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Experimental Investigation of Clearance Effect on Single-lap Joint Using Blind Rivet

BEK Lukáš[1,a], KOTTNER Radek[1,b] and LAŠ Vladislav[1,c]

[1] NTIS – New Technologies for the Information Society, Faculty of Applied Sciences, University of West Bohemia, Technická 8, 301 00 Pilsen, Czech Republic

[a]lukasbek@kme.zcu.cz, [b]kottner@kme.zcu.cz, [c]las@kme.zcu.cz

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Abstract. The experimental investigation of the clearance effect influence on the stiffness and the strength of the riveted single-lap joint using a blind rivet and carbon fibre plates was performed. The investigation for two rivet diameters was performed. For each rivet diameter, samples with four different hole to rivet clearances were prepared while samples were consisting of carbon fibre plates and high strength blind rivets. The samples were loaded by tensile loading up to a failure. Measured force-displacement curves were compared and the average curves for each clearance and the rivet diameter were created.

Introduction

High stiffness and strength in connection with low density predestine composite materials to increasing use of these materials in various applications in sport, automotive, marine, and aerospace industries. Composite structures are usually composed of more composite components or connected to other non-composite parts. Therefore, proper connection must be selected in order to fulfill all requirements of the joint. Widely used joint type is the riveted joint. The possibility of the joining of different materials, low price of rivets, no required fixation of joined components after assembly, and simple creation which includes the drilling of a necessary hole and application of a rivet are the advantages of this joint [1]. However, the strength of the joint can be influenced by the clearance of a hole and a fastener. The creation of a precision hole can be expensive due to the time and a tool needed for this type of operation. Therefore, it is essential to prove whether it is necessary or not.

The clearance effect was investigated in [2], [3], [4], and [5] in case of bolted joint. All these papers concluded that the increasing clearance decreases the stiffness and the strength of the joint. Based on the similarity, this can be concluded also for high strength rivets with solid shank as Hi-Lok, Taper-Lock, Lockbolt, etc. However, the aforementioned joint requires approach from the both sides of the joint for a rivet application. Therefore, blind rivets are widely used due to place restrictions. Due to the fact that the blind rivet shank is reformed during a riveting process, there is a chance that the blind rivet is capable to fill out the clearance and to reduce the negative effect of the clearance effect observed at mentioned high strength rivets with the solid shank.

Therefore, the preparation of test samples and the experimental investigation of the clearance effect on a single-lap joint using the blind rivets were carried out in this work.

Test sample preparation

The single-lap joint test samples were consisting of two carbon fibre components and a high strength TIBULB blind rivet having a diameter of 4.8 mm or 6.4 mm. For the preparation of the carbon fibre components, plates were manufactured by the author in the autoclave ASC Econoclave. The Airbus patented Vacuum Assisted Process (VAP® [6]) was selected as a suitable manufacturing process for the production of the carbon fibre plates. Due to the use of the VAP® membrane, this process brings a benefit of the uniform resin distribution during an infusion resulting in lower material parameter variability and in nearly optimal fibre to resin volume ratio.

The manufactured plates were produced from the non-crimped fabric (NCF) Saertex with the fibres TENAX-J IMS60 E13 24K and from the epoxy resin MSG L285. The plates had the symmetrical layup [90°/0°/+45°/-45°]s. From the manufactured plates, the joint components were cut using a water jet cutter in order to obtain components having the width W=5D, the edge distance E=2D, and the length L=10D, where D denotes the rivet diameter (Fig. 1). To the length of the overall component length, 50 mm for the fixation into a universal testing machine was added. Therefore, components with the dimensions of 107.6 mm x 24.0 mm x 2.4 mm in case of the rivet diameter 4.8 mm and the dimensions of 126.8 mm x 32.0 mm x 2.4 mm in case of the rivet diameter 6.4 mm were prepared.

The hole was done by different reamers in order to produce a perfectly circular hole with the clearance of 0%, 1%, 2%, and 3% compared to the rivet diameter. For each clearance and the rivet diameter, six test samples of the single-lap joint were prepared (Fig. 2).

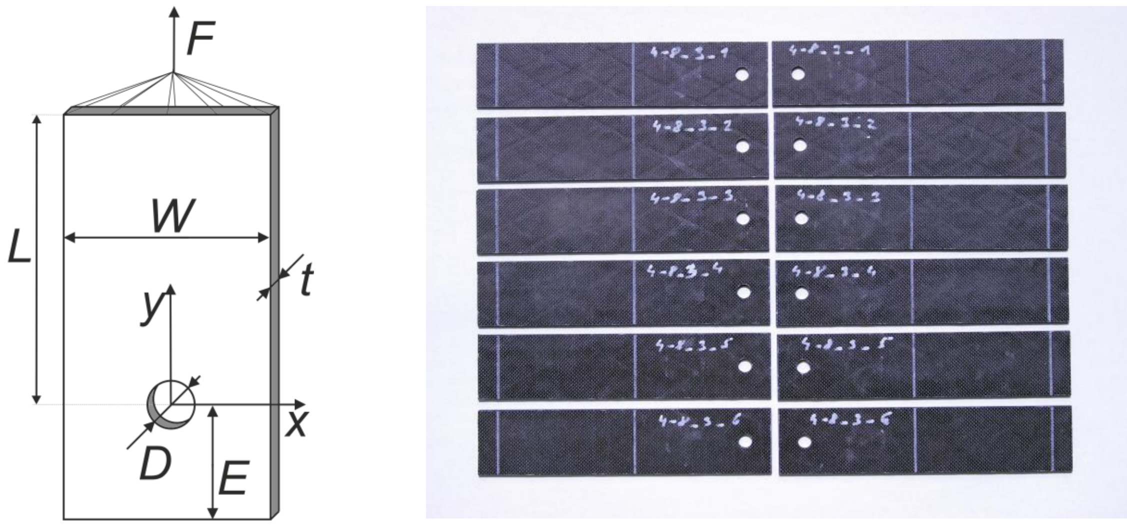

Fig. 1 Geometry of prepared carbon fibre components (left) and example of prepared set with highest hole to rivet clearance of 3% compared to rivet diameter (right)

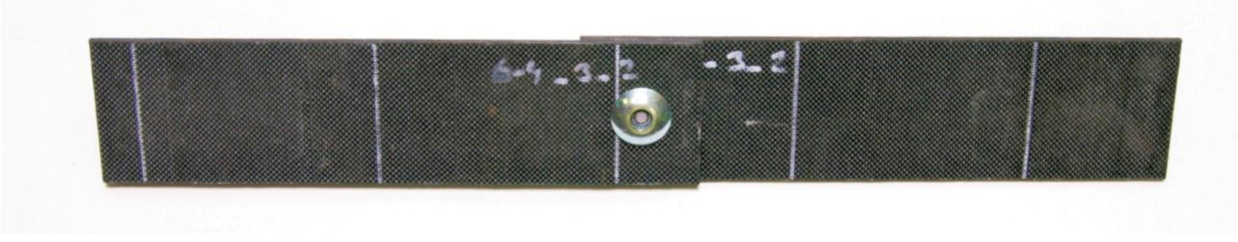

Fig. 2 Example of prepared test sample

Testing and evaluation

The test samples for each clearance were subjected to a tensile loading using the universal testing machine Zwick/Roell Z050. The displacement controlled loading with the constant head speed of 2 mm/min was used. The load was measured using a load cell and the displacement of the sample was measured using an extensometer. The gage length was set to 60 mm. All samples were loaded up to a failure which was determined as the full failure of the joint or the 80% drop of the loading force compared to the ultimate force. In total, 48 tests were performed.

The results for each hole to rivet clearance were statistically evaluated (see Table 1 and Table 2) and the average force-displacement curves were determined (Fig. 3 thru Fig. 6 and Fig. 8 thru Fig. 11). The average force-displacement curves for each hole to rivet clearance were compared (Fig. 7 and Fig. 12). The stiffness and the strength of the joint were main scopes for the evaluation.

Tab.1 Results for samples with rivet diameter 4.8 mm

	Ultimate force [N]			
Sample number	**Clearance 0%**	**Clearance 1%**	**Clearance 0%**	**Clearance 3%**
1	3605.5	3699.6	3953.8	3742.9
2	3847.1	3814.1	3736.7	3826.1
3	3549.4	3788.4	3774.8	3776.4
4	3731.0	3747.2	3904.6	3569.7
5	3737.6	3765.9	3534.1	3837.5
6	3753.5	3651.4	3865.5	4025.5
Average [N]	**3704.0**	**3744.4**	**3794.9**	**3796.3**
St. dev. [N]	**108.1**	**59.9**	**151.0**	**148.1**
COV [%]	**2.9**	**1.6**	**4.0**	**3.9**
B-basis [N]	**3379.0**	**3564.3**	**3340.7**	**3351.0**

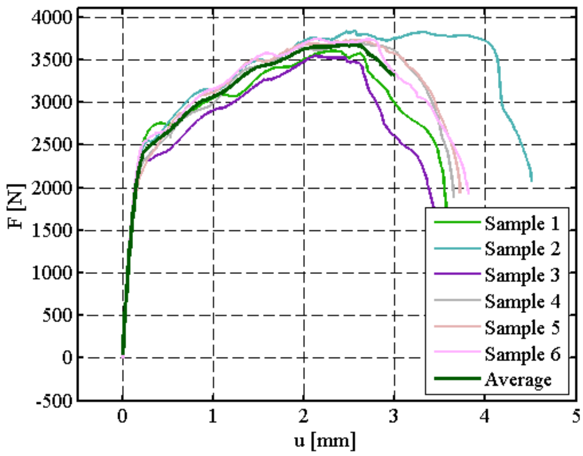

Fig. 3 Force-displacement curves for samples with rivet diameter 4.8 mm and hole to rivet clearance of 0%

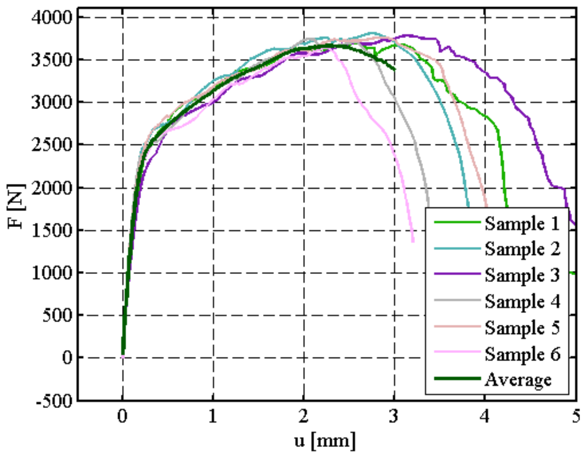

Fig. 4 Force-displacement curves for samples with rivet diameter 4.8 mm and hole to rivet clearance of 1%

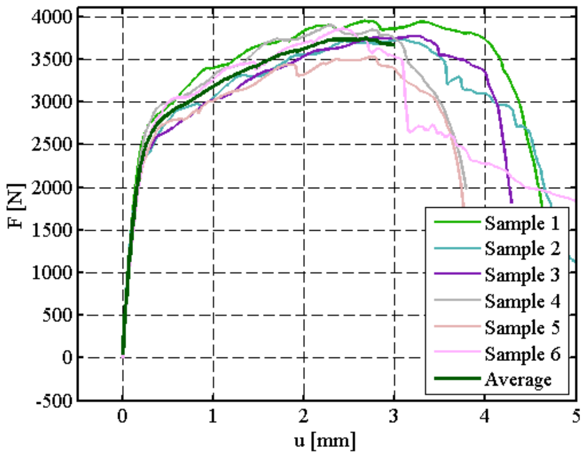

Fig. 5 Force-displacement curves for samples with rivet diameter 4.8 mm and hole to rivet clearance of 2%

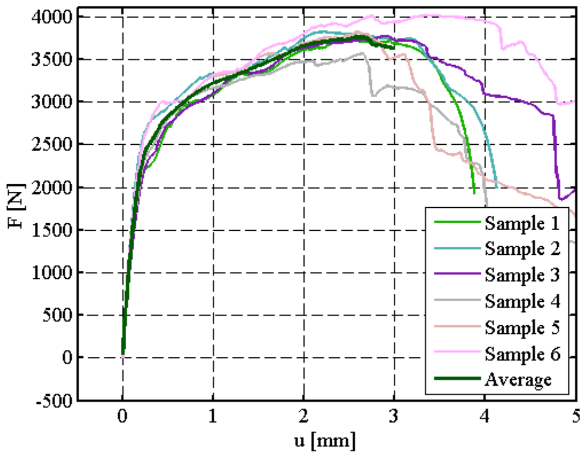

Fig. 6 Force-displacement curves for samples with rivet diameter 4.8 mm and hole to rivet clearance of 3%

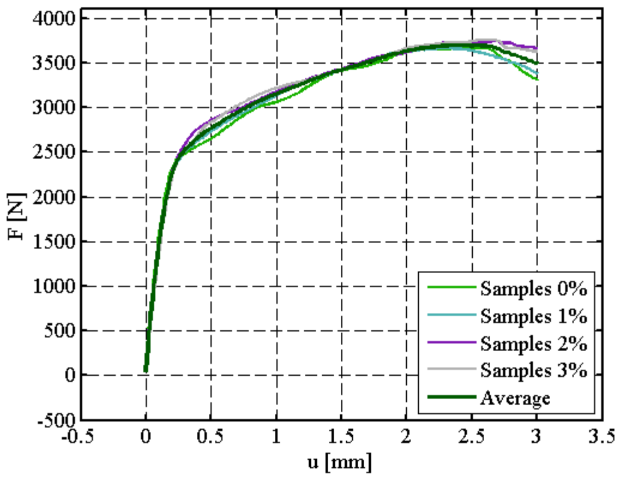

Fig. 7 Average force-displacement curves for samples with rivet diameter 4.8 mm and hole to rivet clearances of 0%, 1%, 2%, and 3%

Tab. 2 Results for samples with rivet diameter 6.4 mm

	Ultimate force [N]			
Sample number	**Clearance 0%**	**Clearance 1%**	**Clearance 2%**	**Clearance 3%**
1	6547.3	6842.1	6883.9	6541.4
2	6659.1	6079.8	6939.0	6471.4
3	6812.8	5948.0	6804.1	6625.5
4	6403.8	6701.7	6134.9	6853.3
5	6519.1	5584.3	6547.5	6876.0
6	6229.0	6417.2	6266.2	6335.4
Average [N]	**6528.5**	**6262.2**	**6595.9**	**6617.2**
St. dev. [N]	201.8	478.5	336.9	214.1
COV [%]	3.1%	7.6%	5.1%	3.2%
B-basis [N]	**5921.7**	**4823.3**	**5582.8**	**5973.4**

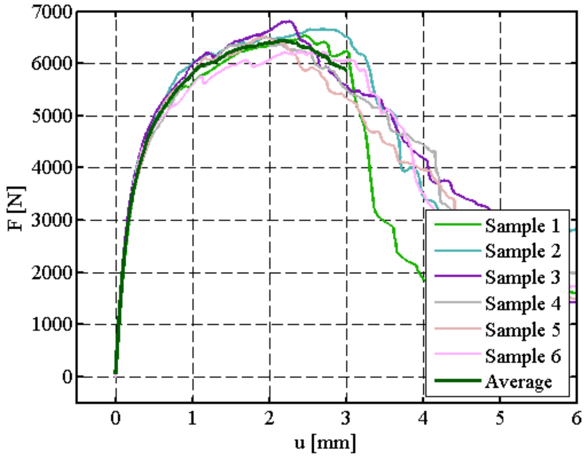

Fig. 8 Force-displacement curves for samples with rivet diameter 6.4 mm and hole to rivet clearance of 0%

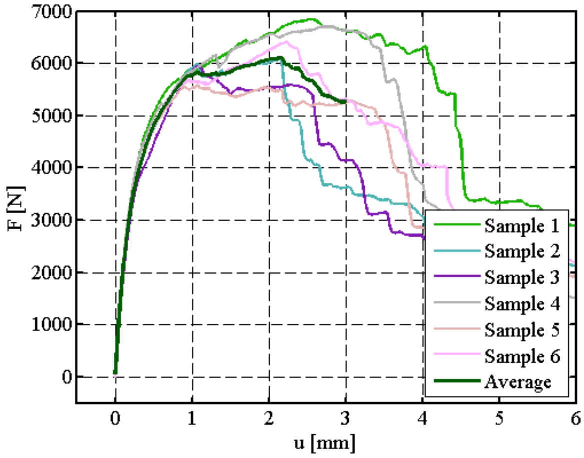

Fig. 9 Force-displacement curves for samples with rivet diameter 6.4 mm and hole to rivet clearance of 1%

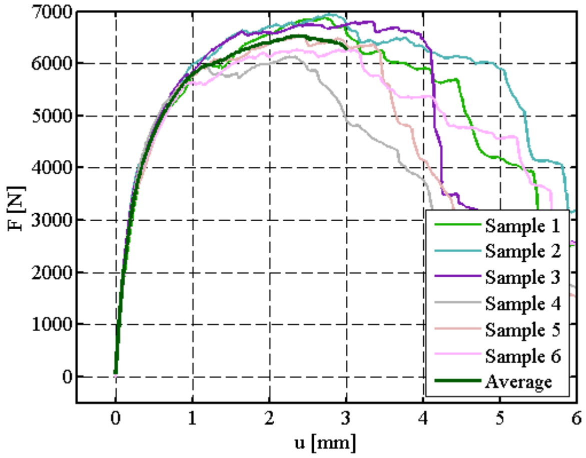

Fig. 10 Force-displacement curves for samples with rivet diameter 6.4 mm and hole to rivet clearance of 2%

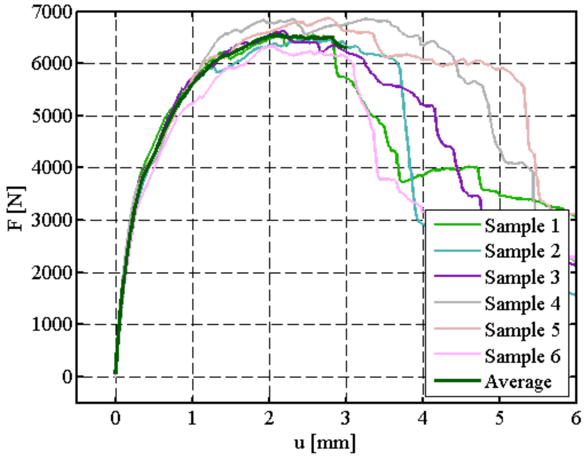

Fig. 11 Force-displacement curves for samples with rivet diameter 6.4 mm and hole to rivet clearance of 3%

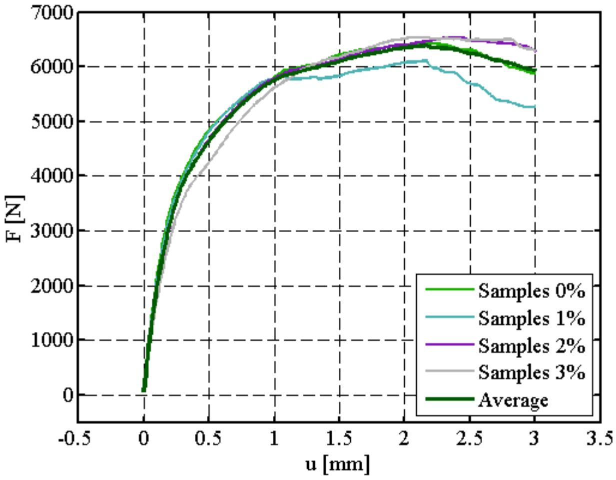

Fig. 12 Average force-displacement curves for samples with rivet diameter 6.4 mm and hole to rivet clearance of 0%, 1%, 2%, and 3%

Result discussion

In case of the samples having the rivet diameter of 4.8 mm, it was observed that the failure occurs in two modes. 15 samples failed due to a rivet failure, 9 samples failed due to the composite bearing. However, the failure mode did not have the influence on the measured ultimate force. The comparison of the average ultimate forces for each hole to rivet clearance (Table 1) proved that there is a negligible difference. The difference between the highest and the lowest average ultimate force was 2.4%.

In case of the samples having the rivet diameter of 6.4 mm, all samples failed due to the composite bearing. The comparison of the average ultimate forces for each hole to rivet clearance (Tab. 2) proved that there is the negligible difference as well. The difference between the highest and the lowest average ultimate force was 5.4%. However, this number is strongly influenced by the pure result of the sample 5 from the set of the samples having the hole to rivet clearance of 1%. Due to the significant difference compared to other samples, it could be determined as an outlier. In case of the removal of this sample, the difference between the highest and the lowest average ultimate force would be 3.3%.

From the comparison of the average force-displacement curves (Fig. 7 and Fig. 12), it can be concluded that the hole to rivet clearance have the influence neither to the strength of the joint, nor to the shape of the force displacement curve.

Conclusion

Series of experiments with the riveted single-lap joint using a blind rivet for joining of carbon fibre plates was performed in order to investigate the influence of the clearance effect on the joint behavior and the tensile strength. Based on the rivet diameter, two failure modes were observed. Based on the comparison of the measured force-displacement curves and the investigated ultimate forces, it was concluded that the clearance effect did not occurred at the blind rivets which is in contradiction with the conclusion made in literature for the high strength rivets with the solid shank.

Acknowledgement

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References

[1] H. Schürmann, Konstruieren mit Faser-Kunststoff Verbunden. Springer Verlag, Berlin, Heidelberg, New York, 2007.

[2] C. T. McCarthy, M. A. McCarthy, Three-dimensional finite element analysis of single-bolt, single-lap composite bolted joints: Part I - model development and validation. Composite Structures, Vol. 71, 2005.

[3] M. A. McCarthy, C. T. McCarthy, Three-dimensional Finite element analysis of single-bolt, single-lap composite bolted joints: Part II - effects of bolt-hole clearance. Composite Structures, Vol. 71, 2005.

[4] T. Ireman, Three-dimensional stress analysis of bolted composite single-lap joints. Composite Structures 43, Elsevier, 1998.

[5] M. A. McCarthy, C. T. McCarthy, Finite element analysis of the effect of clearance on single-shear, composite bolted joints. Journal of Plastics, Rubber and Composites, 2003.

[6] Information on: http://www.vap-info.com.