Survey of Robotic Seam Tracking Systems for Arc Welding

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Abstract

One of the main process problems of robotic arc welding is the consistency which needs to be maintained while making part after part. A quality weld can only be achieved if the weld seam of each part moves less than ½ the diameter of the weld wire from the programmed weld path. Movement of a weld seam can be the result of poor fixturing or variations in the metal forming process. A standard robotic arc welding system does not have the ability to see the changes in the joint location. If unacceptable weld joint variation occurs, an independent method of finding the location of the weld seam must be used to provide the robot controller with information to adjust the position of the weld path. In order to select the correct method, a manufacturer must be familiar with the strengths and limitations of each of the different types of sensor systems available. A sensor can only track the position of the joint if it can recognize and use the features of the joint. This paper will give an overview of four of the common robotic arc welding sensor processes used today. These processes include: Thru-arc seam tracking, Arc voltage control, Laser based vision systems, and Touch sensing.

TAST

For Gas Metal Arc Welding (GMAW), a low cost method of tracking a weld seam is Through Arc Seam Tracking (TAST). This method uses the welding arc as a sensor to measure variations in the welding current which are caused by changes in arc length. For example, a change in stick-out is determined by using the inversely proportional relationship between arc length and arc current. By monitoring the arc current feedback, the robot can adjust the torch's vertical position to maintain a constant stick-out. The lateral location of the seam is determined by using the weave function of the robot. As the torch weaves over the seam, the weld current feedback will oscillate. A valley in the current feedback signal indicates the torch is passing over the seam, while a peak in the signal represents the torch is at either edge of the weave cycle. Changes in the value of the peak current signal indicates to the robot that the torch is moving away from the joint and its position should be corrected.

Due to the violent nature of the welding arc, the weld current feedback signal contains a large amount of noise. This noise can cause trouble in how the robot interprets the feedback signal and therefore, must be filtered out. By performing this filtering and creating a specific algorithm to work with only the necessary feedback information, the TAST process has been able to track lap joints with a top plate as thin as 2mm with 55ipm travel speed.

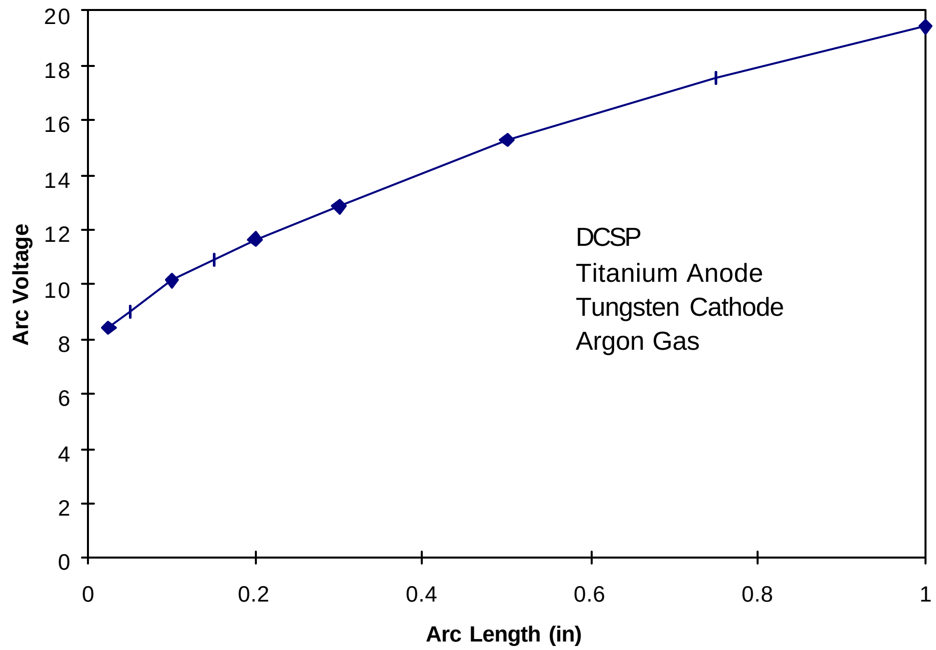
TAST control methods typically have a large number of variables which are used to optimize tracking performance for a variety of applications. This makes TAST relatively difficult for operators to program during the integration period. A good understanding of how these variables effect the TAST process will allow the user to optimize the setting for each application. A utility which helps the user determine the settings of the TAST parameters can create a much more user friendly package. Once these variables are optimized, it is critical that a stable welding process is maintained. Since the weld current is dependent on the weld process, any changes in this process will effect the feedback going to the robot. The cause of these changes can be as minor as a worn contact tip or as significant as a change in the weld schedule. The robot will only know that the weld current feedback has changed and try to compensate by adjusting the torch position.

TAST is an inexpensive method of tracking weld joints. The only hardware requirement is a weld current sensor. The robot must also have software which can interpret the current feedback to modify torch position.

AVC

When using Gas Tungsten Arc Welding (GTAW), the same sensing principle used in TAST can be used to track the weld joint. Instead of using weld current, Arc Voltage Control (AVC) is used to monitor changes in the welding voltage. The weld voltage has a directly proportional relationship with arc length. (Fig. 1) The robot uses this relationship in the same way as TAST to maintain the torch's relationship to the weld seam. Due to the low sensitivity of the feedback signal, AVC is mainly used for vertical tracking, but theoretically can also be used for lateral tracking.

Figure 1
300 Amp GTAW[1]



Like TAST, AVC can be relatively complicated to set-up and maintain. If the GTAW process is only used for vertical tracking and a wire feed system is not used, the amount of variables effecting the AVC settings is significantly reduced. Since the AVC settings depend on the individual weld parameters, a good weld must be made before developing the AVC settings. AVC is also an inexpensive option that only requires some filtering hardware and a robotic software interface. The voltage sensor hardware can be made to work with pulsed or constant weld current.

Laser Based Systems

When material or process conditions create an application that is not feasible for the arc sensors to track a joint, an external sensor can be added to the robot. Of the external sensors available, a laser based sensor provides the most flexibility in the size and type of joint that can be tracked. For sheet metal applications, a laser sensor can track lap joints with material thickness less than 1mm, or butt joints with less than a 1mm gap. In order to track these joints, the laser sensor must be placed in front of the welding torch in such a manner that the laser can scan across the weld joint. A camera inside of the sensor monitors the laser light to determine the location of the weld joint. The joint information is then passed on to the robot which makes any adjustments to the torch location.

Unlike TAST or AVC, the laser sensor does not need to have an arc established in order to get joint information. The sensor can be used to search for the joint location before starting the weld, allowing the robot to place the wire directly on the joint before the arc start. Once the weld is started, the laser can be used to track the joint. The laser sensor can also be used to determine information about the weld joint, such as gap or mismatch. As this joint information changes, the robot can adaptively modify the weld parameters to match the optimal settings for the changing conditions.

A laser sensor creates a relatively complex system which can be affected by the everyday rigors of a harsh production environment. Since the sensor package is attached to the weld torch, it can become an obstruction which limits the torch access to some joints. The sensor package is relatively fragile and the programmer must be careful to create programs while avoiding collisions with the parts and fixtures. Some laser packages also come with a mechanical rotator which turns the sensor around the torch to help position the laser on the joint. While a rotator can reduce the complexity of positioning the laser, it will add to the bulkiness and cost of an already expensive system. In order to justify the cost of a laser tracking system, a study should be performed which indicates the laser sensor would have a significant reduction in weld repair costs.

Touch Sensing

Another method of adjusting a robot path for movement in a weld seam is called Touch Sensing. Touch Sensing does not function as a seam tracker, but instead finds the weld seam and adjusts the entire weld path before starting the arc. The robot finds a seam by using the welding electrode or a separate pointer to make electrical contact with the part. A search pattern is performed by the robot so it can touch the part until it finds out how far the seam has shifted and rotated in up to three dimensions. An offset can then be applied to every weld which is on this seam. This method can also be applied to determine if there is a gap in the weld joint which requires a change in the weld schedule.

The requirements which must be met in order to use touch sensing are very straight forward. Most robotic welding power supplies contain a circuit which can be used for the touch sensing technique, and keep this a very low cost method. The biggest disadvantage comes from the cycle time increase that is added by the robot to perform the search routines. The weld joint must also have an edge which can be found by the sensor. For lap joints, this requires a top plate thickness of 2mm.

Optional Features

Each of these sensing methods can be enhanced with additional options on the robot controller. Coordinated motion with an auxiliary servo table provides additional flexibility in part programming and design. For large weld joints requiring a number of passes, root pass memorization (RPM) can be used to record any joint offset information from the sensor. For each additional pass, the sensor can be turned off and the RPM offset can be played back to maintain the torch placement.

Conclusion

Each type of sensing method presented in this paper has its own advantages and limitations. By fully understanding what these aspects are, a user can best determine what is needed for their robotic application to allow for the maximum productivity. Table 1 gives a comparison of how each of the different sensors can be applied. The user must remember that a welding sensor will not improve the welding process, it will only maintain the correct alignment of the torch to the part. By adding one of these sensor methods to the manufacturing process, additional complexity is introduced to a robotic system. The best way for a robotic arc welding user to consistently make acceptable welds is to develop a manufacturing process which gives consistent weld joint placement, so these sensors are not needed.

Table 1
Sensor comparison chart

	TAST	AVC	Laser	Touch Sense
Seam Finder	N	N	Y	Y
Seam Tracker	Y	Y	Y	N
Adaptive capabilities	Y	N	Y	Limited
Joint types	Lap, Fillet, Butt, Ridge	Lap, Fillet	All	Lap, Fillet, Ridge
Material types	All Steels	All Steals, Aluminum	Non-reflective material	All
Min. Lap thickness	2mm	4mm	.8mm	2mm
Additional cycle time	none	none	< 1 sec per search	1.5 sec per search
Programming complexity 1-5	4	3	4	2
Maintenance requirement 1-5	4	3	3	1
Welding processes	GMAW, Pulsed GMAW, Sub Arc	GTAW, PAW	Most Welding Processes	Most Welding Processes

References

1) Jackson, C.E., “The Science of Arc Welding”, The Welding Journal, April 1960, 129-s to 140-s