Methods of Welding Casing Subjected to Impulsive Loading

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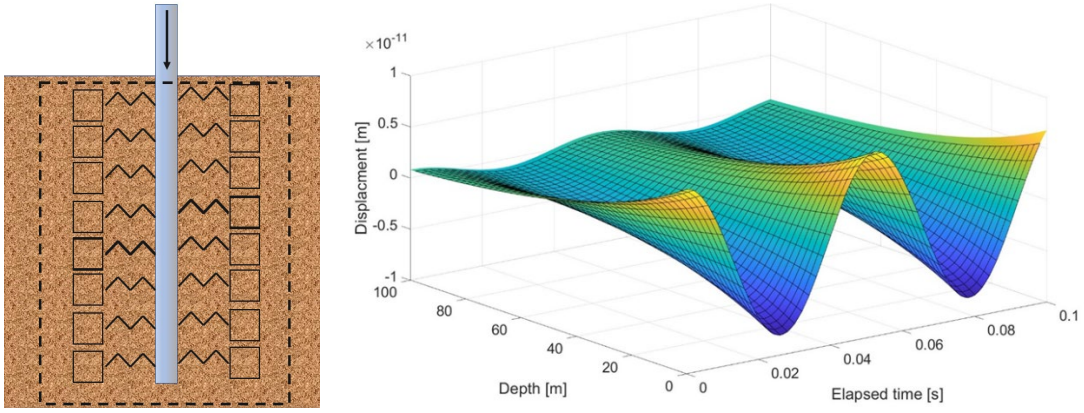
1. INTRODUCTION & OBJECTIVE

In this study, a novel approach to the welding of steel well casings, which are typically used in drilling and driven by a down-the-hole (DTH) hammer, has been developed. This method utilizes a modified form of the American Welding Society's (AWS) D1.1 structural steel welding code. A central aspect of this investigation involved determining load conditions derived from the dynamic forces exerted by the DTH hammer. Notably, these conditions were ascertained through the comprehensive integration of impulse, momentum, and wave propagation principles (Figure 1). This research could contribute to more effective and reliable welding procedures for steel well casings in drilling applications.



(a) (b)

Figure 1. (a) Subsurface Casing Modeled as a slender rod in an elastic medium, (b) Longitudinal Displacement of the Subsurface Model based on an initial displacement

In this research, a series of mechanical tests were carried out to evaluate key welding variables as per the AWS D1.1 standards. The dimensions and materials for the well casing were prescribed by rule 36.21.640 WELL CASING from the State of Montana Department of Natural Resources and Conservation. The acceptable stresses were established, suitable electrode types were determined, and preheat and inter-pass temperature requirements were formulated. By considering the welding position, process, and material thickness, we could apply prequalified welding options directly to the design.

In addition, tensile tests, conforming to [1], were performed to measure the quasi-static response. The stress wave propagation of the impulsive force encountered to drive the casing was analyzed using MATLAB simulation [2-8]. The soil compressibility [9] was counted in this analysis. The results were then compared with the predicted stress values and the corresponding joint designs [10, 11]. Based on these evaluations, we successfully developed a final welding

procedure that optimally aligns with the loading conditions per the modified AWS D1.1 standards.

The devised procedure is being refined and tested on casing coupons to improve the welding process for commercial drill casings. Given the absence of a standardized method for such welds and the high economic costs associated with failure, our research addresses a significant gap in the field. Through our efforts, we aim to provide a reliable, replicable welding procedure that will enhance the efficiency and safety of drilling operations.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

This study established a novel welding procedure for a 6-inch casing (using a DTH hammer) rooted in the AWS D1.1 structural steel welding code. Our design control factor was the stress pulse-derived load of 236 kN. The AWS D1.1-guided allowable stress parameters and material properties were according to Montana's Department of Natural Resources and Conservation.

Our investigations revealed the optimal electrode choice for root pass to be 1/8" E6010, owing to its superior penetration across all joint designs. We found that the E7018 electrode, in conjunction with an E6010 root, exhibited exemplary mechanical properties and load endurance for fill and cap passes.

The proposed joint design adopts a single V-groove, taking inspiration from an AWS-prequalified PJP joint. Given the larger manufacturing bevel of the casing, the design negates the need for a root gap or face, leading to a safety factor of 4.2 upon attaining complete joint fusion.

Our experimental findings suggest that preheating isn't necessary, as cooling rates exhibited negligible implications on material hardness. The utility of weld strapping remains to be determined due to inconclusive evidence. Our innovative welding design significantly reduces the unfused joint area by approximately 64%, potentially lowering failure rates. This design can be qualified for field implementation by a certified welder in adherence to AWS D1.1 qualification standards.

REFERENCES

1. American Welding Society. B4.0 Standard Methods for Mechanical Testing. American Welding Society. 2007.
2. R. Hibbeler, *Engineering Mechanics Dynamics*. Upper Saddle River: Pearson Prentice Hall, 2007.
3. R. Hibbeler, *Mechanics of Materials* 10th ed. Hoboken: Pearson, 2017.
4. D. J. Inman, Engineering Vibration 4th ed. Upper Saddle River: Pearson Education, 2014.
5. W. Stronge, Impact Mechanics. Cambridge: Cambridge University Press, 2018.
6. M. A. Meyers, *Dynamic Behavior of Materials*. John Wiley & Sons, Inc., 1994.
7. R. C. Juvinall, K. M. Marshek, Fundamentals of Machine Component Design, 5th ed. Hoboken: John Wiley and Sons., 2012.
8. H. Shijie Cui, "Dynamic Buckling of Supported Columns Under Axial Slamming," J. of Engg. Mechanics, pp. 513-520, 1999.
9. C. M. Ubani Obinna Uzodimma, "Effect of soil compressibility on the structural response of box culverts using finite element approach," Nigerian J. of Tech., pp. 42-51, 2020.
10. S. Kou, Welding Metallurgy, 3rd ed. Hoboken: John Wiley and Sons, 2021.
11. The Procedure Handbook of Arc Welding 14th ed., The James F. Lincoln Arc Welding Foundation, 1994.