Comparison of Rivet Hole Expansion for Protruding Rivets; Universal and with Compensator

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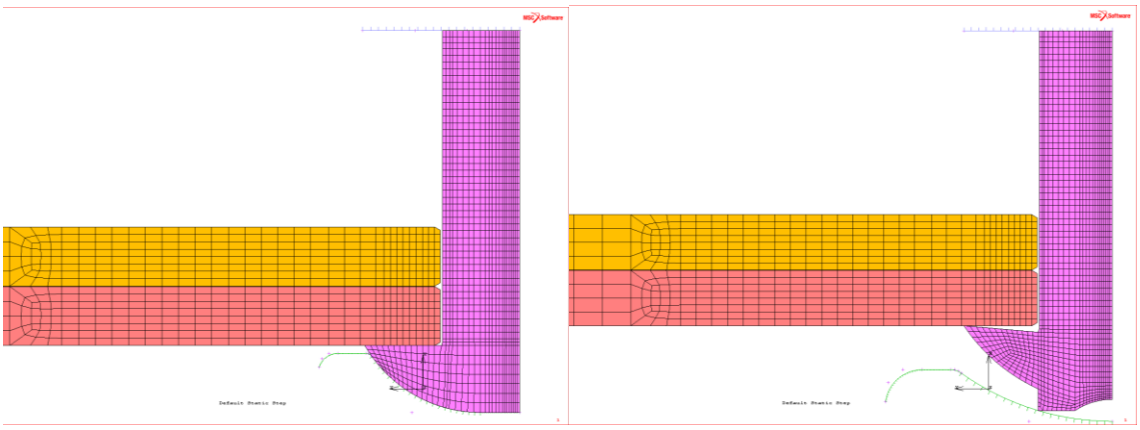
Fatigue is one of the main reasons for airframe failure and cracks initiate very often near rivet holes [1]. Although knowledge about fatigue in riveted joints has been significantly improved since the Aloha airlines incident, failures related to fatigue cracks along such joint still happened [2]. Riveting technology influence strongly fatigue of joint and a number of cycles to failure can vary more than twenty times for the same joint and load [3]. One of the most influencing factors is a squeezing force level. During riveting, a rivet shank fills a hole and deforms sheets by expanding a hole. If the force is high enough, compressive radial and tangential stresses are generated around a hole [4]. It is the same phenomena as in calibration (cold working) process used to increase a fatigue life of elements with holes. The hole expansion, defined as an increase of a hole diameter divided by an initial hole diameter, is the parameter that characterizes the degree of cold working. It can be used to assess a quality of a joint [4] or even to estimate (together with other parameters) its fatigue life [5].

The paper presents the numerical analysis of the hole expansion during riveting for two types of protruding rivets, namely the universal rivet according to the MS20470 standard and the brazier rivet with a compensator according to the Russian branch standard OST 1 34040-79. The analyzed joint consists of two sheets with a thickness of 1.5 mm made of the 2024-T3 alloy and the rivet with a diameter of 4 mm made of the 2117-T4 alloy. FE simulations of a quasi-static riveting were performed with the use of the axisymmetric models. Figure 1 presents the central part of the models.



a) b)

Figure 1. Central part of FE models of joints, a) universal rivet, b) rivet with compensator

The compensator is a small protrusion on the rivet head which is pressed into it during installation. This concept improves the hole expansion on the manufactured head side and increases fatigue life of a joint [6].

Figure 2. presents the results of the performed FE simulations. The hole expansion under the driven head ($z/t \approx 2$) is on the similar level for both cases, while under the manufacture head ($z/t \approx 0$) the rivet with a compensator caused much higher expansion. At the mating surface ($z/t \approx 1$) expansion is significantly higher also for this rivet type, what is important since this is usually a critical area, where fatigue cracks initiate. Another advantage of the rivet with a compensator is the fact, that the hole expansion is much more uniform along the thickness.

Rivets with a compensator were developed for the another alloy (Polish PA25/Russian W65) and lower squeezing force. Probably, a further improvement of its characteristic is possible by optimization its geometry for configuration typical for commonly used rivets. The presented analysis as well as results of fatigue tests [6] convince the author that the concept of rivet with a compensator has significant potential to improve fatigue properties of joints practically without increasing costs.

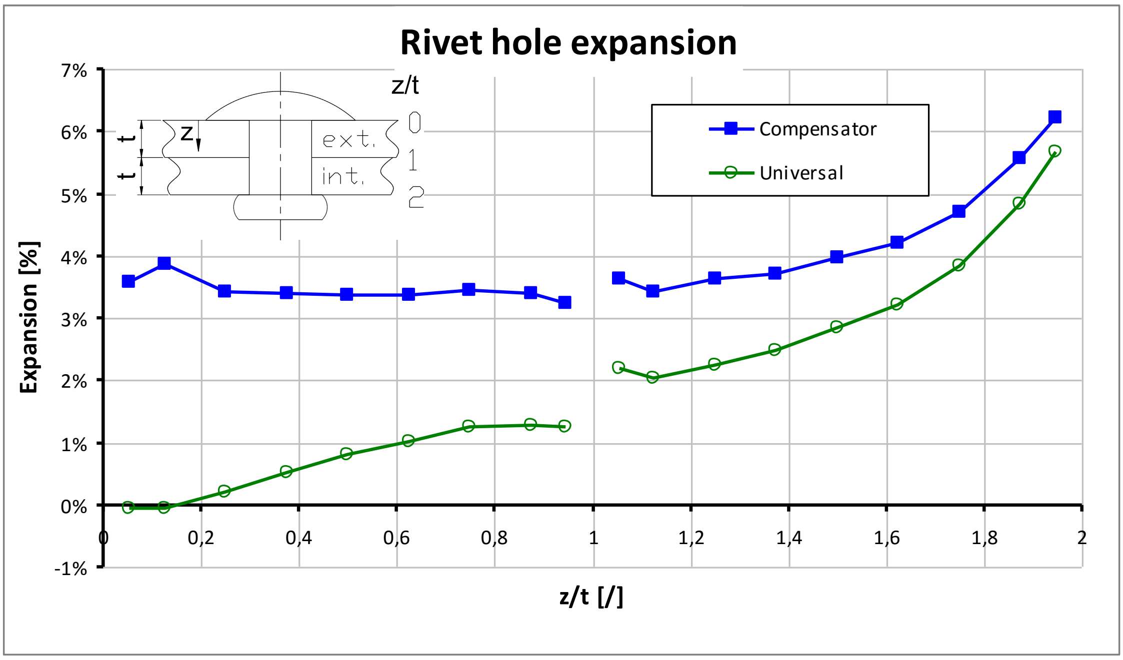


Figure 2. Rivet hole expansion for analysed rivet types

References:

[1] S. J. Findlay and N. D. Harrison, 'Why aircraft fail', *Mater. Today*, vol. 5, no. 11, pp. 18–25, Nov. 2002.

[2] 'Rapid Decompression Due to Fuselage Rupture, Southwest Airlines Flight 812', National Transportation Safety Board, Washington, NTSB Accident Report AAB-13-02, Sep. 2013.

[3] R. P. G. Müller and L. J. Hart-Smith, 'Making fuselage riveted lap splices with 200-year crack-free-lives', in *Fatigue in New and Aging Aircraft*, Edinburgh, Scotland, 1997, pp. 18–20.

[4] R. P. G. Müller, 'An experimental and analytical investigation on the fatigue behaviour of fuselage riveted lap joints', Delft University of Technology, Delft, 1995.

[5] M. Skorupa, T. Machniewicz, A. Skorupa, J. Schijve, and A. Korbel, 'Fatigue life prediction model for riveted lap joints', *Eng. Fail. Anal.*, vol. 53, pp. 111–123, 2015.

[6] M. Skorupa, A. Skorupa, T. Machniewicz, and A. Korbel, 'Effect of production variables on the fatigue behaviour of riveted lap joints', *Int. J. Fatigue*, vol. 32, no. 7, pp. 996–1003, Jul. 2010.

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