E. Contact Models of GMAW Wire Liner Friction: An Inverse Photoelastic Solution[1]

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1.0 Introduction

In gas metal arc welding (GMAW), wire feedability plays an important role in weld quality [1, 2]. During push wire-feeding, the buckled trajectory of the welding wire inside the wire liner can create wire-stall conditions due to excessive contact friction (Figure 1). A photoelasticity-based model of the push wire feeding process was developed to study the effect of buckling and to quantify the wire-to-liner pressure distribution and the resultant friction forces. Using closed-form solutions, a novel inverse-solution technique shows that, during moderate buckling, the contact pressure distribution between the welding wire and the wire liner is uniform in nature. During simulated feeding of aluminum welding wires through Teflon- and Nylon[2]-impregnated liners having a diameter ratio of 2:1 to 4:1, the pressure distribution produces the equivalent of 2.2 N (0.5 lb_f) of normal force at each contact point during applied buckling forces of 50 N (11 lb_f). Additional tests in photoelastic media show the effect of changing the buckling severity and the effect of using alternate contact distributions in the inverse-solution technique.

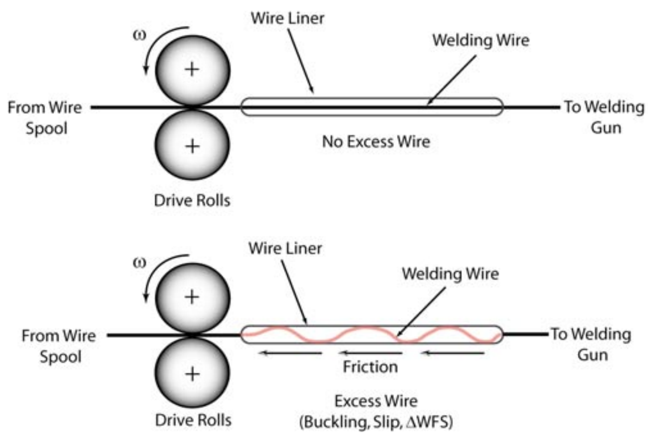

Figure 1. Schematic of the GMAW push wire-feeding operation showing wire buckling.

2.0 Technical Approach

Bends were machined into a polymeric sheet of photoelastic media (c = 0.15 kPa per fringe per meter or 0.9 psi per fringe per inch) to simulate the geometry of the flexible liner package (Figure 2). ER5356 aluminum wires, ranging in diameter from 0.8 to 1.6 mm (0.030 to 0.0625 in.), were fed through the channel and allowed to buckle, thereby mimicking a high-friction condition. Although the photoelastic material has a

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[1] Contribution of NIST, an agency of the U.S. government; not subject to copyright in the United States.
[2] The trademark names Teflon and Nylon are used only to generically describe the material used in this study. The use of such material is neither commended nor discommended.

higher coefficient of friction than the Teflon- or Nylon-based wire liners, the normal contact mechanism owed to buckling is similar. Upon buckling, digital images of the wire shape and the contact fringe patterns were captured to determine the normal contact force. The algorithm in this study uses Flamant-Bousinesq solutions [3] and the subsurface stress distribution [4] between the wire and the liner to fit the data in a least-squares based methodology.

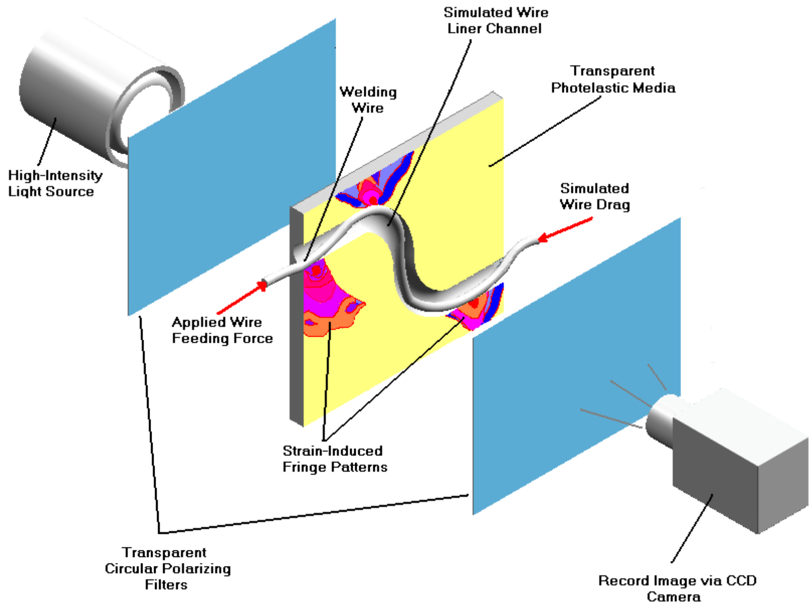

Figure 2. Schematic of the photosensitive material fixture used to measure and record the wire-to-liner contact fringe patterns for a fixed geometry.

3.0 Results and Discussion

An increase in buckling severity[3] increases the normal contact force between the wire and liner. When the normal pressure distribution at the contact interface is uniformly distributed, applied feeding (buckling) forces as low as 44 N (10.0 lb_f) can create contact forces as high as 2.2 N (0.5 lb_f) at each contact point (Figure 3). Visual analyses of the photoelastic images also confirm that the wire contacts the liner in discrete locations, as determined by the buckled shape (Figure 4).

Calibration experiments to generate ideal photoelastic data show the wire-to-liner contact distribution to be a function of the applied normal load and the local curvature of the buckled wire in contact with the liner. Under simulated minor buckling severity (local radii of approximately 64 mm (2.5 in.)), the normal contact pressure between the wire and the liner is uniformly distributed and can be predicted to within 17 % of the actual load (Figure 5). Under simulated buckling conditions at the extreme condition (local radii of approximately 9.5 mm (0.375 in.)), peak loads as high as 12 N/mm (70 lb_f/in.) are observed between the wire and the liner. For typical aluminum GMAW setups, this translates into normal contact forces as high as 18 N (4.0 lb_f) at each contact point. This proves to be significant since an increase in normal contact force is known to proportionally increase the resistive friction force [5, 6]. Consequently,

[3] Buckling severity in this study is measured by an increase in the modal buckling order. For this study it has been characterized by the local curvature of the welding wire in contact with the wire liner.

summed frictional forces for numerous wire-to-liner contact points can produce excessive overall feeding forces that eventually lead to wire-stall conditions. Sensitivity analyses also show the Flamant-Bousinessq solutions and the inverse-solution technique to be accurate to within 17 % of the applied loading value, even if estimates of the contact parameters (such as contact width or contact position) are only within 25 % of the actual value.

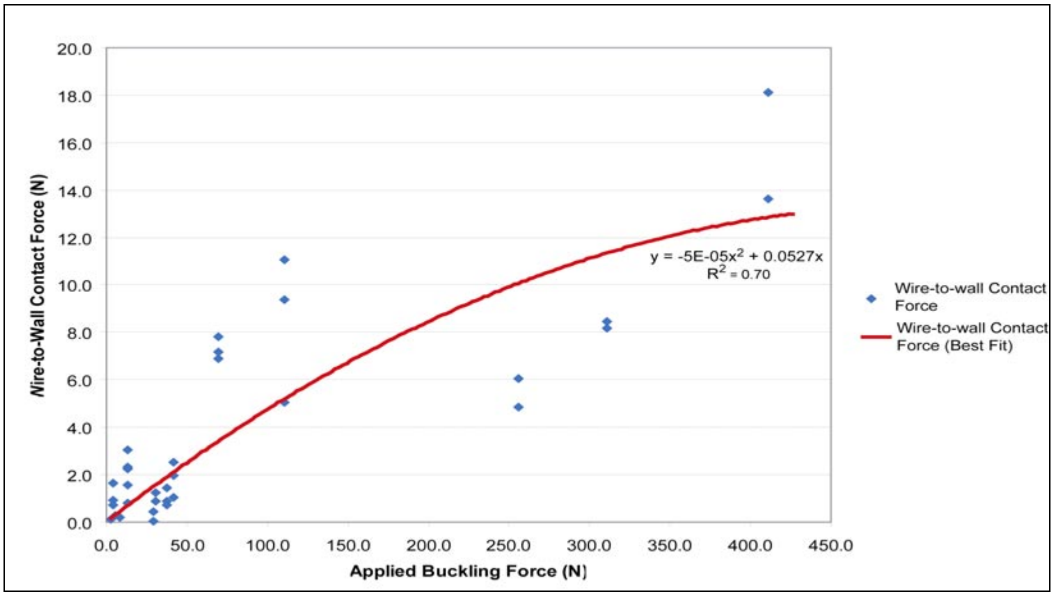

Figure 3. The computed normal force at the wire-to-liner contact interface for planar constrained buckling configurations during simulated push wire feeding in photoelastic media.

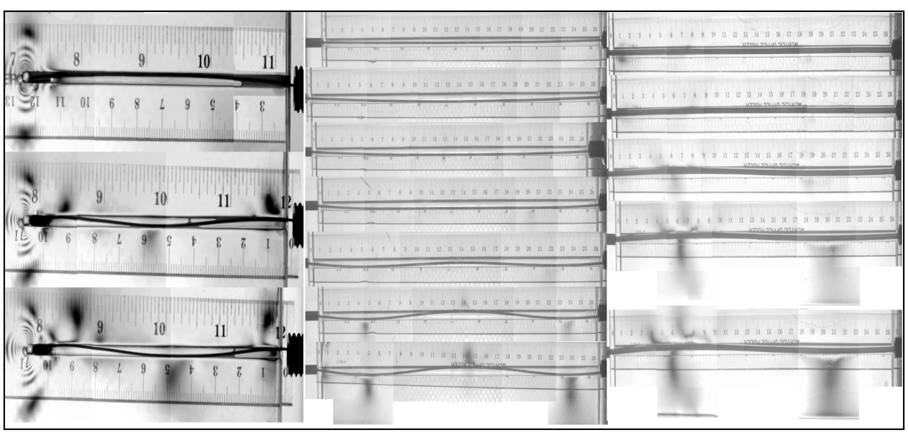

Figure 4. Stress fringe patterns of the buckled welding wire in loads of 0 to 111 N (0 to 25 lb_f). The wire-to-liner combination has a diameter ratio of 4:1 (left and middle) and 2:1 (right).

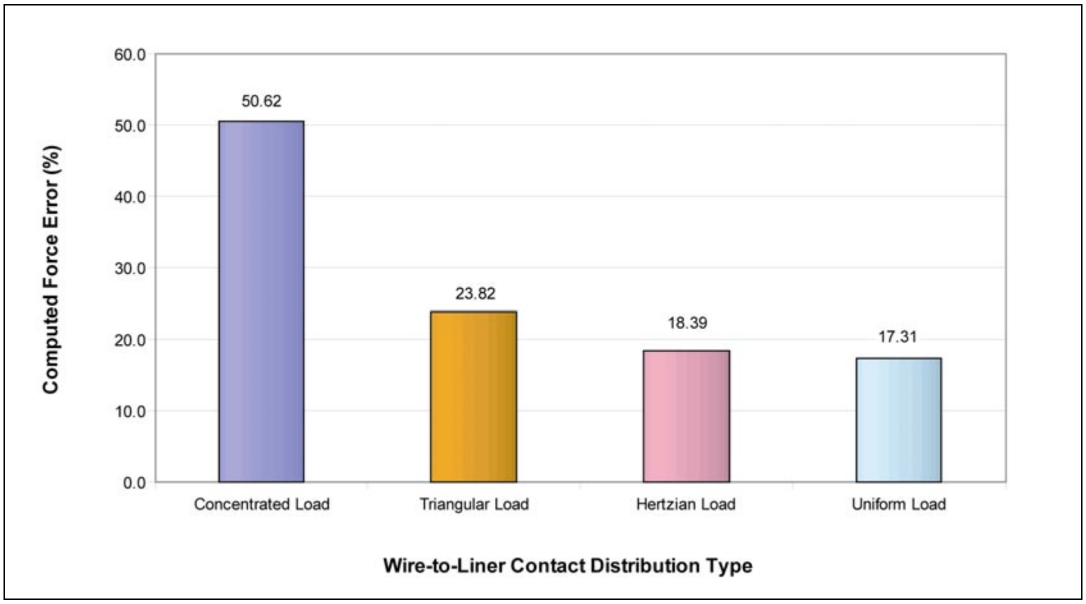

Figure 5. Computed errors in the applied force when using specific contact distributions for the inverse-photoelastic solution of the welding wire in contact with the wire liner.

4.0 Conclusion

This study provides a novel technique for determining the contact load for welding wires subject to buckling during aluminum GMAW wire feeding. Photoelastic experiments show that buckling shape varies with wire liner setup and that the normal contact force increases with buckling severity. An inverse-solution technique allows for a prediction of the contact force and the functional form of the distributed loading attributed to buckling. Under adverse feeding conditions, contact forces as high as 18 N (4.0 lb_f) at each wire-to-liner contact can produce overall frictional forces that exceed the capacities of most wire-feeders, thereby providing the potential for wire-stall conditions.

References Cited:

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