C and D) accepted at 90% confidence level influencing the variation in the impact strength. The percent contribution indicates that the thickness of the pipe only contributes 69.21% and 66.85% of the variation for UTS and YS criterion respectively, parameter, C (depth of crack) aids 13.36% and 12.87% of variation for UTS and YS criterion respectively, bursting pressure, D gives 14.51% and 16.95 of variation for UTS and YS criterion respectively and the crack length gives negligible contribution.

Table 4: ANOVA summary of the UTS failure criteria

Source	Sum 1	Sum 2	Sum 3	*SS*	*v*	*V*	*F*	*P*
A	11.76	6.37	5.60	3.75	2	1.88	486.78	69.21
B	7.81	7.42	8.49	0.1	2	0.05	12.98	1.71
C	6.63	7.55	9.54	0.73	2	0.37	94.76	13.36
D	6.61	7.48	9.63	0.8	4	0.2	51.92	14.51
Error				0.026	7	0.004	1.00	1.21
T	32.82	28.82	33.27	5.40	17			100

Table 5: ANOVA summary of the YS failure criteria

Source	Sum 1	Sum 2	Sum 3	*SS*	*v*	*V*	*F*	*P*
A	13.02	7.38	6.28	4.35	2	2.175	281.53	66.85
B	9.0722	8.29	9.32	0.1	2	0.05	6.47	1.3
C	7.3999	8.72	10.56	0.85	2	0.425	55.01	12.87
D	7.4544	8.27	10.96	1.13	4	0.282	36.57	16.95
Error				0.054	7	0.007	1.00	2.03
T	36.94	32.68	37.14	6.48	17			100

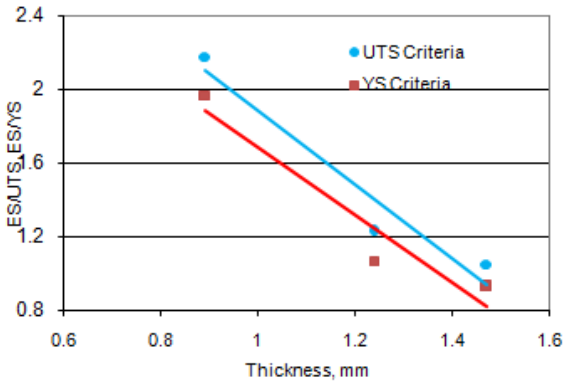

Figure 16: Effect of pipe thickness on failure criterion.

The yield strength and tensile strength of 6061 Al alloy are 276 MPa and 310 MPa respectively. The effect of pipe thickness on the failure criteria is depicted in figure 16. It is noticed that the failure of pipes decreases with an increase in the pipe thickness based on under both the ultimate tensile strength and yield strength criterion. With an increase in the depth of crack and the bursting pressure the failure rate increases. It is also observed that the survival of pipes under ultimate tensile strength criteria is better than the with yield strength criteria. This is owing to fact that the ultimate strength is higher than the yield strength of the material. The failure criteria are plotted for all the test coupons in figure 19. The test coupons 6 and 9 are satisfying both the UTS and YS failure criteria only. Among 6 and 9 the test conditions of test coupon 9 are safer than the test coupon 6.

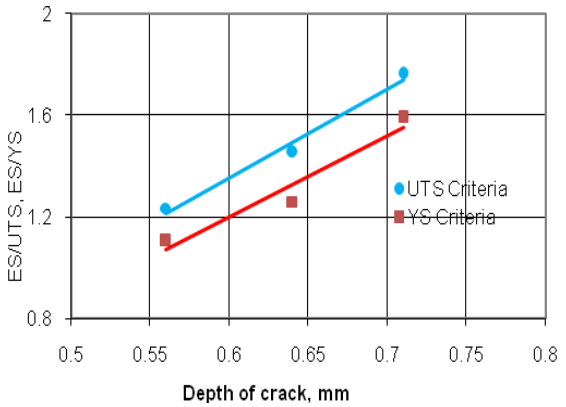

Figure 17: Effect crack depth on the failure criterion.

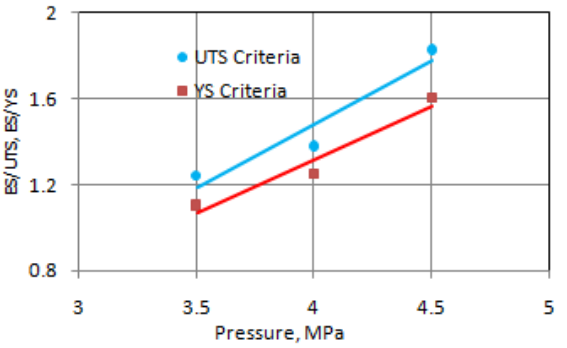

Figure 18: Effect of bursting pressure on the failure criterion.

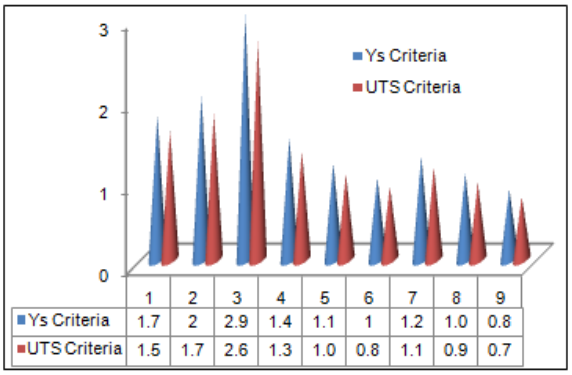

Figure19: Failure criteria based on yield and tensile strengths based on different bursting pressures

5. Conclusions

During crack propagation analysis it was observed that the path dependence of the J-integral was significant during the large deformation of pipes subjected to internal bursting pressure. The predominant control factors of pipe failure were the pipe thickness, depth of crack and bursting pressure. The allowable depth of crack and the bursting pressure were 0.56 mm and 3.5 MPa for the pipe having thickness of 1.24 mm and 0.64 mm and 4.0 MPa for the pipe having thickness of 1.47 mm respectively. The fracture of the pipes was of opening mode (KI).

6. Acknowledgements

The authors thank the University Grants Commission (UGC) – New Delhi for assisting financially this project under PG

project assistantship from SAP-UGC project sanctioned to the Department of Mechanical Engineering, JNT University Hyderabad.

References

[1] P. Hopkins, "Training Engineers in Pipeline Integrity," Western Regional Gas Conference, Arizona, EUA, pp.1-9, 2002.
[2] G. R. K. Kanters,"Pipeline Corrosion and Cracking and the Associated Calibration Considerations for Same Side Sizing Applications," Eclipse Scientific Products Inc., Williamsford, Ontario, Canada.
[3] BS7910, Guide on Methods for Assessing the Acceptability of Flaws in Metallic Structures- Annex G: The Assessment of Corrosion in Pipes and Pressure Vessels, British Standard, 1999.
[4] DNV, Recommended Practice DNV RP-F101 Corroded Pipelines, Det Norske Veritas, Norway, 1999.
[5] G.R.Irwin, "Analysis of stresses and strains near the end of a crack traversing a plate," Applied Mechanics, vol.24, pp.361–364, 1957.
[6] A. Cosham, P. Hopkins,"Best Practice for the Assessment of Defects in Pipelines-Corrosion", Engineering Failure Analysis, pp.1245-1265, 2007.
[7] ANSYS, Inc., www.ansys.com, July 2010.
[8] D. R. Stephens, B. N. Leis, and D. L. Rudland, "Influence of Mechanical Properties and Irregular Geometry on Pipeline Corrosion Defect Behavior", 1997.
[9] Chennakesava R Alavala, "CAD/CAM: Concepts and Applications," PHI Learning Pvt. Ltd., 2008.
[10] Chennakesava R Alavala, "Finite Element Methods: Basic Concepts and Applications," PHI Learning Pvt. Ltd., 2008.
[11] N. Jyothirmayi, A. Chennakesava Reddy, B. Balu Naik, "Finite element analysis of Ti-alloy fracture behavior and experimental validation," National Conference on Advances in Mechanical Engineering, Hyderabad, pp.50-55, 13-14th May, 2005.
[12] A. Chennakesava Reddy, "Finite element analysis of reverse superplastic blow forming of Ti-Al-4V alloy for optimized control of thickness variation using ABAQUS," Journal of Manufacturing Engineering, vol.1(1), pp.6-9, 2006.
[13] Jr. J.Newman, and I. S. Raju, "'An Empirical Stress-Intensity Factor Equation for the Surface Crack," Engineering Fracture Mechanics vol.15, no.1-2, pp.185–192, 1981.
[14] A. Chennakesava Reddy, P. Ram Reddy, B. Kotiveerachari, "Large rotation and large deformation analysis of four-bar mechanism," National Level Technical Symposium Nalgonda, 12th March 2005.