ADVANCED FRICTION WELDING TECHNIQUES FOR HYDRAULIC CYLINDERS

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PRESENTED AT SESSION 9B: NEW WELDING TECHNOLOGIES

4^{TH} BIENNIAL INTERNATIONAL MACHINE TOOL TECHNICAL CONFERENCE

SEPTEMBER 7 – 14, 1988

Sponsored by the

National Machine Tool Builders' Association

McLean, Virginia 22102, U.S.A.

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ABSTRACT

Friction welding has long been recognized as the most cost effective method of producing high integrity piston rod assemblies, which is reviewed. For cylinder body fabrication, it may be used to join gland rings to tubes, and with orientation or radial friction welding to align ports, can weld end caps to tubes. A patent method of sealing an internal flash trap to prevent contamination of the hydraulic system by I.D. flash scale is presented. The relative cost-effectiveness of each method is reviewed.

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Process Description

Friction welding is a solid state joining process that uses rotational motion and high axial pressures (thrust load) to convert rotational energy into frictional heat at a circular interface. The heat produced by this rubbing action raises the intersurface temperature of the two parts to the plastic state where the high thrust load extrudes metal from the weld region to form an upset. When sufficient energy input has occurred (length loss), the rotation is stopped and thrust load increased, to forge the parts together and form a solid state bond. The flash may be removed as part of the machine cycle.

The plastic deformation in the weld zone results in grain refinement, favourable flow line orientation and expulsion of impurities.

There are two variations of the process, conventional Direct Motor Drive friction welding, and Inertia friction welding, which stores kinetic energy in a flywheel mounted to the welder spindle. The dissipation of that energy creates the weld upset. We believe direct drive welding is more appropriate for cylinder manufacture because of better length control, machining capability on the welder and orientation capability.

The latest advances in the process involve improved cycle monitory using PLC's that store parameter control data for multiple parts, and store actual weld parameters (axial force, RPM and length loss every 1/10 second of each cycle run) on a hard disk for historic purposes. The PC is also used by the operator to store setup and tooling data and communicate with the fault and monitor systems.

Quality assurance has been enhanced by the use of automatic ultrasonic inspection equipment to find and reject material defects that could have direct effect on weld integrity. Historically, material defects, (inclusions, seams, laps, etc.) are the single largest cause of potential weld failure.

Piston Rods

The established use of friction welding in hydraulic cylinders is the welding of forged eyes or cast steel clevises to finish-machined and chromed piston rods. (1) Typically, as shown in Fig. 1, a high integrity rod assembly is made by welding the as-forged "nub" of a C1045 forged eye (finished cross-bore) to the unmachined butt end of a finish-machined (roll threaded) C1045 (100,000 psi min. yield strength) prechromed induction-hardened rod. For a 2-1/2" rod, overall length will be held to +/- .040", cross-bore, perpendicularity will be .003"/inch maximum and the as-welded, flash removed weld strengths will be 98,000 psi yield and 130,000 psi ultimate tensile. There is no more efficient way to produce this part, with a hand and hoist loaded assembly rate of 20 pieces per hour.

Flash removal can be accomplished on the welder as part of the cycle with ball screw X-Y contouring to produce required blend radii. Fig. 2 shows a clevis-rod assembly, this design having the flash left in place.

Barrel and Flange Assemblies

For "bolt-on" gland type body designs, friction welding of the barrel/flange assembly shown in Fig. 3 (tubular weld), allows 100% efficient stress levels in the tube wall with no end preparation costs, by welding sawcut tube to a premachined, drilled and tapped flange. Tolerances expected for a 6" cylinder would be +/- .040" on length and concentricity of .030" TIR Max. The external flash may be removed or left in place, but the internal flash must be machined out while finishing the bore of the flange, prior to scive and burnish or honing. I.D. flash removal would be similar in cost to removing the backup ring of a conventional full penetration weld.

Orientation Friction Welding End Caps

Using specially designed regenerative DC spindle drives, it is now possible to stop the spindle of a friction welder in the same angular position every cycle, to accuracies of +/- 0.5 degrees. The obvious application is to weld the end cap or base to the tubular body of the cylinder and orient the port or cross-bore, to the alignment within +/- 1 degree is possible. We operate what we believe to be the only subcontract orientation welder in North America, a 115 ton machine with bar capacity of 8” O.D., 14 square inches maximum.

Radial Friction Welding

Radial friction welding, shown in Fig., 4 as developed by the British Welding Institute (2), is a possible method of welding end caps to body tubes with alignment as required, without having to deal with internal flash. In this method as applied to cylinder manufacture, the end cap and tube would be clamped stationary with a nub of the cap pressed into the end of the tube to support the tube I.D. The weld “rim” is rotated and “compressed in” radially to friction against both parts at the same time, produce weld upset and, when stopped, bond all three pieces together.

The method is effective in the laboratory but has yet to see commercial development or use for cylinder manufacture, because we believe, of the following cost factors:

1) Machine and tooling would be very expensive, probably $750,000 U.S. to weld a 6” bore body

2) Provision of the ring is an added expense

3) The tube end requires premachining where with conventional friction welding it is sawcut only

4) Cosmetic appearance of the deformed ring and flash would probably require machining.

Closed Flash Trap Design

Contamination of the hydraulic system by scale particles and loose metal slivers from the inaccessible interior flash of a tube/end cap body weld has been insurmountable in the past, and has prevented the use of axial friction welding by most manufacturers. A conventional flash trap shown in Fig. 5, requires clearance to the tube I.D. so that it does not “pick-up” and produce its’ own contamination, allowing oil to wash through the flash trap, which is unacceptable. Radial friction welding is one way to avoid this problem but we believe it is not competitive.

A.R.D. Industries Ltd. has a patent for a method of closing the required clearance of a conventional flash trap after the weld is complete, but on the friction welder as part of the weld cycle while the weld area is hot. The resultant closure is not “leak tight” but will prevent migration of any contaminants.

As shown in Fig. 6, the method is carried out by completing a conventional or orientated tubular friction weld with clearance between the flash trap nub and the sawcut tube I.D. Then, immediately after the completion of the weld portion of the machine cycle, while the weld area is hot, the clamp is opened, the machine spindle is restarted to rotate the assembly, a spherical roller or set of rollers is brought into contact with the tube opposite the clearance area and a radial force applied to “roll in” the tube wall and close the flash trap clearance. The weld heat allows the inward upset to occur with much less force than if the assembly were cold, and the subsequent shrinkage on full cooling ensures a tight closure. We believe this method usable on maximum wall thicknesses of 3/8” or 1/2”.

For heavier sections, or where wall deformation is unacceptable, the flash trap itself, machined on the end cap inner end, as shown in Fig 7, could incorporate an annular conical flange, with required clearance. When the weld is complete, a hydraulic ram advanced through the clamp backstop of the welder, would deform the flange and force it outward, again closing the gap, and retaining contaminants inside the trap.

We believe that either of these two approaches, which can be done on conventional friction welding machines and do not require premachining of the tube end, are the most cost effective of any body welding method.

Relative Cost Benefits

Friction welding is not cost-effective where two simple parts could be butted together and a fillet weld deposited to produce an adequately strong assembly. Friction welding can be justified only when it can displace the premachining necessary to produce full penetration multiple pass conventional welds or increase joint efficiency (ie: stress levels) above acceptable levels for cast structure conventional welds.

For piston rods, the subcontract cost of welding (excluding setup) and presumably also internal company friction welding costs, should be in the range of $1.00 – 1.50 U.S. per square inch of cross section. For body welds the same range may be applicable, but although the tubular weld cycle is faster, material handling efficiency and size of parts will have a much greater influence on pieces per hour and weld cost.

Many manufacturers are incorporating friction welders into cell operations with CNC turning centres, producing completed piston rods from chromestock, ready for assembly, with one operator. The same approach can be taken with body assemblies although there are more steps involved.

The elimination of tube machining, gas and consumable costs, combined with the higher production rates of friction welding, easily offset the high hourly cost of this process.

Summary

Friction welded assembly of high integrity cylinder bodies can be as successful and cost-effective as piston rod welding now is. The application of orientation welding to end caps, combined with flash trap closure after welding (available under license from A.R.D.) makes this closely controlled, repeatable process, the method of choice.

References

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2) Nicholas, E.D., Lilly, R.H., "Radial Friction Welding". Advances in Welding Processes Conference, Harrogate, U.K. 1978, P48.