SMART PIPE®

A Trenchless Technology System That Gives A New and Better Life To Disadvantaged High Pressure Pipelines

Objectives of This Presentation

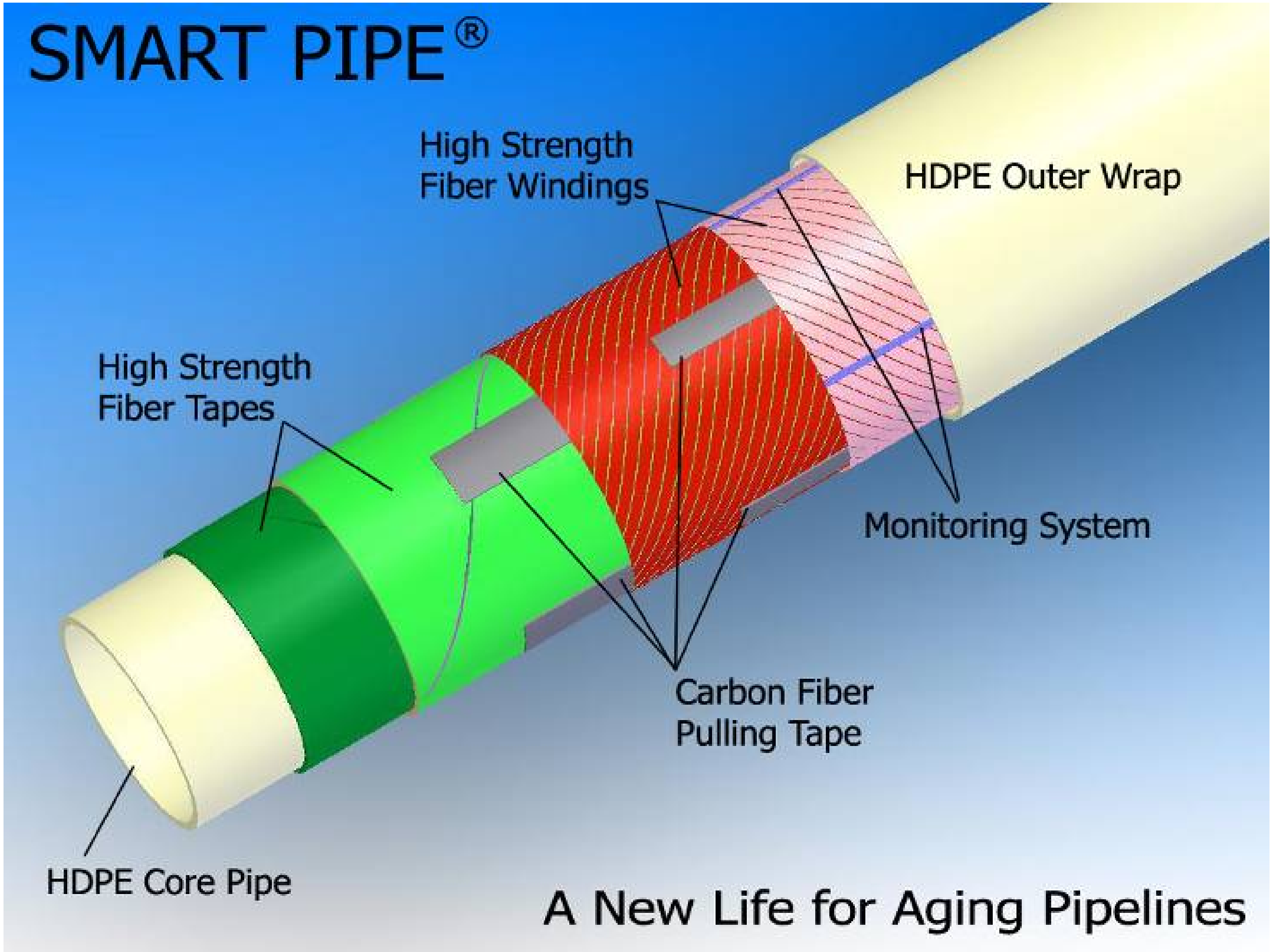
- Review the engineering work that establishes the strength and durability of Smart Pipe®
- Identify possible rehabilitation projects where Smart Pipe® technology is most appropriate

Engineering Basis for the Smart Pipe Concept

Smart Pipe Installations Can Be Tailored and Cost Optimized for Operator Specified Criteria:

- Specified Max Operating Pressure/Temperature
- Overall Length of Line to be Rehabilitated
- Most Challenging Bend (radius + location)
- Specified Safe Operating Life
- Required Factor of Safety

Schematic of Typical Design



Smart Pipe Does Not Have One Single Set of Mechanical Performance Properties:

It is tailored to meet the desired operating criteria and pipe/ground conditions in each individual installation in the most economical manner possible

Smart Pipe Design Variables

- Fiber types (co-helical wrap & pull-in tapes)
- Thickness of fabric in co-helical wrap
- Co-helical wrap angle and coverage (overlap)
- Core pipe material and thickness
- Amount of pull-in tape
- External coating material and mode (spray-on)

Contrasting Mechanical Properties of Ultra High Strength Fiber Materials with Representative Linepipe Steel

Fiber Type	Measured Mechanical Properties			Calculated Strength to Density Ratio (miles)
	Density (lbs/in^3)	Modulus (ksi)	Strength (ksi)	
Dyneema®	.035	15,700	486	219
Spectra®	.035	15,000	435	196
Carbon	.065	34,000	700	170
Kevlar®	.052	18,000	525	159
Vectran®	.050	9,000	412	130
E-Glass	.092	12,000	500	86
Pipe Steel	.283	29,000	100	6

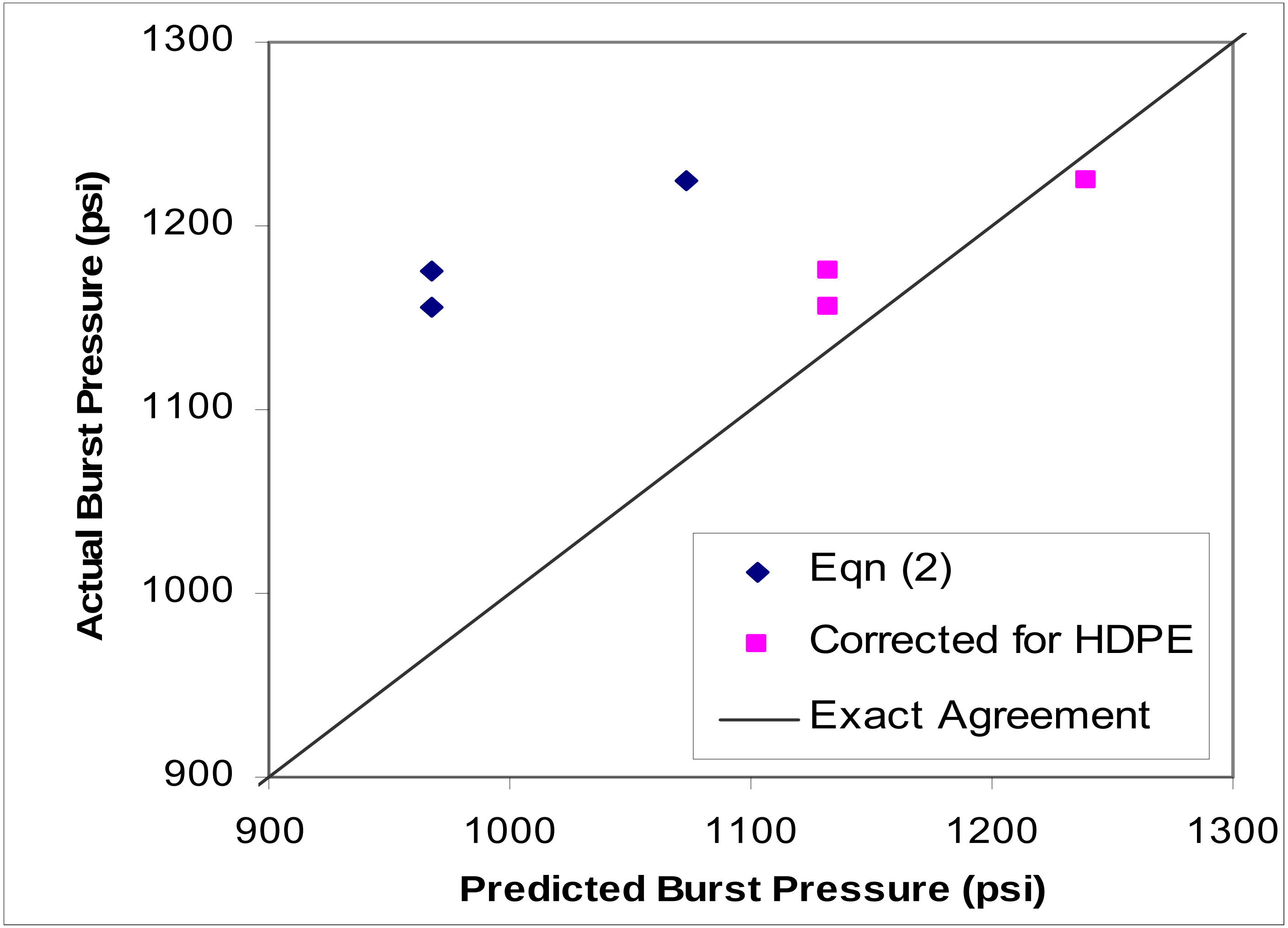
Test Article for First Installation 8” Diameter Pipe

Typical Failure Mode in a Smart Pipe Burst Test (8 inch Pipe)

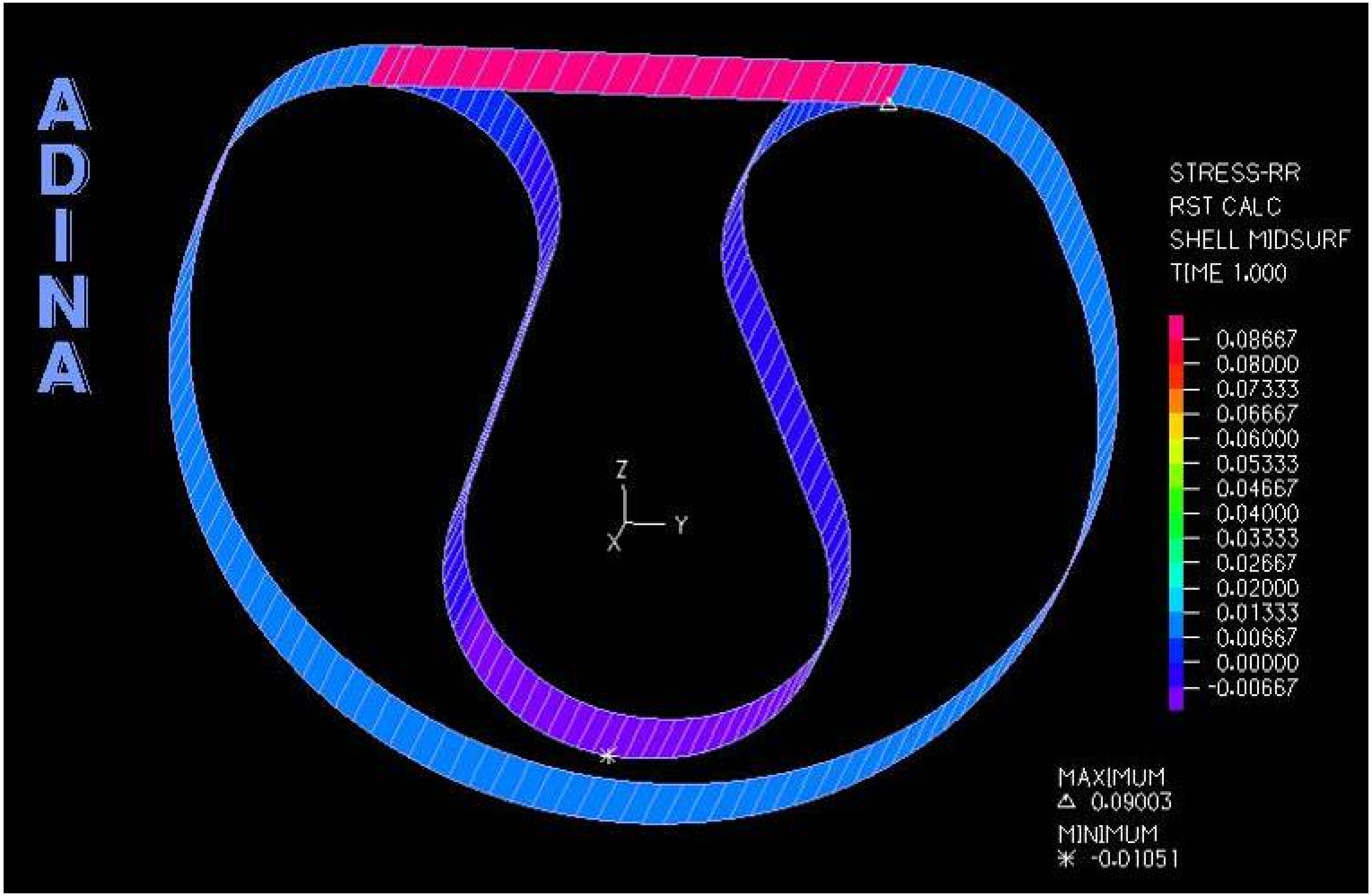
Engineering Design Equation for Burst Strength Estimate Based on Co-helically Wrapped Fabrics

$$p_b = \frac{2 M_h G_h}{D_p} \sin^2 \theta$$

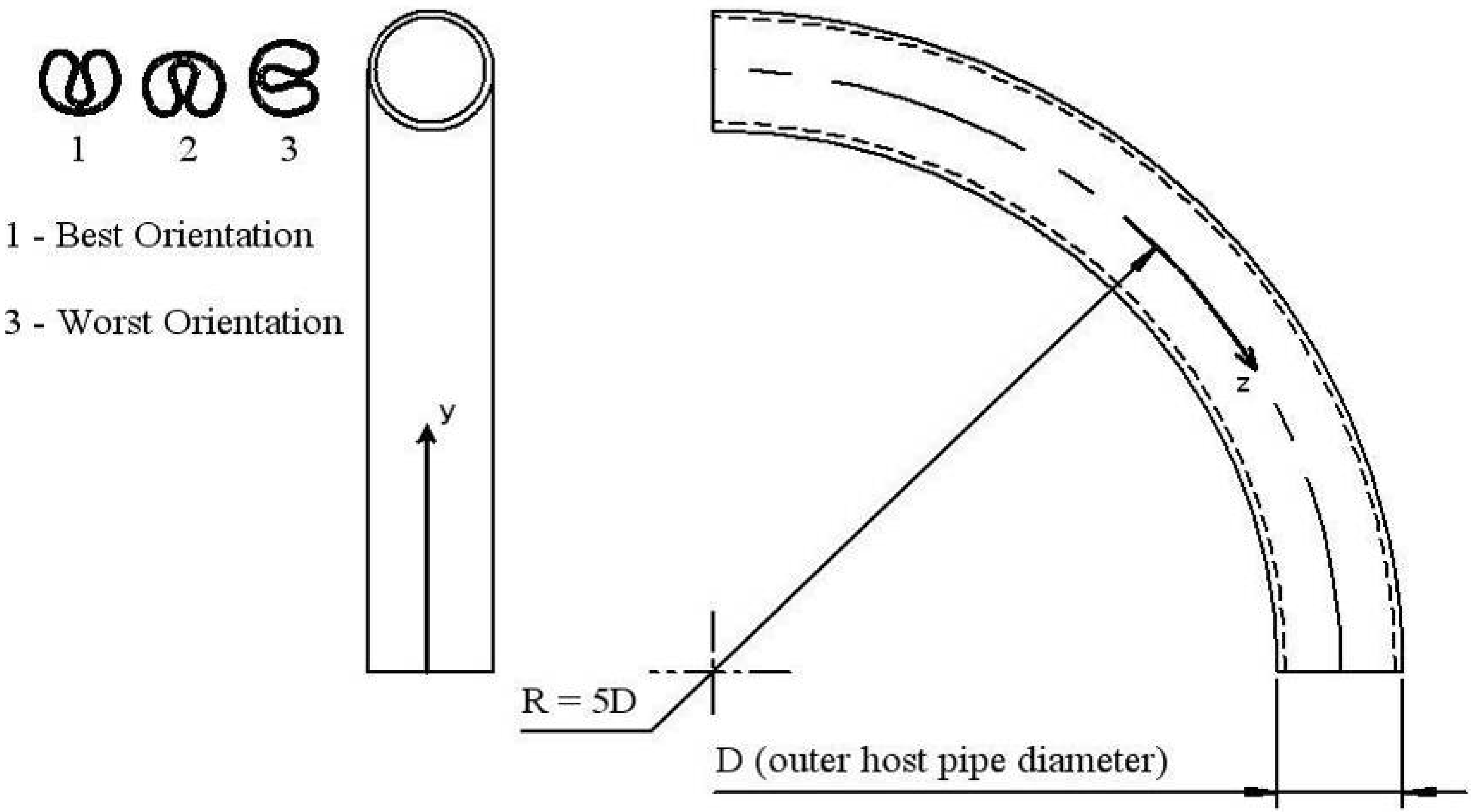
Comparison of Predicted and Actual Burst pressures for First Installation



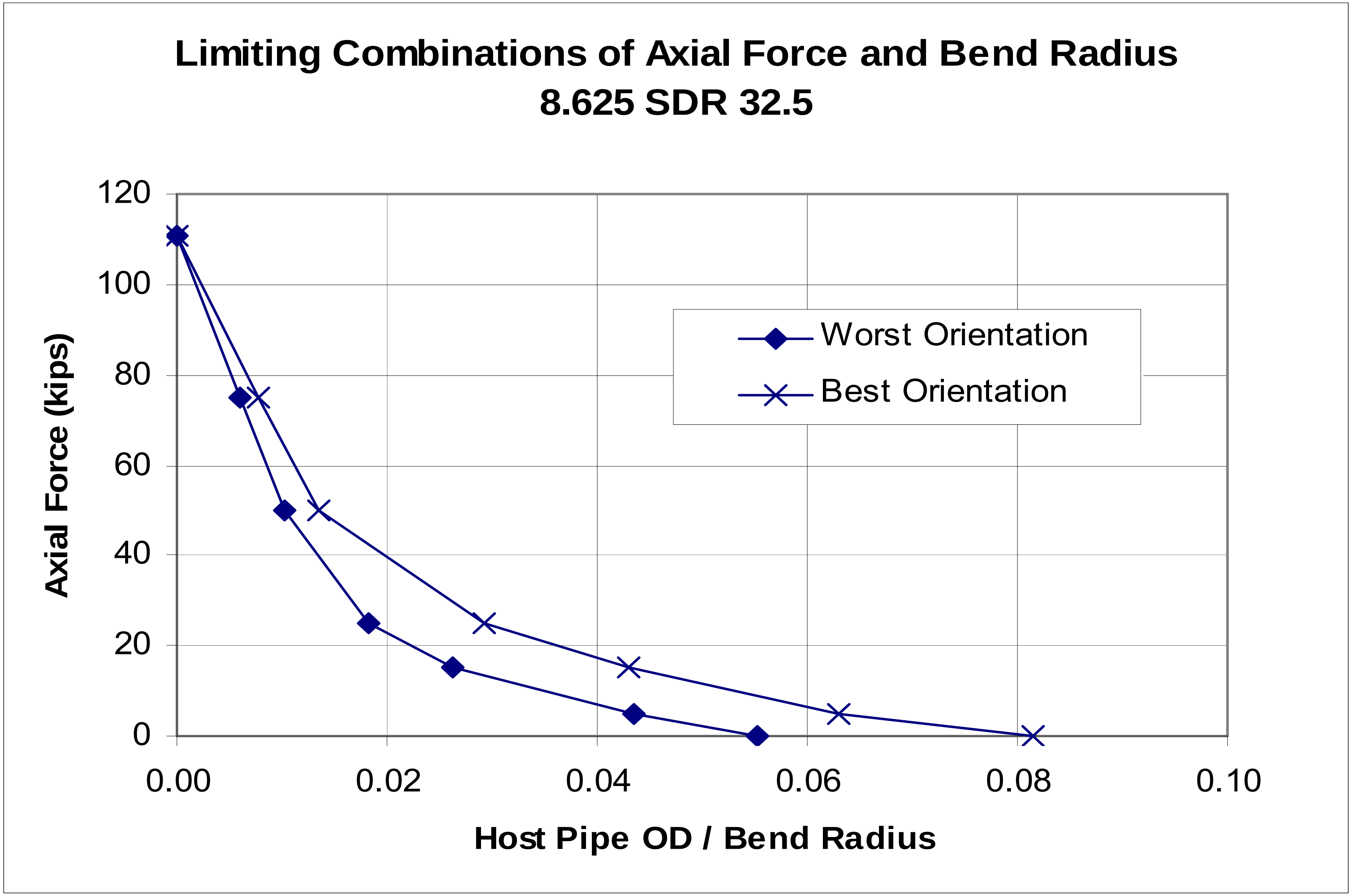
FEA Simulation of Forces Needed to Restrain C-Form During Installation and to Release it in the Reformation Process



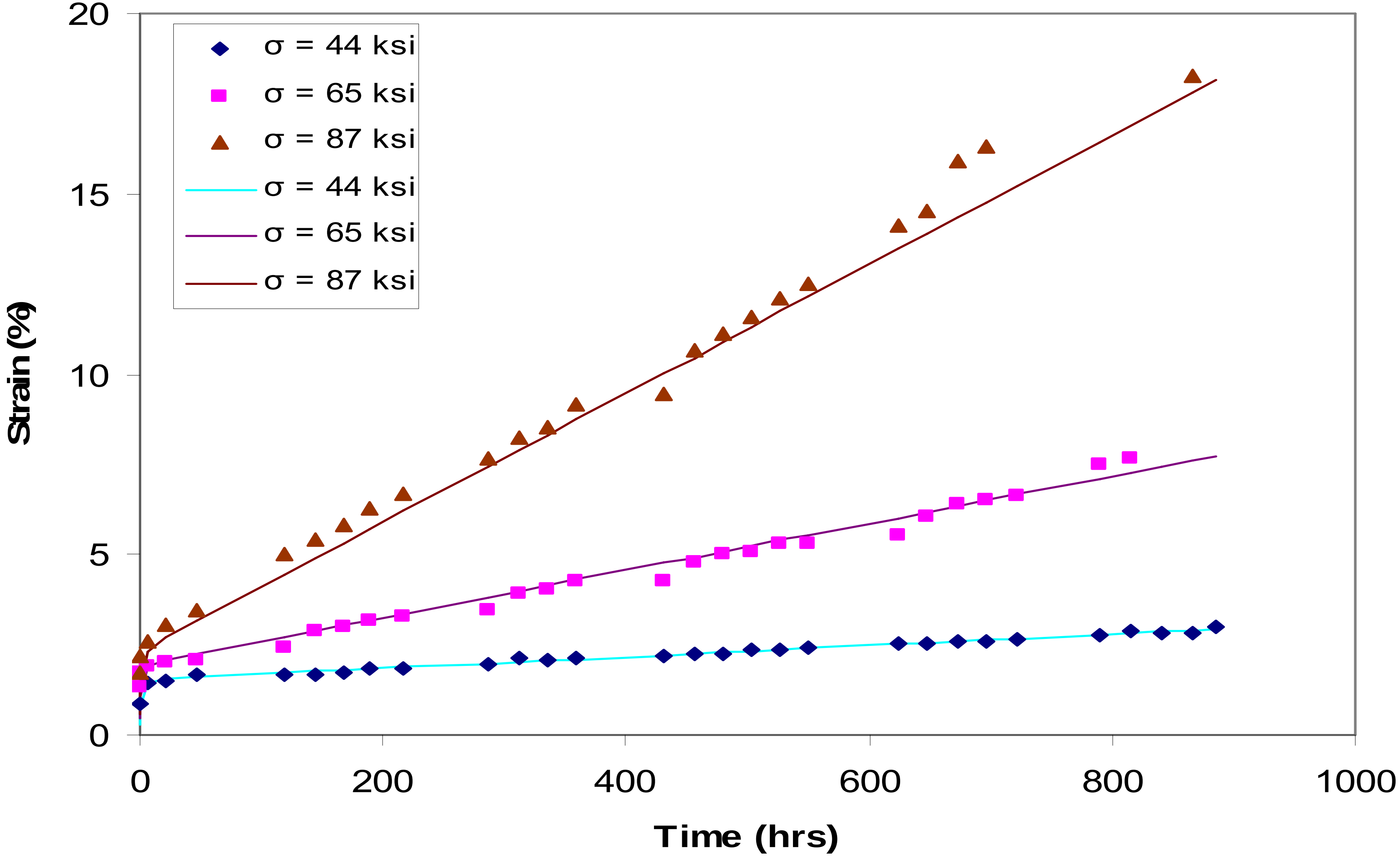
Parameters for FEA Simulations of C-Formed Pipe Pulled Through Bends in a Host Pipe



Results of FEA Calculations on C-Formed Liner Transversing Bends



Creep of Spectra Fibers Under Constant Load at Ambient Temperature



Nonlinear Viscoelastic-Plastic Characterization of Creep in High Molecular Weight PE Fibers as a Function of Stress and Temperature

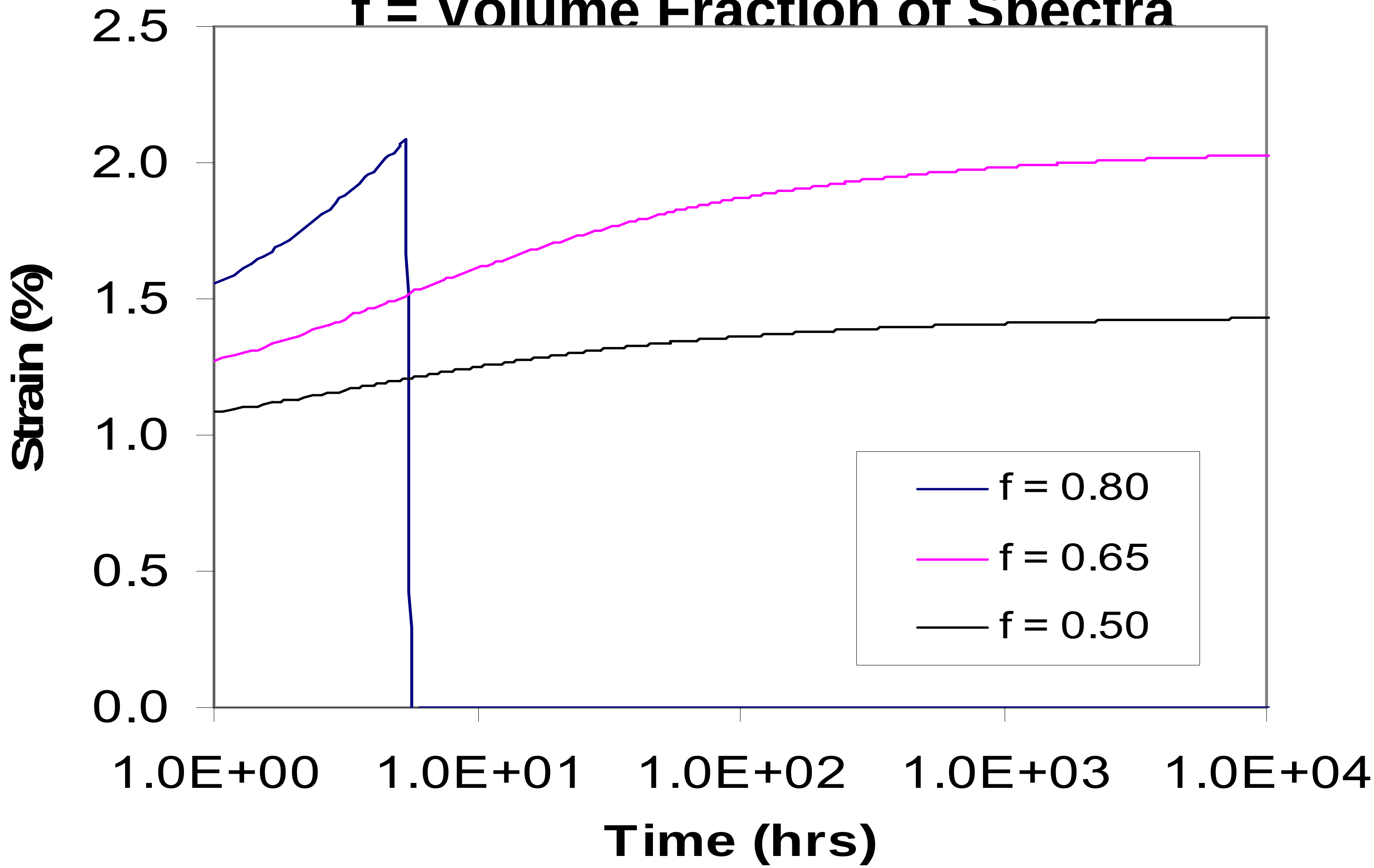
$$\varepsilon(t) = \frac{\sigma}{E} + K\sigma^{n}(1 - e^{-\lambda t}) + C\exp(T - T_R)\sigma^{m}t$$

Long Term Durability: Hybrid Material

- Ultra high strength fibers will provide appropriate level of pressure carrying capability, but cannot be used for more than 5 to 10 years of service
- A combination of intermingled carbon and Dyneema fibers in the form of a hybrid will provide strength for 40 years of service
- This hybrid will also provide a high level of damage tolerance and improved handling properties in the manufacturing process

Calculated Strain History in Dyneema/Carbon Hybrids Under Constant Applied Load

f = Volume Fraction of Spectra



Summary

- Smart Pipe is a project specific engineered solution for many pipeline rehabilitation applications
- Installations are cost competitive in class 1 and 2 locations, but much more economical in class 3 and 4 compared to open trench
- Lifetime costs are significantly less than steel because corrosion protection and smart pigging are unnecessary

Current Operational Status

- Portable factory for 6” to 16” pipe is operable
- First Smart Pipe installation successfully completed in July 2006
- Next installation anticipated for Spring 2007
- Negotiations on installations with major gas/liquid energy companies are in progress

Current Operational Status (Cont.)

- Communications with DoT/OPS are in progress to pave the way for waiver applications
- An industry/OPS supported demonstration project is being pursued with GTI

Point of Contact:

Robin McIntosh

Smart Pipe Company, LP

Houston Technology Center

410 Pierce Street

Houston, TX 77002

Phone: 713-858-4923

E-Mail: robin.mcintosh@smart-pipe.com

Web site: www.smart-pipe.com

The Smart Pipe Team
Thanks You for Your Kind Attention!