Investigating the torsion resistance of pint-to-plate LAMP joints

Tamás Markovits[a], László Ferenc Varga

Department of Automotive Technologies, Faculty of Transportation and Vehicle Engineering
Budapest University of Technology and Economics

[a] Corresponding author: tamas.markovits@gjt.bme.hu

Abstract

Laser assisted metal plastic (LAMP) joining is a developing technology. In this study the pin-to-plate geometry is investigated. This geometry can be applied in many cases when spot type joining is necessary. Based on our previous researches, not just the shear test but also the torsion test is necessary to characterize the bond more precisely. The basically used cylindrical shapes surface was modified and the effect of surface cleaning was clarified. Different metal pin macro geometries to investigate the shape locking effect in case of torsion properties. A flash lamp pumped Nd:YAG laser beam was used to create transmission laser joining. Unalloyed structural steel pin and PMMA plastic sheet was investigated. The torsion properties of the pin to plate joints were also investigated in order to determine the basic effects of pin shapes and surface pre treatments to the maximal torques.

Keywords: *laser, joining, plastic, metal, torsion*

1 Introduction

Utilization of different material types in the same construction are increasing, to exploit the advantages of the material combinations (plastic, metals and ceramics). The usage of these material combinations motivates the development of their joining. The existing hybrid joining technologies like screwing, riveting or adhesive bonding, however these traditional methods have all their own challenges [1]. The laser beam is able to join metals and plastics very fast, accurately and directly, without any additive materials, which are desirable for the industry [2, 3].

The authors have been developing laser assisted pin-to-plate joining of plastic sheets and metal pins for years. According to the results, joint strength can be effectively enhanced by increasing pin surface roughness, proper shape locking pin geometry and sheet thickness: in case of PMMA sheet and structural steel pin the authors reached about 900 N tearing force which is significantly higher than those of similar joinings prepared with adhesives. The effect of pulse settings in case of pulse mode Nd:YAG laser source was investigated as well [4].

In the present research, unalloyed structural steel pins and PMMA plastic plates were bonded by pulse mode Nd:YAG laser source. Our aim was to create pin-to-plate hybrid joints in order to determine not the tearing force, but the maximal torque in case of torsion load of the joints at different pin geometries.

2 Experiments

In the transmission joining process, the upper, transparent plastic sheet transmits the laser beam, while the lower steel pin has to absorb the radiation. Then, the lower metal transmits heat back to the upper plastic, which softening or melts. Due to the applied clamping force between the joining partners, the pin penetrates into the plastic sheet and an adhesive joint is created after cooling down.

In the these research the joining of Ø5 mm steel pins and 5 mm thick PMMA sheets were prepared by using a flash lamp pumped pulse mode LASAG SLS 200 type Nd:YAG laser source ($TEM_{0,0}$). The average laser power was 200 W and 2 J pulse energy was used in each case. The sketch of the experimental setup is shown in Fig 1.

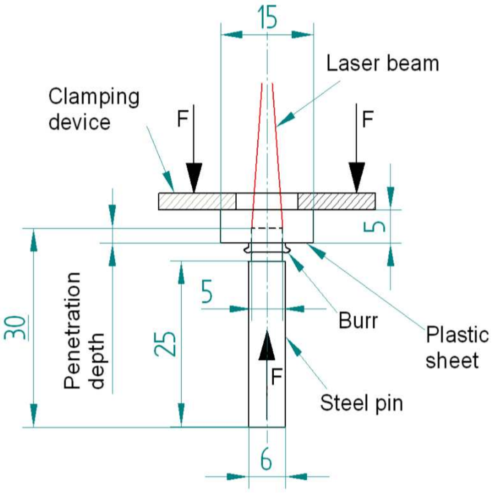


Fig. 1 Experimental setup of the pin-to-plate penetration joints.

The laser spot diameter was 5 mm. The applied different pin geometries are shown in Fig 2, each geometry has a different material volume and therefore a different heat capacity. In order to maintain the same penetration depth of the pins and to be able to compare our results. Average surface roughness of the steel pins ranged between 0.6 – 1.4 µm. To protect the laser head, 5 l/min of Argon shielding gas was applied as well. Acriplex XP type PMMA sheets and unalloyed, cold drawn structural steel, type S235JR, were used. The clamping force was 6 N.

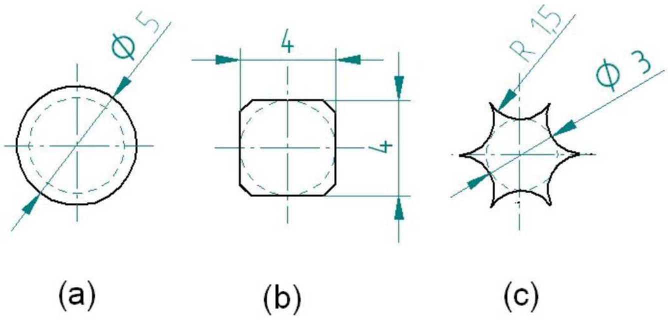


Fig. 2. Geometries of the steel pins on face surface (a) type A, (b) type B, (c) type C

Torque measurement equipment (KISTLER 9273) was aplied for the torsion tests. Torsion tests were performed two days after joint creation. The steel pin was fixed within the torque measuring equipment and the plastic part was rotated by a shape locking jigger element. The torque was measured versus time and the maximal values are determined in each case. The settig parameters are summerized in Table 1.

Table 1 *Setting parameterer*

Setting identifier	Laser average power (W)	Laser spot size (mm)	Penetration depth (mm)	Heating time (s)	Shape geometry type	Surface pre treatment method
Setting 1	200	5	3	variable	type A	no treatment
Setting 2	200	5	3	variable	type A	cleaning
Setting 3	200	5	3	variable	type A	sand blasting
Setting 4	200	5	3	variable	type B	cleaning
Setting 5	200	5	3	variable	type C	cleaning
Setting 6	200	5	3	variable	type D	cleaning
Setting 7	200	5	3	variable	type E	cleaning

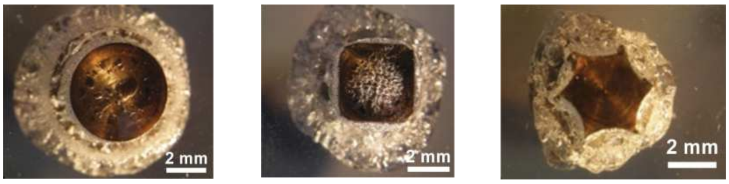
3 Results

3.1 Characterizing the joint

The front view of the created joint can be seen in Fig 3. As the pictures show, the face surface of the steel pin contour are enveloped by the plastic properly. Around the steel pin, the burr of the PMMA is situated on the other side. The bubble formation was very intensive on side surfaces which could harmful for the bond.

In case of setting 1-3 (cylindrical geometry) a 5 mm laser spot was used on a 5 mm face surface concentrically. Therefore all of the laser energy could contribute to creating the joint. In case of modified geometries not the entire laser spot can heat the face surface, then the efficiency of the heating becomes lower. On other hand, the laser had a Gaussian power distribution and so the laser spot is lost at the edges where the power is lower already.

The modification of the cylindrical geometry has an effect on the temperature distribution of the steel pin too, because of the lower heat mass. Moreover, it has an effect on the micro shape locking too. Therefore we had to balance between the better shape locking geometry and the minimal energy loss when choosing the applied geometry.



(a) *(b)* *(c)*

Fig. 3 *Front view of the joints: (a) type A, (b) type B, (c) type C*

3.2 Effect of the surface pre treatment

In case of different sample preparation the reachable maximal torque values can be seen in Fig 4. All of these sample were cylindrical shape where the torsion resistance more influenced by the micro geometry and the specific adhesion on the surface than in case of modified cross sections.

The results match with our earlier expectations that the cleaning process with aceton was useful to enhance the bond between the plastic part and the steel side surface. Approximately 30 % increasing was detected. The blasting process as usually was applied in order to increase the roughness of the surface to enhance the micro shape locking. This pre treatment was able to increase with additional 200 %.

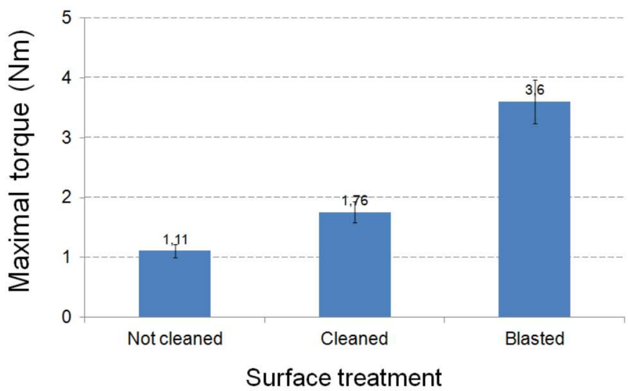


Fig. 4 *Effect of the surface treatment to the maximal torque*

3.3 Effect of the pin geometry

The steel pin modification was also able to enhance the torsion resistance as it can be seen in Fig 5. In case of type A the cleaned surface is presented. The steel pin with rectangular geometry was flowed around by the plastic at the end of the joint creation. Therefore the shape locking could realized as it was expected. The same situation was observed when the six concave shape was investigated. But with the modification of the geometry the bubble formation was more intensive, decreasing the shape locking efficiency. This bubble formation could be the reason why the changes - despite the monotonous increasing – not become higher. The rectangular shape caused a 200 % increasing in the maximal torque. The concave shape (type C) increased more efficiently the resistance with a 270 % comparing to the cylindrical shape (type A) and 30 % more than the rectangular shape (type B).

The typical damage of the plastic sample was the breakage of the plastic parts which means that this is not the bottle neck in the joint. Development of plastic part have to be carry out in the future.

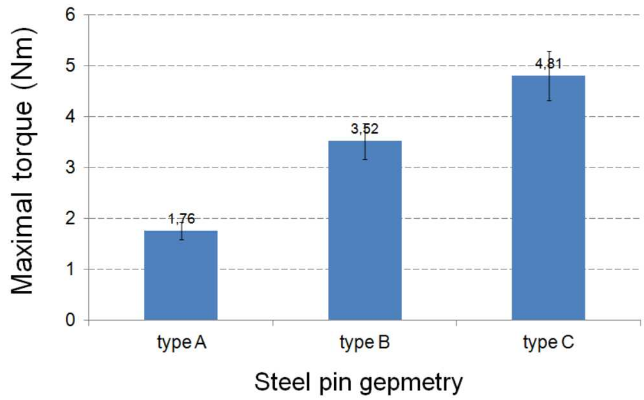


Fig. 5 *Effect of the steel pin geometry to the maximal torque*

4 Conclusion

From the results of this research, regarding the torsion characteristics of the pin-to-plate LAMP joints it can be concluded that:

- It is possible to increase the torsion resistance of pin-to-plate joints with the modification of surface pre treatment or the cross section of steel pin.
- With the pre surface treatment the cleaning with acetone cause 30 % higher maximal torque and the blasting process give additional more 200 %.
- With the shape of the steel pin the maximal torque can be increased by about 200-270 % comparing to the cylindrical one.
- The plastic sheet geometry has an important effect to the limitation of this torsion of resistance. This element is the bottle neck.

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References

[1] S. Katayama, Y.Kawahito. (2008). Laser direct joining of metal and plastic. Scripta Materialia, Vol. 59, pp. 1247–1250

[2] A. Roesne, S.Scheik, A. Olowinsky, A. Gillner, U. Reisgen, M. Schleser. (2011). Laser Assisted Joining of Plastic Metal Hybrids. Physics Procedia Vol. 12, pp. 373–380

[3] Sultana,T., Georgiev, G.L., Baird, R.J., Auner, G.W., Newaz, G., Patwa, R., Herfurth, H.J. (2009). Study of two different thin film coating methods in transmission laser micro-joining of thin Ti-film coated glass and polyimide for biomedical applications. Journal of the Mechanical Behavior of Biomedical Materials, Vol. 2, pp. 237-242.

[4] T. Markovits, A. Bauernhuber, P. Mikula. (2014). Study on the transparency of polymer materials in case of Nd:YAG laser radiation. Periodica Polytechnica: Transportation Engineering ISSN: 1587-3811, Vol. 41, pp. 149-154.