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MEETING PUMP SHAFT MANUFACTURING CHALLENGES USING FRICTION WELDING

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Today challenges material price versus performance in pump shaft manufacturing have gotten tougher with each price increase for raw materials. Friction welding as a way to reduce costs is a viable option for design engineering and new product development. This article provides some background on friction welding for pump shaft manufacturing.

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, which creates the friction and heat that allows both components to reach a plastic state and forge together into a bond. Friction welding involves the use of very unique technology incorporating state of the art monitoring controls. This process is in widespread use by large OEMs throughout the industry.

Friction welding allows pump manufacturers the ability to use composite rather than one piece shafts, promoting more ease in selecting the best materials to suit an application with lessened concern on raw material costs. In essence, this creates a better balance in the selection of optimum material without the heavy price tag.

Cost versus performance criteria abrasion or corrosion resistance, mechanical strength for operating loads, FDA-mandated sanitary characteristics, etc. are realized without sacrificing performance. With 60 percent of the shaft replaceable with lower cost materials, significant savings can be realized for virtually any size and quantity of shafts, considering today's costs of $4.00 to $34.00 per pound for commonly used stainless steels and high nickel alloys.

Dry End Versus Wet End Shaft Considerations

Pump shafts have two distinct ends, the dry end and the wet end. The dry end is sealed and encased (typically in oil) within the housing itself and the wet end outside the pump enclosure- comes in contact with the application. The dry end plays a less critical role in a given application, so less costly materials such as low carbon steel can be used for this portion of the shaft, provided sufficient strength for the application exists.

Conversely, the wet end of the shaft is where "the rubber meets the road" due to its direct contact with the external, ambient conditions of the specific application. This is where the critical needs reside and where much more costly, exotic high nickel alloys such as Hastelloy and high strength stainless are often required.

Cost savings are realized by constructing the composite shafts with the typical two thirds of the shaft's less critical dry end replaced with lower cost steels. Considering the current challenges of both price volatility and surcharges to nickel based materials (often exceeding the material's base cost), these savings can be substantial for OEMs while also promoting significant cost and profit stability on the end product.

With proper selection of the two materials for dry and wet end, strength properties of the original material can typically be met or exceeded. Close state of the art control via monitoring and visual graphing during the weld process and post weld ultrasonic inspection procedures ensure consistent weld joint integrity through a very robust process. Production controls monitor RPM, axial load and displacement of material during welding.

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

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."

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.

Key Material Considerations

On the shaft wet side, a wide variety of stainless steels and nickel based alloys are typically utilized based upon particulars of the application. For instance, 304 stainless , 316 stainless or 174 PH stainless can also be incorporated in friction welding for higher mechanical properties, providing a balance between strength and corrosion resistance.

On the dry side of the pump shaft, the options are virtually endless. Medium and low carbon steels as well as stainless on this end can be incorporated for corrosive resistance if needed. Even with using stainless on this end, cost reductions are often realized. As far as weld integrity is concerned, the 1100 and 1200 series carbon steels with their re-phosphatized and re-sulfurized content (typically manufactured for enhanced machinability) needs to be avoided since the addition of higher sulfur or lead can create complications in the welding process. Although these materials can be welded, mechanical strength cannot be guaranteed but still may be within what's needed for a customer application.

Many alternatives exist to avoid such complications while new weld developments using exotic combinations are being devised constantly with great success.

A Broad Range of Options

When using friction welding, more options are available than only the cost of materials. In designing solutions for pump applications, pump manufacturers can more broadly consider material properties such as strength and corrosion resistance. On the dry end, specific wear resistance, longevity in length of service and related fatigue and the types of loads that shaft will be receiving are all important factors where ideal materials can be more easily integrated into a solution.

Manufacturability benefits can also be realized with friction welding. Shafts can be designed for optimum manufacturability and machinability with significant reduction of machining labor. This reduces perishable tubing costs with faster feeds and speeds, longer life on perishable tools, more uptime on machines and higher output due to faster times on existing equipment. At times, up to 15 percent savings can be realized, buying manufacturers 15 percent to 20 percent more capacity on expensive machine tools and cells.

For practically any selected blank for a pump shaft, endless opportunities exist with respect to size, type, length and configuration, including the use of two different shaft diameters.

Friction Welding and Cost Savings

Based upon the particulars of an application, savings of up to 50 percent to 60 percent on raw material costs can be realized using friction welding after factoring in the cost of the weld. For instance, with a 2.5in diameter highstrength alloy shaft having material that weighs 16 or 17 pounds a linear foot, a 3ft shaft will weigh around 45 to 50 pounds. At $5.00 per pound, this shaft can cost in the range of about $200. If friction welding can allow replacement of around two thirds or 2 ft of the shaft's dry end with lower cost (perhaps $.60 per pound) carbon steel material, this shaft could cost around $125.00.

Although friction welding has been around for more than 50 years, it continues to be one of manufacturing's best kept secrets. Specific to today's cost challenges for high strength, nickel based materials, the ability of friction welding to replace large percentages of this costly material without loss of strength or structural integrity is a strong consideration for cost conscious pump OEMs. It is one of the most economical welding processes available providing increased design flexibility, superior strength and significant cost savings.