

Response letter for the review of: **Numerical Analysis of High Pressure Cold Bend Pipe to Investigate the Behaviour of Tension Side Fracture**

Dear Editor,

We thank the reviewers for the detailed and careful observations and recommendations for our paper. We have modified the manuscript and have taken the observations and notes into consideration. Below is a detailed response to the reviewers' comments. The reviewer comments are listed in **boldface**.

Reviewer 1:

**The major issue that this paper discusses is unclear. What is the major conclusion in this paper?**

We thank the reviewer for indicating this deficiency in the text. In order to clarify the main objective and conclusions of this paper the following two paragraphs are incorporated to the "Introduction" and "Discussion and Summary" sections respectively.

*"The main objective of this paper is to investigate the buckling at the location of cold bends and how it might eventually lead to the loss of containment capability of the pipe due to fracture in the tension side of the buckle. Furthermore this investigation is used to define a criterion for the allowable curvature and bending angle of a cold bend pipe in the field conditions to prevent the fracture and the loss of containment capability of the pipe."*

*"On the basis of the graphs in Figure 10 and Figure 11, an appropriate failure criterion would be the point at which the plastic strain on the compression side stops increasing while the corresponding plastic strain on the tension side starts increasing dramatically. For our model this was observed at an applied 260 mm horizontal displacement of the loading pin which corresponds to a total bending angle of approximately 20° and a curvature of  $9.5 \cdot 10^{-5} [mm^{-1}]$ . The initial bending angle and curvature of the model were 12° and  $5.6 \cdot 10^{-5} [mm^{-1}]$  respectively."*

**Regarding the references, there is only reference number [2] in the text. All the references should be referred in the text at the appropriate position.**

The references number [1], [2], [3] and [4] are referenced in the "Introduction" section

If you want to discuss the observation induced from a series of FEA results, you should show the comparison of the FEA results such as different internal pressures, pipe geometries, and so on.

We thank the reviewer for pointing out this missing part in the text. In order to compare the system response for different internal pressures, the load displacement curves showing the variation of the reaction force at the loading pin with respect to increasing displacement loading have been plotted for 4 different internal pressures. The load-displacement curves and their interpretations are incorporated in the “Results” section of the paper.

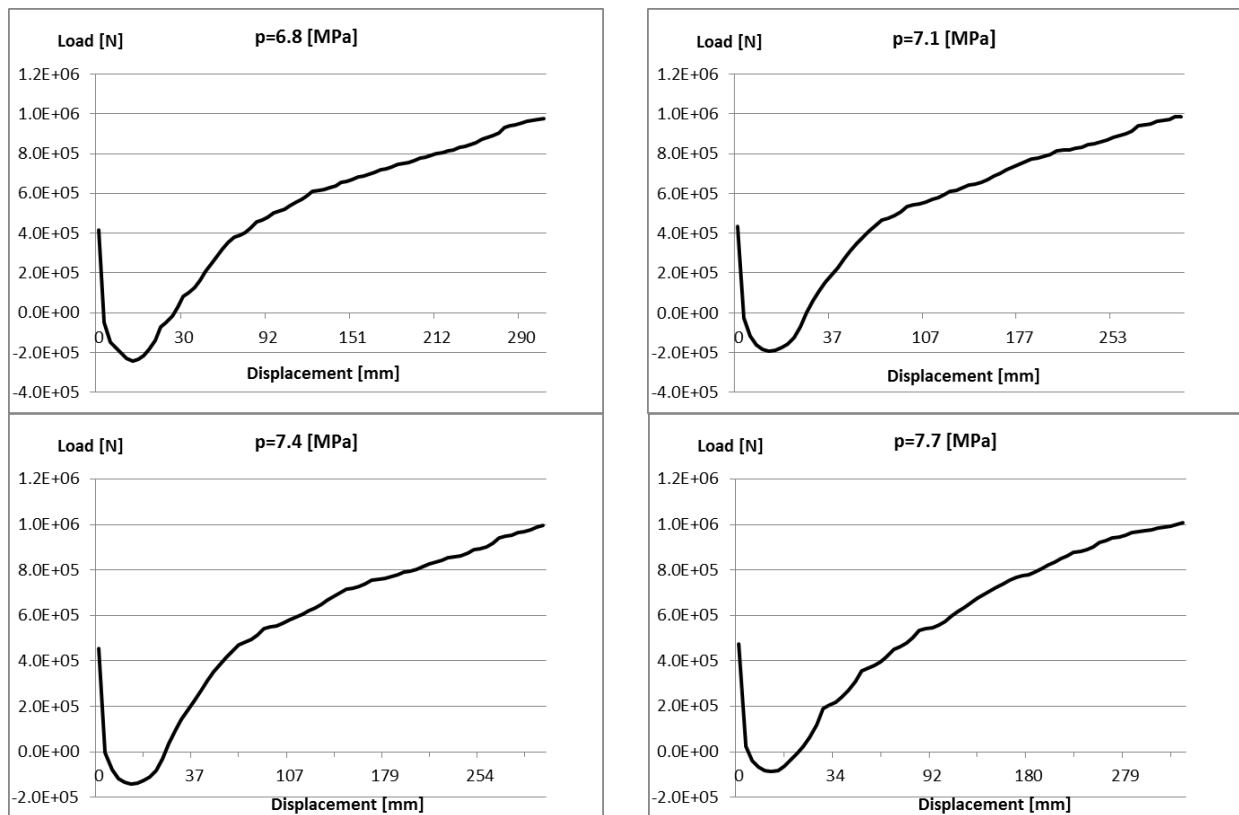


Figure 9: Load-displacement response under bending load and internal pressure

*“It can be observed that there are minor differences between the load – displacement curves for the different internal pressure cases. The common feature of the 4 graphs is that the buckling in the compression side of the pipe takes place in the early stages of the applied bending load although there is no sharp transition to the post-buckling. These curves have been generated by plotting the variation of the reaction force at the loading pin with respect to the displacement of the loading pin in the positive x-direction. Since the increase in the pipe curvature is proportional to the applied displacement and since the model maximum moment is proportional to the reaction force in the x-direction, these curves also give an idea about the change of the maximum moment in the system with respect to the cold bend curvature. The graphs in Figure 9 show that the sign of the reaction force changes directly after the start of the displacement load step. This change of sign is related to the direction of the applied forces due to the internal*

*pressure and due to the external displacement loading. Since these two applied forces have opposite signs it follows that the greater forces caused by the internal pressure lead to negative values of the total reaction force at the beginning of the displacement load step. As the applied curvature increases the magnitude of the associated reaction forces exceeds the magnitude of the reaction forces associated with the internal pressure and the sign of the total reaction force becomes positive.”*

Reviewer 2:

**Work in Japan has already demonstrated this phenomenon, and the authors should include references to this.**

We thank the reviewer for indicating this deficiency in the text. The following paragraph has been incorporated in the “Introduction” section along with the reference to the previous research conducted in this field.

*“The outcome of this experiment was that after the buckling load of the pipe was reached the further loading of the pipe eventually led to a sudden fracture on the tension side of the pipe and the loss of containment capability. Similar experiments have been carried out by Miki et al. [4] which showed the influence of internal pressure on ductile fracture behaviour using pressurized and un-pressurized tension tests in the presence of girth weld defects.”*

**Regarding the content of the paper it is felt to be a bit short on essential details like material properties assumed/used.**

The following paragraph has been incorporated in the section “Numerical Analysis of the Experiment” in order to describe the material model used in the finite element analysis.

*“The grade of the simulated pipe corresponds to 448 MPA specified minimum yield strength. In the finite element model the Young’s modulus of 210700 MPA has been used. To simulate the plastic behaviour of the material a metal plasticity model with isotropic hardening has been applied. In this model a linear increase in the stress from 448.16 MPA to 530.9 MPA is assumed for a plastic strain increase of 5%.”*

**This lack of data is closely linked to a missing discussion on the criterion for fracture on the tension side to occur.**

We thank the reviewer for pointing out this missing part in the paper. The following paragraph has been incorporated in the “Results” section to clarify the fracture criterion proposed in the paper.

*“However at this stage of the displacement controlled loading a decrease in the slope of the curve showing the maximum plastic strain at the tension side is observed. This gives us a means*

*for determining the amount of displacement loading which shall not be exceeded in order not to risk the containment capability of the pipe. Using this method the allowable maximum bend angle and curvature of the cold bend can be calculated. Assuming that the axis of the cold bend pipe is contained within a circle of decreasing radius  $R$  during the entire simulation, the curvature  $\kappa$  of the cold bend can be approximated using the equation  $\kappa = 1/R$ . Calculating the cold bend radius when 74% of the displacement loading has been applied gives the criterion for the maximum allowable curvature.”*