Finite Element Analysis of Pipes Considering The Effects of Stress Concentration Factors Due to Dents

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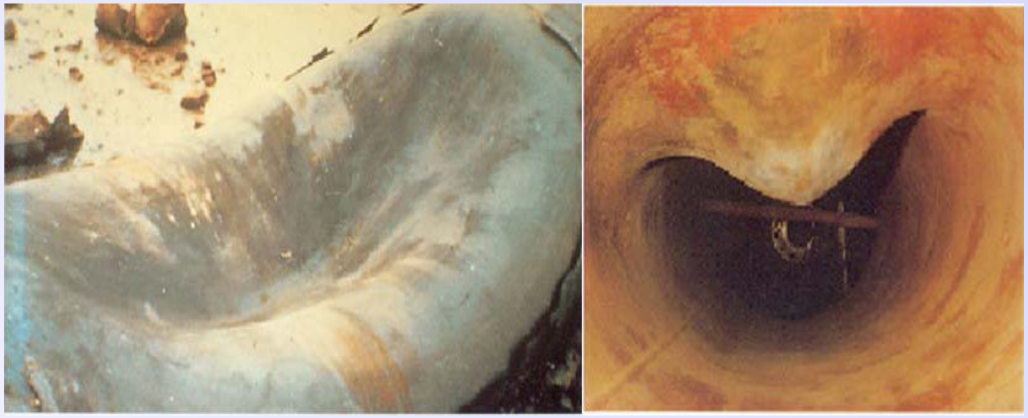
Main Topics

- Introduction
- Geometry and Materials
- Numerical Models
- Results and Discussion
- Conclusions
- References

Introduction

- Pipes can be subjected to mechanical damage such as corrosion, cracking, dents or other defects.
- These defects can be associated with impacts due to falling objects such as anchors, trawling, rocks or landslides.
- Dents are the most common type of defect, thereby causing an inward displacement of the surface of the pipe.

Introduction

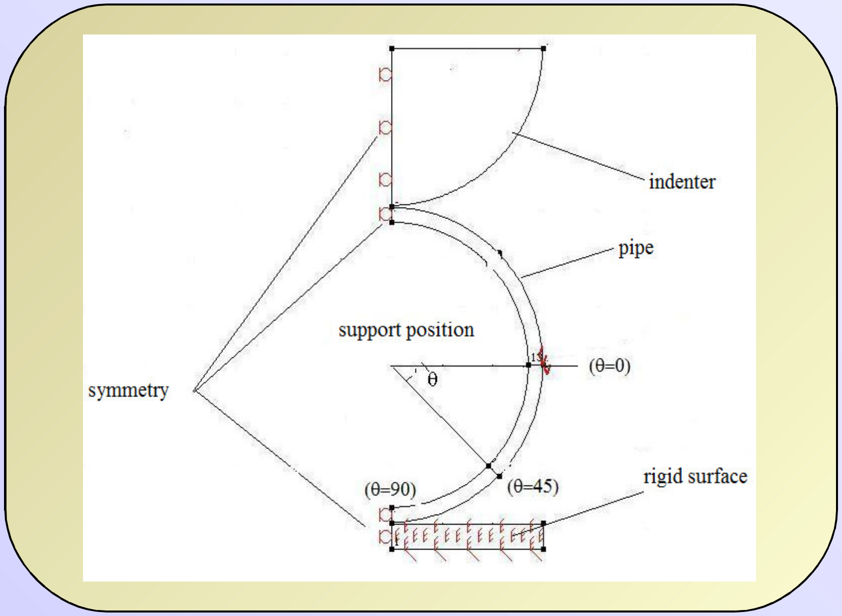


- Dented Pipes

- Mainly, the dents can cause a localized stress concentration.
- The main objective of this work is to investigate the effect of stress concentration on dented pipes due to variation of some parameters such as cylindrical indenter diameter, thickness of the pipe and angle of support.

Geometry and Materials

- The pipes were laid on a rigid surface whose length is the same size of the external diameter of the pipe and thickness of 10mm.
- Different angles of support (θ) are considered, respectively, 0º, 45º e 90º.



Geometry and Materials

- The main geometric parameters of the models are presented in Table 1.

D(mm)	Di(mm)	t(mm)	d(mm)
120	12	2	2.4
	30	2.4	4.8
	60	3	7.2
	90	4	9.6
	120	6	12

Table 1 – Geometric Parameters of the Models

Geometry and Materials

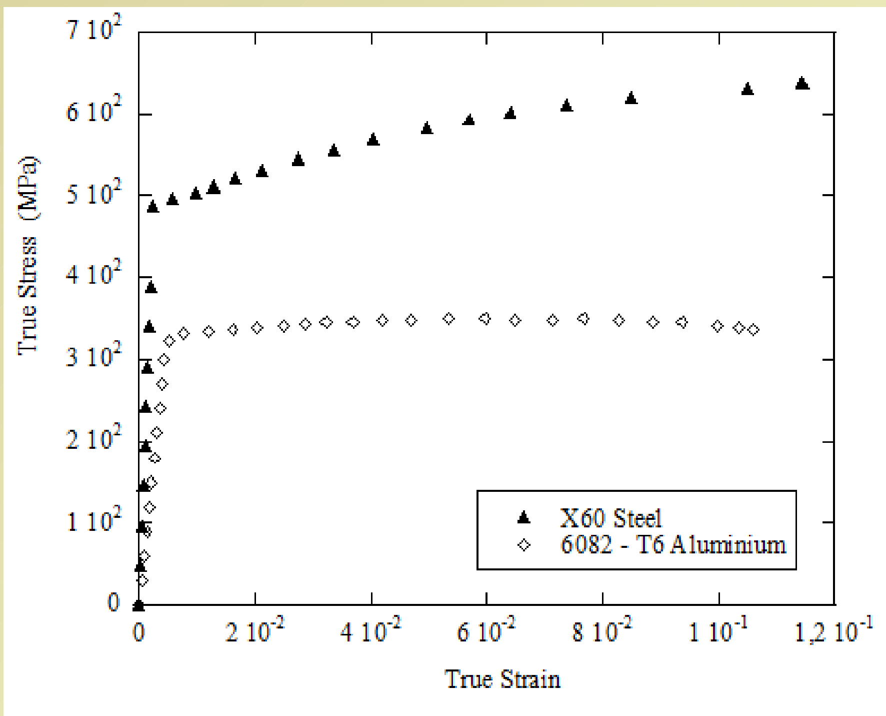
- The dent depth was taken as 2%, 4%, 6%, 8% and 10% of the external diameter of the pipe whereas the indenter diameter was 10%, 25%, 50%, 75% and 100% of the previous parameter.
- Two different materials were also used:
  - 6082-T6 Aluminum
  - X60 Steel
- Their main mechanical properties is shown in Table 2

Properties	6082-T6 Aluminum	X60 Steel
E (MPa)	70000	206820
σ_y (MPa)	300	485
σ_u (MPa)	351	574

Table 2 – Mechanical Properties of the Materials

Geometry and Materials

- Stress-strain curves of both materials.



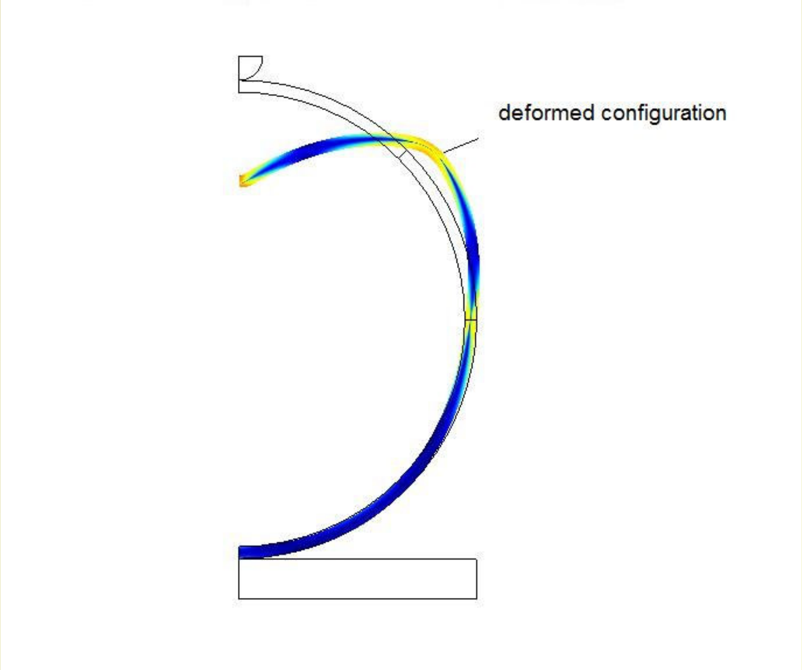
Numerical Models

- The numerical models were developed within the framework of Comsol. Eight-nodes, quadratic and two-dimensional elements were used in the analyses. A sensibility study of the mesh was carried out so as to evaluate the accuracy of the results and computational effort.
- It was adopted a mesh with 734 elements, however, the region near the indentation was more refined with 560 elements.
- Plane strain, frictionless contact, nonlinear geometric analysis were also considered in the model.

Numerical Models

- Analyses Steps
  - The dent is generated by means of a prescribed displacement using a cylindrical indenter
  - And after that, the indenter is removed. The indenter is modeled as a rigid surface.
  - The deformed configuration is stored after the indenter is removed and used to calculate the stress concentration factor by means of applying an internal pressure of 0.1MPa enough to generate an elastic response.

Numerical Models



$$K_t = \frac{\sigma_{\max}}{\sigma_{nom}}$$

- The stress concentration factor is calculated by the ratio between the maximum Von Mises stress and the nominal stress at the centre of the dent.

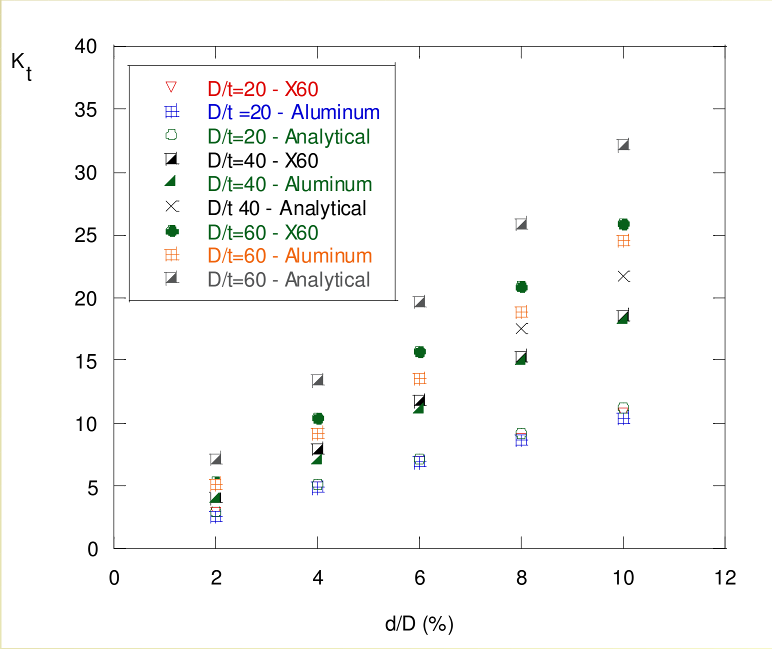
Numerical Models

- The numerical results are compared to an analytical equation (RINEHART, 2007)

$$K_{ana} = 1 - 1.74 \times \frac{d}{D} + 5.22 \times \frac{d}{t}$$

Results and Discussion

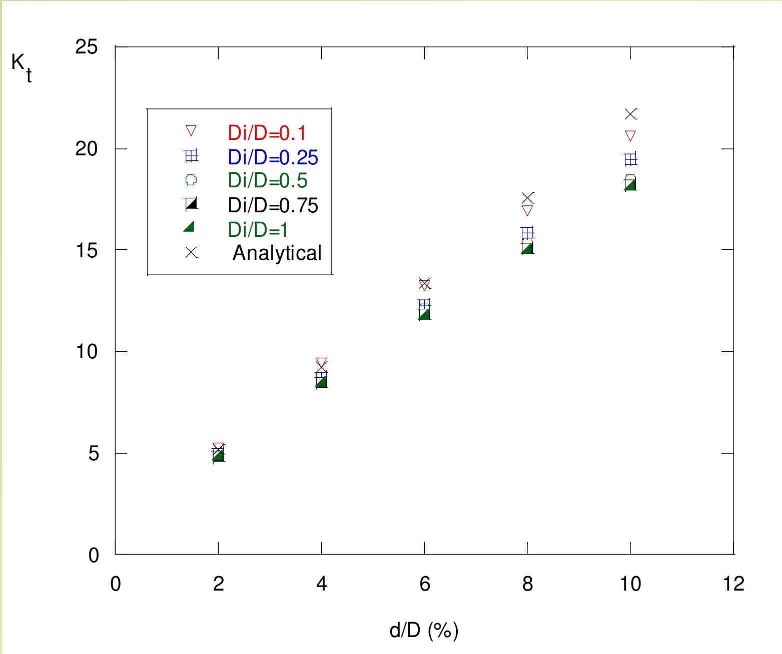
- The influence of the variation of different D/t ratios are compared to different type of materials and dent depth (d).
- An increase of the D/t ratio also causes an increase of the stress concentration induced into the defect (dent).



Results and Discussion

- This figure shows the influence of the variation of the indenter diameter on the stress concentration factor for different d/D ratios.

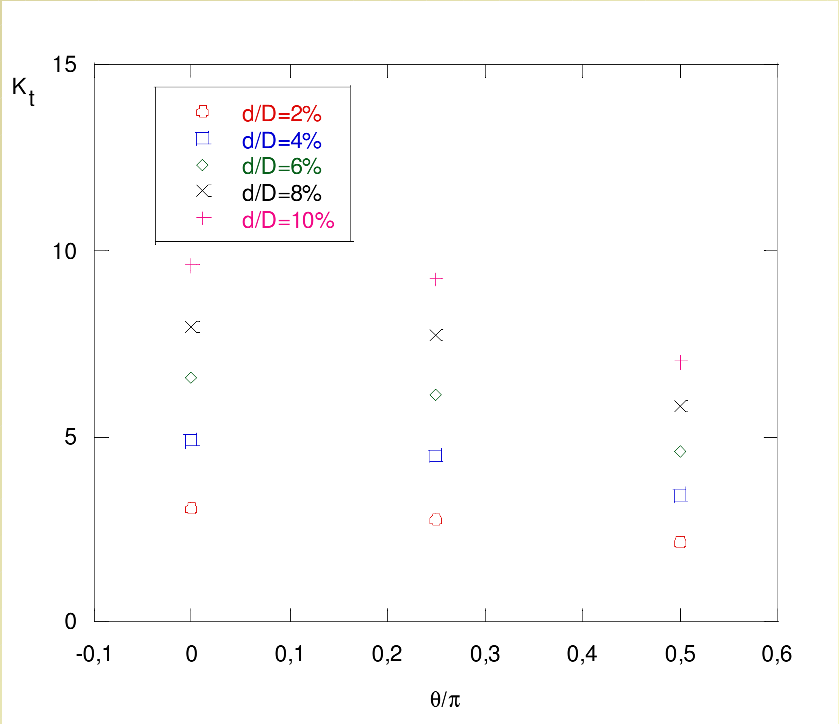
- It worths mentioning that the stress concentration factor increases as lower as the indenter diameter.
- It is also observed that the analytical equation has a favorable response to using low indenter diameter.



Results and Discussion

- This figure shows the variation of the angle support of the pipe.

It seems that lower angles increase the stress concentration factor due to the proximity of the support in relation to the indentation region.
Conversely, higher angles substantially decrease the stress concentration factor induced on the model.



Conclusions

- An increase of the D/t ratio also triggers an increase of the stress concentration induced into the defect (dent).
- The analytical results are more conservative in relation to numerical ones, mainly for deeper dents.
- It was also observed that lower indenter diameters have a more detrimental effect on the stress concentration induced on the model than higher indenter diameters.

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