Analyzing Parameters Affecting Maximum Surge Pressure in Pipelines

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"Pipeline Integrity Management"

-Maintaining Safety & Reliability of the Pipelines

Authored and Presented by

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About the Authors

Gaurav Bhende

Gaurav is the founder of Protton Engineering, a specialized engineering consultancy firm providing total engineering and design solutions to the process and petrochemical sectors. He has 17 years of specialized industry experience in piping and pipeline static and dynamic stress analysis, GRE/FRP pipe stress analysis and underground pipe stress analysis.

He has successfully conducted several professional training courses on stress analysis using the CAESAR II software for international engineering companies and Institutes. He has also participated as a speaker in various internationally recognized forums, and has had a number of articles published in international journals.

Prajakta Joshi

Prajakta Joshi is currently working for Aker Solutions as a principal process engineer. She has 12 years of experience in executing conceptual, FEED and detailed engineering for the chemical and refining industries.

Prajakta has developed special expertise in the thermal design of shell and tube heat exchangers. She has a special interest in exploring alternatives to optimize the process design. She has also authored an article on relief load estimation of gases, vapors and supercritical fluids.

Contents

What is Surge Pressure?

- Surge pressures occur in a pipe transporting fluid as a result of a change in the flow velocity, e.g. if a valve is closed or opened too rapidly.
- The change in flow velocity creates a force due to rate of change of momentum.
- The pressure wave travels with the velocity of sound in the fluid (i.e. it travels at almost acoustic or sonic speed.) As this wave propagates, it creates transient fluctuations in pressure and flow conditions throughout the system.
- Over the time, with dampening action due to friction, the wave diminishes to stabilize the system at a new steady state condition.

- VIDEO

Typical surge failures

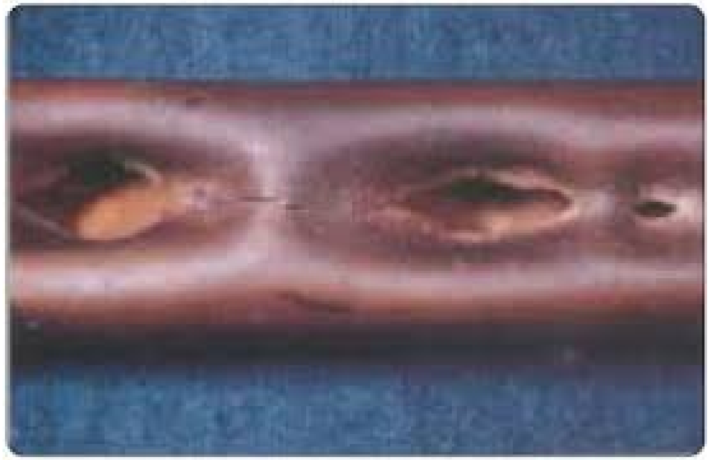
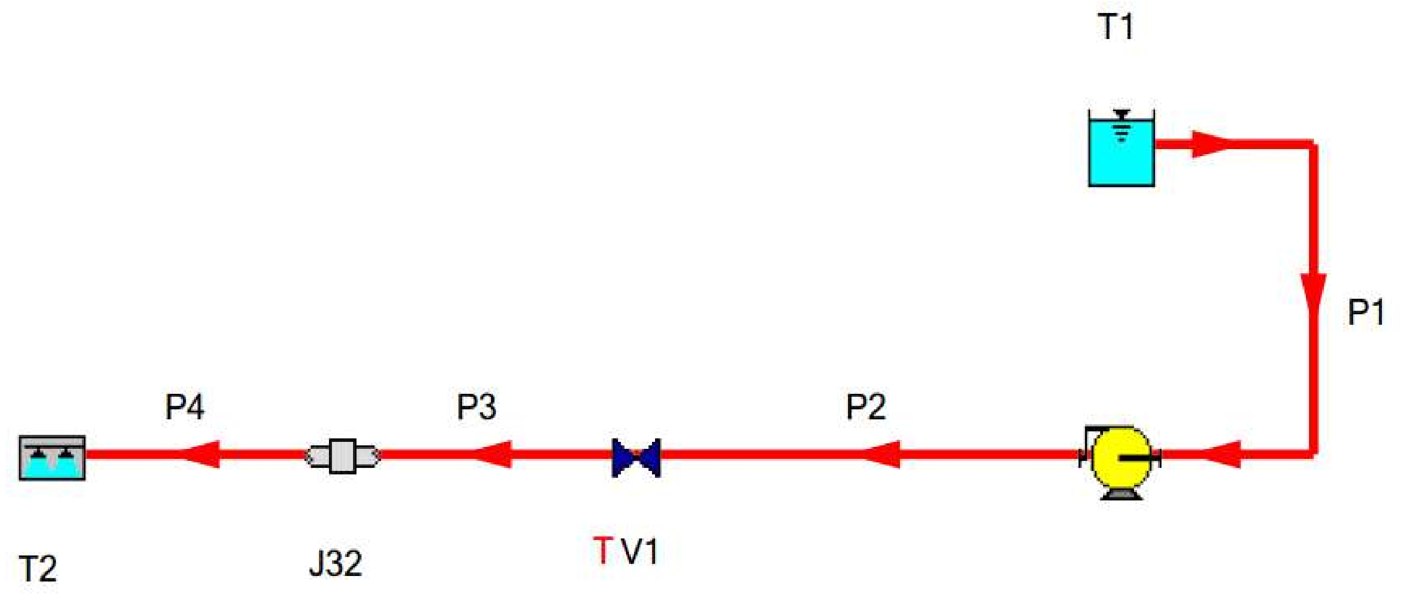


Figure #1

Cast Iron Pipe Broken from Water Hammer

Case Study



A fire water pump is continuously running to pump the fire water into a distribution system. The on/off valve is closed instantaneously resulting in a transient event.
Line size = 12 inch, CS Schedule 40, flow rate of 650 m^3/hr at a 65˚C temperature and 2 barg

Methods of Evaluation

Manual Calculation (Joukowsky equation)

- $\Delta P = \rho * a * \Delta v$
  - Where:
    ΔP = Maximum pressure rise, Pa
    ρ = Liquid density, kg/m3
    a = Pressure wave velocity, m/s
    Δv = Velocity change, m/s
- The pressure wave velocity 'a' is given by:

$$a = \sqrt{\left[\frac{1}{\left(\frac{1}{K}+\frac{d}{tw}*\frac{1}{E}\right)*\rho}\right]}$$

  - Where:
    K = Liquid Bulk Modulus, Pa
    d = Pipe internal diameter, m
    tw = Pipe wall thickness, m
    E = Young's modulus of pipe material, Pa

ρ	**= liquid density, kg/m**	**= 980.48 kg/m^3 at 65°C**
Δv	= velocity change, m/s	= 2.5 m/s
K	= Liquid Bulk Modulus, Pa	= 2.1085 e+9 Pa
d	= pipe internal diameter, m	= 0.3048 m
tw	= pipe internal diameter, m	= 0.3048 m
E	= Young's Modulus	= 2.01221e^{+11} Pa

Manual Calculations results in
Surge Pressure = **33.45 barg.**
force magnitude= DLF x Ax P
F = 2*726*33.45*9.81 = 476kN, which is unrealistic.

Methods of Evaluation

Dynamic Calculation

- Preferred
  - Efficient and cost effective tool
  - Limitations of manual calculations
- Surge pressure calculated by manual method is too conservative
- Effects not accounted for in manual method
  - Valve coefficient (Cv)
  - Valve characteristic curve / valve closing profile
  - Valve closing time
  - Pipe length

Effect of Variables

- The following parameters are considered as ‘variables’:
  - Valve closing time
  - Valve Cv
  - Valve closing profile (based on type of valve)
  - Pipeline material of construction / modulus of elasticity
  - Fluid properties (e.g. density)
  - Length of pipeline

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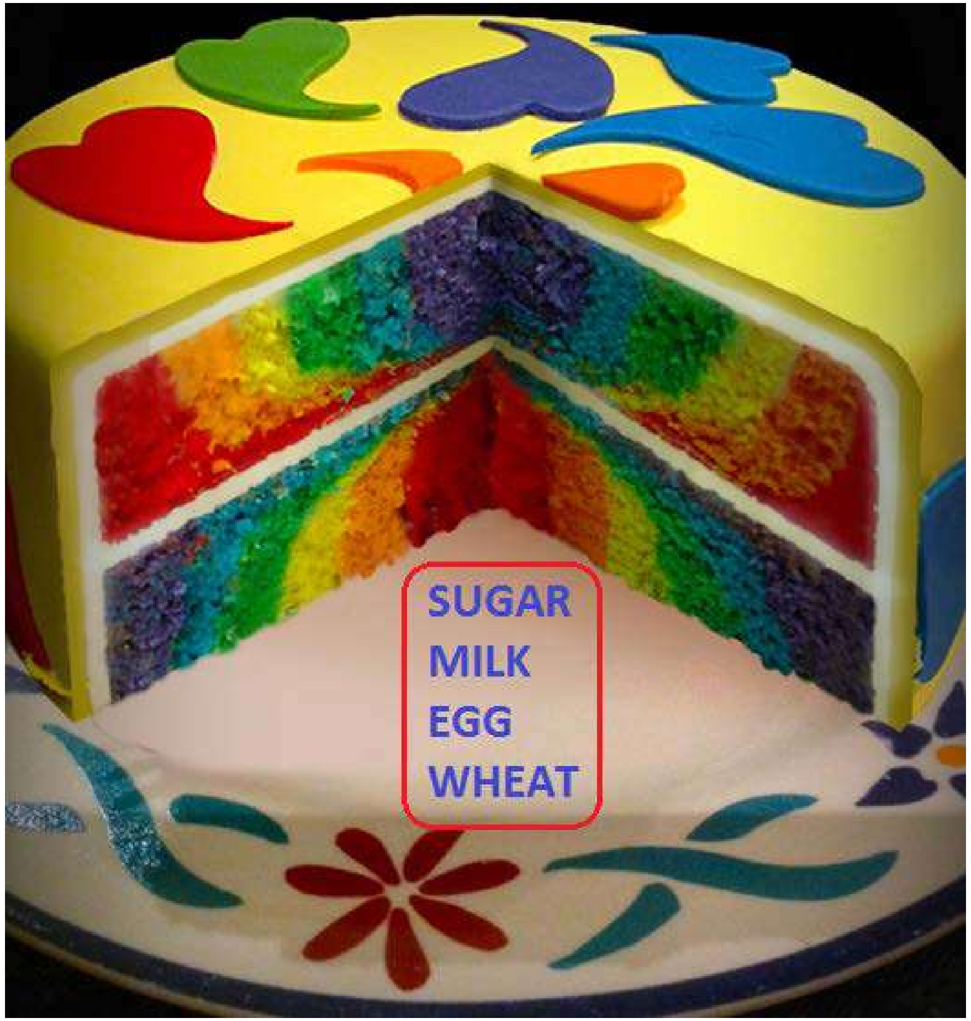
Statistical Approach

Analysis of Variance (ANOVA)

- Statistical methods to study the effects of given parameters in a system
- Method based on experimental results
- Minimizes the number of experiments to be performed
- Gives level of factors which can produce best results
- ‘Smaller is better’ approach used



Analysis of Variance

Sr.No.	Valve Closure Time (sec)	Valve Cv	Valve Closing Profile	MOC	Pipe Schedule	Density (kg/m³)	Pipe Length (km)	Surge Pressure (barg)
Trial	1	2	3	4	5	6	7	Results
1	5	3300	Quick Opening	E least (PVC)	40	1000	0.5	17.54
2	5	3300	Quick Opening	E max (Steel)	120	800	4	29.49
3	5	4200	Ball	E least (PVC)	40	800	4	14.28
4	5	4200	Ball	E max (Steel)	120	1000	0.5	21.35
5	30	3300	Ball	E least (PVC)	120	1000	4	16.35
6	30	3300	Ball	E max (Steel)	40	800	0.5	12.95
7	30	4200	Quick Opening	E least (PVC)	120	800	0.5	21.6
8	30	4200	Quick Opening	E max (Steel)	40	1000	4	27.01

- ARRAY L_7 (2^7) : Levels 2 and Variables 7

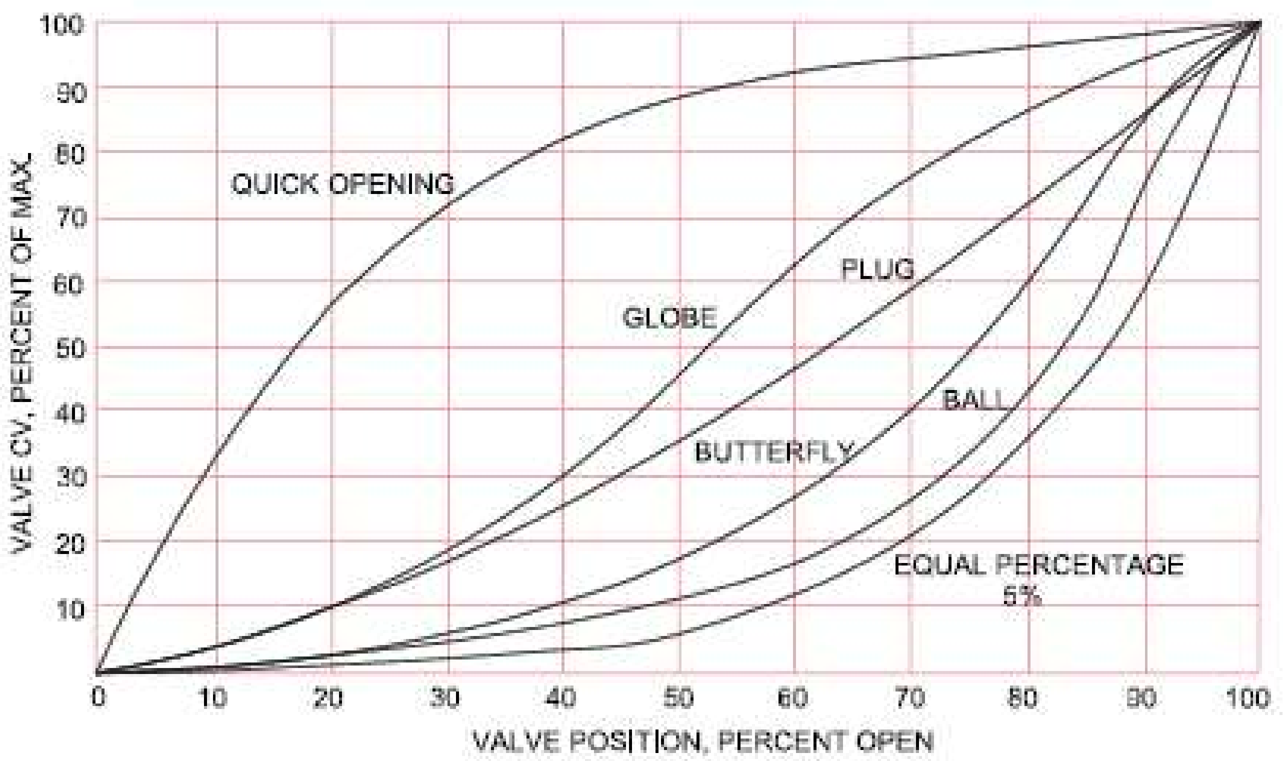
Comparing ANOVA Results for Various Parameters

Sr. No	Variable Factor	P
1	Valve Closure Time (seconds)	1.153
2	Valve Cv	3.195
3	Valve Closing Profile	48.037
4	Modulus of Elasticity (bar)	22.531
5	Pipe Schedule	14.748
6	Density (kg/m^3)	0.785
7	Pipe Length (km)	9.550

Significant Factors

Hierarchy of the Governing Parameters

- Valve closing profile
- Modulus of elasticity of pipe
- Pipe schedule
- Pipe length



Thanks for being patient… Enjoy the conference