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TORSION CHARACTERISTICS OF PIN-TO-PLATE LAMP JOINTS

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1. Introduction

The utilisation of different type base materials (metal, palstic) and their combinations requires their joining too. The laser beam is able to join metals and plastics very fast, accurately and directly, without any additive materials, which can make their utilization effective and desirable for the industry [1, 2].

The authors have been dealing with transparent-absorbent laser joining, a.k.a. laser assisted metal plastic joining (LAMP 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 poly (methyl methacrylate) (PMMA) sheet and structural steel pin the authors reached about 900 N tearing force which is significantly higher than those of similar joining prepared with adhesives [3]. The effect of pulse settings in case of pulse mode Nd:YAG laser source was investigated as well: the pulse time, pulse power and pulse frequency can influence the behavior of the plastic material at the same average power level and so have a strong effect on the quality of the joining [3, 4]. The good joint strength can be explained by different types of adhesion mechanisms, like physical and probably chemical adhesion.

In the present research, 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, which can be a characteristic requisition as well.

2. Experiments

In the course of our research the joining of Ø5 mm steel pins and 5 mm thick PMMA sheets were prepared by using a pulse mode LASAG SLS 200 type Nd:YAG laser source ($TEM_{0,0}$). The avarage laser power was 200 W and 2 J pulse energy was used in every cases. The experimental setup can be seen in Fig. 1 a).

The focal spot diameter of laser beam was 5 mm, coincidence with the head surface of steel pin. The applied different pin geometries are shown in Fig 1, each geometry have a different material volume and therefore different heat capacity. In order to keep the penetration of the pins into the plastic sheet the same and to be able to compare our results, the laser interaction times were adjusted between 7.2 and 4.9 sec. Average surface roughness of the steel pins was 0.6 – 1.4 µm. To protect the laser head 5 l/min of Argon shielding gas was applied as well. The used materials were Acriplex XP type poly(methyl methacrylate) sheet and S235JR type unalloyed, cold drawn structural steel. The clamping force was 6 N. The torsion tests were carried out by a torque measurement equipment (KISTLER 9273). The maximal torque was observed in each case.

In every case we determined the interaction time based on the same penetration dept which was 3 +/- 0.1 mm. An example could be seen in Fig 3 where the penetration can be seen as a function of the heating time in case of cylindrical pin. The measured values show a monotonous increasing with the increasing heating time as we excepted from our earlier experience. In this way it was possible to determine the necessary heating time in pin geometry.

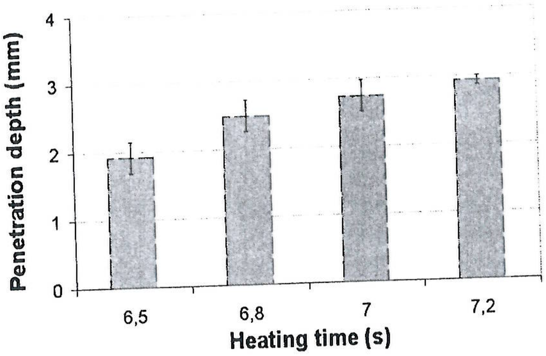


Fig. 3 The effect of heating time on the penetration depth (cylindrical pin)

Examining the interaction times, our earlier hypothesis was proved. At the same laser spot size, the necessary interaction time was lower in every modified geometry, as compared to the cylindrical one, to reach the 3 mm penetration depth. In case of the 5 mm spot diameter, it was between 12 and 20 %.

Examining the torsion properties the torque was measured as a function of time and the maximal values were given in the diagrams which were reached during the tests.

In the Fig 4. the maximal torque values can be seen as a function of the penetration dept in case A type pin geometry. It can bee seen that the torque is basically increasing with deeper penetration but not as monotonously as the penetration - heating time correlation. Probably the deviation of the creation and the torsion test could has an effect at the same time. In this setting the 3 mm deep penetration caused at lest 3 Nm maximal torque. It will be the basic value and the other cases will be compared with this one in order to determine the way where we are able to increase the maximal torque with changing steel pin geometry.

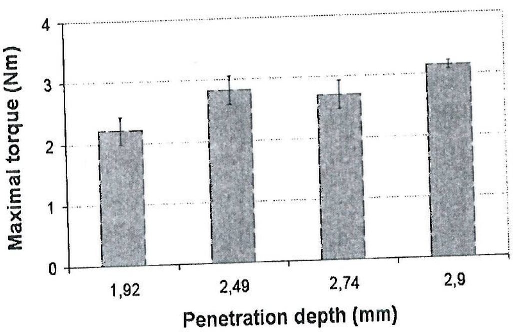


Fig. 4 Effect of penetration depth on the maximal torque (cylindrical pin)

The effect of the shape of the steel pin can be seen in Fig 5 where the laser parameters were the same. In this case the torque values does not show the expected increasing torque values. The 4 times milled concave geometry (type B) shows some increasing and the six

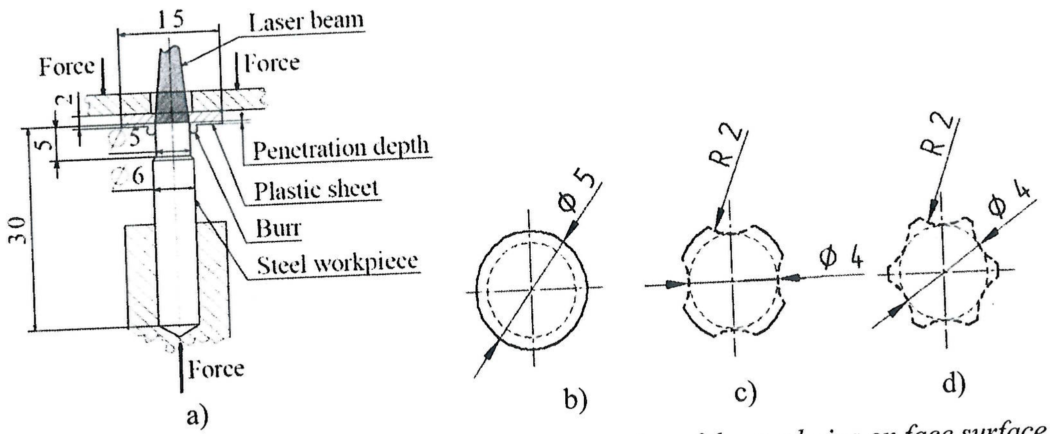


Fig. 1 Setch of experimental setting (a) and geometries of the steel pins on face surface: (b) type A, (c) type B, (d) type C

3. Results

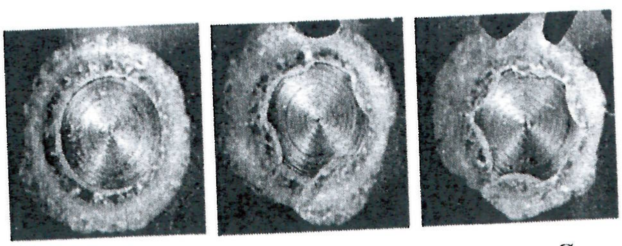
Analyzing the created pin to plate joint it can be seen that the steel pin penetrated into the plastic part depending on the heating time in a certain spot size and laser power setting. In the initial case a 5 mm laser spot size was used on a 5 mm in diameter face surface concentrically. Therefore all of the laser energy was utilized to create the joint. In this case the interaction time was 7 s. If the geometry of the steel pin was changed concave (type B and C) some part of the laser spot was lost necessarily, but these geometries give better shape locking against the torsion loads.

If not all of the laser spot heats the face surface than the efficiency of the heating becomes lower and the not used beam parts could cause problems, because this part of the beam goes out under the control.

In other hands the laser had a Gaussian power distribution. Thus the laser spot can be lost at the edges where the power is lower.

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

The front view of the created joint can be seen in Fig 2. As the pictures show the face surface of the steel pin contour are filled around with the plastic properly. Around the steel pin the burr of the PMMA is situated on the other side.



type A *type B* *type C*

Fig. 2 Front view of the joints. Photos are taken through the PMMA sheet after joining times milled concave geometry (type C) shows just higher increased average values. The increased values remain below our earlier expectations, but the torsion failures could explains this phenomena.

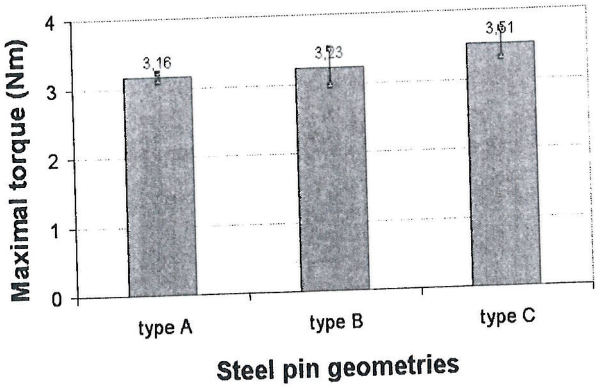


Fig. 5 Effect of the shape of the pin to the maximal torque

4. Conclusions

From the result of this research work connecting to the torsion characteristics of the pin to plate LAMP joints we can conclude that:

- With increasing heating time the penetration is higher and the deeper penetration cause higher maximal torque values.
- With the shape of the steel pin the maximal torque can be increased about 10 % but the values are really depend on the strength of the plastic sheet. Plastic sheet strength could be influenced by the sizes of the plastic material sample.

Acknowledgement

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