ABOUT THE USE OF LASER WELDING FOR THE ASSEMBLY OF AUTOMOBILES

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Abstract: Laser beam welding (LBW) is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. The process is frequently used in the automotive industry. The authors of this work present general aspects of the laser beam welding. These refer to a high energy beam process that continues to expand in modern industries and new applications because of its many advantages like deep weld penetration and minimizing heat inputs. The turn by the manufacturers to automate the welding processes has also caused the expansion in using high technology like the use of laser and computers to improve the product quality through more accurate control of welding processes.

Keywords: beam, laser, welding.

1. THE FUNCTION OF LASER

The function of all laser beam welding processes is based on the principles of the excitation of atoms using intense light, electricity, electron beams, chemicals etc., and the spontaneous and stimulated release of photons. In general, there are two types of lasers used for laser welding: CO2 and Nd: YAG (Yttrium Aluminum Garnet Neodimyum). Lasers generate light energy that can be absorbed in the material and converted into energy (heat). Laser beam welding has high power density (on the order of 1 [MW/cm²]), resulting in small heat-affected zones and high heating and cooling rates. The spot size of the laser can vary between 0.2 [mm] and 13 [mm], though only smaller sizes are used for welding.

2. LASER WELDING PROCESS

We can transmit this energy from source materials, using optical elements of delivery that can focus and direct energy very precisely.

Since the laser emits coherent radiation, the energy beam divergence is minimal and can travel long distances without losing a significant part of the quality and quantity of energy. The high power of the laser energy melts and evaporates the material. Vapor pressure, dislocation molten metal forming a cavity - the keyhole. The keyhole in the metal provide transfer of laser energy and guides the laser beam deep into the material. In fig.1 are shown the components of the laser welding process.

![Fig.1. Laser welding process [4].](image)

The laser welding technology can be used for micro joints as well as for thicker parts (25……30 [mm]). Hybrid laser-arc welding introduces a secondary energy source to the weld pool area (see Fig. 2). It combines typical laser welding benefits - high travel speeds, limited heat-affected zone (HAZ), narrow weld joint, and good bead appearance with those of gas metal arc welding (GMAW): process energy efficiency, gap-bridging, slow cooling rates, and energy coupling efficiency. Laser beam attenuation (scattering and absorption) caused by vapor particles evacuating the keyhole or weld area reduces the amount of beam energy coupled to the base material. The GMAW wire can be introduced before or after the laser beam.
3. LASER WELDING COMPONENTS

The majority of high power laser welding installations in the automotive industry consists of cross flow CO₂ lasers in the power range of 3 [kW] to 5 [kW]. The laser beam is directed to the workstation and focused on the part by the use of copper mirrors. Weld depth and width depend on the process parameters, which are: laser power, speed, focuses spot size and position shield gas flow and direction. The laser weld is a non-contact process, an easily controlled tool, and well suited to automation or CNC systems.

4. WELDING CALCULATIONS

Knowing the size of the focused spot is helpful in calculating energy density at the work surface. For a fundamental mode (TEM₀₀) beam:

\[ S = \left( \frac{4l}{\pi} \right) \cdot \left( \frac{F}{D} \right) \quad [\text{mm}] \quad (1) \]

where:
- \( S \) - Focused Spot Diameter;
- \( l \) - Laser Wavelength;
- \( F \) - Focal Length of Objective Lens;
- \( D \) - Diameter of Laser Beam.

For a multimode beam:

\[ S = F \cdot f \quad [\text{mm}] \quad (2) \]

where:
- \( F \) - Focal Length of Objective Lens;
- \( M \) - Laser Beam Divergence.

If one assumes the part to be welded as a semi-infinite solid, with a constant incident heat flux, then the temperature distribution as a function of depth into the material is given by:

\[ T(x,t) = \left( \frac{2E}{K} \right) \cdot \left( \frac{kt}{p} \right)^{\frac{1}{2}} \cdot \exp\left(\frac{-x^2}{4kt}\right) - \frac{x}{2} \text{erfc}\left(\frac{x}{2\left(kt\right)^{\frac{1}{2}}}\right) \quad (3) \]

where:
- \( T(x,t) \) - Temperature at a distance \( x \) below the work surface, at a time \( t \) after start of constant heat input;
- \( E \) - constant heat flux input;
- \( K \) - thermal conductivity;
- \( k \) - thermal diffusivity;
- \( x \) - depth below surface;
- \( t \) - time after start of heat flux input;
- \( \text{erfc} \) = complimentary error function.

At the surface (\( x=0 \)), the temperature rise will be:

\[ T(x,t)_{x=0} = \left( \frac{2E}{K} \right) \times \left( \frac{kt}{p} \right)^{\frac{1}{2}} \quad (4) \]

5. METALLURGICAL CONSIDERATIONS

The effect of welding on various materials depends upon many of their metallurgical properties such as "hot strength". After the applied energy is removed, the melt pool solidifies and then it slowly cools to the same
temperature as the surrounding material. During this cooling, the material contracts, creating tensile stresses in the fusion zone. Materials that have a low tensile strength at temperatures near their melting point are said to exhibit "hot shortness," which often results in cracks appearing in the weld.

Similarly, other thermal transformation, such as the martensitic transformation of high carbon steel, also can lead to cracking in or near the weld.

To overcome this tendency, special precautions such as pre- and post-welding heating of the material is necessary. However, virtually no thermal distortion occurs during laser welding. The lower heat input requirement has other benefits, such as being able to use fixtures that do not need to withstand large thermal expansion forces or to act as heat sinks.

Chemical reactions, such as oxidation or nitriding, with atmospheric gases at high temperatures can pose problems, particularly when the oxides or other elements formed have disassociation temperatures far above the melting point of the metal. The result is brittle, porous welds.

Covering the welding area with an inert gas such as argon or helium minimizes these reactions in most cases. For some materials, it may be necessary to weld within a sealed chamber to prevent outside contamination.

For welding aluminum to hermetically sealed semiconductor packages, the introduction of silicon-aluminum alloys vastly improves the weld by providing a solidification temperature significantly lower than the parent material.

6. APPLICATIONS

Current and future industrial applications of aluminium laser welding includes fast ferries, aluminium car components (e.g. Audi) and airframe structures.

Transmission laser welding is now widely used for joining thermoplastics in industry, using laser sources with wavelengths from 0.8-1.1[µm], such as diode, Nd:YAG and fiber lasers. The radiation at these wavelengths is less readily absorbed by natural plastics. Laser absorbing additives are therefore put into the lower part or applied as a thin surface coating at the joint. The parts are positioned together before welding and the laser beam passes through the upper part to heat the joint at the absorbing surface of the lower part (Fig. 6). The absorber in or on the lower plastic is typically carbon or an infrared absorber with minimal visible color, which allows a wide range of part colours and appearances to be welded. Transmission laser welding is capable of welding thicker parts than direct welding, and since the heat affected zone is confined to the joint region no marking of the outer surfaces occurs. The maximum thickness of the upper part is determined by the transmission properties of the material; transmission laser welding is only possible if over 10% of the energy is transmitted to the joint interface.

Transmission laser welding can also be used to weld film and sheet materials. The laser source is scanned over the two parts just in advance of clamping using a roll processing method.
7. CONCLUSIONS

The method of laser welding in the manufacturing of the body-in-white can evidently improve the performance of the anti-impact and anti-corrosion for the car body structure. The laser welding owns merits of high welding speed, low residue stress, and the usage of laser welding in the automobile industry can reduce the weight of automobile parts, costs of production and materials etc..

REFERENCES