Investigation on mechanism of ultrasonic welding AZ31B/5052 joint with laser texturing on mental surface

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Abstract

The ultrasonic welding was carried out to improve the quality of dissimilar Al/Mg alloy joint. The effects of laser texturing on the microstructure and mechanism of AZ31B/5052 joint connected by ultrasonic welding were also investigated. A series of laser texturing experiments on Al alloy (5052) and Mg alloy (AZ31B) were performed to determine the process parameters and their effect on ultrasonic weld quality, especially on weld strength. Little effect was attained by optimizing welding parameters in improving mechanical properties. Both welding parameters and different texture pattern were investigated to obtain good weld quality. The connection mechanisms of joints were discussed based on the analysis of weld interface morphology and microstructure evolution. Mechanical analysis of particle and movement of material atoms were analyzed in the study to explain the connect mechanism. The results show that the better lock-interface and larger lap shear strength were attained by laser texture addition and optimal welding parameters. Compared with the untextured joint, swirling bonding interface was obtained after the laser texture. The laser texture with grid pattern was found to raise the strength up to 26% higher maximum tensile-shear load than the joints obtained with the untextured surface.

Keywords Ultrasonic welding · Laser texture · Surface contact · Connect mechanism

1 Introduction

Energy conservation and emission reduction have deep-rooted in normal daily life and industrial manufacture. Aside from promoting clean energy, lightweight materials and composites are the most direct and effective way. For every 10% drop in vehicle quality, fuel consumption will drop by 8% and emissions by 4%. Among the lightweight materials, magnesium alloy and aluminum alloy stand out in low density, high intensity, machinability, and recyclability. AZ31B magnesium alloy has been applied to aircraft wheel hub and car manufacturer. 5052 aluminum alloy performs well in formability and welding. The most abundant chemical element in 5052 is Mg. Thus, AZ31B magnesium alloy and 5052 aluminum alloy can be connected in some ways [1, 2].

Ultrasonic welding (USW) is different from other solid-state welding technology because of its high welding efficiency, short welding time, low heat input, and precision control [3–6]. Thus, this technique is suitable for non-ferrous soft metals and their alloys, such as copper, aluminum, brass, gold, and silver [7]. At high-power ultrasonic welding technology of AZ31B/Al5052 dissimilar combinations, the optimum joints were obtained through reasonable selection of sonotrode patterns and optimization of welding parameters. The joints with mechanical interlocking phenomenon and discontinuously distributed Mg17Al12 with low thickness could reach high tensile lap shear strength at 59.4 MPa [8]. Researchers also observed that the strength of dissimilar joints was attained to be 35% higher with Cu interlayer than without Cu interlayer [9]. Mg/Al (USW) joints welded with a Zn interlayer in between displayed the maximum shearing strength about 89.6% greater than those of joints without a Zn interlayer [10]. These findings can improve mechanical property of Mg/Al joints by higher power facilities or interlayer;
meanwhile, test cost increases. In the application of ultrasonic welding industry, a variety of parameters are generally used to optimize the parameters. Taking Emerson Branson as an example, the use of smearing additives and surface texture is more common [11].

As a result, many researchers commit themselves into seeking innovative and inexpensive ways to ultrasonic welding of dissimilar metals. The Fe-Al joints obtained with the textured steel were found to have up to 25% higher maximum tensile-shear load than the joints obtained with the untextured steel [12]. The surface roughness gradients on brass sheets are obtained directly by nanosecond laser texturing and found it is related to contact of material [13]. As a novel technique for fabricating surfaces with roughness and wettability gradients, it can be applied to chemical sensors and smart surfaces.

There has been little research on strengthening Mg/Al different material joints of solid-state bonding by laser texturing before welding. In this study, an alternative welding approach to increase the bonding area between steel and aluminum alloy without modifying the laser-generated temperature profile is proposed and investigated. In this paper, an alternative seam welding approach increases the bonding area between magnesium and aluminum alloy. A nanosecond pulsed laser is used for texturing the surface of magnesium and aluminum alloy prior to ultrasonic seam welding in order to locally increase the bonding area between these two dissimilar metals. At first, laser texturing was mainly used to increase the surface roughness of the roll, to lubricate the roll, and to extend its working life. In this process, the laser interacts with the surface material. The main mechanism is that the instantaneous, high-density energy generated by the laser on the surface of the material causes the heterogeneous metal on the surface of the material to melt and vaporize, making it in the form of gas escape the surface of the material. At the same time, the shock wave generated by the melting of the heterogeneous material causes the impurity particles not in the melting area to generate elastic potential energy, overcome van der Waals force and capillary force, and eject and break away from the surface of the material, thereby achieving the vibration peeling effect of the oxide film on the surface of the metal material and leave pits on the surface of the material. The aim of this work is to select the optimum parameter and investigate the impact of different laser-generated textures on the mechanical properties (strength) of the Mg–Al welds as well as to understand the mechanism of their formation.

## 2 Experimental procedure

### 2.1 Material

Commercially available 1.0-mm-thick sheets of 5052 aluminum alloy and 1.0-mm-thick AZ31B magnesium alloy were used as base metals in the experiments. The magnesium and aluminum are 60 mm long and 20 mm wide. They were polished by 400# sandpaper and ultrasonic cleaned with alcohol. It aimed to remove impurities and oxides from material surfaces. Table 1 shows the chemical composition of these two metals [14]. The basic mechanical properties of AZ31B Mg and 5052 Al alloy are shown in Table 2.

### 2.2 Laser texturing of alloy

The low power laser machining system is from RUNQIA ETLC. It is used to texture the metal. The controller contains RQM-0100 operating system providing a pulse to ejector with f = 254 mm F-theta lens and emits the pulse power of 100 W, wavelength of 1064 nm, and focusing spot diameter D of 50 μm. The parameter range of this device is shown in Table 3.

| Table 1 | Chemical composition of AZ31B Mg alloy and 5052 Al alloy (wt-%) |
|---------|---------------------------------------------------------------|
| Material | Si     | Fe      | Cu | Mn | Zn | Cr | Al     | Mg     |
| 5052     | 0.25   | 0.40    | 0.10 | 0.10 | 0.10 | 0.15 | Rest   | 2.2~2.8 |
| AZ31B    | 0.08   | 0.03    | 0.10 | 0.2~1.0 | 0.6~1.4 | 0.10 | 2.5~3.5 | Rest    |

| Table 2 | Basic mechanical properties of AZ31B Mg alloy and 5052 Al alloy |
|---------|---------------------------------------------------------------|
| Material | Yield strength (MPa) | Ultimate tensile strength (MPa) | Elongation (%) |
|----------|---------------------|-----------------------------|----------------|
| 5052     | 152                 | 235                         | 9              |
| AZ31B    | 65                  | 185                         | 15             |

| Table 3 | Technical parameters of laser generator equipment |
|---------|---------------------------------------------------------------|
| Device parameters | Parameter range |
| Scan width | 0~80 mm |
| Laser power | 100 W |
| Laser wavelength | 1064 nm ± 5 nm |
| Pulse frequency | 10~100 KHZ |
| Scan speed | ≤ 6000 mm/s |
| Equipment power | ≤ 1500 W |
| Power input | 220 V |
The laser-induced craters were classified into grid and parallel line, which is decided by scanning mode. Besides, the diameter and depth of craters were influenced by scanning track and distance of laser beam \((D)\), the distance from one spot to the center of another spot. Following the texture process, three different test textures (Fig. 1) were fabricated on the surface of the metal. The ranges of texturing parameters are shown in Table 4. Each texture of each mental was produced at least 5 coupons, providing a mass of samples for morphological observation, ultrasonic seam welding, and tensile experiments.

### 2.3 Ultrasonic welding of textured Al to Mg

After cleaning the textured and untextured surface of the mental, the AZ31B Mg alloy was placed under the 5052 Al alloy because 5052 Al alloy tends to adhere to sonotrode tip. During welding, the overlapping area is 40 mm \(\times\) 20 mm and welding actual connection area is 20 mm \(\times\) 4 mm shown in Fig. 2c. The textured surface of both the AZ31B and the 5052 was opposite positioned. According to the formula (1), when coefficient \(k\), hardness of material \(H\) (HV), and thickness of the workpiece \(\delta\) (mm) are known, the welding power \(P\) (W) is confirmed. Then, the welding pressure \(F\) (MPa) and welding amplitude \(A\) (m) can be generally speculated in the case of friction coefficient and vibration frequency \(f\) (Hz) known in formula (2) [15].

\[
P = kH^{1/2}\delta^{3/2}
\]

(1)

\[
P = 4\mu SFAf
\]

(2)

The ranges of welding parameters involved in the experiment are shown in Table 5. The Mg/Al USW joints were manufactured using an ultrasonic welder system (MW-2040) with a maximum energy of 4000 J and a frequency of 20.0 kHz (Fig. 2a). The tip of the sonotrode was 40 mm long and 4 mm wide. The surface of sonotrode patterns was composed of rectangular-pyramid-shaped teeth (Fig. 2b).

The AZ31B/5052 joints produced at least 5 samples at the same welding parameters. Each 3 samples were applied to the tensile-shear tests by 200 kN MJDW-200B microcomputer-controlled electronic universal testing machine; the experiments carried out with constant cross-head speed of 1 mm/ min and at room temperature. One was used to observe the microstructure of fracture using type microscope. The interface morphologies of joints were obtained using an optical microscope (LeicaDM4M) and scanning electron microscope (SEM).

### 3 Results and discussion

#### 3.1 Selection of textured pattern and optimization of welding parameters

The mechanical properties of the ultrasonic beam welding joints depend on the welding parameter to a great extent. In this paper, the effects of amplitude levels, pressure, and welding energy during process of Mg/Al joints were discussed. The lap shear test results of Mg/Al joints are shown in Fig. 3. When the amplitude level is 55%, the maximum tensile load increased at 0.2 MPa in Fig. 3a. The tensile lap shear strength originally increased, reached a peak value about 1300 J, and then decreased with increasing welding energy at 0.25 MPa and 0.3 MPa. The excessive pressure made more frictional motion between the sonotrode and workpiece resulting into AZ31B crash, which leads to low tensile load at high pressure. The maximum tensile load was obtained at 0.1 MPa pressure, 65% amplitude level due to unstable pressure in the air compressor in Fig. 3b. In general, the tensile load increased with higher pressure and higher amplitude level. Increasing the welding energy can increase welding time to ensure contact of material. While exorbitant input made the sonotrode press into AZ31B even leads to

![Fig. 1 Test textures fabricated on the surface of mental. a Texture A; b texture B; c texture C](image)
breakage at 70% amplitude level, 1600 energy, and 0.3 MPa pressure in Fig. 3c. When amplitude level is 60% and energy at 1600 J, the tensile load of the joint was better. At 0.3 MPa pressure and 1600 J energy, the maximum load was obtained at 55% amplitude. According to three welding parameters, the best lap shear load of the Mg/Al joints can be obtained at 55% amplitude, 1600 J energy, and 0.3 MPa along with the best accuracy.

It is seen that the strength of 5052Al-AZ31BMg dissimilar joint with laser textured before was 26% higher than that without textured. This would suggest that the bonding of textured Mg/Al interface was superior to that of untextured interface, due to the clearer surface, along with the rolling interface line. It is clear that the addition of texturing significantly increased the tensile lap shear load, especially texture A, primarily as a result of the rolling interface line.

In the results of texturing, more intensive distribution on the surface, higher shear strength was achieved. This has resulted in better lubrication effect due to more channel to promote the flow of materials [16]. Figure 4 reflects the shear performance of the joints with different contact surfaces. It can be seen from the figure that when the texturing pattern A is used, the best shear performance of the joint is 1648 N. There are obvious cracks and material adhesion phenomena on the shear surface of the fracture. The furrows produced by the material texture morphology in the welding area are all filled with molten material, and the texture morphology cannot be distinguished. There is not much difference between the strength of the joint between morphology B and the untextured material. Combining the fracture morphology of the joint with the texture B in Fig. 5b, e, it can be found that the friction between the Mg material and the Al material is not sufficient at this time. The indentation of the anvil is obvious, the morphology of the Mg side is obvious, the material does not undergo obvious plastic deformation and flow during the welding process, the Mg and Al are not fully contacted and combined, and the material does not form a good joint. The texturing morphology C increases the strength of the material joint by about 10%, and there is no obvious tearing or material adhesion on the material surface, as shown in Fig. 5c, f, but the texturing morphology of the fracture surface is not clear. It shows that a certain degree of plastic deformation has occurred on the surface of the material, but the material combination is still insufficient.

The magnified observation of the Mg side joint fracture of the texturing morphology C shows the micromorphology shown in Fig. 6. From Fig. 6a, it can be seen that the surface of the texturing material is parallel to the ravine; in Fig. 6b,

**Table 5** Welding parameters of ultrasonic welding

| Specific instructions            |
|----------------------------------|
| Welding energy/J                 |
| 500, 1000, 1500, 2000            |
| Vibration amplitude level        |
| 55%, 60%, 65%, 70%               |
| Pressure/MPa                     |
| 0.1, 0.2, 0.3, 0.4               |
c, they are different morphologies far from the center of the fracture and close to the center of the fracture. It can be seen that after the laser texturing method is used to process the material, while pits appear on the surface of the material, the molten metal impacted by the laser will condense on the metal surface again. Because the laser spots are closely arranged, the molten metal is also connected into a strip. Straight line, and the molten metal surface area is larger near the spot, and the melting area between the spot gaps is smaller. Under the same magnification, the pits at the edge of the fracture are cleaner, and the area of molten metal on both sides is smaller, while the pits near the center of the fracture are not clear, and there is more metal debris on the surface. It may be the stress concentration of the Mg material in the welding center, the material flow is obvious, and the Al material that flows after contact with the Al material re-integrates into the pits, and the molten material at the ridges and protrusions is shattered by the friction of the welding process, leaving fragments on the surface of the material. After magnifying I in Fig. 6a, we get Fig. 6d. It can be found that the gullies in Fig. 6a are not continuously distributed. After magnification, it is found that the fat bumps of the pits are not as shown in Fig. 6b, c, clear, but there are obvious friction marks, indicating that during the welding process of Mg and Al materials, the material stress distribution at the edges is not uniform, only the textured bumps are in contact, and during the shearing experiment, the Mg material adheres to the Al material, forming scratches on the surface of the Mg material.

Fig. 3 Shear tensile load of Mg/Al ultrasonic welding joints produced with different amplitude levels pressure and welding energy: a different welding energies; b different welding pressure; c different welding amplitudes

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A mass point $Q$ was chosen to analyze force situation shown in Fig. 7. As 5052 Al was clapped and AZ31B Mg pulling up, the point received both resistance by 5052 Al and friction due to relative motion between materials. The angle formed by the tangent of the contact surface at the point indicates the friction direction. Before laser texture, the tensile lap shear strength was calculated by

$$\sigma = \frac{F}{S_Q}$$  \hspace{1cm} (3)

The shear force is measured by universal testing machine and is the area of point. After laser texture, the tensile lap shear strength was calculated by
$\sigma = \frac{F'}{S_Q}$  \hspace{1cm} (4)

$S_Q$ is the same as in formula (3), while $F' > F$ because of

$F' = F_1 + f \cos \alpha$  \hspace{1cm} (5)

Thus, $\sigma' > \sigma$ can be inferred, which may explain laser textured material get better mechanical properties.

### 3.2 Surface morphology and cleaning effect of laser texture

As can be seen from Fig. 8a, the surface was covered with the impurities and oxides, which impede the combination of materials. Pulsed laser can breakdown the oxides effectively especially in aluminum alloy [17] and crater left on the surface in Fig. 8b. The overflow of hydrogen may lead to the ring crater [18]. The melting pool was produced by laser beam and adjusted by the processing parameters. It contains fewer impurities impulse by laser than no-cleaning surface.

Scanning track of line texture is shown in Fig. 8b. The yellow circle represents the spots that make up the track. Under the action of the X galvanometer, the pulsed spot will transform from a point spot to a linear arrangement. On this basis, when the spot arrangement reaches the boundary of the selected area, due to the deflection of the Y galvanometer, another linear arrangement parallel to it will be formed in space. The distance between the two lines after deflection is the longitudinal distance of the line, $d$ is the lateral distance of the spot, $r$ is the radius of the laser texturing spot and $s$ is the longitudinal distance of the spot. It is clearly shown that obvious staggered morphology is formed on the surface of the material in Fig. 8c. When it turns into grid texture, the
laser transmitter emits laser in X direction at the first time and turns to Y direction in second time. The coverage of the spot \( c \) on the surface of the material can be calculated by formula (6):

\[
c = \frac{S_l}{S}
\]

(6)

where \( c \) is the coverage rate, \( S_l \) is the spot area, and \( S \) is the scanning area. According to formula (6) to calculate the coverage of the three topography, it can be seen that the coverage of the parallel line topography [19]:

\[
c_{\text{line}} = \frac{Ng2f_cg\pi r^2}{Wg\left[4f_cgr + 2f_c - 1\right]g} 
\]

(7)

In formula (7), \( N \) is the number of horizontal spots, \( W \) is the width of laser texturing, and \( f_c \) the frequency of the one-dimensional galvanometer. The number of horizontal spots per unit time is equal to \( 2f_c \). Considering that the laser scanning speed \( v \) is uniform, and in a unit time, the number of spots appearing in laser scanning is the same as the pulse frequency \( f_c \), then

\[
N = \frac{f}{2f_c}
\]

(8)

Substituting formulas (8) and (9) into formula (7), formula (10) can be obtained:

\[
c_{\text{line}} = \frac{Ng2f_cg\pi r^2}{Wg\left[4f_cgr + 2v - \frac{v}{f_c}\right]} 
\]

(10)

For topography B and topography C, they share the same texture width \( W \), spot size, and scanning speed \( v \). The coverage \( c \) is only related to the frequency of the one-dimensional galvanometer \( f_c \). According to the monotonicity of the function, it can be seen that due to the monotonicity of function, the frequency of texture B is larger, so \( \frac{C_B}{C_C} < \frac{C_C}{C_A} \). In the texturing area of the same size, the light spot area caused by the grid morphology is significantly larger than the line morphology; therefore, \( \frac{C_B}{C_C} < \frac{C_C}{C_A} \). It is found that the coverage rate of the topography A is the largest, and the better removal effect of oxide film can be obtained. Therefore, the mechanical properties obtained by morphology A are the best.

Figure 9a is the image of the region A in Fig. 8a after magnification of 200 times by SEM. The semicircular trace in Fig. 9b is the turning point of the laser track, and the
green dot is the detected oxygen element. Figure 8a clearly shows that in the upper half of the laser-textured material surface, there are fewer oxygen elements attached. While in the untextured part, oxygen elements are evenly distributed on the surface of the material and densely distributed at the laser turning point. It may be that the temperature at the turning point is so high that caused thermal processing and oxidation on the surface. The molten metal reacts with oxygen in the air, and the oxygen content on the surface of the material decreases and then increases. The laser does work at a uniform speed on the surface of the material, and the energy emitted by the laser per unit volume in the track edge area and overlapping area is greater than that in other areas, which also causes the temperature of this area or the duration of laser action per unit area to be higher than other areas. This caused the turning edge and overlapping area of track containing more oxygen content than the untextured surface. The spot was difficult to be observed at the turning as shown in Fig. 9b due to collective effect of both X galvanometer and Y galvanometer.

3.3 Interface morphology analysis

The essence of ultrasonic welding is to do work through the friction force generated by high-frequency vibration, so as to realize the connection of materials. The tribological problem can be started from the contact problem. During friction, the actual contact area between materials is much smaller than the apparent contact area. According to previous studies [20], the contact between materials usually occurs at the small order of magnitude. Once the material contacted with each other, the irreversible plastic deformation and fracture happened. Therefore, they occur in a stochastic manner in the rapidly changing points of the surface. Using discrete thinking, the contact between materials is characterized as the contact between elemental cells, and the frictional contact processes that occur in the range of about 100 nm include elastic-plastic deformation, fracture, particle separation, and their re-fusion at a contact surface, and even mechanical occlusion occurs. As shown in Fig. 10, the red cells are Mg, the blue cells are Al, and the silver-gray
and dark green cells are metal oxides on the surfaces of Mg and Al, respectively. Before untextured, there is a dense oxide film on the surface of metal material. Before plastic deformation occurs, the oxide film on the surface of untextured material is closely arranged. In the process of ultrasonic welding, the material undergoes plastic deformation, accompanied by the phenomenon that the oxide is shattered, and finally, the joint is formed in the stage of atomic remelting. The processes in micro contacts giving rise to irreversible changes of the surface topography are plastic deformation, detaching of wear particles, and their reintegration into the surfaces in Fig. 10. Plastic deformation leads to a mass transport along each surface, while the detaching and reintegration processes lead to a mass transfer between the contacting surfaces. Both processes can be macroscopically modeled as a stochastic transport of material either along the surface of untex- tured material or to and from the surface. This picture of a stochastic mass transport can be used as a basis for a simple phenomenological model of processes leading to changes in surface topography.

From a microscopic point of view, when the Mg material and the Al material are very close, the Mg atoms and Al atoms start to contact, resulting in atomic contact surfaces. These contact surfaces are called “bridges.” The total contact area of the bridge is the actual contact of the material. Combining with Fig. 12, it can be seen that the textured surface joints have obvious mechanical occlusion, and compared with the textured morphology of the grid format, the grid morphology of the parallel line type has a poor cleaning effect on oxides, and the element flow is not as obvious as the grid.

It can be seen from Fig. 11 that in the process of just contacting the Mg material and the Al material, ignoring the uncleaned oxides on the surface of the material, the metal atoms can fully contact without a “barrier.” Since the occlusion of the contact interface can be regarded as the result of the staggered contact of material atoms, the diffusion mechanism of atoms in solid solutions is mostly vacancy diffusion, that is, atoms with smaller diameters are more likely to diffuse into the voids of atoms with larger diameters. When the welding machine applies pressure, in the interstitial solid solution of Mg atoms, the Al atoms act as diffused atoms, and their diameters are relatively small; they occupy the interstitial position and move from the Al plate to the interstitial movement of the Mg atoms in the Mg plate. At this time, the Al atoms in the quasi-liquid layer of the Al material have not come and filled their own vacancies, and the Mg atoms in the quasi-liquid layer of the Mg material move to the larger Al atomic gap to supplement the position. During this process, complementary Mg atoms and Al atoms share electrons, thereby forming interatomic bonds. As the shear stress in the ultrasonic welding process has been changing, the atoms in the quasi-liquid layer have been moving, and more metal-to-metal bonding has formed the morphology of the mechanical lock of the contact interface.

As shown in Fig. 12, the occlusion of the contact interface can be regarded as the result of the interlaced contact of material atoms. The diffusion mechanism of atoms in solid solution is mostly vacancy diffusion; when the welding machine applies pressure in the interstitial solid solution of Mg atoms, the atomic diameter of Al atoms (diffusion atoms) is relatively small, and they occupy interstitial positions, where they can easily migrate from one position to another, thereby forming interatomic bonds. The welded joint was observed under an ESEM environmental scanning electron microscope with a magnification of 300 times, and as shown in Fig. 13a, the contact interface of the untextured ultrasonic welding joint was a nearly straight line, and the biting was not obvious. The material contact interface after the texturing morphology A has formed a clear occlusal morphology.

As shown in Fig. 13b, the Mg/Al bite is obvious, and the pits on the material surface due to texturing are filled with each other. When the Mg material is subjected to the
normal pressure of the welding machine, due to the different lateral shrinkage between the materials, frictional movement occurs between the magnesium and aluminum. When two materials come into contact, the first layer of material will be plastically deformed. At this time, the particles on the top layer of the material surface will fall off due to wear. As the anvil continues to press down, these particles will reintege into the material surface. At this time, the distance between the workpieces to be welded is getting smaller and smaller, and the interface bonding is getting tighter and tighter. The fallen particles are equivalent to the added intermediate interlayer placed in the magnesium-aluminum joint, and the particles are deeply embedded in the Mg–Al matrix material under the high-frequency oscillation of the welding head. The analysis during the soldering process may cause the particles and substrate material to sinter together due to the high temperature. For untextured materials, the surface metal oxide is approximately thick. When the welder anvil is pressed downward, the high-frequency ultrasonic vibration cannot completely crush the oxide [21].

Fig. 12 Contact interface of joint

Fig. 13 Contact interface of joint: a untextured Mg/Al contact interface; b textured Mg/Al contact interface; c distribution of elements in the untextured Mg/Al contact interface; d distribution of elements in the textured Mg/Al contact interface
Therefore, when the joint is formed, the desorption and remelting of the metal oxide particles occur before the metal atom contact, which hinders the combination of dissimilar metal elements. As shown in Fig. 13c, the green oxygen element is distributed at the material contact interface.

On the textured material, the metal oxide on the surface is reduced by laser erosion, and the forming special morphology is distributed at the material contact interface. As shown in Fig. 13d, the green oxygen element contact, which hinders the combination of dissimilar metal elements. It can be seen from Fig. 13d that when the anvil is pressed down, the pits of the magnesium material texture are filled with aluminum, and the protrusions at the edges of the pits are squeezed against the aluminum, forming a mosaic shape. It is not difficult to find the presence of element C at the junction of the two materials, indicating that holes are formed when the two materials flow and remelt, leading to the filling of the mosaic material.

4 Conclusions

In this study, the high-quality joint of textured AZ31B Mg/5052 Al was successfully achieved by ultrasonic welding. The influence of laser texture on the microstructure and mechanism of AZ31B/5052 joint connected by ultrasonic welding was investigated in the way of mechanical analysis of particle and movement of material atoms. The patterns of laser texture in this study were arranged evenly without overlapping. The main results of this work included as follows:

1. The optimum tensile strength for the Mg/Al joint was obtained at 1600 J welding energy, 55% amplitude level, and 0.3 MPa pressure. The optimum shear load of the Mg/Al joint was about 1300 N with untextured surface.
2. Laser texture can remove the oxide layer on the surface of material effectively. The tensile shear strength of adhesive bonded joints was increased 26% after grid texturing. Grid texture owns the highest coverage rate, which leads to the best cleaning effect to form the vortex-like structure.
3. Rough surface contains many channels which revealed hydrophilicity can improve material flowage significantly. Obvious vortex-like structure was shown at the joint interface. The bonding mechanism of Mg/Al joints was inferred as metallurgical bonding characterized mechanical locking.

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Declarations

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