Analysis of Experimental Testing of Clinched Joint

MALÝ Pavel[1,a] and LOPOT František[1,b]

[1]CTU in Prague, Department of Designing and Machine Components, Technická 4, 166 07 Prague 6, Czech Republic

[a]pavel.maly@fs.cvut.cz, [b]frantisek.lopot@fs.cvut.cz

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Abstract. This paper describes the analysis of experimental testing of specimens that are two sheet metal plates connected with clinched joint. The strain gauge was used to obtain uniaxial stress in the vicinity of the clinched joint. The measurement results and specimen behavior were also analyzed with help of FE simulations.

Introduction

Clinching method signifies a developing technology for connection of sheet metal plates in different branches of industrial production. Therefore, there is a need to describe thoroughly both the clinching process and the resulting properties of the clinched joint, [1].

Method

The experimental method for testing clinched joint specimens with use of a strain gauge is described in [2].

Instrumentation and investigated set of specimens. The specimen with the strain gauge near the clinched joint was loaded in a special testing stand. The loading was applied by a hydraulic cylinder, measured by a force sensor and loading velocity was controlled by a proportional valve. The uniaxial stress on the surface was obtained with help of a strain gauge near the joint. Scheme of the specimen is in figure 1.

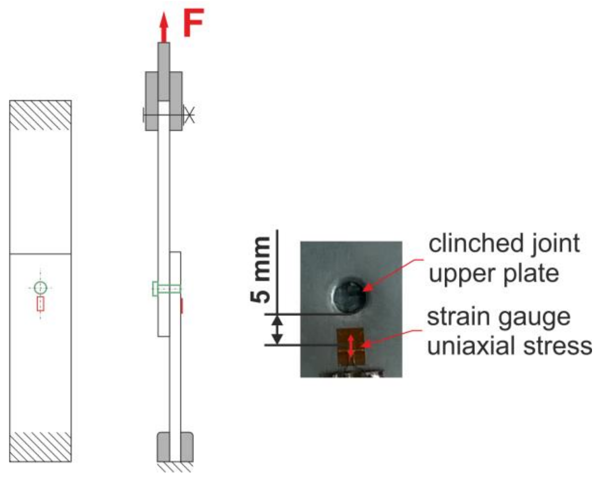

Fig.1 Scheme of the specimen with position of the strain gauge

The specimens for the testing were produced from two sheet-metal plates with thickness of 3 mm and material DX51D + Z275 that were connected with the TOX®-Clinching round point of diameter 10 mm. The shear load strength of the used clinched joint according to the specimens supplier (TOX®PRESSOTECHNIK) is 5100 N. The maximum loading during the experimental testing did not exceed this limit value of the joint shear strength.

The specimen that was subjected to the testing and analysis has the width of 40 mm, the length of both connected plates is 280 mm and the specimen is designated as 01-40.

Data analysis

Data processing was made in Matlab. The dependency of the measured data (loading force and uniaxial stress) are plotted in the graph as is shown in figure 2.

The course of the measured and processed data is specific with the loop when the loading and unloading do not have the same course. See figure 2 for the specimen 01-40 where course for different maximum loading and velocity of loading is compared. The change of slope for loading occurs in the interval of 1000 and 1500 N for testing with maximum loading more than 2000 N. The part with slope 2 during loading for testing with maximum loading of 1000 N is not so significant and occurs when reaches approximately 800 N. The testing with maximum loading of 500 N is not characteristic with the loop, the loading and unloading courses are identical.

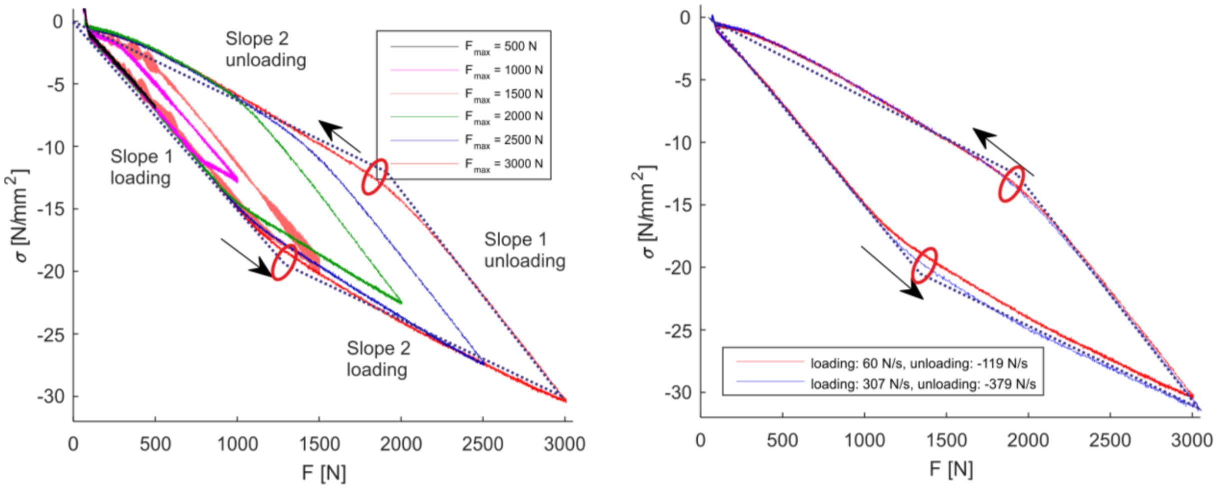

Fig.2 Processed data – comparison of magnitude and velocity of loading

The value of load when the change of the slope occurs for unloading is dependent on the maximum load. However, the sizes of slopes are identical both for loading and unloading parts of the course and therefore the loop is symmetrical and closed. This behavior can be described by the influence of the testing stand properties, additional bending of the plates or non-linear behavior of contact in the joint.

In general, the testing process was designed to be quasi-static, thus the velocity of loading was relatively small and any dynamic behavior was not expected and noticed. Anyway, measurements with different velocities of loading and unloading were conducted for the comparison of the loading velocity influence. Graphs of the results are shown in figure 2. The ratio of two velocities for loading was approx. 5 (60 N/s vs. 307 N/s) and for unloading approx. 3 (-119 N/s vs. -379 N/s). The two resulting courses of the measurement are considered to be identical, therefore the influence of the velocity of loading in the range used for experimental testing is not significant.

FEM analysis

FEM analysis in the engineering software Abaqus CAE was used to support the description of the experimental testing and measured data analysis. The complex description of the FE analysis of the clinched joint model can be found in [3]. The above mentioned bending of the specimen that is shown in figure 3 was not measured with the used testing method but it was analyzed with the help of FEM simulations

The simulation model of the specimen 01-40 uses 3D model of the clinched joint, i.e. interlock of upper and bottom plates created with use of standard hard surface-to-surface contact with friction coefficient $f = 0.1$ and tie connection. Scheme of the simulation model is shown in figure 3 where the boundary conditions and paths of the upper plate for the results analysis are specified. The starting point of the paths is marked with circle. The place of interest corresponds to the position of the strain gauge on the upper plate of the experimental specimen.

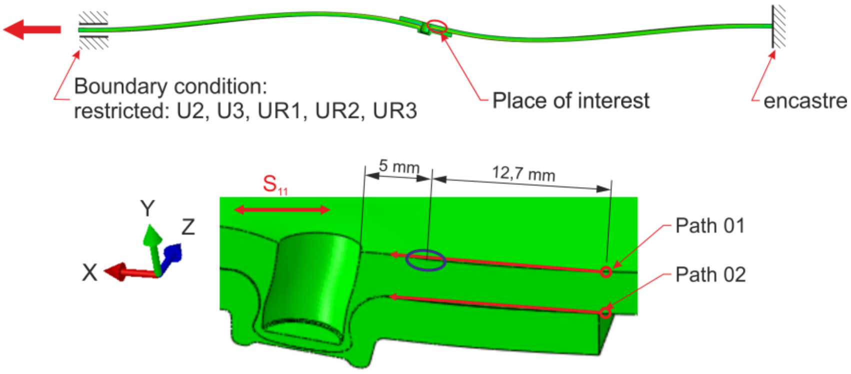

Fig.3 Simulation model with boundary conditions for FE analysis

The resultant stress in X direction (S11) along two paths of the top plate is chosen for the analysis. The detailed view on the results in the place of interest and the course of S11 value along path 01 and path 02 for corresponding loading of 3000 N are in figure 4. The unidirectional stress in the place of the strain gauge (path 01) is approximately -31 N/mm².

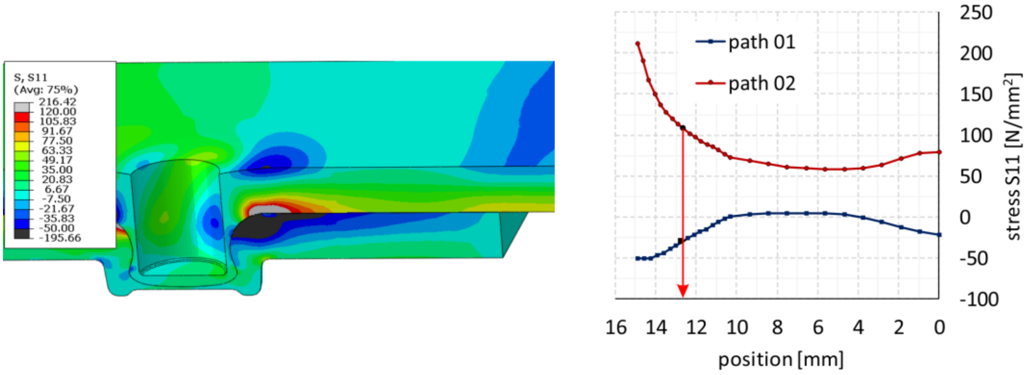

Fig.4 Results of FE simulation

The tension and bending stresses in the upper plate can be determined using the results of uniaxial stress (S11) along the two paths according to equations 1 and 2

$$S_{tension} = (S_{11(path01)} + S_{11(path02)}) / 2 \quad (1)$$

$$S_{bending} = (S_{11(path02)} - S_{11(path01)}) / 2 \quad (2)$$

The graphical representation of the tension and bending stresses is plotted in figure 5 with the marked position of the place of interest (strain gauge position). It is obvious from the FE simulation results that the stress along the upper plate is evenly distributed with the peaks near the clinched joint. The ratio of bending and tension stress ($S_{bending}$ / $S_{tension}$) changes along the upper plate in the range from 0.9 up to the 2.1. The bending stress in the upper plate is higher than tension stress at the beginning of the considered section and significant near the joint.

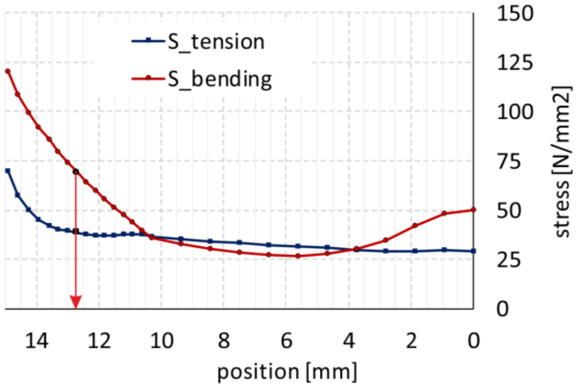

Fig.5 Tension and bending stress in the upper plate

If we focus on the FE analysis results in the specific interval in the place of interest defined with the length 2 mm (position of strain gauge ± 1 mm), the average value of tension stress is 39 N/mm² and bending stress 70 N/mm². The value of these stresses ratio is 1.8.

Conclusions

The experimental method was thoroughly described and verified by the detailed analysis of the data and with help of FE simulations that were used especially for analysis of the specimen bending. It was found out that the bending stress in the place of the strain gauge is significant, approx. 1.8 higher than tension stress. The average value of the uniaxial stress obtained by FE simulation for loading of 3000 N in the interval of 2 mm long in the place of interest (strain gauge) on the upper plate is -31 N/mm². The measured stress by the strain gauge for the same loading is approx. -29.5 N/mm². The two values correspond each other, however they are also influenced by various measurement errors and simulation configuration, e.g. boundary conditions.

The described method of experimental testing of clinched joints with uniaxial strain gauge was designed so that it could be used for further testing of complex structures connected with more clinched joints. The description of the clinched joint behavior is further subjected to the study with help of three approaches, i.e. experimental testing, FE simulations and mechanical description, [4].

References

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