LOAD DISTRIBUTION ANALYSIS IN THE CONNECTION OF THREE CLINCHED JOINTS ARRAY IN THE ROW

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Abstract
This article describes the experimental method with help of strain gauges used for testing of sheet-metal plates connection of three clinched joints in the row. The real behavior of the connection and the distribution of the total loading into each joint was observed.

Key words: *clinched joint; joints array; sheet-metal; experimental method; strain gauge*

INTRODUCTION

There are many production technologies that create structural components from sheet-metal plates. These methods are suitable and used in many industrial branches such as automotive, aerospace, or production of electric appliances and furniture. The crucial advantage is light weight with high strength at the same time. All final assemblies consist of many components, therefore suitable joining method is needed, clinching is one of those methods. This joining method is based on the plastic deformation of the base material and is characterized with many advantages. The creation of the round clinched joint is shown in figure 1. Connections of the sheet-metal parts are mainly composed of more joints so that the desired properties of the assemblies are achieved.
There are different methods how to obtain parameters of various machines elements and complex assemblies. Simulation methods represent one important group, the other one includes experimental methods. The applications of computational simulations, analysis and experimental measurement can be found in *Berka et al. 2015, Dub et al. 2014*.
This text is focused on the experimental testing of the specimen of sheet-metal plates connected by the row of three clinched joints. The experimental measurement with help of strain gauges was done to verify the analytical method, FE simulations (*Malý et al. 2015, Malý et al. 2016*) and theory of connections design described in (*Cvekl et al. 1976, Wittel et al. 2013*).

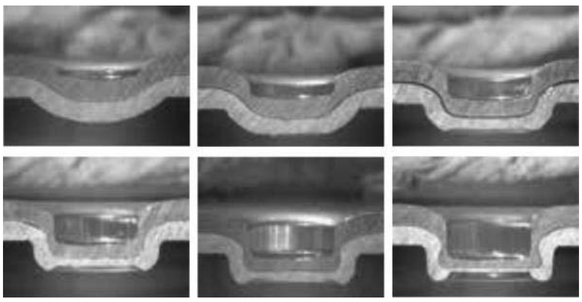

Fig. 1 Creation of the round clinched joint *(www.tox-de.com)*

MATERIALS AND METHODS

The used method was based on the experimental testing of the specimens by the unidirectional nondestructive test when the uniaxial stress near the joint is measured with help of the strain gauge, reported by *Malý 2017*.
Investigated set of specimens. The set of six specimens summarized in the table 1 was subjected to the experimental testing, Each specimen is the connection of two sheet-metal plates from low-carbon steel (1.0226) with the thickness of 3 mm and specific width (cross-section). The connection was created by the set of three equally spaced clinched joints in the row. The scheme with strain gauges notation and position with respect to the clinched joint can be seen in figure 2. Also the real sample with strain-gauges and wiring is shown in figure 2.

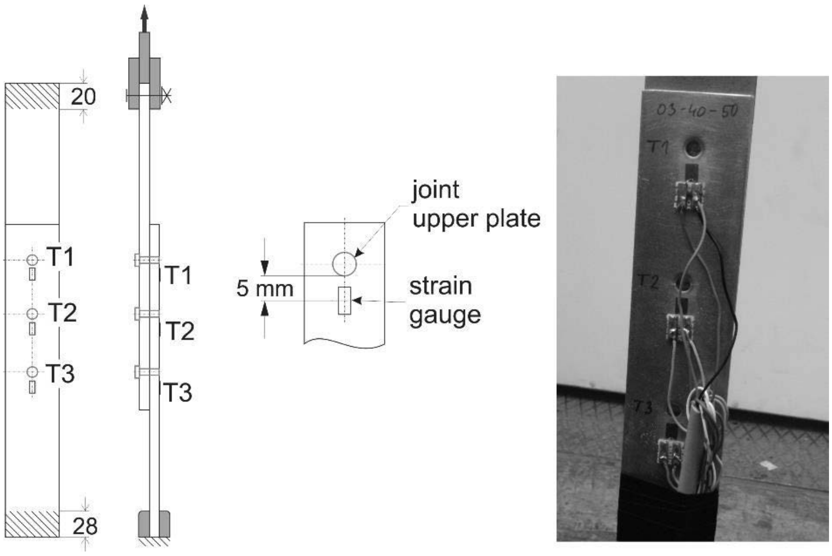

Fig. 2 Scheme and real sample of tested specimen

Tab. 1 Set of tested specimens

Specimen	Cross-section mm	Joints spacing mm
03-40-20	40×3	20
03-40-30	40×3	30
03-40-40	40×3	40
03-40-50	40×3	50
03-40-60	40×3	60
03-80-30	80×3	30

Instrumentation and measurement protocol. The detailed scheme of the testing stand that was designed and built for the realization of the testing can be seen in figure 3. The loading to the specimen was applied by a hydraulic cylinder (HM) with help of the loading system mechanism. Velocity of the hydraulic cylinder movement, i.e. velocity of the loading, was controlled by the proportional valve (PV). The actual loading force was the controlled variable and was measured by HBM force sensor (*www.hbm.cz*). The loading cycle consist of smoothly increases from 70 N to the maximum value and decreases back to the minimum value.

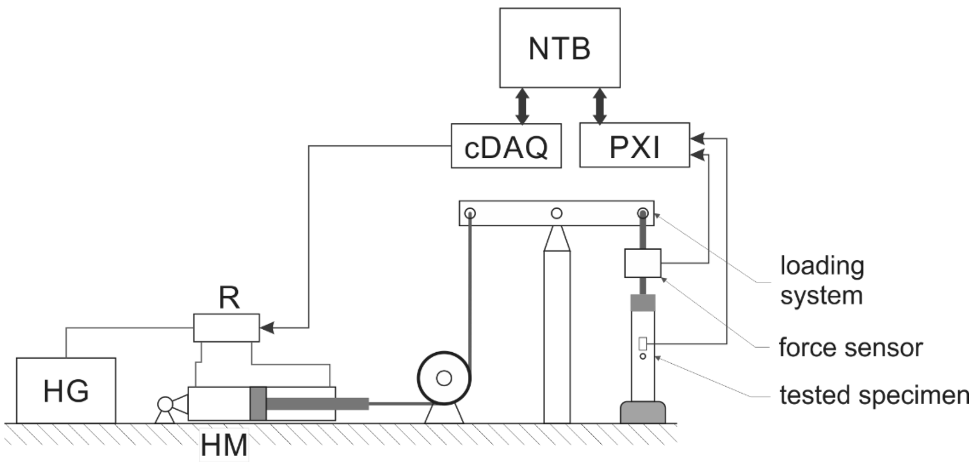

Fig. 3 Scheme of the testing stand

Data acquisition and processing. The testing equipment was controlled and the data were measured with National Instruments apparatus and LabView software (*www.ni.com*). Measured data were processed in Matlab software. Figure 4 represents the example of time dependent measured data, i.e. loading force and uniaxial stress outputs from the three strain gauges near the joints.

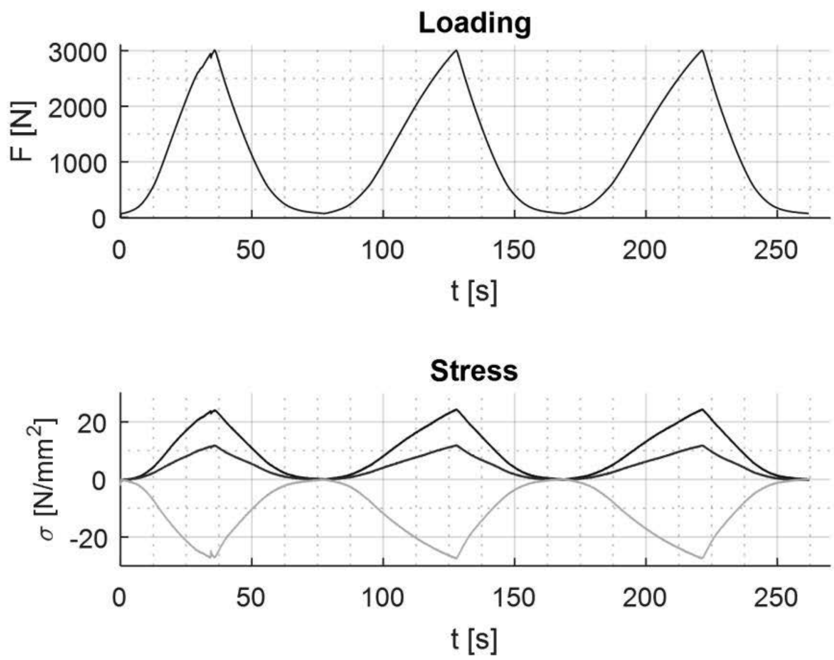

Fig. 4 Measured data

The graph in figure 5 shows the identification of dependency between loading force and measured stress for each strain gauge. It is visible the nonlinearity of the loading and unloading part of the cycle which can be explained by the influence of the testing stand properties.

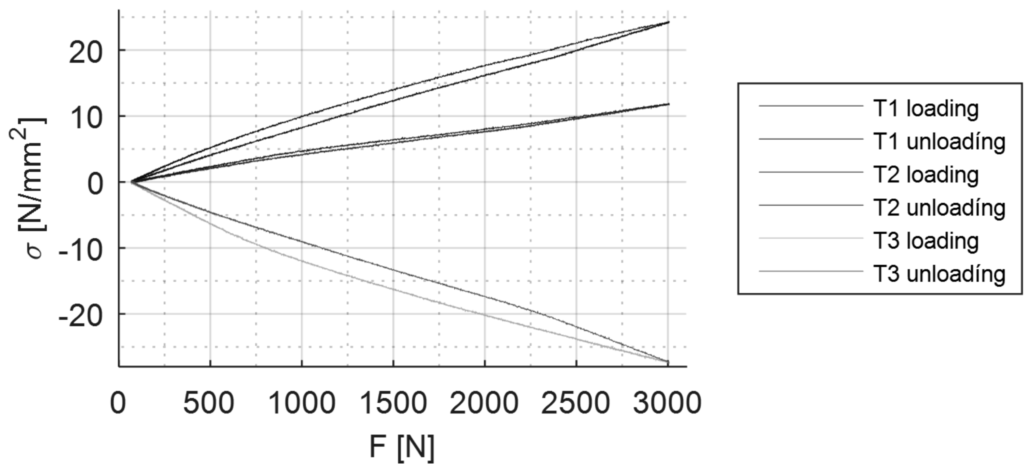

Fig. 5 Processed data

RESULTS AND DISCUSSION

The measured and processed data are summarized in table 2. The distribution of the total loading force between three joints was done assuming some simplifications and limitations of the used measurement method. The measured value from the strain gauge T3 is influenced by the additional bending of the specimen, so the assumption of the equal loading of joints T1 and T3 was used.

It is obvious from the results that the outside joints (T1 and T3) are loaded more than the inside joint (T2). This corresponds to the theoretical analytical calculations and FE simulations.

Tab. 2 Determined loading of each joint

Specimen	T1 %	T2 %	T3 %	Total loading %
03-40-20	40.13	19.75	(40.13)	100
03-40-30	39.75	20.49	(39.75)	100
03-40-40	36.72	26.56	(36.72)	100
03-40-50	36.58	26.85	(36.58)	100
03-40-60	33.97	32.05	(33.97)	100
03-80-30	38.21	24.94	(38.21)	100

CONCLUSIONS

This article describes the experimental method using strain gauges that can be used for nondestructive measurement of connections comprising from the array of single joints in the row. It is possible to obtain the load distribution between the joints in the connection with help of this method. The above described experimental method is subjected to the further verification, improvement and analysis using simulation methods.

ACKNOWLEDGMENT

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