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Remote Laser Welding: The Future of Automotive Manufacturing

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ABSTRACT

Global Automobile industry has adopted laser technology as early as 1973 into its manufacturing process, starting from Ford Motor Co. use of laser welding system for underbody operation over its assembly line. In modern times the solid- state laser is gaining popularity and evolving very fast. Laser technology has become integral part in automotive industry right from laser cutting to laser welding in gear parts welding, manufacturing air-bags and welding engine components like injection values, welding tailored blanks and welding hydro formed parts. Companies like Volkswagen AG. have been using lasers to produce its car bodies and now has over 800 high-power laser systems placed in its manufacturing plants globally. The same goes for Audi AG., BMW AG., Nissan Motor Co. Ltd., Toyota Motor Corp., Hyundai Motor Co., and Volvo as they have been using lasers for joining and welding metals for many years.The purpose of this paper is to illustrate the technology of remote laser welding instead of traditional methods in the automotive industry. (Photonics, 2024)

Keywords: laser Technology, Automotive Industry, Manufacturing Processes, Remote, solid-state Laser.

اللحام بالليزر عن بُعد: مستقبل صناعة السيارات

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ملخـــــص البحـــــث

اعتمدت صناعة السيارات العالمية تقنية الليزر منذ عام 1973 في عملية التصنيع، بدءًا من استخدام شركة فورد موتور لنظام اللحام بالليزر لتشغيل الهيكل السفلي على خط التجميع الخاص بها. في العصر الحديث، اكتسب الليزر ذو الحالة الصلبة شعبية كبيرة وتطور بسرعة كبيرة، ومن هنا أصبحت تقنية الليزر جزءًا لا يتجزأ من صناعة السيارات بدءًا من القطع بالليزر إلى اللحام بالليزر في لحام أجزاء التروس، وتصنيع الوسائد الهوائية ولحام مكونات المحرك مثل قيم الحقن، ولحام الفراغات المصممة، ولحام الأجزاء المشكلة بالماء. تستخدم شركات مثل فولكس فاجن إيه جي الليزر لإنتاج هياكل سياراتها ولديها الآن أكثر من 800 نظام ليزر عالي الطاقة في مصانعها على مستوى العالم. وينطبق نفس الشيء على أودي إيه جي، وبي إم دبليو إيه جي، ونيسان موتور المحدودة، وتويوتا موتور كورب، وهيونداي موتور، وفولفو حيث تستخدم الليزر لربط المعادن ولحامها لسنوات عديدة، الهدف من هذه الورقة هو توضيح تقنية اللحام بالليزر عن بعد بدلًا من الطرق التقليدية في صناعة السيارات.

الكلمات الدالة: تكنولوجيا الليزر، صناعة السيارات، عمليات التصنيع، ليزر الحالة الصلبة عن بعد.

1. INTRODUCTION

1.1 Laser Welding for Manufacturing Car Bodies

Welding is achieved when different parts are heated, melted, fused and settled together. Laser uses light energy which the materials absorbed and gets heated. The focused light beams of laser can be visible or infrared which is directed to a very small and precise point. Lasers are one of the most efficient methods for applying thermal energy to small spots. Laser comes with different power range and size depending on its usability and penetration requirements (USlasercorp, 2011).

Generally, for welding operation two types of lasers are commonly used: CO2 and Nd:YAG (solid state) lasers. Both these lasers operate in infrared region invisible to eyes. CO2 laser is more power full than Nd:YAG laser which can generate power greater than 10 KW whereas Nd:YAG can produce up to 500 W. Based on different applications these two lasers can be used in welding process (USlasercorp, 2011).
Figure (1) shows Laser Welding for Manufacturing Car Bodies.

Fig 1. Laser Welding for Manufacturing Car Bodies [2]

1.2 Process Description for welding car bodies

With the use of high power lasers over the body of automotive the following operations can be done such as welding of top roof, doors, truck lid, underbody and side panels. The laser energy first melts and then evaporates the metal body. Pressure is applied at the molten metal which is displaced and gap or cavity is created which is known as the keyhole. This Keyhole guides laser beam deep into the metal by transfer of laser energy absorbed. Thus, very narrow and deep weld is created using high power laser and is called deep penetration welding. Finally welding gas is passed into the formed weld used for shielding purpose. The welding gas should be inert in nature; it should not chemically react with the base surface. Examples for shielding gases which can be used are Helium, Carbon and Hydrogen. As Helium is expensive gas mostly Carbon and Hydrogen are used (Linde, 2024).
Figure (2) shows high power lasers over the body of automotive

Fig 2. High power lasers over the body of automotive. [3]

2 TRADITIONAL METHOD FOR WELDING CAR BODIES

Spot Welding: In spot welding operation two copper electrodes are used and placed in jaw form on both sides of the material to be joined or welded. Pressure is created to hold both electrodes in the same place tightly together and then an electrical current flow through the materials from the electrodes. The principle behind this method is that the resistance of the materials is higher than the electrodes used. So when electricity is passed through them heat is generated which melts the metals and pressure from the electrodes push the melted spots in the materials to unite. Current is stopped and after sometime united metal is solidified. Here the amount of current, time of hold and pressure are very critical part (Engineersedge, 2024). Spot welding is usually used to weld different sheet metals with small thickness. Welds formed by this method is discontinues and overlapped work pieces are usually formed. Here heat is generated and pressure is created without the use of filler material in specific

area. This method has been a very common method for welding in automobile industry. Normally in an automobile industry robotic arms are used to form spot welds for a car body in an assembly line formation (EWF.BE, 2007).

Figure (3) shows traditional method for welding car bodies

Fig 3. Traditional method for welding car bodies. [5]

3. ADVANTAGES OF LASER WELDING OVER TRADITIONAL METHODS

- Single sided welding-This is one of the main advantages of laser welding that it requires only one side access to the welding location. On the other hand, the classic resistance spot welding needs both sides of the joining location for placing its upper and lower electrodes. Thus, laser can be used for various designs and solutions.

Figure (4) shows Single sided welding

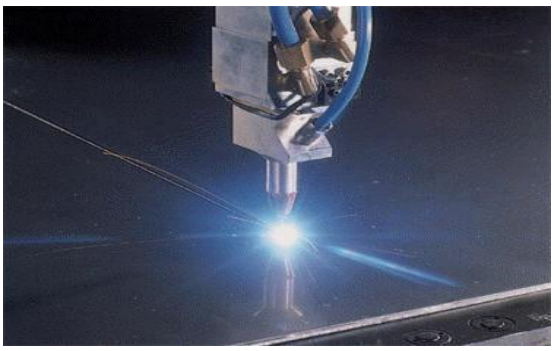

Fig 4. Single sided welding. [6]

- Invisible Joints-With use of laser brazing technology where an arch is used with laser in a beam trap configuration and by positioning laser welds at the edges on the sheet, it is possible to create almost invisible joints during laser welding. This makes laser welding ideal for fittings of truck lid, doors and tailgate apertures. Figure (5) shows joints-With use of laser brazing technology.

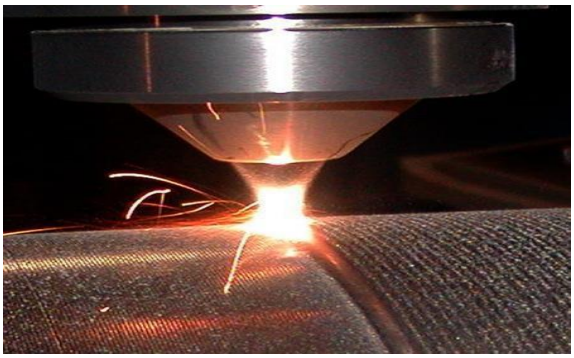

Fig 5. Joints-With use of laser brazing technology. [6]

- Material Reduction-With the use of laser welding much smaller flanges are used than what spot welding requires for size of openings in side door. More than 50% flanges used are reduced giving automobile reduced weight and fine visibility. This space left can be used by cantrail, pillar and sill sections, this increases stiffness and strength.
- Increased Process Speed-As laser are used using robotic arms and programs and can be used without touching the body or part to be welded has resulted in high productivity, use or lower body shop space and short cycle time. Thus the overall quality and accuracy of the final product is improved using laser welding (Thefabricator, 2024). Figure (6) shows laser using robotic arms

Fig 6. laser using robotic arms. [6]

3.1 Disadvantages of Laser welding

- High Initial Cost-Although laser has many useful advantages but its biggest disadvantage is its high investment cost. Installing a high-performance modern laser welding machine is very expensive and requires trained personnel to handle it.
- Tight Tolerances-The most important thing in

laser welding is the precise positioning of the materials to be welded. Only precise positioning can yield successful results.

- Limited Repair options-As laser welding is used by only some industry and is very new technology of welding. Only limited and specific places are available for repair and maintenance of laser machines (Thefabricator, 2024).

- **Volkswagen laser welding in manufacturing car bodies**

Since 1993 the company has been investing in the laser technology for the manufacturing of its car bodies. The company has now more than 800 high-power lasers placed in its production plants globally. The newly launched Passat is now seen as remarkable manufacturing engineering work. The company has used laser for cutting and welding this model which has resulted into better handling experience, reduced weight and thus less fuel consumption. Figure (7) shows Passat car

Fig 7. Passat car. [6]

The company has used around 400 4-KW Solid-state lasers in six manufacturing plants around the world. **Passat** rear shelf has been produced using disk laser with a robotically control arm (Photonics, 2024).

Recently Volkswagen introduced its 5th generation version of the Golf. This new model contains 70 meters of laser welds. The company used 250 4-KW Nd:YAG lasers in its five manufacturing plants to produce this car. The lasers have been primarily used on body sides and underbody. Also, company used Hybrid laser technique of laser brazing to attach trunk lid opening in the drain channel, the roof to the body sides and the split skin panel to trunk lid (Thefabricator, 2024).

- **Advance laser welding using Remote laser welding**

Conventional laser systems use robotic arms to guide and position over the welding surface, still most of the time the welding system is in the hold mode, which decreases the efficiency and throughput of the system. To overcome this problem Remote laser welding can be used in the automotive manufacturing. Remote welding uses a focusing optic system and scanning mirror which is used to manipulate the laser beam over the work piece. Scanning mirrors are highly dynamic and light weight which enables fast indexing in welding process. Thus the laser spends more time welding parts and less time in waiting for the position of the next weld to be created. The system results in higher efficiency, low costs and less robotic stations or arms (Pennwell, 2011).

3.2 Application of Remote Welding in Automotive Industry

It has many applications which include seating operations like forming frames, tracks, panels and recliners. White body operations like welding doors, joining hang on parts, putting side walls, fixing real panels, forming pillars and trucks. Interior operations like positioning rear shelf and hat rack. These applications are done with reduced cycle time, flexible programs weld shapes with optimum strength and customized design, giving longer glass life and reduced clamping stations. These applications are done using a robot and scanner optics system. This process of remote welding is also commonly known as welding on the fly (Pennwell, 2011). Figure (8) shows Remote Welding in Automotive Industry

Fig 8. Remote Welding in Automotive Industry. [7]

3.3 Conditions for Remote Welding

There are basically three preconditions for using remote welding, firstly the laser used should be a solid-state laser as the beam source which can be easily coupled with the flexible fiber optic cable. This is very important when joining components and parts in 3D space using a multi-axis robot. Secondly the laser beam quality should be excellent with adequate power output. Beam quality is defined by focus ability of the laser, how long the focal lengths is required which is normally between 4-8mm- mrad is required to achieve desired focused spot size. The typical power output for the solid-state laser must be about 4-6KWs. Last is the proper axis synchronization between the robot and the scanner control, time and speed synchronization is very important consideration for remote welding (Pennwell, 2011).

4. RECOMMENDATION

Currently Volkswagen is having more than 800 high power solid state laser for its car body welding and manufacturing purpose if the company decides to use Remote Welding technology at its various parts and integrate its laser system and robotic arms with fiber optics reflective system and able to synchronize them using computer programs, the end result will be higher utilization and efficiency, low costs and less robotic stations. The company can use its research and development department to work on this technology and further enhance the use of variable focus positions, weld quality controlling, system programming using offline and online simulations software The Following advantage for Volkswagen can be:

• Higher throughput and utilization within its existing laser welding system.
• More free space and less body shop area requirements.
• Reduced cost of production with high efficiency and decreased time.
• Advance modern design using automated and programming technique. The following disadvantage for remote welding can be:
• Highly critical method and requires excellent synchronization
• Requires Advance programming system and manpower.
• High initial investment cost.

5. CONCLUSION

Laser welding is the need for the modern automotive industry, from welding roofs to engine components laser are been used. They have made it possible to control cost of production using economics of scale for large production line over an assembly line operation in an automobile manufacturing plant. Laser and robots have made the entire welding process of the car body automated and inexpensive. The technology is gaining more and more power day by day as the cost of laser is becoming economical for automobile industry. The company like Volkswagen has pioneer itself in using laser technology has able to become one of the leading automobile manufacturers in the world. In terms of welding car body's laser technology has almost overtaken traditional spot welding technique with the ability to weld using from single side access and producing uniform and invisible welds it can made possible to produce exceptional automobile designs. The technology is very fast evolving and changing the way cars are been manufactured and new technologies like remote welding is the future of laser welding in the automobile industry. The combination of optics, lasers, robots and information technology will help car makers to be competitive and grow in the near future.

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