Advantages and Disadvantages of Metal Cored Wires

In today’s world, fabricators have a wide range of choices in deciding the best welding process and consumable to use in a particular application. Many different considerations are necessary including welder skill, equipment, and availability of the consumable, environmental issues and the economics of the process. What is the best method to accomplish the task of joining two pieces of steel? One rapidly growing process is being seen in the use of metal cored wires. Higher duty cycles, faster travel speeds; low fumes and better cost effectiveness are some of the primary reasons. By exploring the advantages and disadvantages of the metal cored wires, you can best determine whether this is a process that you should employ to increase productivity and ultimately your profitability.

Background

Since the day the carbon arc process to join two pieces of metal was discovered, we have been looking for ways to improve upon the process. At the turn of the century, Oscar Kjellberg developed the first coated electrode. In the 1930’s the first inert gas welding process (GTAW) was used as well as the first submerged arc welding (SAW). The main goal in every advancement was to improve first the integrity of the weld and second to improve upon the process itself, to make it faster, more efficient, and more cost effective through higher productivity. In 1948 the solid wire process was developed and this expanded the usage of continuous solid wire applications that were not readily adaptable to the SAW process: i.e. vertical and overhead welding.

Manufacturers and fabricators who depended a great deal on the welding process for their finished products were not totally satisfied with these improvements. They wanted more. In the 1950’s there were many innovative designs for continuous welding that would give the end user higher deposition rates. Unfortunately, most had flaws and were not commercially viable. It was not until around 1957 that the flux cored wire process as we know it today was first introduced to the market. The first flux cored wires were large diameter, 1/8” (3.2 mm) and 5/32” (4.0 mm) diameters. In those days, the 3/32” (2.4 mm) diameter was a “small diameter” flux cored wire. Flux cored wires provided better metal penetration, smoother arc transfers, lower spatter levels and were overall easier to use than solid MIG wires, but they were limited to flat and horizontal positions and the equipment to use them was heavy and cumbersome. As flux cored wires developed, smaller diameters began to emerge onto the welding scene, which led to the ability to weld in all positions. Advancements in equipment also made welding with flux cored wires more comfortable for the welder. Now for the first time high deposition rates were obtainable in the vertical and overhead positions. Acid (rutile) slag systems gave high welder appeal, good mechanical properties and lent themselves to many applications formally welded with the MIG or SAW process.

However, flux cored wire manufacturers and fabricators did not stop their developments and quest for a continuous process that was faster, better and more economical. They needed to overcome one last hurdle, to achieve both high deposition
rates or the amount of weld metal deposited per hour and high deposition efficiencies, how much of the welding consumable actually becomes part of the weld deposit. Could we reach the high productivity level of flux cored wires, but maintains the high deposition efficiencies of the solid MIG wire process? The answer came in the form of a fabricated composite cored wire known as the metal cored wire.

Metal cored wires are classified under the American Welding Society specification with solid MIG wires (AWS A5.18-93 for mild steel, AWS A5.28-98 for low alloy and AWS A5.9-93 for stainless steel). Metal cored wires will carry the same basic classification for strength level and chemical composition as solid MIG wire, but are denoted by a “C” for composite wire. For example, a 70 KSI metal cored wire having a chemical composition and mechanical properties similar to an E70S-6 solid wire would be classified as an E70C-6 composite wire. Considered to have some characteristics similar to flux cored wires and other characteristics similar to solid wire, metal cored wires do share a similar construction to flux cored wires and performance similar to solid MIG wires.

The outer metallic sheath of a cored wire conducts the electrical current for welding. Because of the fabricated, composite nature of cored wires, their current carrying density is greater, which improves deposition rates at equal current levels when compared to solid MIG wires.

The internal components of a metal cored wire are composed chiefly of the alloys, manganese, silicon, and in some cases, nickel, chromium and molybdenum as well as very small amounts of arc stabilizers such as sodium and potassium, with the balance being iron powder. Metal cored wires give the benefit of being able to have alloy compositions formulated for specific applications in smaller batches than the normal large heats of solid wire. Many alloy compositions employing chromium, nickel and molybdenum are now available including austenitic and ferritic stainless steel alloys. Metal cored wires have little to no slag forming ingredients in the internal fill of the wire. Just like solid MIG wire, welds made with a metal cored wire will only have small silicon islands from the deoxidized products that appear on the surface of the weld. This allows for multiple pass welding without deslagging.

So, how do metal cored wires fit into a particular welding application? When is a metal cored wire the correct choice? What are the factors that need to be considered in choosing a metal cored wire? Do metal cored wires really offer that much benefit over flux cored wires or solid MIG wires? When making a major process change in the welding of an application, it is normal to ask a lot of questions. The whole process can become a bit overwhelming to the point that no decision is made. In order to prevent that from happening, the remainder of this paper will look at both the advantages and possible disadvantages of using metal cored wires.

High Deposition Efficiency

Whenever a weld is made, a percentage of the welding consumable is lost to slag, spatter and fume. Deposition efficiency relates to the amount of a consumable that becomes deposited weld metal. The higher the deposition efficiency of a consumable, the lower the amount of that consumable is wasted by not becoming part of the deposited weld metal. Because of the characteristics of a flux-cored wire, slag covering the molten weld puddle, they are efficient in the range of 84-89%...
depending upon the diameter and slag volume of the particular wire design. Solid MIG wires are highly efficient based on virtually non-existent slag. Solid MIG wires will typically exhibit efficiencies in the range of 95-98% depending upon the mode of the transfer used. Deposition Efficiency A true “spray” transfer under high Argon shielding gas mixtures will yield the highest deposition efficiency. Metal cored wires with their arc characteristics being similar to solid MIG wires and very low spatter level as well as low slag volume, also exhibit deposition efficiencies in the 92-98% range with the selection of spray transfer mode and high Argon shielding gas mixtures. When solid wires are used in the “short arc” transfer mode or with higher CO2 content shielding gas, some deposition efficiency will be lost due to the increased spatter level. This is also true with flux cored and metal cored wires. Changes in transfer mode and shielding gas will have an effect on the deposition efficiency. In some high-speed applications, solid MIG wires are used at lower voltages to avoid a large spray column. Using a solid MIG wire at voltages that produce a high spray column could produce undercut, underfill and can prevent the high travel speeds required for productivity. This practice produces a higher level of fine spatter, which decreases the deposition efficiency of the wire. When the same practice is used with metal cored wires, the level of fine spatter is greatly reduced. Along with obtaining a better deposition efficiency, maintenance costs for tooling and equipment can be lower.

Deposition Rates
Deposition Rate Comparison The deposition rate of a welding consumable is the measurement of how much weld metal is deposited within a given time period. Deposition rates along with deposition efficiency are the leading determinants of the cost effectiveness of a consumable. Generally expressed as pounds per hour (Kg./hr) flux cored and metal cored wires have some of the highest deposition rates of all of the welding consumables. Flux cored and metal cored wires are capable of having deposition rates as high as 12-14 pounds per hour (5.4-6.4 Kg/hr) for a 0.045” (1.2mm) diameter wire. This compares to a solid MIG wire in the same diameter of 8-10 pounds per hour (3.6-4.5 Kg/hr). The high deposition rates coupled with high deposition efficiencies and low slag volume will allow the metal cored wire to be used at higher travel speeds resulting in increased productivity. A general rule of thumb that has been used is that when a deposition rate of 9 pounds per hour or greater is achieved with a metal cored wire versus a solid MIG wire, the economics of the weld will show a cost savings in favor of the metal cored wire.

High Duty Cycles, High Travel Speeds
Any continuous welding process will inherently have a higher duty cycle, or the amount of continuous arc time. This makes sense. Deposition Travel Speed The SMAW process of stick electrodes requires the welder to stop in short intervals of the weld to de-slag and change electrodes. The duty cycle for SMAW electrodes is considered to be in the range of 20%. This translates to only 12 minutes of welding every hour an arc is generated. With a continuous process such as cored wire or solid MIG wire, the duty cycle increases to as much as 50% of the time or 30 minutes per hour for arc generation. This is one factor that makes the use of automated or robotic welding so attractive, the ability to use a continuous process. Along with the increase in duty cycle comes the benefit of faster travel speeds. Automated welding is only limited to the supply of parts to the weld station and the travel speed of the process. Solid MIG and flux cored wires can contribute to the higher duty cycles, but only metal cored wires have the capability of combining high duty cycles with high travel speeds to exploit these factors without sacrificing bead appearance, penetration and weld integrity. Increases in travel speed of 35-40% are not unrealistic when converting from a solid MIG wire to a metal cored wire. Increased duty cycles and higher travel speed can significantly reduce the cost of welding. Fabricators who for the first time use a metal cored wire in an automatic application are often surprised at the ability to increase in travel speed while maintaining weld integrity and bead appearance.

Low Slag Volume, Low Spatter Levels
Coupled with increase duty cycle of a consumable is the decrease in removing slag from the weld. This is one of the biggest advantages solid MIG wires have over flux cored wires. Because of the compositional characteristics of the metal cored wires, they also have a very low slag volume like solid MIG wires. The advantage of metal cored wires comes in decreased spatter levels that need to be cleaned from the parent material prior to finishing. In many cases, the small silicon
islands formed on the weld are easily removed. Metal cored wires tuned to the proper welding parameters and using high Argon mixes for shielding gas will also have a decrease the amount of spatter.

This is especially an advantage to continuous operations where the part moves from an assembly/welding operation directly into a cleaning and painting operation. Cleaning of weld spatter from a fabricated piece can cost significantly in post weld clean up. One particular application in which this was very evident was in a mobile crane manufacturer who went from a basic slag flux cored wire to a metal cored wire and saved an average of 12-14 man hours per unit in post weld cleaning prior to painting. Metal cored wires have the advantage of having arc stabilizers in both the internal components as well as applied to the surface of the wire. The arc stabilizers enhance the arc characteristics as well as minimize the spatter levels.

Economics

The real payback for any change in process or welding consumable comes with the economics of the change. How can we do it better, but at a less cost per unit. A common mistake is to try to obtain the incumbent filler metal at a lower price. Because the actual cost of the filler metal for welding is a small percentage of the total, maximum savings are not achieved. When breaking down the actual cost per pound for a deposited weld, the cost of the filler metal only contributes approximately 15% of the total cost. Other factors such as labor and overhead, equipment, electrical cost, deposition efficiency and deposition rates of the filler metal can have a much larger impact. Bottom line with a filler metal is that it is not how much it costs per pound that counts, but how much it costs per pound to use. An analogy to this would be in purchasing paint. Take one brand that costs $10 per gallon versus another brand that cost $20 per gallon. If the lower priced paint takes additional coats for coverage and does not cover the same square footage per gallon, any savings in the purchasing price is lost. The same can be true of choosing the correct filler metal to maximize the cost per pound of deposited weld metal.

Consider an actual application using 0.052’’ (1.4 mm) E70S-6 MIG wire welded under pulse conditions at 425 inches per minute wire feed speed, 24.5 volts and travel speed of 70 inches per minute. This was converted to metal cored wire welded and at the same wire feed speed, voltage and travel speed. Because of the benefits of the metal cored wire, the travel speed could be increased to 85 inches per minute, or a 20% increase. Not only was the travel speed increased, increasing the through put, the number of necessary repairs diminished as did the amount of time to make repairs by 10%. Because the line time cost was calculated in dollars per minute, a huge saving in real dollars was realized from even small advances in productivity improvement. The cost per pound for the metal cored wire was more than the cost per pound for the solid MIG wire, but the realized savings more than offset any additional cost for the metal cored wire.

In another application, a 0.040”diameter (1.0mm) ER409Cb solid MIG wire was welded under pulse conditions at 180 amps, 20 volts and 19.6 inches per minute travel speed for a thin wall tube. Conversion to an 0.045” (1.2 mm) EC409Cb metal cored wire welded under pulse conditions at 190 amps, 21 volts and 27.5 inches per minute travel feed speed. Not only did the travel speeds increase, but an additional advantage was seen in the ability of the metal cored wire to bridge gaps due to poor fit up. This also contributes to a lower defect rate and the need to rework parts off line. The results are on the average a 40% increase in production, lower consumable cost per pound of weld metal and lower maintenance cost.

Disadvantages to Metal Cored Wires

So far this paper has been weighted to show the advantages of converting solid MIG wires or flux cored wires to a metal cored wire, but there are disadvantages as well. To gain the fullest potential benefit from using a metal cored wire, an automated or robotic set up is required. Expecting the maximum potential increase in travel speed to be met and consistently maintained in a hand held operation is expecting a lot from a welder. Automated systems are consistent and do not tire nor do they need breaks. As long as a continual supply of parts are supplied, an automated system keeps on working. If a current application is being handled only by hand held welding stations, a capital investment would need to be made in an automated system. Repetitiveness of an application is necessary to minimize set up and jig costs. Experience in programming a robot is necessary due to an increase in weld puddle fluidity. Such would be the case in welding a small
diameter tube where the positioning of the torch to the part is more sensitive with a metal cored wire. The cost of the automated system has to be taken into account also as well as the ability to provide a reasonable payback on the investment.

In order to obtain a spray transfer, which is the best mode to provide excellent wetting in of the bead and to minimize spatter, high Argon gas mixtures are required. Although high percentages of Argon in the shielding gas reduce fumes generation these types of shielding gases also generate more heat and higher amounts of radiant light. Water-cooled welding guns as well as protection from not only the arc, but also reflected light are essential for a safe work place. This is another reason automated systems help in maximizing the benefits of metal cored wires. They are not as susceptible as a welder to the effects of the additional heat and radiant light generated.

To gain all position capability with a metal cored wire, like the solid MIG wires, either a short arc transfer mode or pulse mode is required. Short arc would be eliminated due to the significant drop in deposition rate, deposition efficiency and increase in spatter. Most pulse machines do not contain a program specifically for metal cored wires. Although not absolutely necessary, the development of a synergic curve and pulse parameters does enhance the performance of a metal cored wire. If existing equipment is not able to pulse or does not have a pulse program specifically for metal cored wires and the desire to enhance the arc and operability is there, the equipment manufacturer will have to make adjustments and program modification to the power source. Depending upon the machine manufacturer, these adjustments may be able to be made to the current power sources.

A significant increase in productivity and throughput in one station will be negated if the subsequent stations down the line cannot handle the additional parts. It would not be an advantage to increase productivity by 30-40% in a weld station if the station is only operated 50-60% of the time due to parts backing up. Payback on the investment would be extended to the point of being unattractive to most. When considering the increase in parts per hour that can be achieved from changing to the higher productivity metal cored process, the stations down the line from the operation also need to be considered as far as their capability of handling the increase from productivity gains.

Conclusion

The industry to a large extent still views metal cored wires as being somewhat Marketing smoke and mirrors. It is sometimes very hard to understand how a product that has a higher cost per pound as a filler metal will actually save money when evaluated as cost per pound deposited, or the true cost for the welding application. It is not until actual results are obtained that the reality of what can be achieved is believed. It is human nature to believe what is in front of our eyes rather than what someone is promoting today. Trying metal cored wires in your application could result in significant improvement in productivity. Evaluating the total picture should result in being able to identify specific benefits over the consumables that may be currently being used. Among these benefits, which translate into cost savings, are high deposition rates, high deposition efficiencies, high duty cycles, high travel speeds, low slag volume and low spatter. In addition, the newer technology offered by manufacturers would give the operators the added benefit of lower fume generation rate for a safer, healthier weld environment. Metal cored wires can be a benefit regardless of whether they are used in a hand held operation or in an automated weld station. From hand held to simple automation to a full multi-process robot, metal cored wires can and do offer benefits over other choices in consumables.

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