HEADS UP!

Wobble head applications in laser welding aluminum and copper

by Bryce Samson and Mustafa Coskun, IPG Photonics; Giuseppe Barbieri and Francesco Cognini, ENEA-Casaccia Research Center, Rome; Sergio Cassarini and Marco Franzosi, IPG Photonics (Italy), Milan, Italy
In a previous article in Shop Floor Lasers, the technology of beam oscillation or “wobble head” laser welding was introduced. In this follow-up article, some of the specific application areas that benefit from the technique are described in detail, including aluminum welding for automotive and difficult-to-weld dissimilar metal parts.

Wobble head technology is compatible with 12-kW power handling from commercially available fiber lasers. Furthermore, it is compatible with automated seam tracking. Traditional welding accessories, such as assist gas ports and coaxial nozzles, are discussed in this article as are some of the benefits of utilizing filler wire with the wobble head.

Adoption of lighter and stronger materials in automobiles has led to a number of significant challenges in welding these structures. A recent study [1] of automotive aluminum alloys for tailored welded blank body parts highlighted the problems associated with traditional laser welding and investigated the benefits of the new wobble head laser technology, including systematic studies of butt and lap joint welding.

Other examples extend to electric vehicle infrastructure, where battery manufacturing often requires joining of dissimilar highly reflective materials such as aluminum and copper, which is very challenging using traditional laser welding (see Figure 1).

The recent introduction of a new, cost-effective, easy-to-integrate technology, based on a beam wobbling technique, is helping overcome some of these difficulties in welding materials such as copper and aluminum with high brightness fiber lasers at 1 micron [1-3].

This technique is helping to overcome porosity and hot cracking issues with laser welding of some materials, while helping to make the part-fit up to three times more forgiving in some studies [4]. By enabling independent control of penetration depth, spot velocity, weld speed and seam width, the technique has applications in welding small, temperature-sensitive assemblies (for medical parts), as well as cosmetically attractive welds without the need for postprocessing.

Figure 1. Examples of laser welding in automotive batteries include bus bar welding and battery cans where aluminum and copper welds are typically required.
Independent control of the amplitude and frequency of the oscillation is achieved through the galvo-mirror controller, allowing more flexibility in stabilizing the keyhole melt during the welding process, with typical frequencies up to 300 Hz used in most applications. Power handling of commercial wobble welding heads is now available up to 12 kW.

Stability of the keyhole melt is a critical factor when laser welding difficult highly reflective materials such as copper and aluminum. This is partly due to the tendency to spatter, and in the case of some aluminum alloys, a high level of porosity due to the viscosity and surface tension of the melt when using more traditional laser welding techniques. Recent studies [1-3] have shown the reduction or elimination of these problems with the beam wobble technique, including a recent systematic study with and without filler wire on automotive aluminum alloys [1].

Overall, the wobble head technique allows for better temperature management of the part. Because the
beam passes near any given point of the weld multiple times, the ramp in temperature and cooling rates is slower than in traditional laser welding, which helps eliminate defects and manage spatter.

In addition, this welding technique is compatible with typical welding accessories such as assist gas ports and coaxial nozzles that enable plume suppression and can help control spatter; techniques that are not readily compatible with the scan heads used in remote welding.

In addition to stabilizing the keyhole melt and reducing porosity in the subsequent weld, the beam wobble technique has proven valuable for alleviating the part-fit requirements for laser welding, as shown in Figure 3.

Using one of the programmable shapes (infinity in this case) and optimizing the amplitude and frequency of the oscillation, an increase in the acceptable seam gap of three times that achieved in conventional laser welding has been demonstrated.

An example of the wobble head technology being used to control weld seam diameter and depth (through the wobble amplitude parameter) in copper welding with a 1-kW single-mode fiber laser [4] is shown in Figure 3. Laser power, wobble frequency and weld speed are constant throughout this data set.

**Application to automotive aluminum**

A recent study [1] investigating butt and lap joint welding in automotive aluminum alloys utilized a commercial wobble welding head in conjunction with a 2-kW fiber laser. As with previous work, the study found the wobble head technology invaluable for these difficult-to-weld materials, providing additional process parameters to manage the hot cracking and porosity susceptibility associated with laser welding of aluminum.

This particular study investigated AA-6082 T6 (2 mm thick) welded to AA-5754 H111 (1.5 mm) with and without filler wire in butt and lap joint weld configurations, as shown in Figures 4 and 5. The wobble head technology allows for the controlled...
Whether you’re replacing capital equipment or purchasing consumables, finding and qualifying new suppliers adds to the workload of an already busy shop owner or production manager. Sorting through the thousands of companies that provide products to the metalworking industry can be both time consuming and frustrating. But that’s about to change!

U.S. Metalworking Sourcebook is a powerful, easy-to-use online resource that brings buyers and sellers together. The Sourcebook is a research search tool already seen by over 280,000 job shop and OEM buyers of all levels throughout the U.S., Canada and Mexico. It was developed by Techgen Media Group, publishers of Fab Shop Magazine, Shop Floor Lasers and Welding Productivity. We know metalworking, and we know how to help you find the supplier that best matches your needs, and with only a few keystrokes.

WE’VE TAKEN SOME OF THE WORK OUT OF METALWORKING.

Log on to USMetalworkingSourcebook.com today to activate your listing. More than 3,000 companies are already included.

The maximum diameter and frequency of oscillation, in this study, were 3.9 mm and 300 Hz, respectively. The optimal welding speed (V), laser power (P) and amplitude of wobble (k) for each welding configuration are shown in Figure 5. The addition of the filler wire to the welding process has led to a considerable increase in optimized welding speed.

Weld porosity was studied using digital radiography, with the conclusion that butt joint welding had the lower porosity, likely a result of the easier gas/vapor escape in this geometry compared to the lap joint.
Micro-hardness and tensile testing were used to qualify the welding process in each case. The results are summarized in Figure 6a, where the tensile strength of the various welds is graphed. The dotted line indicates the tensile strength of the base material (AA-5754 H111) of the thinner side of the sample. Indeed in this study, every butt joint exhibits high tensile strength with failure occurring at the level of the base material [1]. Investigation of the fracture load on the lap weld width is also shown in Figure 6b, and benefits from increased weld width, which is in turn controlled via the wobble amplitude function (see Figure 3) with a further benefit from the addition of filler material to the process.

**Application to copper**

Aluminum-to-copper overlap welding for the battery industry is the final application reviewed, as shown in Figure 7. In this case, the penetration depth is a critical parameter to minimize the intermetallic formation (ideally less than 10 microns), which can be controlled by the speed of the process in traditional laser welding. However, in the case of utilizing the wobble head technique, there is additional control of the weld width and penetration through the amplitude and frequency functions on the wobble head. This additional process control can prove vital in the welding process of dissimilar materials.

The results in Figure 7 show the result of an increase in wobble amplitude (from 0.2 mm to 1.2 mm) on the subsequent weld width, along with fine control and reduction of the penetration depth, which subsequently improves the mechanical properties of the weld between the aluminum and copper parts.

Wobble head technology is fully compatible with higher power multimode fiber lasers, and the cross sections of copper welds using 5-kW fiber lasers operating together with the wobble head is shown Figure 8. In the case of the higher power levels,
The difficulties associated with laser welding of materials such as aluminum and copper using 1-micron lasers can largely be overcome by using high-brightness fiber lasers together with the latest wobble head technology. This technique offers additional beam control, which in turn enables stabilization of the keyhole melt during the welding process. Commercial wobble welding heads are now rated to handle up to 12 kW of continuous wave power.

Figure 7. Effect of wobble amplitude on the weld width of aluminum-to-copper parts, while controlling the penetration depth and intermetallic layer between the materials.

greater penetration depth is achieved (up to 4 mm in this case) and, as in the previous study, the additional process flexibility associated with the wobble head technology is used to control the keyhole and stabilize the melt during the process. Commercial wobble welding heads are now rated to handle up to 12 kW of continuous wave power.
Wobble head technology is fully compatible with higher power multimode fiber lasers.

The results are reduction or elimination of porosity and spattering traditionally associated with laser welding of these materials.

The additional degrees of freedom achieved through independent amplitude and frequency of the wobble head oscillation, when combined with the high brightness and power available from the fiber laser, are the key to this new welding process. Examples presented here are laser welding of difficult-to-weld materials such as automotive aluminum and copper, as well as welding of dissimilar materials which requires fine control of the intermetallic mixing region enabled by the wobble head welding technique.

In addition, the technology offers significant advantages in part-fit through relaxed tolerance on seam gap and seam offset compared with traditional laser welding processes. The applicability of the technique with single-mode and multimode high-power fiber lasers is also shown in this study. Finally, the technology is compatible with standard welding accessories such as assist gas delivery ports, coaxial nozzles and filler wire, offering a major advantage over alternative techniques.

References


