Lasers Offer Advantages for Welding Steel Wheel Rims

The properties of laser-welded wheel rims were considered good enough for the process to be used in production in the auto industry

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The use of lasers has increased and become widespread in many manufacturing operations, such as material processing, measuring, quality control processing, and automation. It is a competitive, energy-saving process with high user satisfaction.

Due to its many advantages, laser processing has replaced more conventional methods and techniques in the industry. Laser technology has become widely used in Germany where it has been implemented into its automotive industries. It offers reduced labor costs, taxes, and material costs as well as energy savings. Lighter, safer, and better-quality designs have been put on the market and new parts created as a result of laser processing. The common advantages of lasers in automotive industrial operations include the following (Refs. 1–10):

- High-speed operation;
- High reliability and repeatable quality;
- Multipurposes, includes welding, cutting, and marking;
- Processing using noncontact tools (since tool wear does not occur there is no need to change the tool);
- Automation;
- Enables the creation of new designs, operations, and measurements that were previously deemed impossible;
- High-density energy transportation to a narrow point;
- Deep, narrow, and controllable penetration;
- Suitability for joining numerous materials with different characteristics;
- A decrease in or no need for physical or chemical operations before and after the processing.

For these reasons, manufacturers in the wheel rim industry have implemented laser processing.

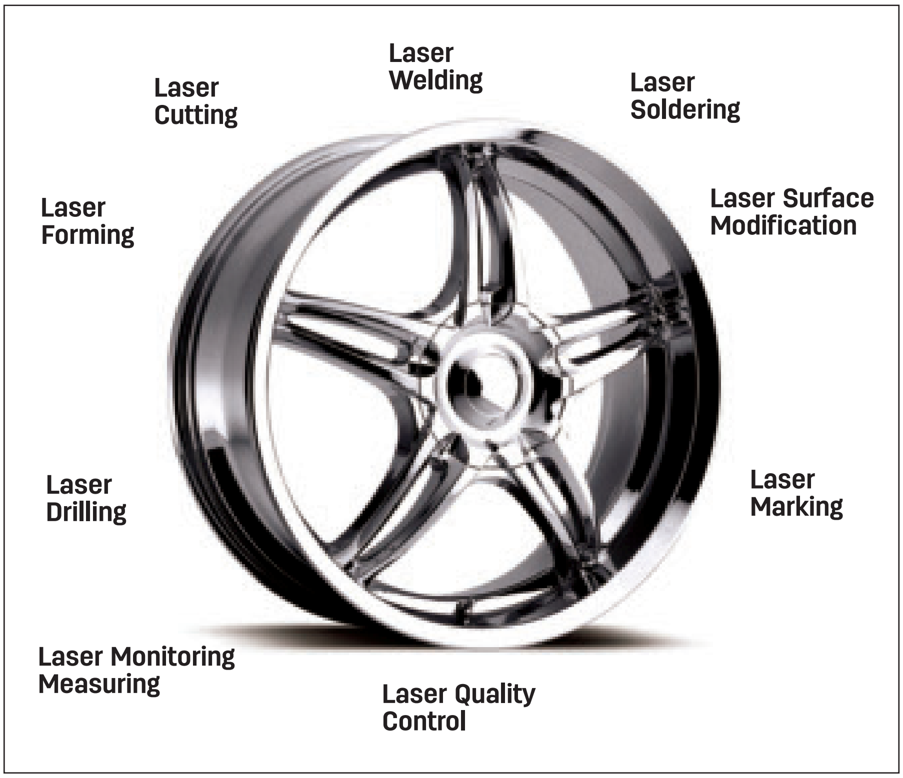

Fig. 1 — Laser processing used in the manufacturing of wheel rims.

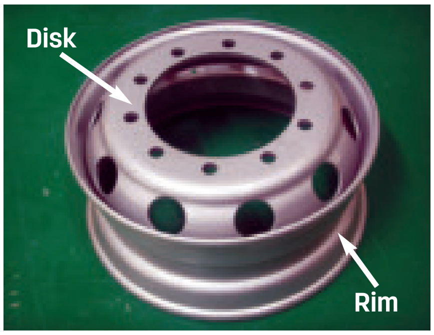

Fig. 2 — A steel wheel rim and the basic parts, rim and disk.

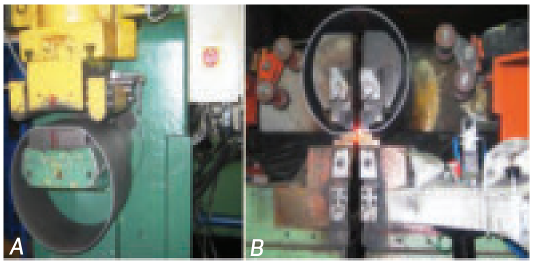

Fig. 3 — Rim manufacturing process. A — Bend and flattening process; B — upset butt welding.

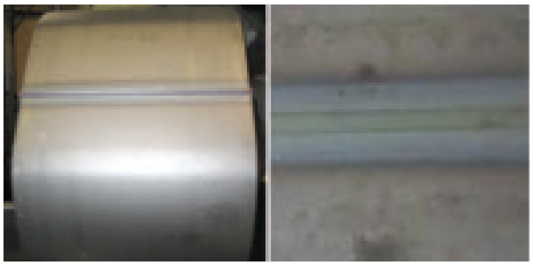

Fig. 4 — Rim manufacturing process, weld joint with fin surface after scarfing process.

Fabricating Wheel Rims

Conventional Manufacturing of Steel Wheel Rims.

Since steel wheel rims are a basic product of the automotive industry, manufacturers look for new ways to design the rims to better compete in the marketplace (Refs. 4, 5). In particular, the manufacture of steel wheel rims entails much processing in production lines, and this is a disadvantage in terms of cost. So, the use of laser welding in the manufacturing of steel wheel rims is now being considered to reduce costs.

Figure 1 shows schematically the laser processing used to manufacture steel wheel rims. Wheel rims consist of two basic parts: the rim and the disk — Fig. 2. The manufacturing methods and assembling techniques are based on cold forming and welding methods. Steel sheets with good welding characteristics are used in manufacturing.

The first step in the manufacturing process is to obtain blanks with the proper specifications and surface quality. The prepared blanks for producing the rims are rounded using a rounding machine, then the ends of the materials are banded and flattened using a press before the butt joining process. The flattened ends are joined with flash welding or upset butt joint welding — Fig. 3. After the welding operation, fins present on the surface and at the corners of the welds are removed with a scarfing and edge-trimming machine — Fig. 4. When these operations are completed, the rims are rerounded with a press and formed into their final shape with cold roller machines and presses.

The disk materials, which are cut as circular blanks, are formed with flow forming machines or presses. The center holes, ventilation holes, and bolt holes are punched out with presses, then lathed and countersinked to precise dimensions.

The rims and disks, which are formed last, are pressed against each other then welded using the submerged arc or gas metal arc welding processes. After these operations, to eliminate the distortions due to the welding process, the wheel rims are pressed again. At the end of assembly, the wheel rims are painted.

Wheel Rim Manufacturing Using Laser Welding.

There are few publications about using laser processing in the manufacturing of wheel rims. In addition, using the laser welding method is more common when compared with other methods. For instance, Caprioglio developed and patented a system to assemble rim to disk with laser welding (Ref. 4). BBS International GmbH uses laser welding in its wheel rim designs (Ref. 5). Dawes in his laser welding book illustrates a laser butt joint welded steel rim, and it is seen that the ductility is enough for cold forming (Ref. 6).

Laser Advantages and Disadvantages

Laser welding offers a number of advantages and disadvantages compared to conventional methods, such as flash and butt resistance welding, submerged arc welding, and gas metal arc welding in wheel rim manufacturing.

Laser Advantages Include the Following:

- Since the laser head has no direct contact with the material, it is not necessary to change the tools routinely; however, in flash and upset butt welding, the electrodes should be changed periodically.
- Since no flash occurs in the application of the laser welding, there is no damage to the machine and there is no pollution in the vicinity of the operation.
- Because the surface of the laser welded material is quite smooth, it is not necessary to implement finishing operations after the welding process. This saves the added expense of these operations normally required after flash and butt resistance welding.
- Laser welding speed is as fast as that for upset butt resistance welding and faster than submerged arc welding and gas metal arc welding.
- Laser welding consumes much less electrical power than the flash and butt resistance welding processes. For example, the butt joint welding machine used in the Hayes Lemmerz Jantaş wheel rim factory is 960 kW, but a 50-kW fiber laser (its wall-plug efficiency is more than 25%) consumes only 200 kW.
- Lasers produce narrower weld zones compared with the other welding processes.
- Generally, there is no need for filler material in laser welding.
- It is possible to apply a lap joint with laser welding during the rim to disk welding operation.
- Lower thermal distortions occur using laser welding when compared with submerged arc and gas metal arc welding.
- By using laser welding and tailored

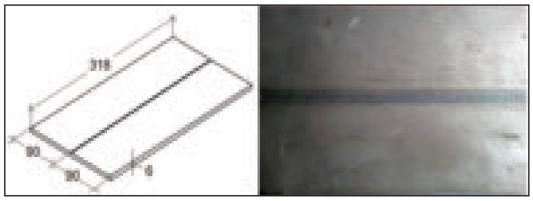

Fig. 5 — Dimensions of the welded samples and specimens after laser butt joint welding.

Fig. 6 — Nd:YAG 4000-W laser machine and robot welding mechanism.

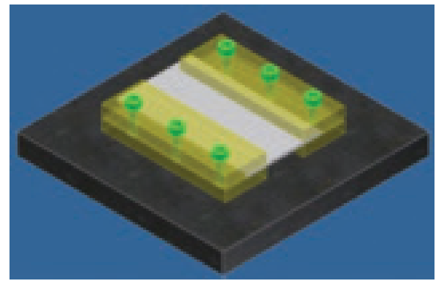

Fig. 7 — Clamping apertures for butt joining of the materials with laser.

blanks, it is possible to manufacture the rims with different wall thicknesses and different local mechanical properties in different regions in accordance with the load distributions in service conditions. The weight of the parts can be reduced by these means.

Laser Disadvantages Include the Following:

- The edges to be joined with laser welding should have a smooth sheared zone. Before and during the welding process there must be almost a zero root opening between the abutting edges, otherwise good quality joints cannot be obtained.
- A fixing or clamping apparatus or a special construction is required in laser welding, as is required in flash and resistance butt welding.
- Environmental conditions (dust, humidity, etc.) must be appropriate for the laser.

Tests and Results

To determine whether laser welding is a practical method to use, steel wheel rim materials were welded using laser and upset butt welding. The specimens for testing were removed from the welded materials. These specimens were subjected to tension and bending tests, and their Vickers hardness values were measured.

The material used in the experiments was 6-mm-thick (RSt 44-2) S275J2G3 (DIN EN1002) steel, the same material used in steel wheel rim manufacturing. The mechanical and chemical properties of the material are shown in Tables 1 and 2, respectively.

The dimensions of the welded materials are shown in Fig. 5. The material welded with butt resistance welding was subjected to a scarfing and edge trimming process after the welding operation in question. Welded material was cut from the flattened region and test samples were removed from the part.

The material welded with the laser was taken from the line after the bend and flattening operations then interrupted from the smoothed region. Before welding, the material edges were milled to avoid any defects during welding due to cutting with blades and the slitting process. In the mechanical cutting process, full flat edges could not be obtained and sometimes curvature occurred at the edges due to the force of the blades or the tools.

The prepared material was welded with a Trumpf HD 4006 Nd:YAG 4000-W and Arcmate120i Fanuc robot — Fig. 6. The welding process was applied double-sided. The reason for this is although the laser has enough power for one-sided welding, the apparatus clamping the parts for the operation was not appropriate for it. A proper apparatus for butt joints is shown in Fig. 7. During the laser welding operation, laser power P = 2500 W, focus length f = 150 mm, welding speed V = 8 mm/s, and Ar gas flow = 7.5 L/min, BPP: 25 mm*mrad parameters were used for the sample tests.

Weld Properties

After the laser welding process, the appearance of the weld joints was evaluated. No cracks were observed on the surface of the material due to the welding process, and quite regular and smooth weld joints were obtained that required

Table 1 — Mechanical Properties of (RSt 44-2) S275J2G3 Steel

Yield Strength Re (N/mm^2)	Tensile Strength Rm (N/mm^2)		Elongation-% A
min.	min.	maks	min.
275	410	510	28

Table 2 — Chemical Properties of (RSt 44-2) S275J2G3 Steel

% C	% Si	% Mn	% S	ppm N	% Al	% Cu+Cr+Ni
maks. 0.18	0–1.150	maks. 0.020	maks. 0.008	maks. 90	0.02	maks. 0.30

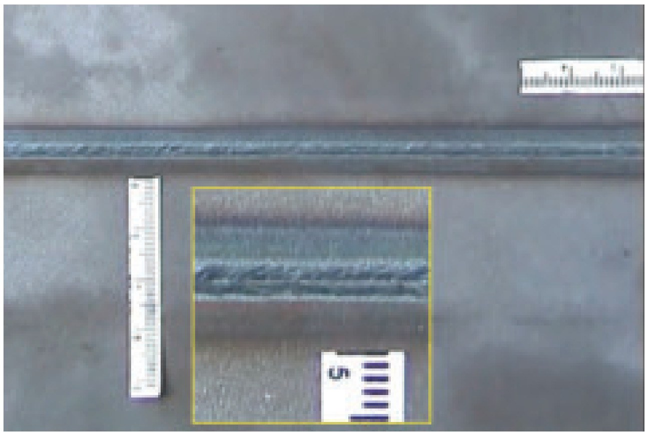

Fig. 8 — Surface of the laser butt weld joint.

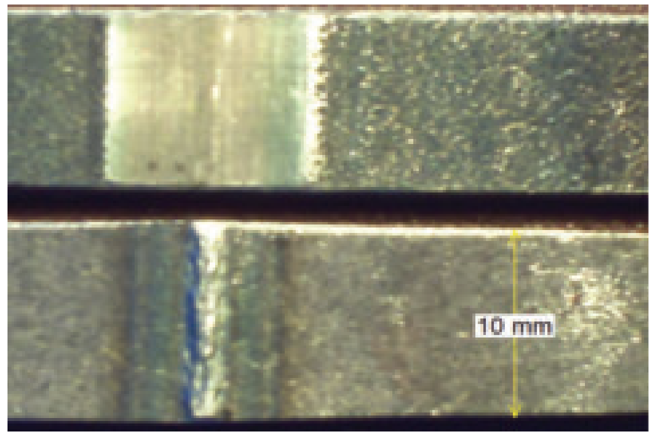

Fig. 9 — A comparison of the butt resistance and laser welded samples.

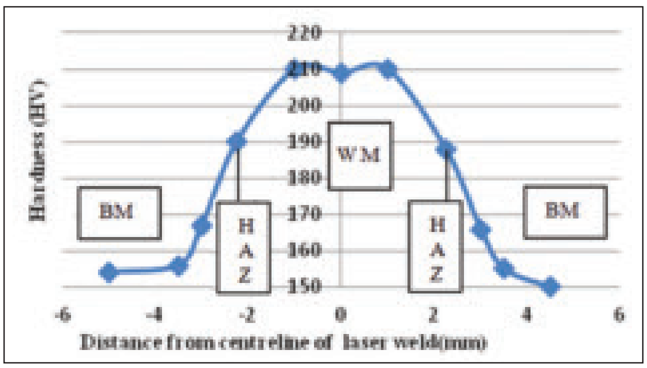

Fig. 10 — Hardness profile of laser butt joint welding. WM = weld metal, HAZ = heat-affected zone, BM = base material.

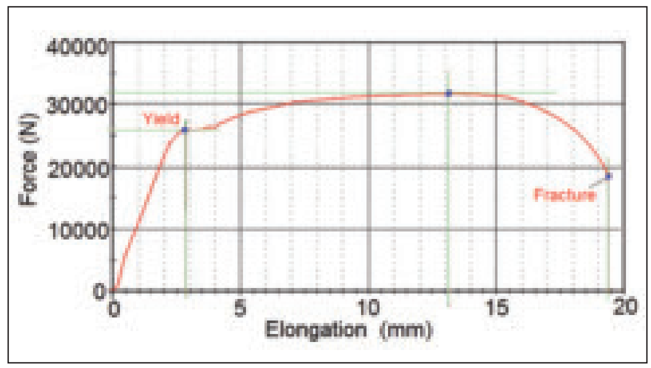

Fig. 11 — Force elongation diagram of the laser butt welding joint.

no additional processing. The width of the joint was 2 to 2.5 mm. The appearance of the laser weld is shown in Fig. 8. There is no undercut on the surface of the weld joints. A line occurred in the middle of the joint. The reason for this was the influx of the molten metal into the key hole, which is formed as long as the laser head moved forward during the welding process. The line is regular and continuous and shows that good quality joints can be achieved. As a matter of fact, the macro view verified these assumptions. No defects were determined in the macro section of the weld such as porosity and incomplete fusion. A narrow HAZ was obtained as expected. The comparison of the laser and butt resistance weld joint appearance is shown in Fig. 9.

Our study of the properties of the welds started with the microhardness test. The fusion zone and base metal were examined. A 19.64 N load (F) was applied for 10 s in all hardness tests. When the hardness of the laser weld was compared with the upset butt resistance weld, the hardness of the laser weld was approximately 25 Vickers greater in the center of the fusion zone — Fig. 10.

It had been thought that the reason for the higher hardness values is the effect of a faster cooling rate of the fusion zone with laser welding.

The tension tests were applied in accordance with 287 EN 895, 1996 standard. At the end of the tension tests, diagrams having close properties to the base material were obtained — Fig. 11. The fractures occurred quite far from the fusion

Table 3 — Tension Test Values

Tension Test Specimens No.:	Yield Strength Re (N/mm²)	Tensile Strength Rm (N/mm²)	Elongation-% A	Reduction in Area (% Z)
1	364.58	441.14	30.01	63.0
2	372.16	464.09	26.2	68.2
3	352.3	419.24	31.06	62.5
Means	363.01	441.49	29.09	64.6

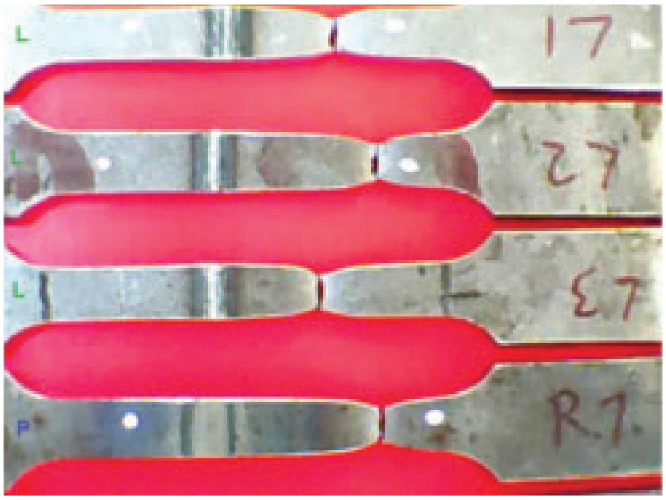

Fig. 12 — Tension test specimens after the test. As seen, fractures occurred at the base metal region.

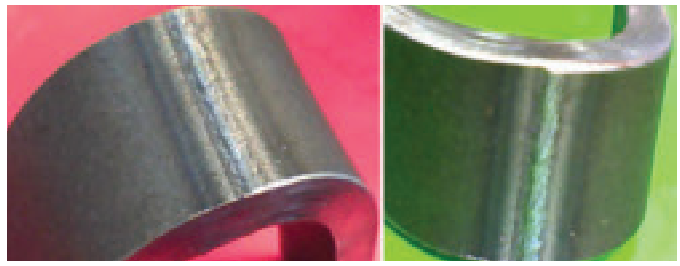

Fig. 13 — Laser welded specimens to which bending tests were applied.

zones — Fig. 12. This situation shows that the joints have sufficient strength. The test values are shown in Table 3. In order to test the ductility of the weld specimens, three-point bending tests were carried out according to EN 910.

The dimensions of the specimens were 6 × 24 × 180 mm. At the end of the bending test, no cracks were observed on the specimens as shown in Fig. 13. It has been determined that there was no worsening of the mechanical and technological properties of the laser welded steel wheel materials after the three-point bending tests.

Conclusion

• After evaluation by tension tests, three-point bending tests, hardness tests, and macro views, the properties of laser welded wheel rims were considered good enough to use this process in production in the auto industry.
• Test results gave no disadvantage for the laser welds when compared with the flash and butt resistance welds in terms of mechanical and technological properties, and the laser welded steel wheel rims were of good quality. The fractures occurred quite far from the fusion zones, and the hardness of the laser weld was greater in the center of the fusion zone; however, no high values were obtained. No crack was observed at the end of the bending test and the ductility was good.
• On account of the lower energy consumption, laser welding has great advantages. In addition, there is no need for the extra finishing process required after flash and upset butt welding with the scarfing process, which may lead to notching during the cold forming operation.
• It is possible to create new, lighter and rigid designs and optimization for wheel rims with the use of laser welding.◆

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