AMERICAN FRICTION WELDING, INC.
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MEETING HYDRAULIC CYLINDER ROD MANUFACTURING CHALLENGES USING FRICTION WELDING

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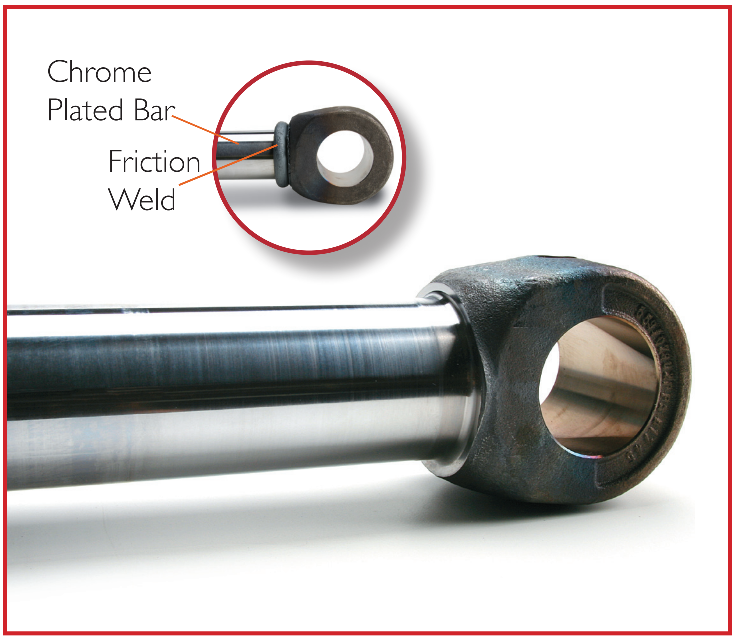
1) Introduction

According to leading industry sources listed in ManufacturingTalk.com, friction welding has become widely accepted as a competitive and effective process and a valid, proven alternative to complex forging and CO2 / fusion and flash-butt / resistance welding techniques. Within the hydraulics industry specifically, most principle manufacturers use friction welding for the production of piston rods, including such market leaders as JCB™ in the United Kingdom and Caterpillar™ in the USA for its line of earth moving equipment. Although JCB™ and Caterpillar™ produce their own friction welded piston rods, they both obtain assistance from American Friction Welding as a second tier supplier.

Today's hydraulic cylinder manufacturers are challenged with tough delivery schedules, material strength requirements, and cost savings. These challenges provide yet more affirmation for the use of friction welding and the advantages it can provide in the manufacturing of hydraulic piston rods. The following article explains the process of friction welding, the metallurgical integrity of friction welding and detail why this proven production method is beneficial specific to hydraulic piston rods.

2) The Friction Welding Process

Although the term "welding" is used in defining the friction welding process, it bears no resemblance to conventional welding as no filler material is involved. Instead, two components are rubbed together at a controlled rotational speed creating the friction and heat that allows both components to reach a plastic state and be forged together forming the bond. Friction welding of safety critical parts such as piston rods involves the use of very unique technologies incorporating state-of-the-art monitoring controls that optimize repeatability and quality control using ultrasonic inspection.



The weld playback graph below outlines the principle phases of the process; parts contact, the first and second friction phases and lastly, the final forging phase. The details of these critical phases are as follows:

<u>Parts Contact</u>

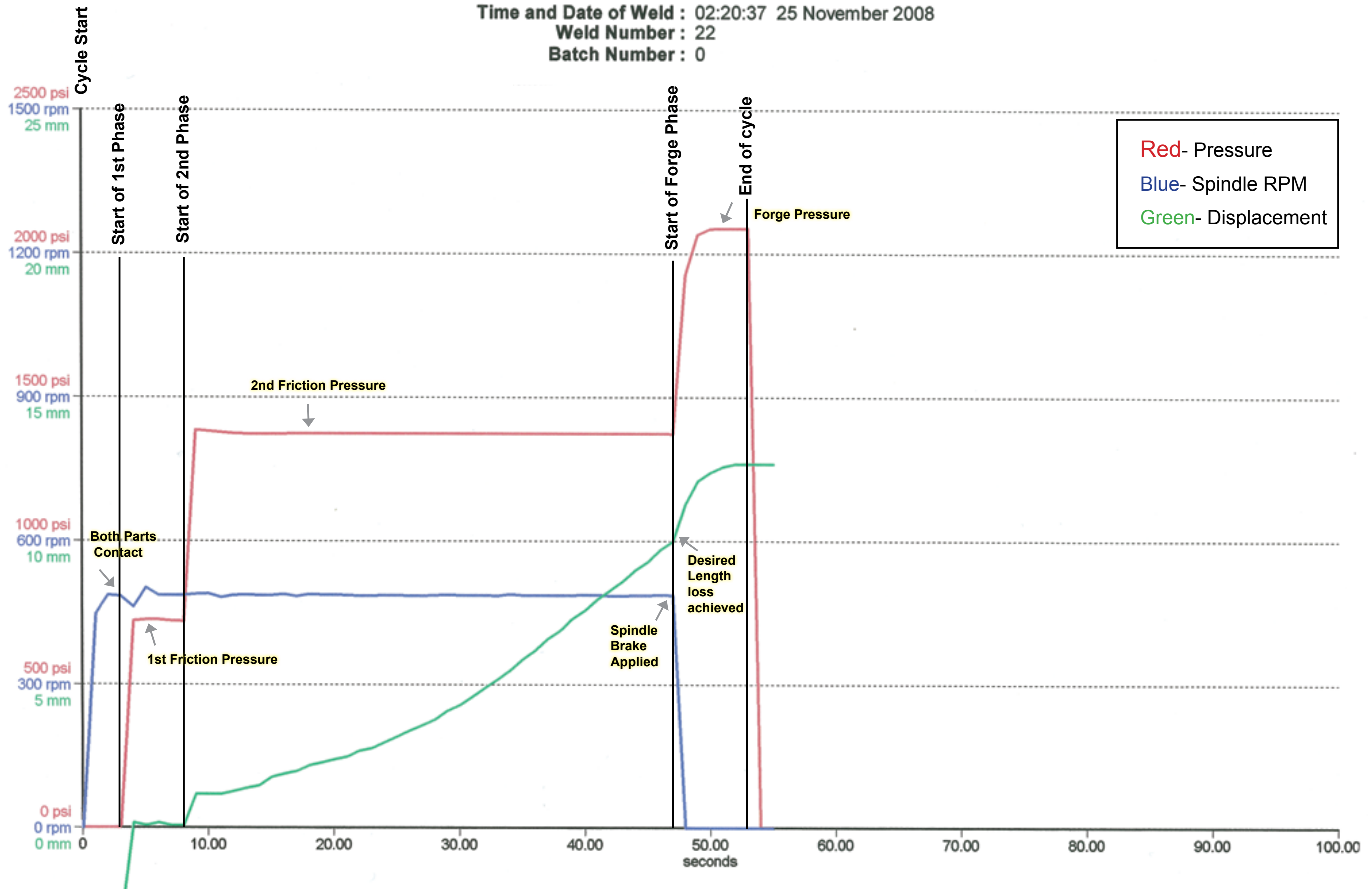
Parts come in contact with each other and part lengths are verified to be within pre-welded length tolerance.

American Friction Welding

30 Ton New Britain Friction Welder

Weld Playback Graph

Time and Date of Weld : 02:20:37 25 November 2008
Weld Number : 22
Batch Number : 0



* Generated with Thompson Friction Welding™ Weld Play Back Software

First Friction Phase

The spindle begins to rotate and the parts are pressed in contact with each other with a force of 3,000-6,000 pounds per square inch of weld area. Typically pre-heating of the weld interface occurs with no material displacement at this point. Friction duration is controlled by time. The purpose of the first friction phase is to burn off any light oils or light oxides at the weld interface.

Second Friction Phase

This phase controls the amount of material length loss. Approximately 2/3 of total material displacement occurs. Welding force of 6,000-12,000 pounds per square inch of weld area is applied. The three methods of controlling the amount of material length loss in this friction phase are the use of ***Time, Constant Distance*** and ***Position.***

With the ***Time*** method of controlling length loss, a simple timer is used to count the number of seconds the machine is at 2nd friction pressure. When the pre-set time is achieved the machine goes into Forge Pressure and rotation is stopped. This method is not used much since glass scales have been added to most modern equipment.

With the ***Constant Distance*** method of controlling length loss each time the two components make initial part contact, the machine zeros a precision glass scale. When the pre-determined amount of material length loss is achieved, the machine goes into forge pressure and rotation is stopped. This method is most common. Incoming material lengths must be within tolerance otherwise outcoming weldments will be out of tolerance.

The last method of controlling length loss in Second Friction is by ***Position***. During the initial set-up the stack up of both components is measured and using a precision glass scale the machine is calibrated using this measurement. The material length loss is subtracted from the measurement and this value (or trigger position) is entered into machine. Independent of component length, the machine will go into forge phase when the trigger position is reached. This method produces the greatest repeatability of overall length on the weldment. Since heat produced during 2nd friction phase would not be consistent from part to part, it will not make up for out of spec component lengths.

Forge Phase

The final phase in friction welding is the forge phase. The spindle is forced to a stop and both components are pressed against each other at extreme pressure and allowed to cool. Typically, approximately 1/3 of total material displacement occurs during this phase. There is no control as to how much material is displaced in the forge phase but it is dependent on the amount of heat generated in the Second Phase and the amount of pressure applied. Forge phase duration is controlled by time(typically only 5 to 15 seconds) and a forging force of 12,000-24,000 pounds per square inch of weld area is applied.

3) Metallurgical Integrity of Friction Welding

Craig Brown, metallurgical engineering manager at Stork Technimet has performed extensive analysis of friction welded joints. Comparing friction welded to conventional welded joints, Brown states, "In general, the heat affected zone (HAZ) is less extensive and has a narrower width than the HAZ of a conventional weld that incorporates a filler material. HAZ mechanical properties are similar to the base metal, but, depending upon the temperature achieved during welding, the cooling rate and the post-weld thermal treatment, all three can change the weld properties. If all are controlled correctly, welds will have the necessary integrity."

In his Metallurgical Evaluation of Two Piston Rods report #0706-20202 dated June 11, 2007, Mr. Brown evaluated two induction hardened piston rods with friction welded forged eyes. A tensile specimen was extracted from each of the pieces at the weld interface to allow evaluation of weld integrity and microstructure at the weld joint. A microhardness survey was conducted through the fusion zone.

He concluded that the cross sections through the two piston rods showed good fusion between the eye and rod material with no evidence of a lack of fusion. Microstructures of the base metals, heat affected zones and fusion zones were consistent with properly welded components along with expected slightly higher hardness than the adjacent HAZ in the fusion zones.

The successful friction weld, according to Brown, will be free of porosity, lack of fusion and oxide inclusions. If done right, none of these will be present. On rare occasions, one might see very fine oxides that are dispersed through the center of the joint. The primary risk and challenge is temperature control at the weld interface. If it's too cold, there may be a poor bond between the materials. If too hot, the weld may be brittle, and, depending upon the alloy content, cracking could occur. The principal challenge is evaluating the quality of the weld below the surface, which is why ultrasonic inspection is so essential.

4) Substantial Benefits in Piston Rod Manufacturing

Delivery Schedules

Timely delivery is the principle problem with single piece piston rods due to the inordinate amount of machining needed to prepare them for cylinder assembly. Essentially, burnout from plate for pistons may be acceptable for smaller rod quantities keeping in mind that they may require 30% or more additional machining time than friction welded piston rods. For larger quantities however, there is no question that friction welding has proven to be most cost effective.

Friction welded piston rods can have the internal or external threads completely machined before welding. In most cases the friction welded rods are machined from 20 ft sections of induction hardened and chrome plated bar. The eye can be forged or machined from bar stock as well with a simple hole bored and a flat milled before welding. This type of machining can be done much quicker than machining the piston rod from one piece plate stock due to the interrupted cut that has to be dealt.

Material Strength Requirements

Additionally, it has been proven that friction welding is the most economical way to get a full-strength bond vs. stick welding which fuses only the outside peripheral of the weld rather than all the way through to the center like Friction Welding. It is a better alternative than conventional stick welding since the friction weld is free of porosity issues which could cause stress risers (notches) that will propagate a fatigue failure. Friction welded induction hardened chrome-plated rods to forged eyes creates a joint with tensile and yield properties equal to parent materials throughout the weld area.

Outside of internal quality control, finished parts are ultrasonically inspected for voids or lack of fusion or shipped to accredited laboratories for metallurgical evaluation and/or a variety of mechanical testing. This may include torsion, tensile and normal bend testing over particular radii for specific applications. Parts are typically rated for loads far exceeding the intended applications.

Friction Welding and Cost Savings

Based upon the particulars of hydraulic piston rods, savings of up to 15% on costs with increases of 20% on overall piston rod strengths have been achieved.

Overall machining time can be reduced by as much as 15% by pre-machining both rod and forged eye prior to welding with no special weld preparation needed.

5) Conclusion

Although friction welding has been around for more than 50 years, it continues to be one of the manufacturing's best kept secrets. Specific to today's cost and delivery challenges for hydraulic piston rods, the ability of friction welding to fulfill critical demand without loss of strength or structural integrity is a strong consideration for cost-conscious hydraulic cylinder manufacturers or equipment OEM's. Friction Welding is one of the most economical welding processes available - providing increased design and manufacturing flexibility, superior strength and significant cost savings. In almost every instance, the decision to adopt friction welding technology can result in substantial benefits.