November 2023

Laser Ablation of Electrode to Extend RSW Electrode Life and Save Production Cost

Feng Wu
Novelis Inc.

Yan Lin
Novelis Inc.

Julio Malpica
Novelis Inc.

Joao Felipe Carvalho de Moraes
Novelis Inc.

Dechao Lin
Novelis Inc.

See next page for additional authors

Inventor(s)
Feng Wu, Yan Lin, Julio Malpica, Joao Felipe Carvalho de Moraes, Dechao Lin, Jinwen (Kevin) Duan, and Tao (Atom) Wang

Laser ablation of electrode to extend RSW electrode life and save production cost

Inventors:

Feng Wu

Yan Lin

Julio Malpica

Joao Felipe Carvalho de Moraes

Dechao Lin

Jinwen (Kevin) Duan

Yu Guo

Tao (Atom) Wang

Novelis Inc

Published date: 2023.11

Contents

1. RSW electrode laser ablation process description

RSW electrodes need to be reconditioned due to electrode erosion after a certain number of welds, reconditioning of the welding electrodes is typically done with the use of sharp rotating blades that remove the top-most layer of the electrode material(0.1~0.2mm). Automakers worry about the consumable cost of the weld shop and wish to reduce the number of electrodes used. This desire drives them to investigate a method to reduce the cost of the electrode material or elongate the life of the electrode. Electrode laser reconditioning, or cleaning, could be introduces to increase the electrode life and save production costs.

Use of laser ablation techniques to create topography of millimeters or micro-features on the electrodes, to change the microscopic contact between aluminum surface and the electrodes. This leads to a change in resistance of the aluminum/electrode. Moreover, micro-texturing of the electrode surface can be optimized to minimize wettability of molten aluminum. These may help delay or even avoid aluminum sticking to the electrodes. Such techniques may increase electrode life and weld quality at the same time.

This invention presents an RSW electrode cost saving solution for resistance spot welding of aluminums, including apparatus with automation, ablation process and method. It is achieved by cleaning with a laser ablation process that minimizes the metal removal amount each time compared to a current mechanical electrode dressing method (Laser ablation 0.02mm vs electrode dressing 0.2mm). To make it effective and reproductive, the laser ablation process is preferably performed on the welding electrode prior to serious electrode sticking. RSW on various aluminum grades and joint stacks have been tested and validated in a lab scale, it has shown that the electrode life with laser ablation lasts at least 10 times longer in total than that of current electrode dressing method.

The whole process illustrated in Fig. 1 below. Described herein is a novel electrode reconditioning process for aluminum resistance spot welding (RSW), which results in great electrode cost saving in production in various cases. It reconditioned the electrode using a laser cleaning/ablation machine from the very beginning (start from new electrode), welding, recondition the electrode again after erosion (better not to sticking), followed by next round of welding, it lasts more than 300 times of reconditioning till one pair of tip to be consumed, while current electrode dressing lasts only 30 to 40 times of reconditioning.

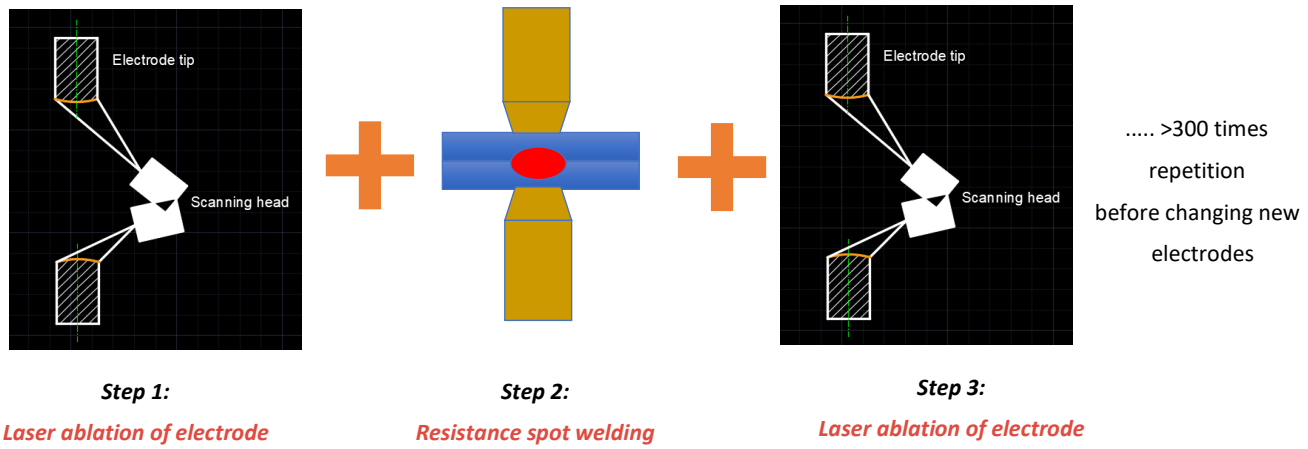


Fig. 1: Tip reconditioning and RSW process using automated laser

2. RSW electrode laser ablation machine setting

There are two different settings possible to achieve the desired laser process for tip refreshing purpose, method 1 is to clean the electrodes with stationary laser, method 2 is to clean the electrodes facilitated by cobot or small size robot(with movable laser head at least in 3-axis), method 3 is to integrate the laser ablation system into the resistance spot welding gun.

2.1 RSW electrode laser ablation using stationary laser

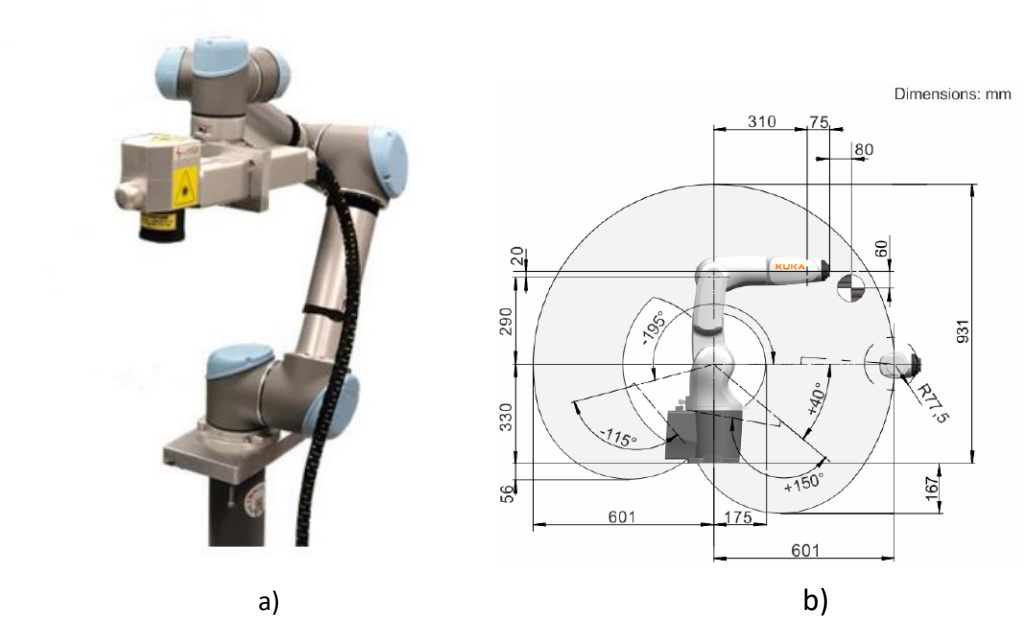
Method 1 is to clean the RSW electrode with a laser head to be fixed in a stationary location, laser head rotating from upper to bottom (at least 180 degrees of rotation angle) to clean the upper electrode and lower electrode of resistance spot welding gun separately. Fig.1 shows an unlimited example of fixed laser ablation setting.

Source: from Loop technology

Fig. 2: Fixed laser ablation setting with head rotating

2.2 RSW electrode laser ablation using extra cobot or robot

Method 2 is to be automated by an extra robot, the robot load equal or above 4Kg could work in this application, since the laser ablation head normally could be less than 4Kg, so a small robot could work in this case, when resistance spot welding is completed, welding gun moves to the laser ablation robot, then laser ablation robot could be either stays in a position or moves to the designated position to conduct electrode ablation. The key for this process would be positioning accuracy, lenses cleaning protection and EHS aspects as well, the extra robot for laser ablation as shown in below Fig. 3 as an unlimited example.



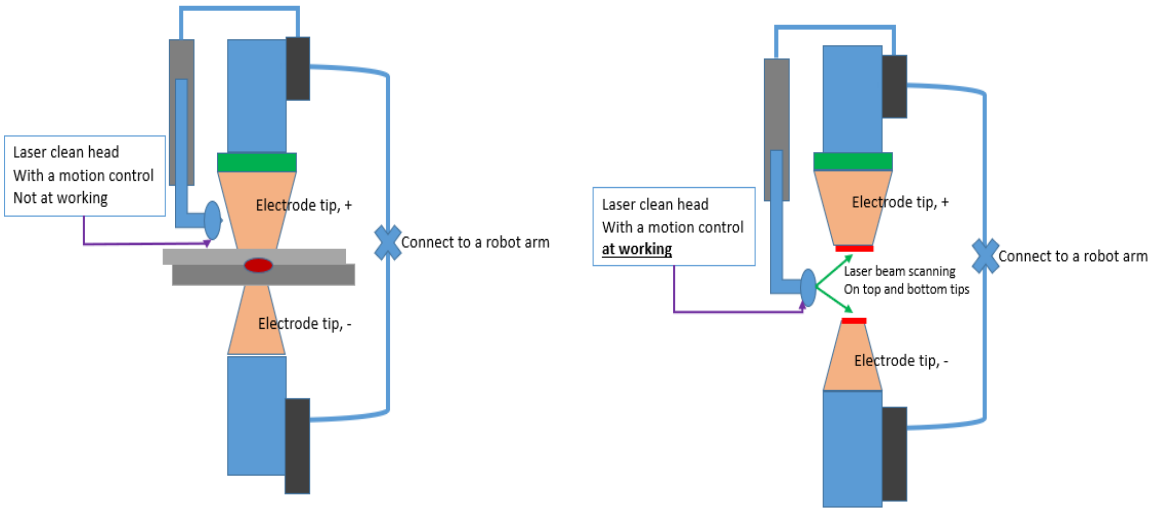
a) b)

Source: a) Mini-laser ablation cobot from laser photonics, b) Small robot for light-duty applications-Kuka

Fig. 3: Automated setting of electrode laser ablation process using extra robot

2.3 RSW electrode laser ablation integrated into welding gun

Method 3 is to integrate the laser ablation system into the resistance spot welding gun, as is shown in Fig.4, when RSW machine is working, the laser ablation system stays in preparation, not at working status. When welding finish, welding gun will be open(perhaps not necessary) and laser ablation head moves to cleaning position, followed by laser ablation process, the welding and ablation process will be repeated more than 300 times till welding electrode need to be replaced.



a) RSW at work b) RSW pause, electrode laser ablation at work

Fig. 4: Sketch of laser ablation system integrated into resistance spot welding gun

3. Welding result-Electrode laser ablation VS electrode dressing

3.1 Electrode laser ablation topographies description

As an unlimited example in Fig.5, the electrode reconditioning is conducted using a 250W gauss mode laser ablation source, laser dot with overlap around 20 to 50%, 1-2 times of ablation, cycle time around 1s to 2s, the surface roughness varies from center to the edge due to electrode radius, SA from 4.2µm(center) to 5.6µm(edge). as is seen in microscope, the topography is in mountain shape with low and high point, the high point would be effective to pierce through oxidation layer to stabilize contact resistance and improve welding electrode life. Other surface topographies would probably work as well, or perhaps there are better topographies which need to be further developed.

As is shown in Fig. 6, laser ablation can recondition the electrode effectively at only one time, in Fig. 7 and Fig. 8, the topography of the electrode radius rarely changes from 1st time of laser ablation to the 100th time laser ablation, which means the electrode can be always at the similar status after each time of laser ablation. The electrode material removal is only 0.8mm as per 100 times of laser ablation, which means each time only 8µm is removed, while electrode dressing removes 200µm each time.

Laser ablation of the electrode to extend RSW electrode life and save production cost
Feng Wu et al.

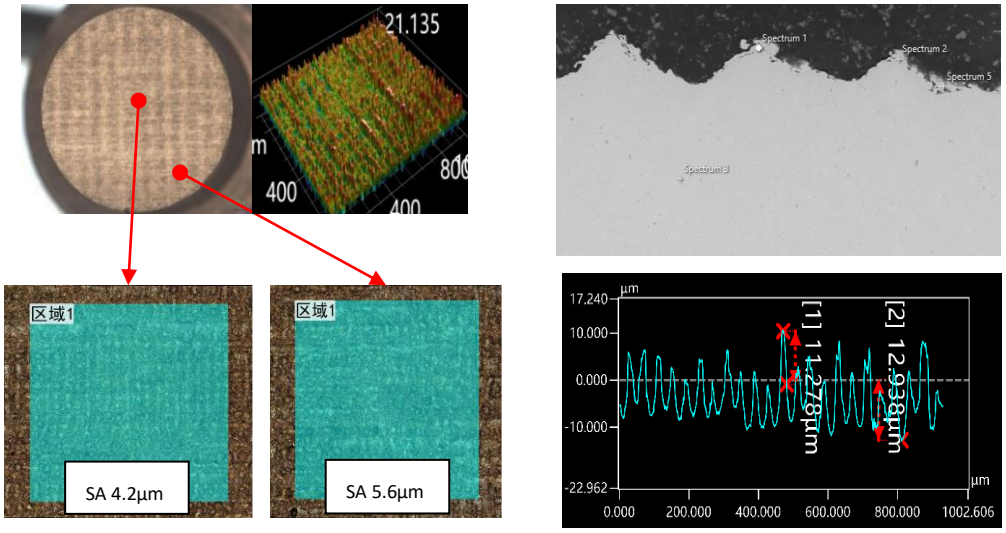
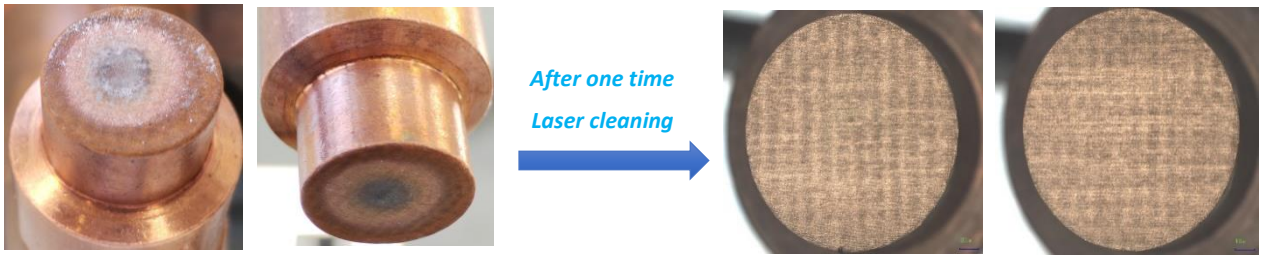
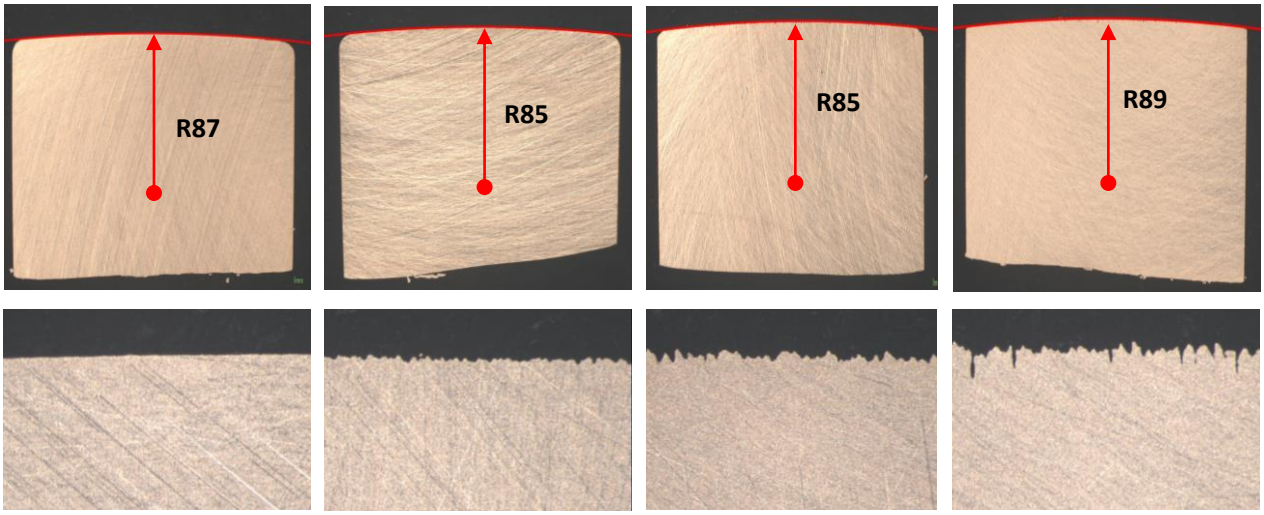


Fig. 5 Electrode laser ablation topography (unlimited example)



RSW after 50 spots(+) RSW after 50 spots(-) after Laser ablation (+) after Laser ablation (-)

Fig. 6 Electrode status before and after one time laser ablation, joint stacks 5182_1.5mm(2T)



Original tip Electrode radius | Laser ablation 5 times Electrode radius R85 | Laser ablation 30 times Electrode radius R85 | Laser ablation 100 times Electrode radius R89

Fig. 7 Electrode radius from starting point to 100th time of laser ablation (only laser ablation no welding)

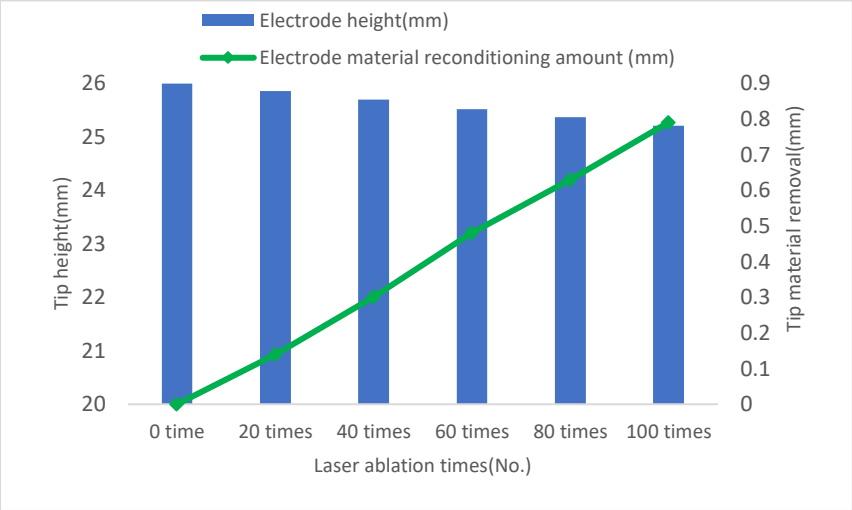
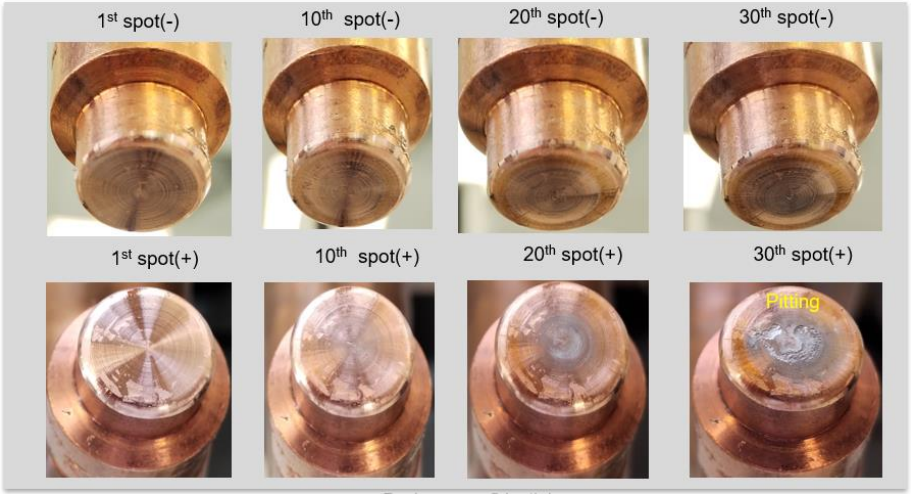


Fig. 8 Electrode height and electrode material removal till 100th of laser ablation (only laser ablation, no welding)

3.2 Welding result at various joint combinations

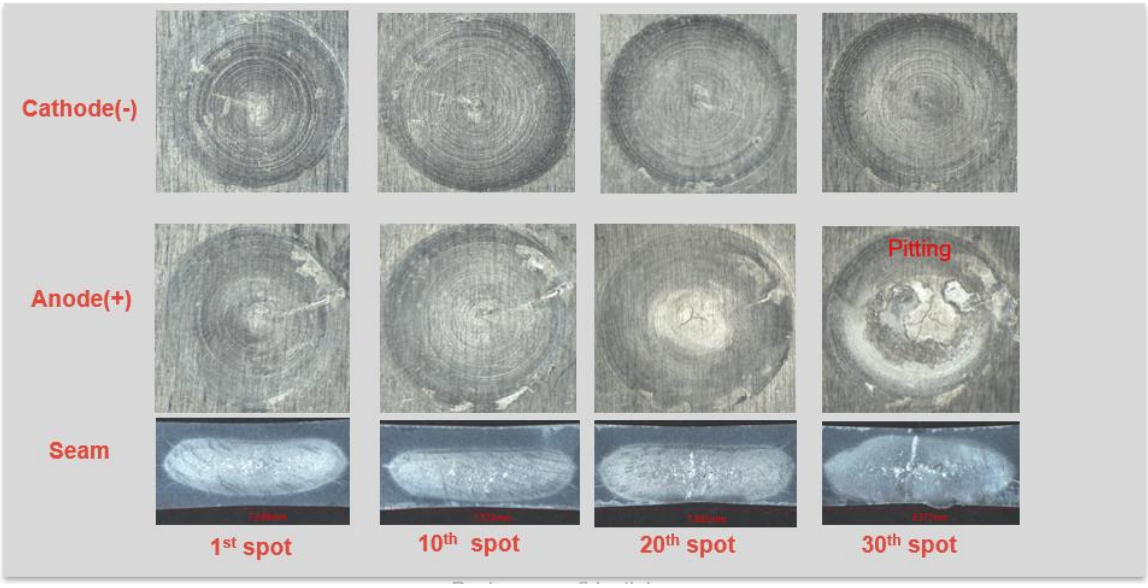
3.2.1 Joint stacks: 5182_1.5mm_O(2T)

5182_1.5mm_O(2T) with electrode dressing has electrode life of only 20 spots, the electrode degraded very fast, electrode dressing removes 0.2mm of electrode material each time, one pair of electrodes can only weld less than 600 spots, while laser ablated electrode lasts around 50 spots after each time of reconditioning, since laser ablation removes less than 20 μm each time, one pair of electrodes can welding actually over 10000 spots, that is great advantages over electrode dressing, detailed result as shown in Fig 9(a-e), the electrode degradation of electrode dressing comes earlier than that of electrode laser ablation.

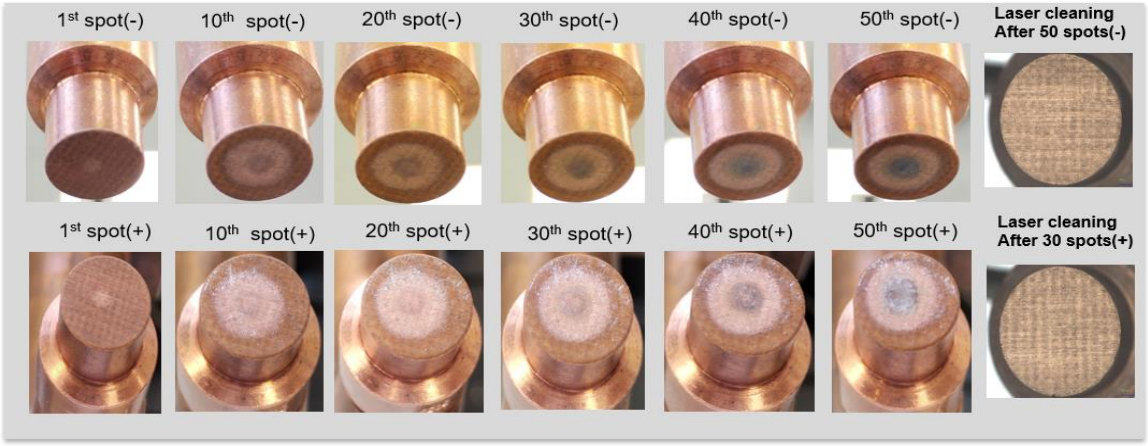


a) RSW electrode status @ electrode dressing

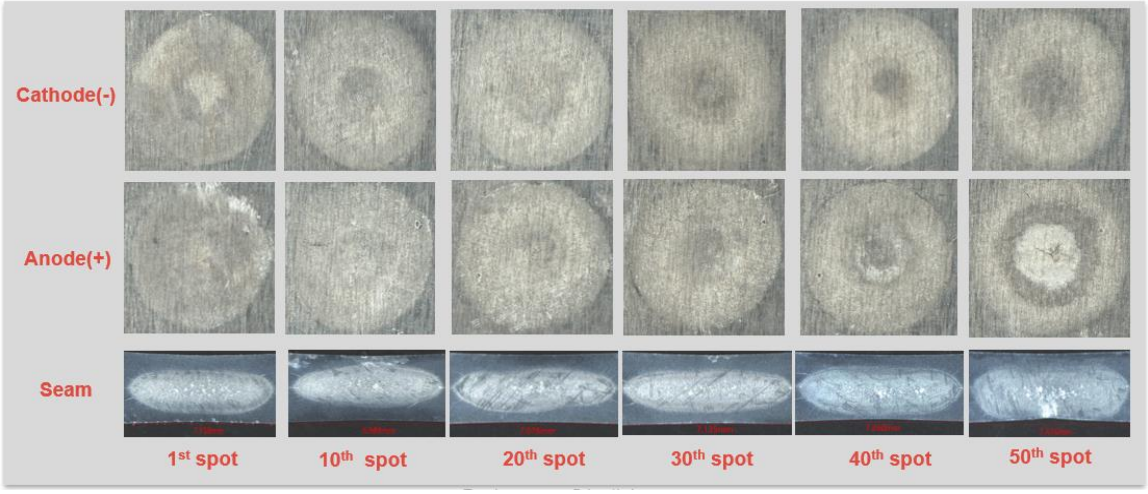
Laser ablation of the electrode to extend RSW electrode life and save production cost
Feng Wu et al.



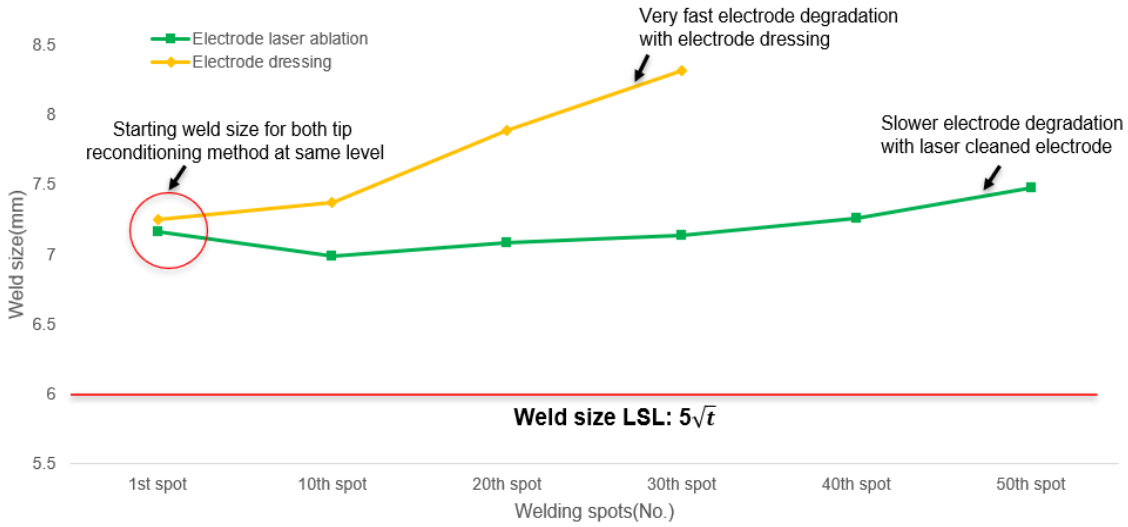
b) Material surface status @ electrode dressing



c) RSW electrode status @ electrode laser ablation



d) RSW material surface status @ electrode laser ablation

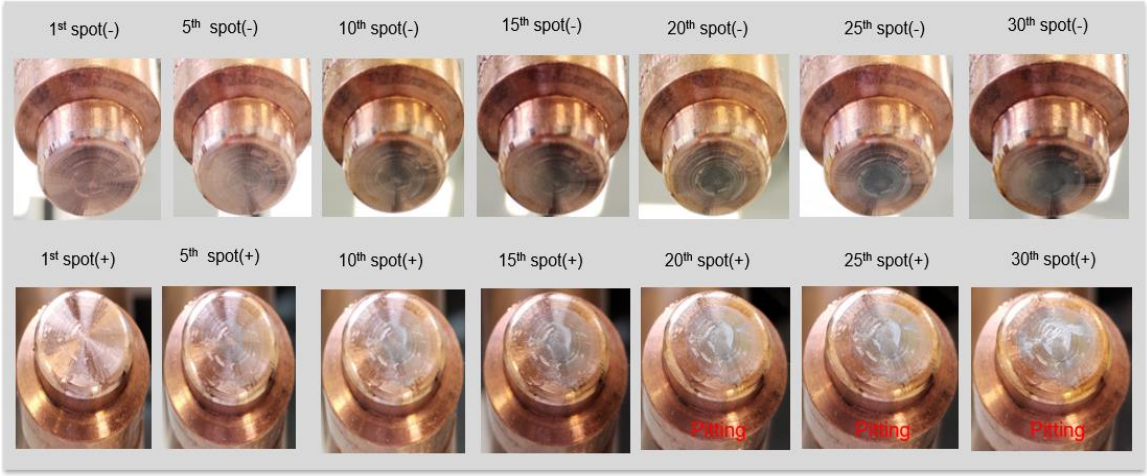


e) RSW weld size comparison electrode dressing VS electrode laser ablation

Fig. 9 Comparison of RSW result electrode dressing VS electrode laser ablation(5182_1.5mm_O)

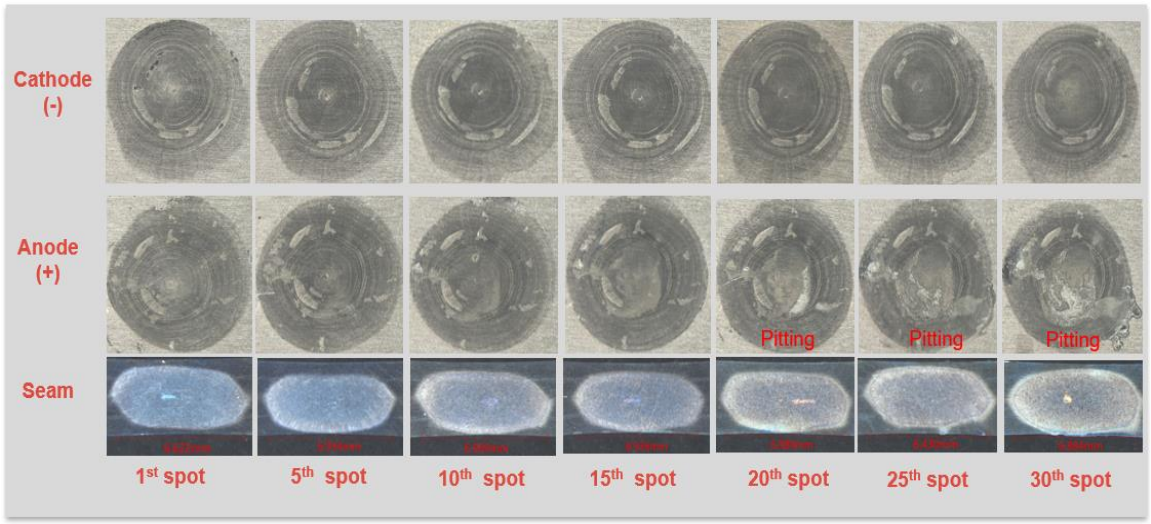
3.2.2 Joint stacks: 7075_1.8mm_T6(2T)

7075_1.8mm_T4(2T) with electrode dressing has electrode life around 15 to 20 spots, the electrode degraded very fast, electrode dressing removes 0.2mm of electrode material each time, one pair of electrodes only weld less than 600 spots, while laser ablated electrode lasts around 30 to 40 spots after each time of reconditioning, since laser ablation removes less than 20 μm each time, one pair of electrodes can welding actually over 10000 spots, that is great advantages over electrode dressing.

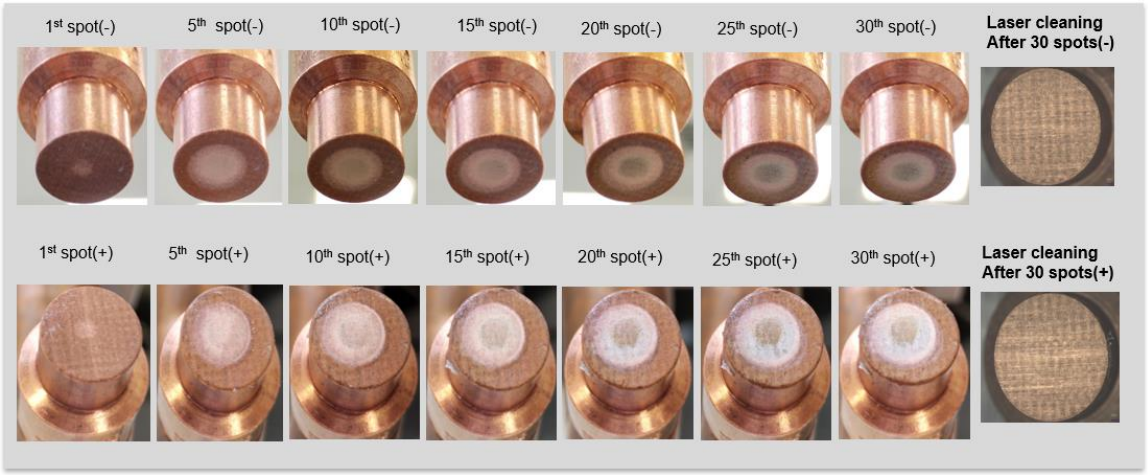


a) RSW electrode status @ electrode dressing

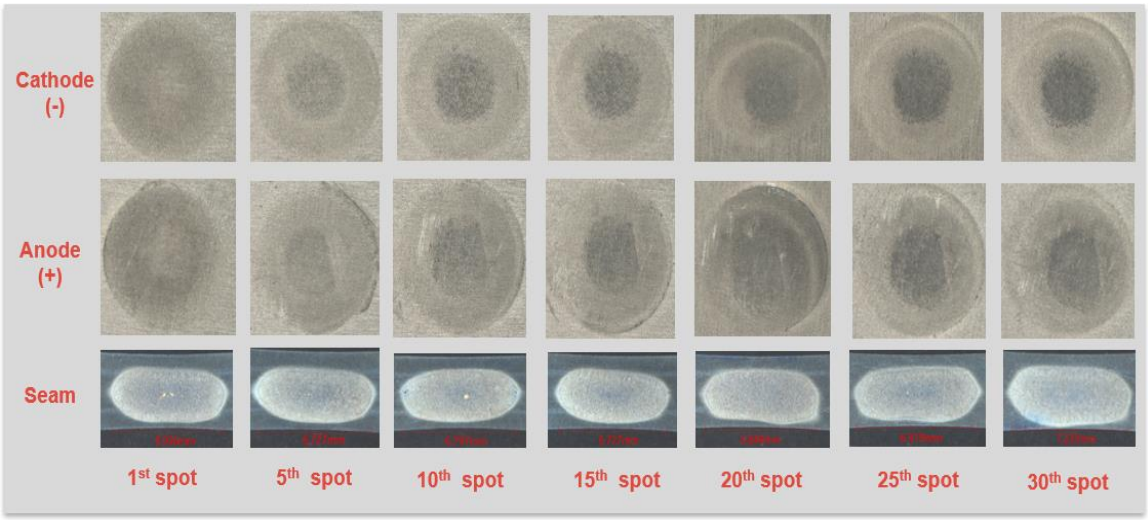
Laser ablation of the electrode to extend RSW electrode life and save production cost
Feng Wu et al.



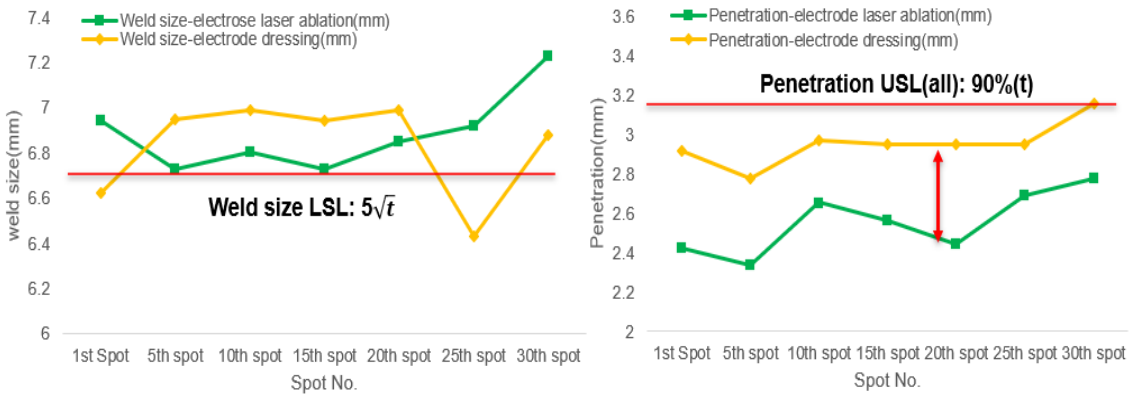
b) Material surface status @ electrode dressing



c) RSW electrode status @ electrode laser ablation



d) RSW material surface status @ electrode laser ablation



e) RSW weld size/penetration comparison electrode dressing VS electrode laser ablation

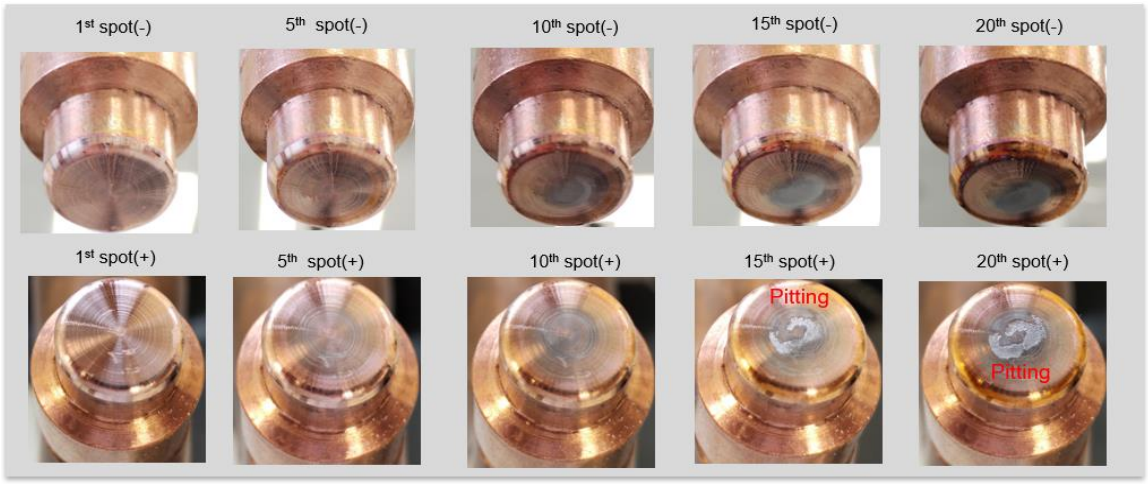
Fig. 10 Comparison of RSW result electrode dressing VS electrode laser ablation(7075_1.8mm_T6)

As shown in Fig 10-e, The RSW welds penetration using laser ablated electrode is generally lower than that of electrode dressing, which means the heat transferred to the electrode is generally lower, that's beneficial for electrode life extension.

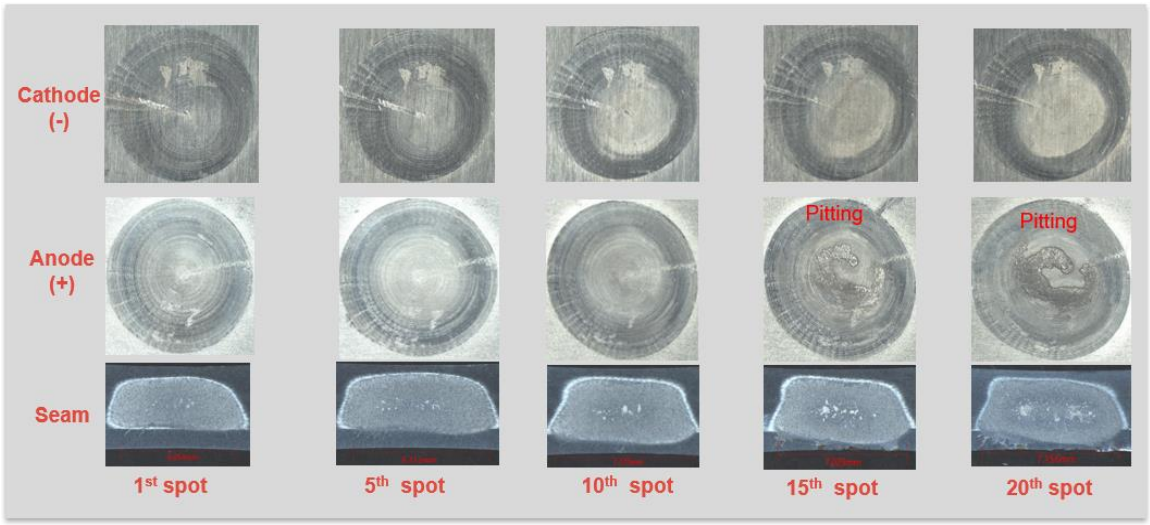
3.2.3 Joint stacks: 6111_3.0mm_T4/6014_0.95mm_T4

6111_3.0_T4/6014_0.95_T4(2T) with electrode dressing has electrode life around 10 to 15 spots(thin sheet at anode side), the electrode degraded very fast, electrode dressing removes 0.2mm of electrode material each time, one pair of electrodes can only weld less than 400 spots, while laser ablated electrode lasts around 20 to 25 spots each time of reconditioning, since laser ablation removes electrode material less than 20 μm each time, one pair of electrode can welding actually around 9000 spots, that is great advantages over electrode dressing. detailed result as shown in Fig 11(a-e).

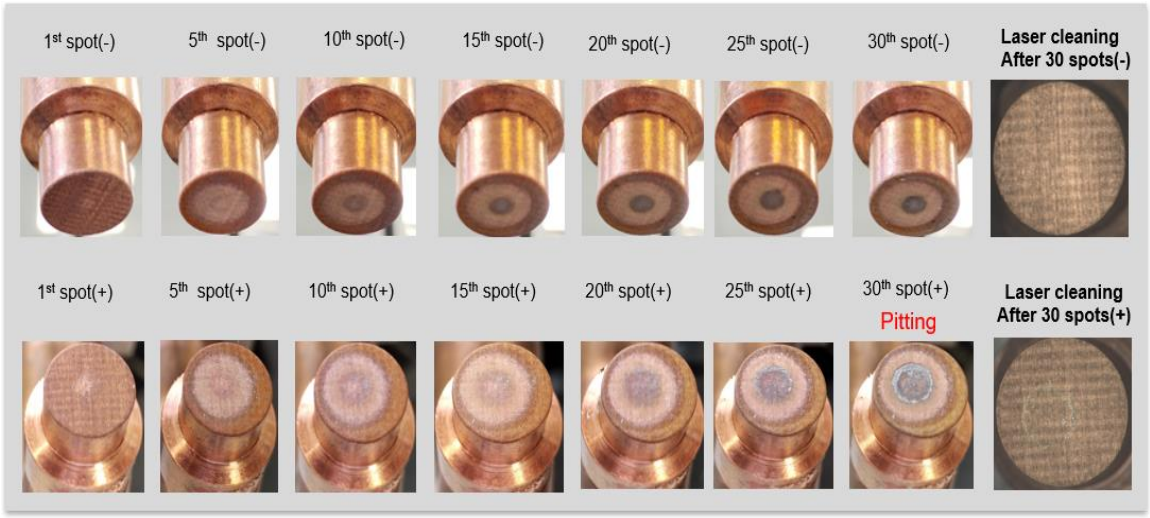
RSW electrode pitting/sticking comes earlier with electrode dressing, generally the penetration growth rate of the welds(at thin sheet side) with electrode dressing is higher than that of electrode laser ablation, which means the heat transferred to the electrode with laser ablated electrode comes slowly than that of electrode dressing, and benefits electrode life.



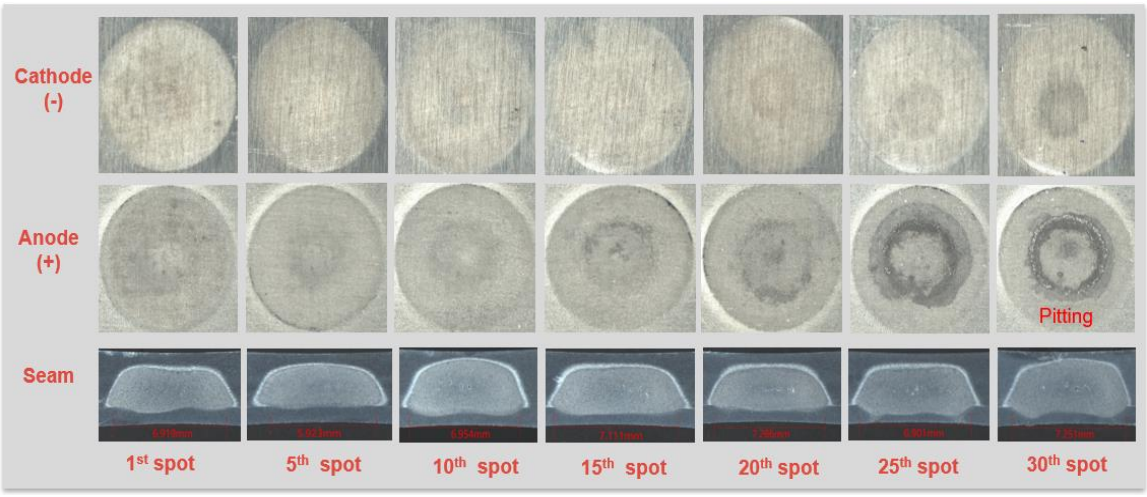
a) RSW electrode status @ electrode dressing



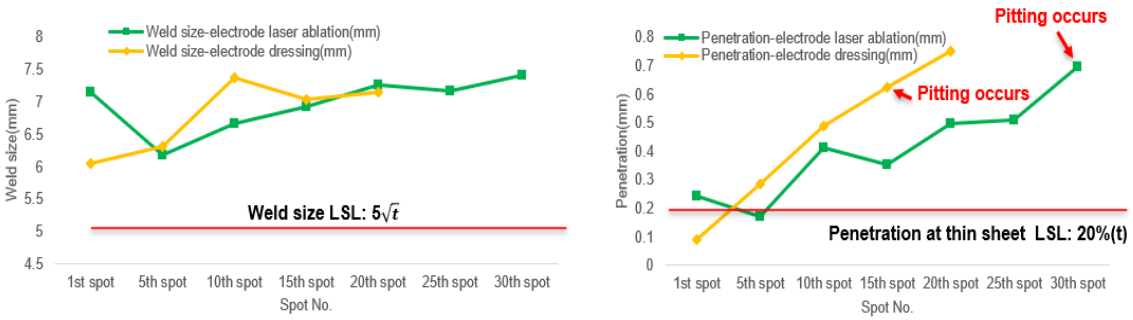
b) Material surface status @ electrode dressing



c) RSW electrode status @ electrode laser ablation



d) RSW material surface status @ electrode laser ablation



e) RSW weld size and penetration comparison electrode dressing VS electrode laser ablation

Fig. 11 Comparison of RSW result electrode dressing VS electrode laser ablation(6111_3.0mm_T4/6014_0.95mm_T4)

4. Summary

Table 1 Electrode life comparison electrode laser ablation VS electrode dressing (one pair of electrodes)

Joint stacks	Electrode life and total welded spots per electrode-electrode laser ablation		Electrode life and total welded spots per electrode-electrode dressing	
	Electrode life(spots)	total electrode life per one pair of electrodes (300 times reconditioning)	Electrode life (spots)	total electrode life per one pair of electrodes (30 times reconditioning)
5182_1.5mm_O/ 5182_1.5mm_O	40	12000	20	600
7075_1.8mm_T6/ 7075_1.8mm_T6	30	9000	15	450
6111_3.0mm_T4/ 6014_0.95mm_T4	25	7500	13	390

The overall comparison of electrode life with electrode laser ablation and electrode dressing as shown in table 1, electrode laser ablation shows great advantages over electrode dressing in terms of electrode life per single time reconditioning as well as electrode life per one pair of electrodes consumption. As consideration for mass production, machine setting which fulfil series production efficiency, EHS aspects could be the focusing point to promote this technic into application.

As for costing saving, as shown in table 2, a benchmarking of aluminum intensive BIW of 2000 aluminum spots was selected, guessing one series production line need 100 laser ablation machines to clean the electrodes, the total cost saving would be close to 17 million RMB a year for only one model of car if electrode laser ablation to be applicated in automotives, the major saving comes mainly from electrode cost saving.

Table 2 Cost calculation with electrode laser ablation method VS electrode dressing

Benchmarking BIW-weld spots(No.)	2000	2000
Annual sales(volume)	100000	100000
Weld Spots/year	200000000	200000000
Example-electrode life-5182(spots No.)	20	40
Electrode cost/pair(RMB)	80	80
Electrode material removal/time(mm)	0.20	0.02
Total usable electrode length(mm)	7 (original 10)	8 (original 10)
Electrode reconditioning cycle time(s)	5	5
Weld spots/pair(spots No.)	700	16000
Total processing times(No.)	35	400
Electrode consumption/year	285714	12500
Electrode cost/year(RMB)	22857143	1000000
*100*electrode reconditioning machine cost/8 years(RMB)*	8000000	50000000
*100*electrode reconditioning machine cost/year(RMB)*	1000000	6250000
*100*Aluminum RSW machine cost/8 years-set(RMB)*	150000000	150000000
*100*Aluminum RSW machine cost/year-set(RMB)*	18750000	18750000
Auxiliary cost-Compressed air, cooling water, electricity, maintenance/year	2000000	2000000
Cost total/year(RMB)	44607143	28000000
Cost per spot (RMB)	0.22	0.14
Total cost saving/year(RMB)		**16607143**