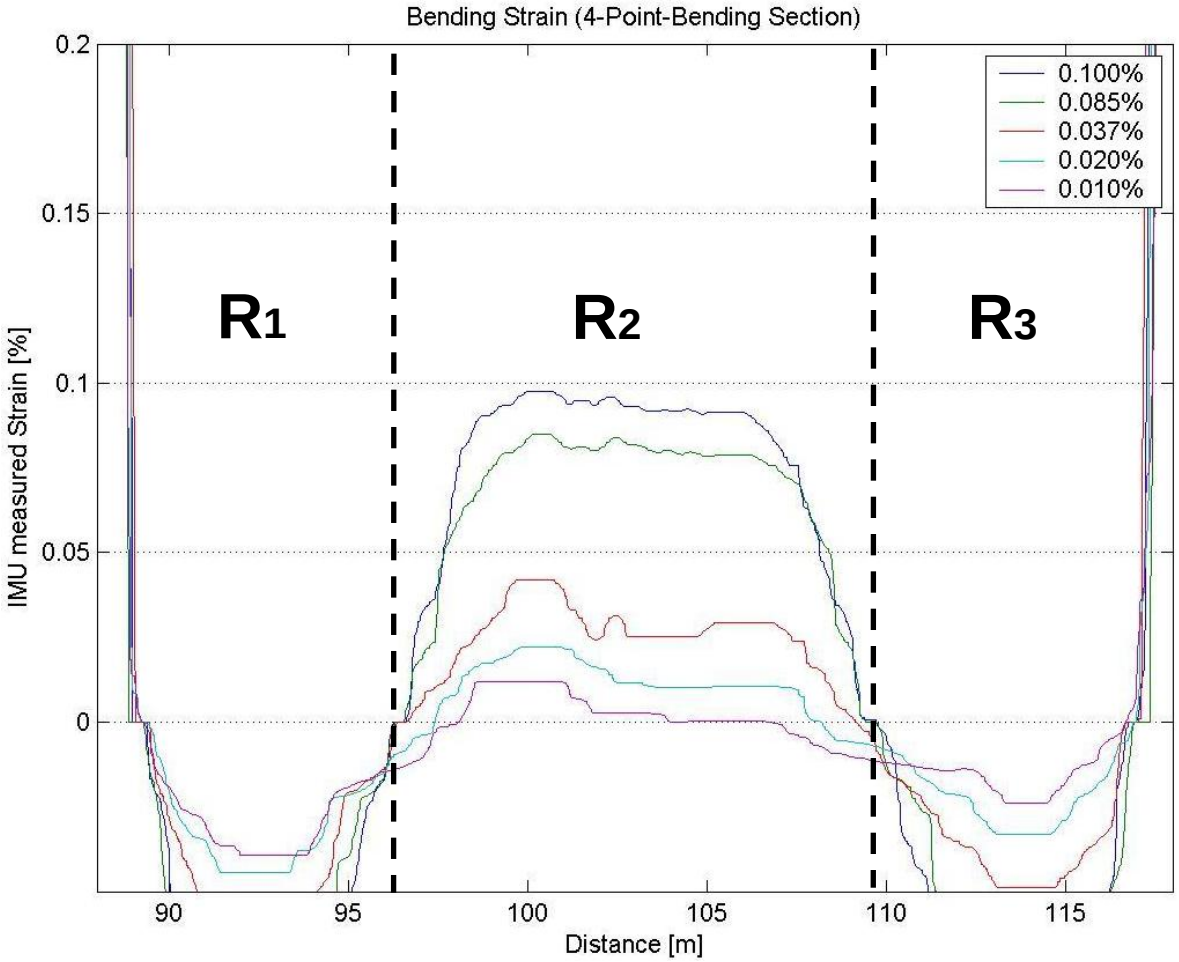
Detection of Bending Strain

Typical Bending Strain Radii:

- Strain Radius at the End of Displacement

Detection of Bending Strain

Bending Strain [%]:



R1 =
Begin of Displacement

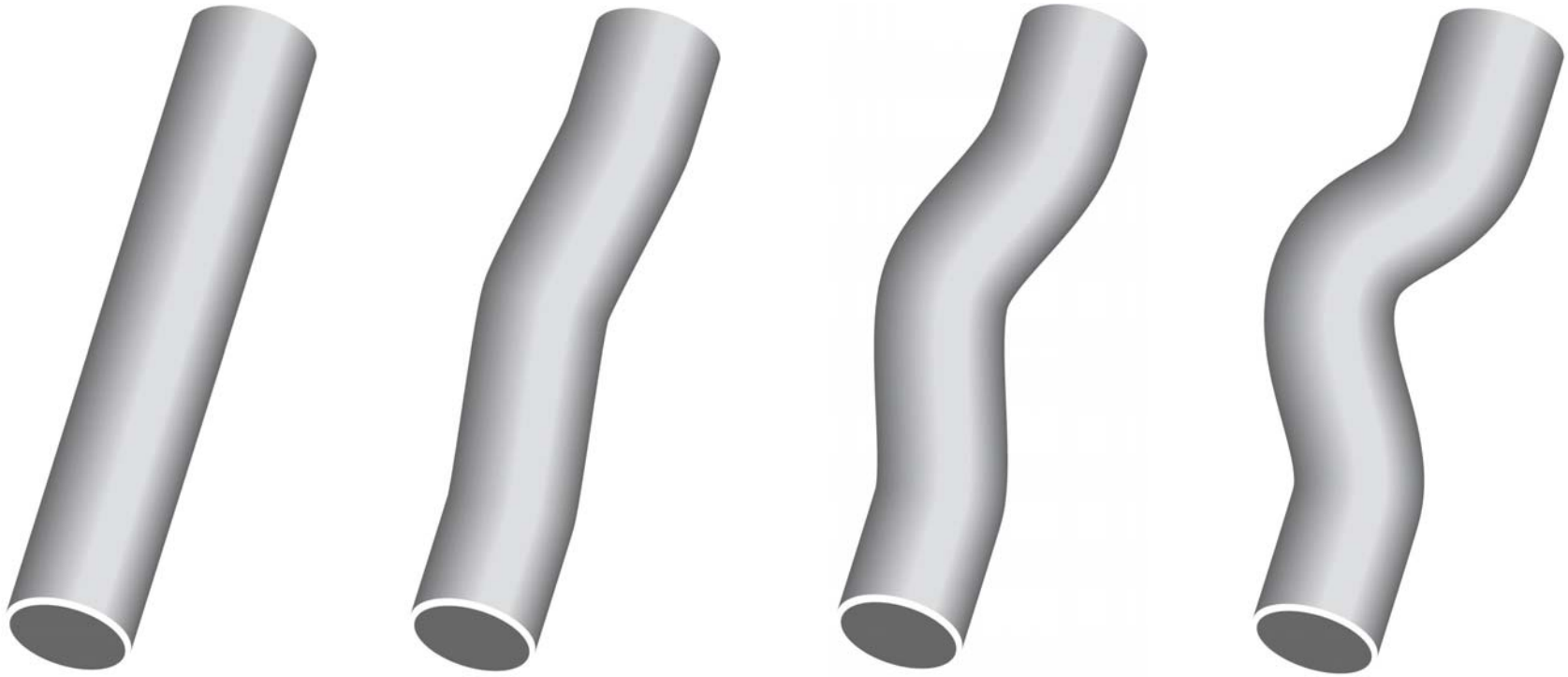
R2 =
Maximum of Displacement

R3 =
End of Displacement

- Strain Values in 4-Point Bending Area

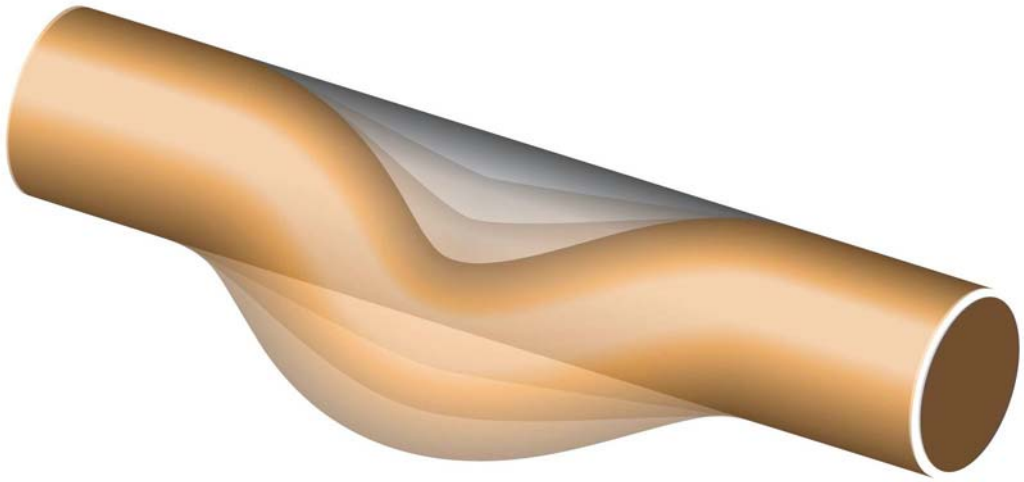
Repeatability

Subsequently induced Bending Strain:



- Bending Strain Series inspected several times
- High Repeatability of Bending Strain levels

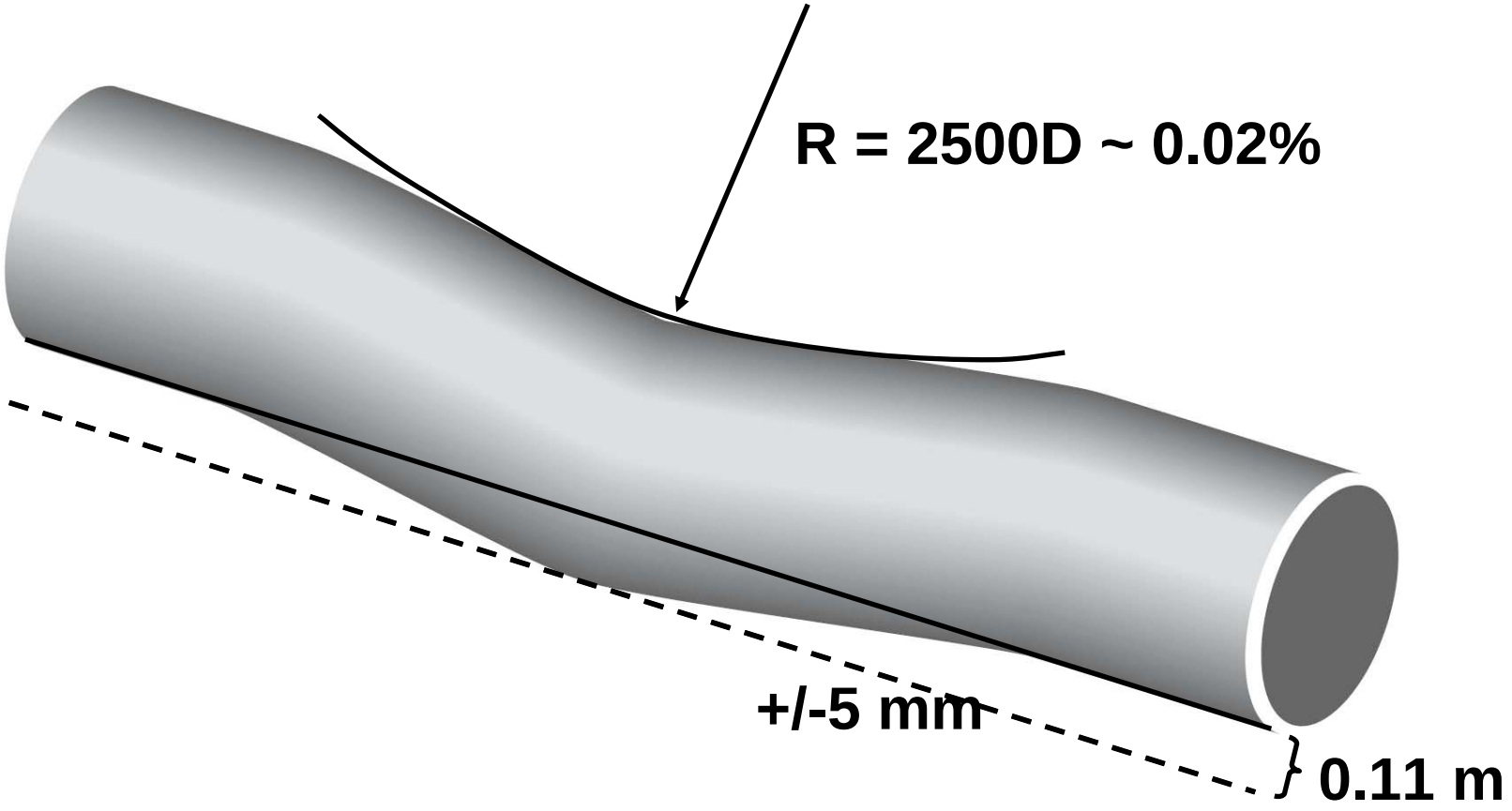
Accuracy of Bending Strain:



- Comparison of several Bending Strain Results
- Accuracy reaches 0.002% or +/-5 mm displacement over 20 m of 16" Pipeline

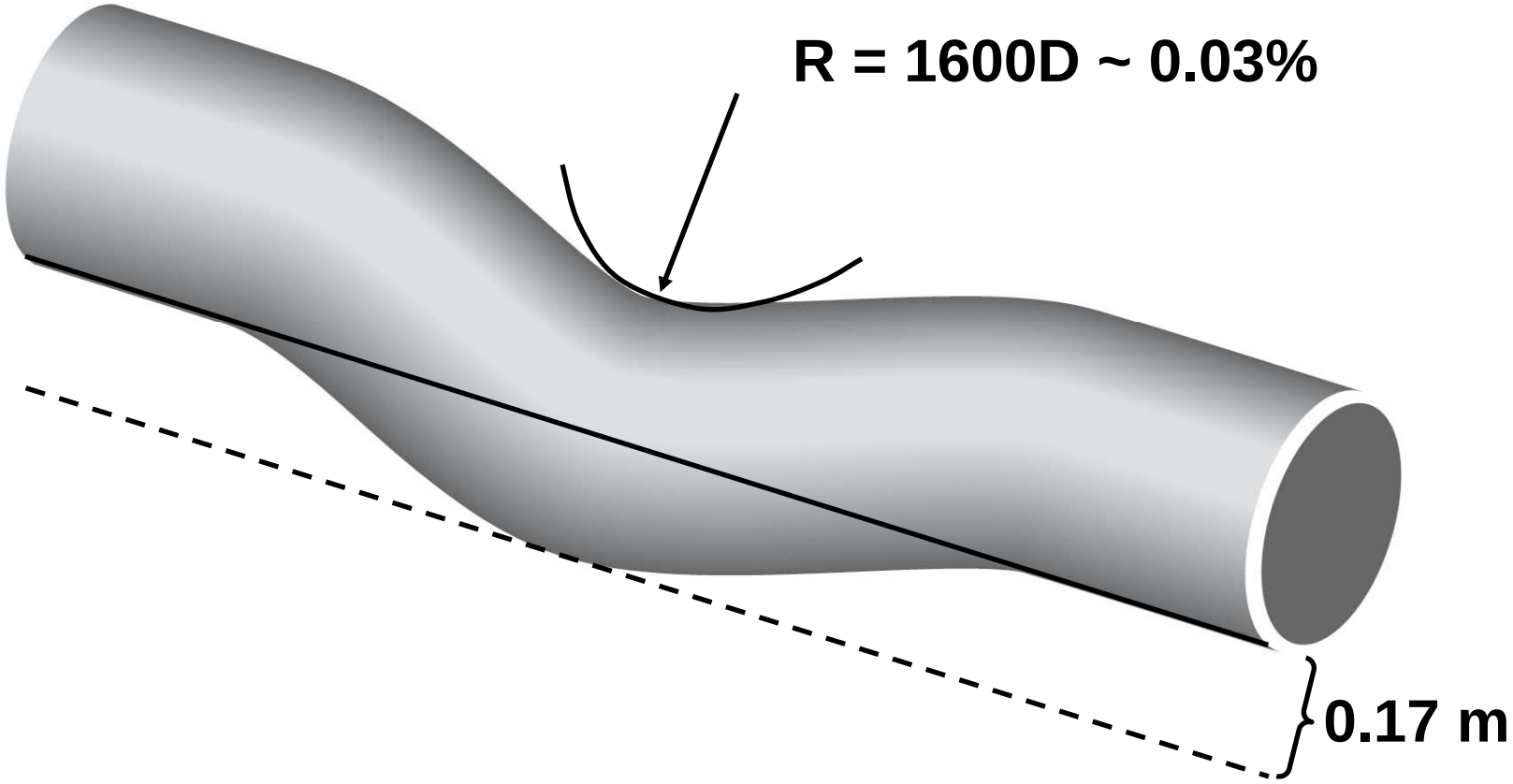
Distinction, Accuracy

Bending Strain and Displacement Accuracy:



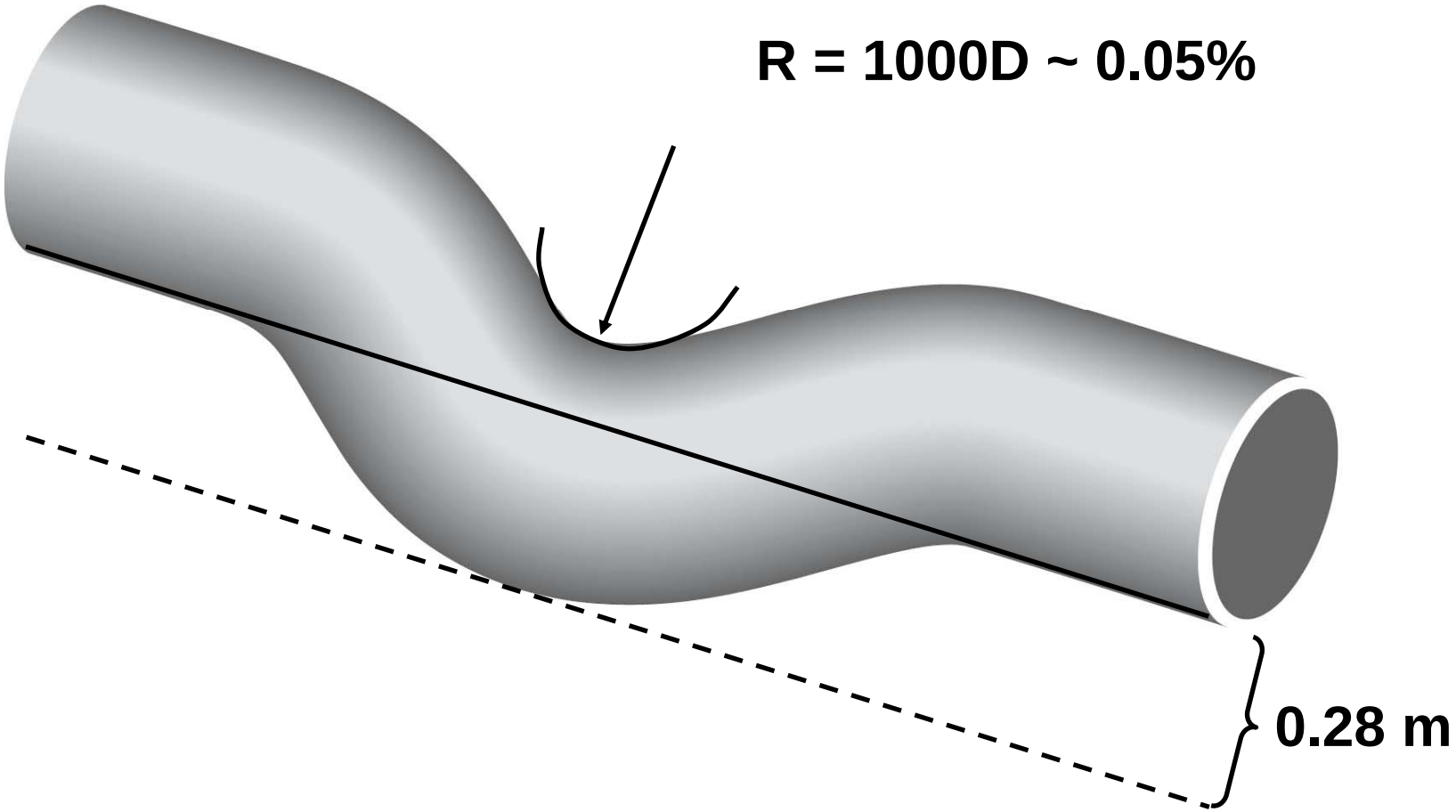
- Accuracy in Bending Strain equivalent to Displacement

Bending Strain and Displacement over 30 m Distance:



- The larger the bend radius the smaller the displacement

Bending Strain and Displacement over 30 m Distance:



- Smaller Bending Strain Radius with more displacement

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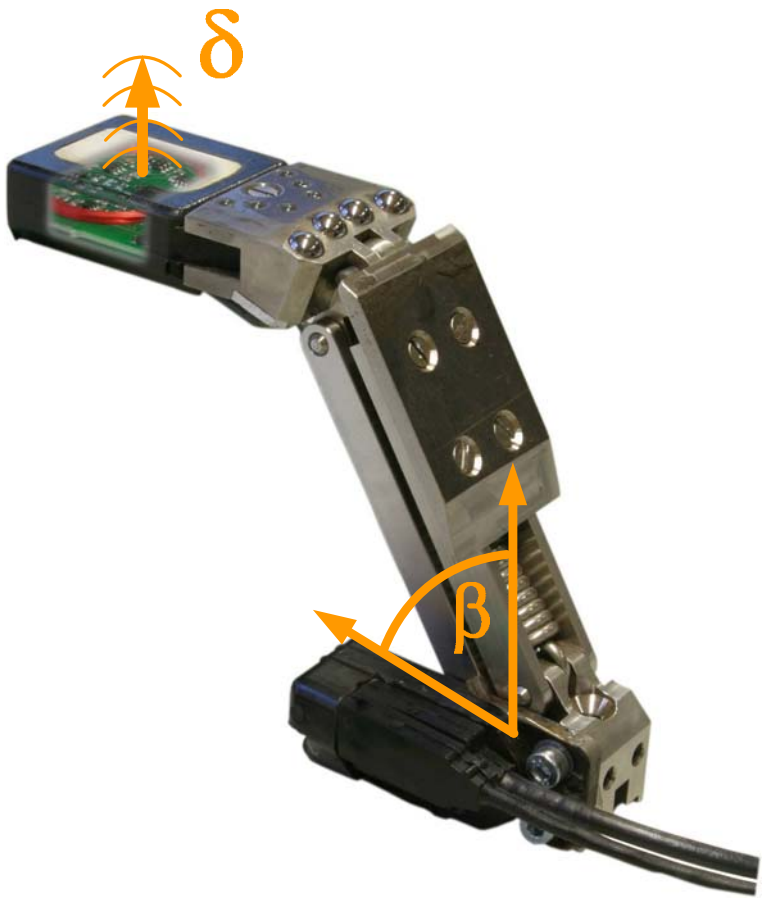
Mechatronic Sensor



Radius Measurement

=

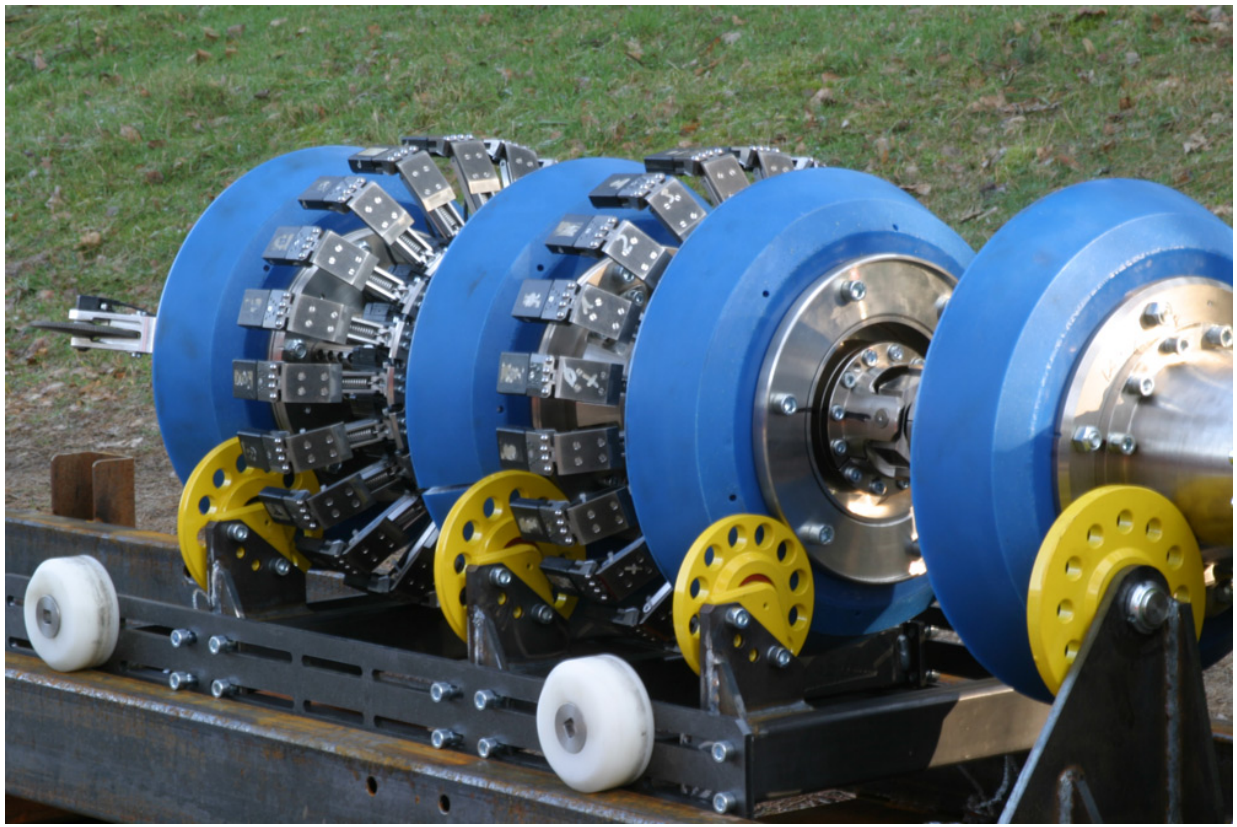
δ Touchless Proximity Sensor

+

β Electronic Angle Sensor

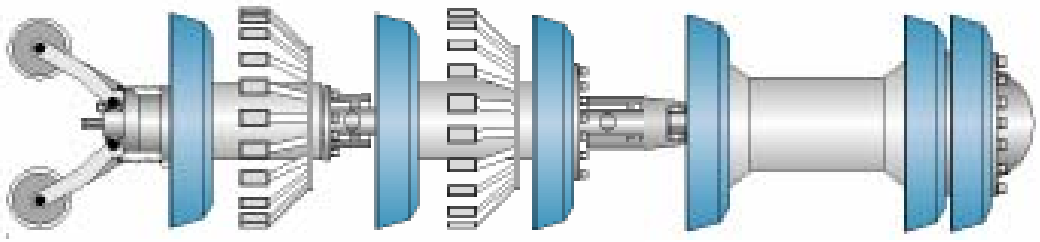
Single Geometry Inspection

ROSEN Extended Geometry Tool (RoGeo·Xt)



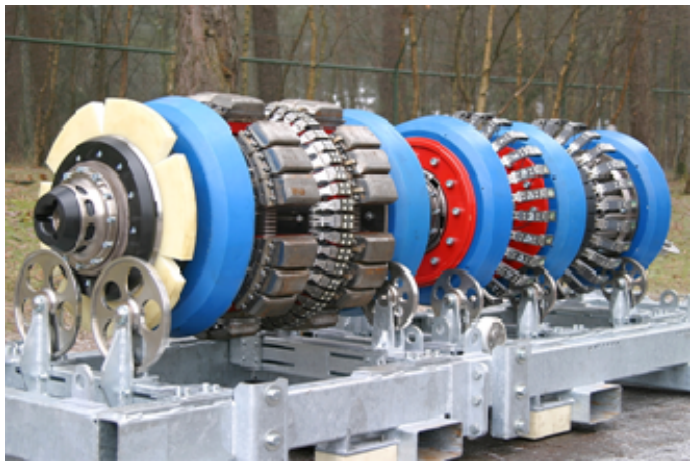
Two plane system:

100% coverage

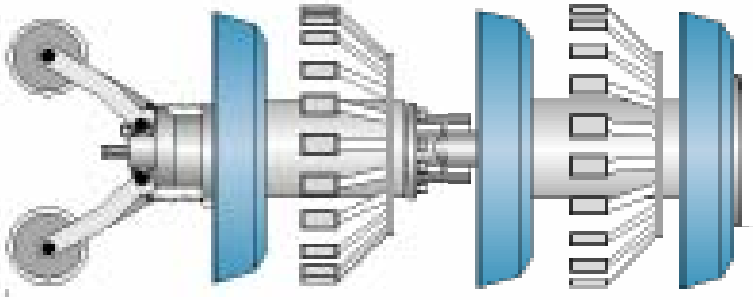


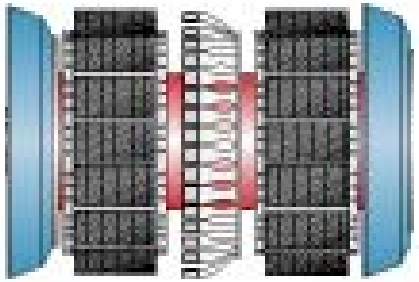
Multi Purpose Tools

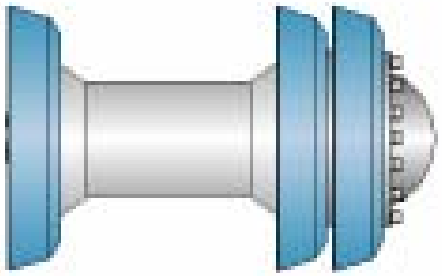
Mechatronic Sensor



MFL-tool with XYZ mapping



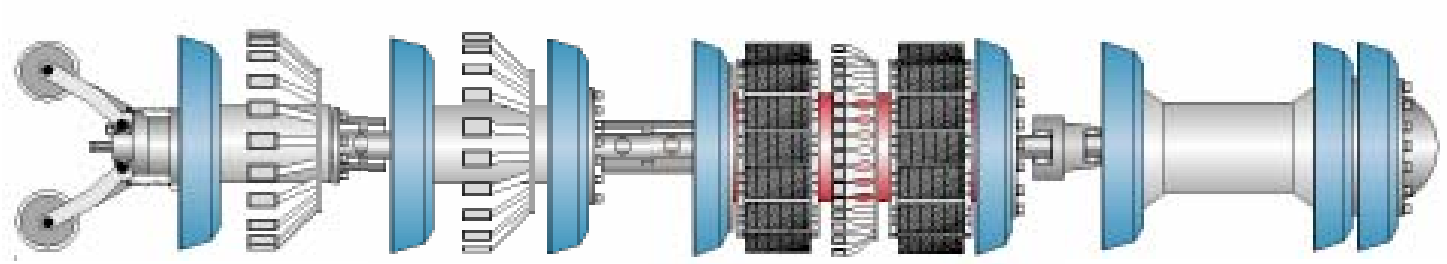




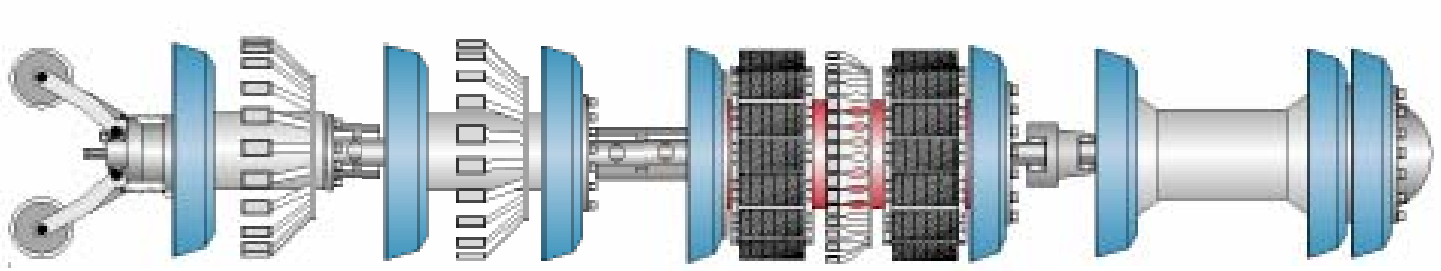
Contents

Conclusions

- Strain Detection confident from 0.01% and higher
- Repeatability of all induced Strain levels with 90%
- Accuracy of 0.002% / 5 mm displacement over 20 m of 16" Pipeline
- Combined Inspection Tools for Strain and MFL Inspection



Conclusions



Thank you for joining this presentation.