Periodica Polytechnica
Transportation Engineering

46(2), pp. 59-62, 2018
https://doi.org/10.3311/PPtr.11528

RESEARCH ARTICLE

Investigation of Laser-material Interaction in Case of Aluminium Brazing Process

Tamás Markovits[1*], András Jászberényi[2]

Received 02 April 2017; accepted 29 September 2017

Abstract

This research work is connected to the applicability of laser source in case of brazing of aluminium materials. Based on our earlier research results it become clear that the brazing flux material is able to improve the laser absorption in case CO_2 laser source. A new brazing flux material (Fontargen F 400 MD EVO2) and the CO_2 laser interactions were investigated to determine the applicability of laser as a heating source. The application of laser strongly depend on the value of absorption of laser energy into the aluminium base material. From our new result it can be seen that the applied flux can improve the laser absorption, thus the laser heating, but the implementation of brazing process with this flux material brings further challenges.

Keywords

laser, brazing, flux, aluminium, interaction

[1] Department of Automotive Technologies,
Faculty of Transportation and Vehicle Engineering,
Budapest University of Technology and Economics,
H-1111 Budapest, Stoczek u. 6., Hungary

[2] FHL Björn Hungary Kft.,
H-8060, Mór, Velegi u. 5-7, Hungary

[*] Corresponding author, e-mail: tamas.markovits@gjt.bme.hu

1 Introduction

The application of aluminium materials in case of vehicle constructions is growing continuously due to the strategy of weight reduction. However, the application of aluminium means further challenges in case of many manufacturing technologies like pressing, welding, brazing comparing to the steel material, because of the different physical and mechanical properties of aluminium.

The brazing technology applied for many years in the automotive industry in case of the joining of sheet and tube elements.

The heat sources are also being developed continuously. An advanced solution is nowadays the laser heating. Many researchers are dealing with the application possibilities in case of steel to aluminium (Gatzen et al., 2016), aluminium to cooper (Solchenbach et al., 2013) and aluminium to titan (Tomashchuk et al. 2017) brazing or welding.

During the brazing process the base material are not melted. Therefore the heat input is lower than the welding technology. Less heat accumulation will cause less inner stress and less deformation after the cooling process. But brazing needs special additional material, like the filler metal which has lower melting point than the base material and the flux material which helps to decrease or eliminate the oxide layer on the surfaces and improve the wetting properties.

The additional material like the brazing filler and the applied fluxes are also being developed continuously. Some advanced materials are tested and predict new directions (Xiao et al., 2016; Tang et al., 2013).

Applying the laser as a heat source in every technology when the material manufactured by heat the laser-material interaction is one of the most important technological issue. The authors have more research experience in the field laser-material interactions. Not only in case of metals but also in case of polymers (Markovits et al., 2014). As in our earlier investigation, it became clear the applied brazing flux has a high impact on the efficiency of the laser heating. In case of different laser sources, the effect could be very different. We determined that in case of CO_2 laser a special KF_3-AlF based flux is able to increase the absorption and help the brazing process. In other laser like the Nd:YAG laser we found that the brazing flux had no effect to the absorption, due to the big differences in the wavelength of the laser (Markovits et al., 2007; Wang et al., 2000).

In this research work, our goal was to investigate the main characteristics of laser material interactions between a new brazing flux material and CO_2 laser source in order to determine the effect on the heating efficiency and the laser brazing process.

2 Experiments

The experiments were carried out in two steps. In the first step the heating efficiency were investigated. In the second step the laser brazing process.

2.1 Heating efficiency

During the first experiment the effect of the applied Fontargen F 400 MD EVO2 type brazing flux was investigated in case of aluminium sample. The experimental setup can be seen in Fig. 1.

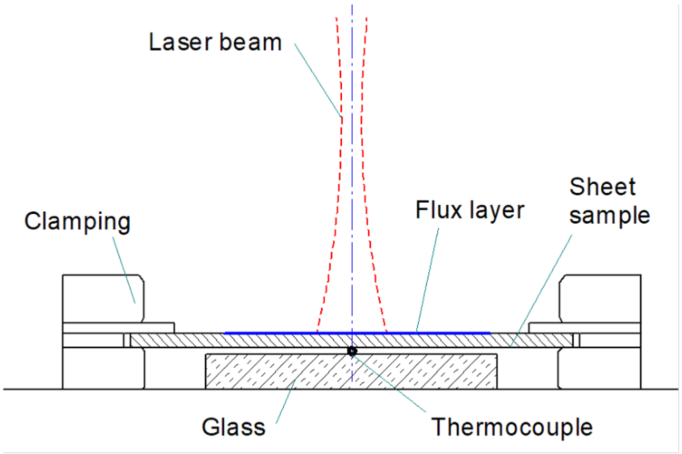

Fig. 1 Experimental setup of heating efficiency

The CO_2 laser beam with $TEM_{0,0}$ power distribution was guided to the processing head, which focused the beam and a positive defocus were used in order to increase the diameter of the laser spot to 8 mm at the middle part of the sample. The power of the laser was 400 W. There was no movement between the sample and the processing head. During the experiment just the laser was switched on for a 30 seconds. This process time was enough to reach the range of brazing temperature.

The sample material were pure aluminium (99.5 %, AA1050) sheet with the geometry: 30 x 30 x 1 mm.

The brazing flux was a lithium cloride based material (LiCl (25 - 50%), $KAlF_4$ (5 - 10%), ZnF_2, AlF_6K_3, KF (≤ 5%), Na_3AlF_6, $ZnCl_2$, NaF, ZnO (≤ 2.5%)). The flux were used in a form of brazing pasta, which is a pre-mixed, dense liquid material.

The clamping unit fixed the sample onto a glass sheet to eliminate the heat conduction from the sample. A K-type thermocouple was used to detect the temperature at the bottom part of the sheet.

The thermocouple was positioned between the Al sheet and the glass part. In Fig. 2 the prepared experiment can be seen before the laser heating.

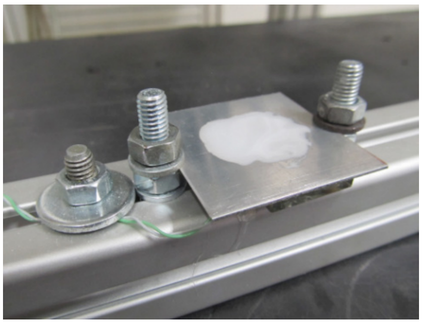

Fig. 2 Photo of the setup with flux material, before the laser irradiation

The green electric wire shows the thermocouple which was evaluated with Denkal 6 type controller. The measured data was recorded by a PC. The laser heating were carried out with and without flux material 3 times in each cases. Evaluation of the process was carried out by the video records and the measured temperature graphs.

2.2 Laser brazing

After the laser heating process the laser brazing possibilities were investigated. The experimental setup can be seen in Fig. 3.

In these experiments the same clamping unit, base plate, laser, laser spot size (8 mm), laser power (400 W) were used. The applied tube sample was an AA3103 type Al-Mn alloy with outer geometry 20 mm, length 30 mm and 1.2 mm wall thickness. The tube sample was placed in the middle of the Al sheet sample and a brazing wire in a form of ring was placed around the tube. The diameter of the wire was 2 mm. The plate, the tube and the filler material were covered with the Fontargen flux material before the test.

The laser was positioned into the middle of the tube, therefore it did not heat directly the wire. The tube was heated from the inner reflexion of the beam. This experimental setup was successfully carried out in our earlier experiments.

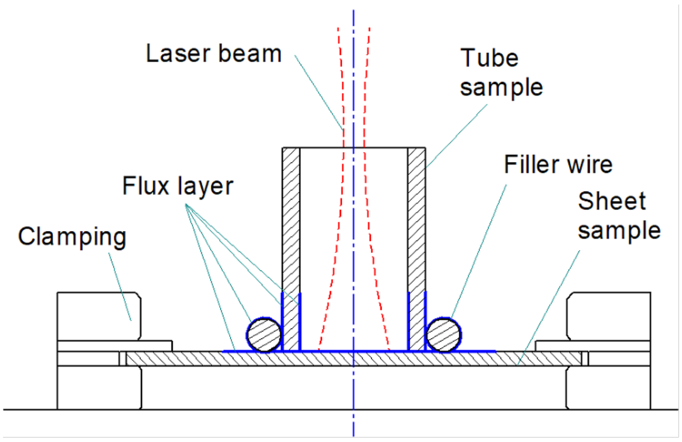

Fig. 3 Experimental setup of laser brazing of aluminium

During the heating the laser was switched on for 30 seconds and the event was detected with a normal optical camera. The video records were evaluated frame by frame later in order to pair the main events and the times.

3 Results and discussion

3.1 Effect of flux on the heating efficiency

The result of the heating efficiency was evaluated by the analysation of recorded picture frames and the comparison of measured temperatures.

When flux was not used the pictures did not show any information because the laser-aluminium plate interaction has not got any visible effect. Just the temperature increased and there was no other action.

The main events are illustrated in the Fig. 4, when the flux was placed on the sample. Some characteristic frames are collected from the heating process. The picture shows the start state when the laser switched on. At this moment steam was created and within 1 second the flux material started to burn with a high flame despite the Argon shielding gas. The size of the flame reduced and at the 13 s the flame went away.

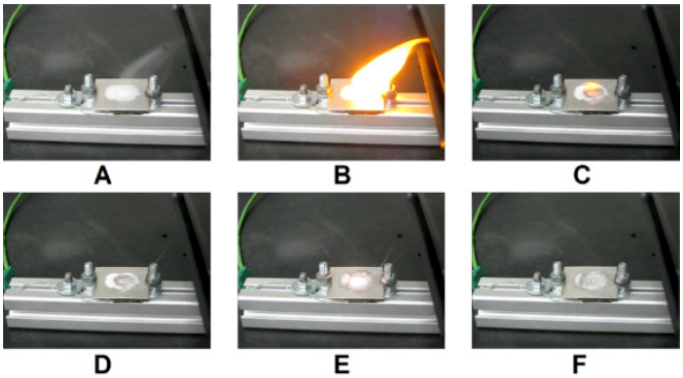

Fig. 4 The process of laser heating, (A) start of irradiation, (B) start of flame, (C) reduction of flame, (D) melting of flux, (E) end of irradiation (F) cooled sample

The flux material started to melt and around the laser spot where the laser did not irradiate the flux directly a foam formation was occurred.

The heating efficiency was evaluated by the measured temperatures. The thermocouple measured the temperature at the bottom part of the sheet sample. Due to the 1 mm thick plat thickness and the good heat conduction of the pure aluminium the temperature is close to the upper surface temperature. Every setup were repeated 3 times. The result can be seen in Fig. 5.

The diagram shows the increasing temperature in both cases. The curves with green colour represent the heating process without flux layer. In this case the temperature increasing monotonously, but during 30 s the maximal value is less than 150 °C, because of the high reflexion of the aluminium at the laser wavelength. It would be too slow for brazing process if we compare with the existing heating solutions.

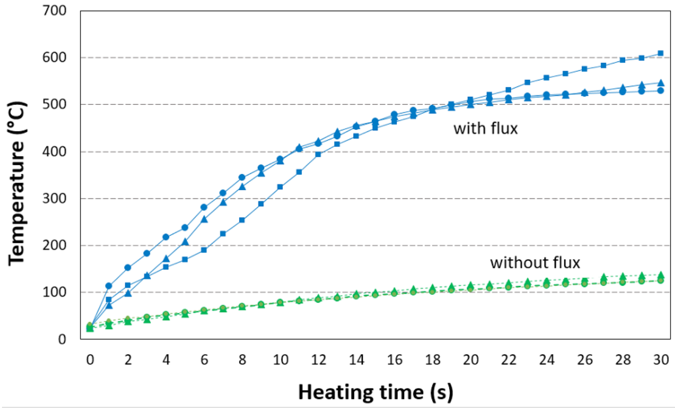

Fig. 5 The laser heating efficiency depending on the presence of flux material

The blue curves represents the laser heating with flux layer. In this case the temperature increasing faster. The 150 °C reached within 2 s. The maximal temperatures were between 500-600 °C, which is suitable for the brazing.

If we compare the setups, we can conclude that the presence of the flux material on the surface increases the heating efficiency. As we can see from the visualisation of the process a flame was created during the interaction. This flame gave additional heat, therefore the measured temperature was created from the laser energy and the flame energy. At this research stage it is not separable, but the difference did not came just from the flame, because in the first second the temperature increased faster and the flame created just later. Probably the flame has also a strong effect.

There is a question as to whether the flux can perform the original wetting task after the burning. It can be answered by the brazing experiment.

3.2 Effect of flux on the laser brazing process

In the second part of the experiment the brazing processes of aluminium were carried out. The process was analysed by the recordings of the camera. The main events were detected and the typical times were measured. Some typical picture frames are presented in Fig. 6.

From the frame sequences it can be seen that at the initial state the tube was placed in the middle of the sample. At t0 when the laser was switched on steam was created in the tube, due to the laser flux interaction. After 0.6 seconds the flame is created as it was detected during the heating process. The flame was created just in the tube it suppose that the direct laser-flux interaction caused the flame not the high temperature. The flux did not burn outside the tube. It helps to perform the wetting task of flux, allows the filler metal to flow in to the gap and create a brazed joint.

Analysing the video frames some main events were detected during the brazing process. It can be seen in Fig. 7. The main events are: creation of steam, creation of flame, reduction of flame, melting of flux, melting of filler.

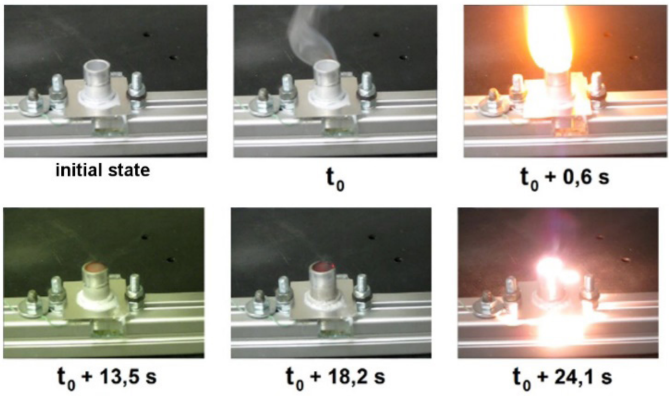

Fig. 6 The main steps of laser heating against the time

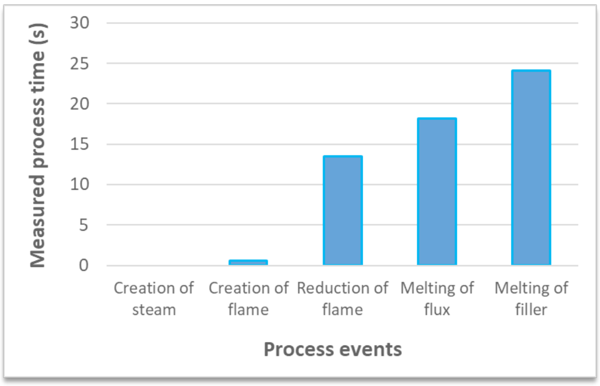

Fig. 7 Main events and process time during laser brazing

Evaluating the brazed plate and tube samples, the brazed joint was created successfully. The flux material was able to fulfil the wetting task thus the flame did not hinder the joining process. The laser beam was able to heat up the aluminium plate, the tube and the filler metal too at the same time with indirect heating. The filler material melted by the heat of plate and tube and flowed into the gap with the force of capillarity. After switching of the laser the filler solidified and the joint was created. We can conclude that the laser brazing can be carried out with this flux material, but the burning of the flame has a big influence of the control of the process. The plate is overheated during the process in some cases. A typical joint picture can be seen in Fig. 8.

In the photo the remaining flux material can be see and the burned tube due to the flame creation. Despite the brazing is suitable the flame burning have to be solved in future research work in order to keep the technology in control.

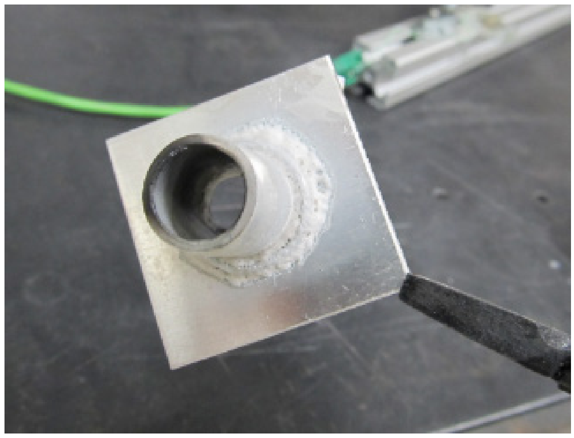

Fig. 8 Typical result of laser brazed aluminium sample

4 Conclusion

The result of our research have confirmed our earlier expectations, that the brazing flux has a high impact onto the heating and brazing process too. Based on these results the next points can be stated as a conclusion:

- the applied brazing flux increases the CO_2 laser absorption in case of aluminium materials
- some components of the applied flux burn out and create flame due to the laser interaction
- the burning of the flux produces additional heat during the interaction for a certain time period of heating process
- despite burning the flux can help the wetting of the filler material
- the laser brazing can be carried out with the applied flux material, but the burning have to be solved to keep the process in control

Acknowledgement

The project is implemented under the Széchényi 2020 programme (GINOP-2.1.1-15-2016-00918). The authors would like also to thank to Gellért Patty for taking part in the research work from BME.

References

Gatzen, M., Radel, T., Thomy, C., Vollertsen, F. (2016). Wetting and solidification characteristics of aluminium on zinc coated steel in laser welding and brazing. *Journal of Materials Processing Technology*. 238, pp. 352–360. https://doi.org/10.1016/j.jmatprotec.2016.07.026

Markovits, T., Bauernhuber, A., Mikula, P. (2014). Study on the transparency of polymer materials in case of Nd:YAG laser radiation. *Periodica Polytechnica Transportation Engineering*. 41(2), pp. 149-154. https://doi.org/10.3311/PPtr.7117

Markovits, T., Takács, J. (2007). Effect of the KF-Alf3 brazing flux on the heating of aluminium by ND:YAG laser. In: *5th International Conference on Laser Assisted Net Shape Engineering*, Erlangen, Germany, pp. 285-292.

Solchenbach, T., Plapper, P. (2013). Mechanical characteristics of laser braze-welded aluminium–copper connections. *Optics & Laser Technology*. 54, pp. 249–256. https://doi.org/10.1016/j.optlastec.2013.06.003

Tang, Z., Seefeld, T., Vollertsen, F. (2013). Laser brazing of aluminum with a new filler wire AlZn13Si10Cu4. *Physics Procedia*. 41, pp. 128-136. https://doi.org/10.1016/j.phpro.2013.03.060

Tomashchuk, I., Sallamand, P., Méasson, A., Cicala, E., Duband, M., Peyre, P. (2017). Aluminum to titanium laser welding-brazing in V-shaped groove. *Journal of Materials Processing Technology*. 245, pp. 24-36. https://doi.org/10.1016/j.jmatprotec.2017.02.009

Xiao, B., Wang, D., Cheng, F., Wang, Y. (2016). Development of ZrF4-containing CsF–AlF3 flux for brazing 5052 aluminium alloy with Zn–Al filler metal. *Materials and Design*. 90, pp. 610–617. https://doi.org/10.1016/j.matdes.2015.11.025

Wang, X., Takács, J., Krállics, Gy., Szilágyi, A., Markovits, T. (2000). Experimental research on laser-material interaction. *Periodica Polytechica Transportation Engineering*. 28(1-2), pp. 143-152.