How to cite this article:

Authors: Waldemar Witkowski, Krzysztof Kurc
Title of article: „Deformacja powierzchni blachy górnej połączeń typu clinching", („Shape deformation of the clinching joints upper sheet")
Mechanik, Vol. 91, No. 3 (2018): pages 253-255
DOI: https://doi.org/10.17814/mechanik.2018.3.42

Shape deformation of the clinching joints upper sheet

Deformacja powierzchni blachy górnej połączeń typu clinching

WALDEMAR WITKOWSKI
KRZYSZTOF KURC *

The paper presents the results of the experimental studies of the clinching joints upper sheets shape deformation. In the joint forming process a one punch and different die were used. The numbers of movable segments were: two, three and four.
KEYWORDS: clinching, ATOS IIe optical scanner, 3D measurement of clinching joint shape

In the case of thin-walled elements and structures, apart from a wide range of conventional bonding techniques (riveting, welding, welding, gluing, soldering, screw connections [1-4]), modern joining methods are also available, e.g. by friction welding [5, 6] or plastic deformation of joined elements in the cold (including so-called clinching) [7-11]. The choice of connection type depends on a number of factors - material, strength and technological - and the type and purpose of the structure being assembled.

The basic parameter determining the connection is the maximum force transmitted through the connector. The magnitude of this force can be determined in various ways (with the use of experimental studies, analytical formulas or numerical tests) [12-14].

Forming the embossing causes a bulging of the joined sheets on one side (from the matrix side) - the use of a flat matrix [15] is an exception. From the side of the stamp, a depression is created. The range of the deformation area of the upper plate in the place of the consolidation depends on the shape of the forming tools and the pressure of the joined elements. Lack of pressure or its inadequate value results in significant bending of the sheets in relation to the correct integration process. The range of the deformation area of the plates during SPR technology (self-piercing riveting) was presented by Cai et al. [16]. The example of the car door panel shows that it is possible to predict the deformation of the entire element due to numerical simulation. The influence of the type of joining technology (SPR, clinching) on the radial extent of deformations of joined plates outside the pressure zone was presented by Eckert and others in work [17]. Coppieters et al. [18] determined the effect of selecting additional forming tools (die scraper, clamp pressure) and their stiffness on the shape of the lock and the extent of deformation of the joined plates for connections formed by a rigid matrix. The use of segmented die matrices determines different material flow conditions to the die cut.

* Dr inż. Waldemar Witkowski (wwitkowski@prz.edu.pl), dr inż. Krzysztof Kurc (kkurc@prz.edu.pl) – Wydział Budowy Maszyn i Lotnictwa Politechniki Rzeszowskiej

The sheet material fills the space between the segment and the punch die and between the segments. For this reason, the shape of the embossing from the bottom side is more distorted than on the upper side (fig. 1).

The article presents the influence of the forming die design on the shape of the deformation of the upper plate of clinching joints. The deformation measurement was made with the ATOS IIe optical scanner (due to the possibility of using optical measurement technology in industrial conditions). Such a scanner can be integrated with the mini-pulser, the appropriately programmed movements of which allow to carry out the measurement on the production line, without having to carry or remove the element [19].

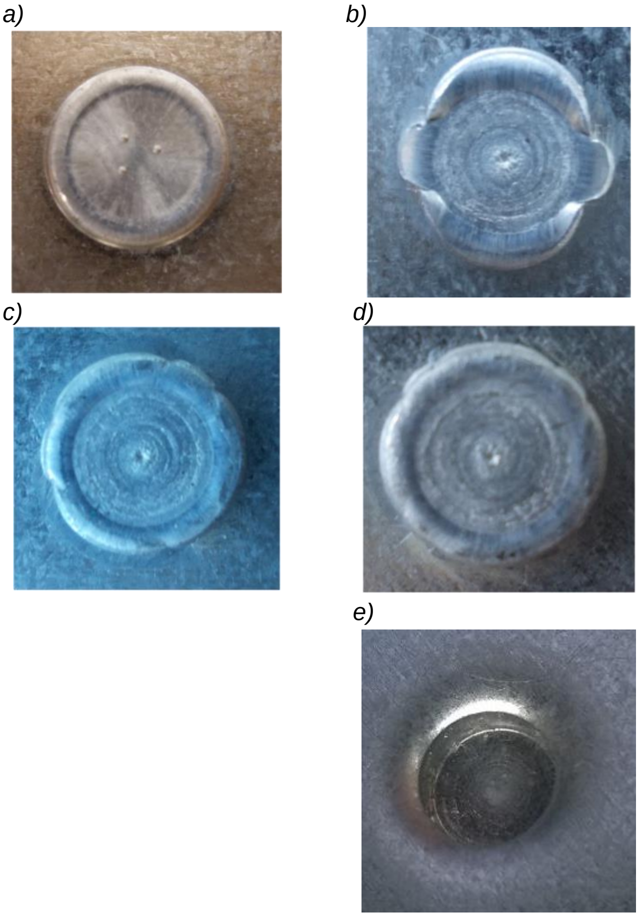

Fig. 1. View of the embossing from the bottom side and directions of measurement for a uniform matrix (a), two-segment (b), three-axis (c) and four-segment (d) and a view from the upper-plate side (e)

Scope, methodology and results of experimental research

The clinching connections were used to connect steel sheet DX51D+Z/275 (according to PN-EN 10346: 2015-09, material number 1.0226), 275 g/m² galvanized hot-dip coating with a thickness of approx. 20 μm. The dimensions of the combined samples were 50 mm × 50 mm × 1 mm (fig. 2). Strength properties and chemical composition [20] are shown in tabs. I and II.

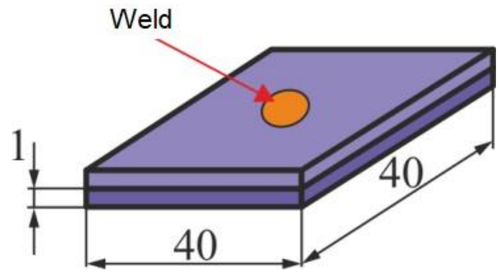

Fig. 2. Geometry of the tested sample

TABLE I. Mechanical properties of sheet DX51D+Z/275 (average values)

Sheet material	E, GPa	$R_{p0,2}$, MPa	R_m, MPa	A_t, %
DX51D	187,96	330,52	438,96	29,72
Marks: E – longitudinal elasticity coefficient (so-called Young's modulus), $R_{p0,2}$ – conventional yield strength, R_m – tensile strength limit, A_t – total elongation of the sample				

TABLE II. Chemical composition of DX51D+Z/275 sheet (maximum content in %)

Sheet material	Mn	Si	C	P	S	Ti	Fe
DX51D	0,6	0,5	0,12	0,1	0,045	0,3	Remainder

Clinching connections were made at the Press Joints Laboratory at the Department of Machine Design at Rzeszów University of Technology. A ToxPressotechnik frame press with EMPK type electric drive was used to form the joints. Technological parameters of the forming process have been defined in the press control software, as recommended by the device manufacturer.

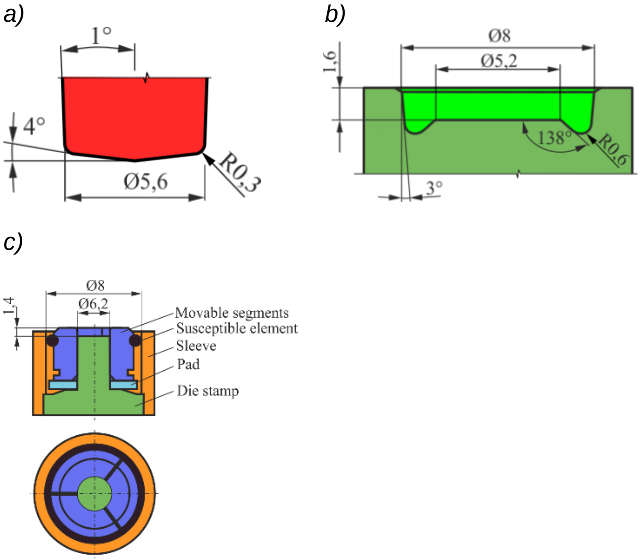

Fig. 3. Dimensions: a) punch, b) uniform die pattern, c) segment matrix

The diameter of the forming die was 5.6 mm (fig. 3a). Connections were made for a single matrix and a matrix with a segmental structure (from two, three and four segments). The depth of the bottom of the uniform matrix was 1.6 mm (fig. 3b) and segmented - 1.4 mm (fig. 3c). Due to the radial movement of the matrix segments divided at a depth of 1.6 mm, it is not possible to obtain a properly formed lock - the loss of the continuity of the bottom sheet in the place of the pass is lost. The depth of the segment matrix cut can be adjusted using washers. The inner diameter of the punch scraper (pressure sleeve) was 7.5 mm, and the outside - 14 mm.

The parameter X (minimum thickness of the bottom of the ribs) was 25% of the total thickness of the joined sheets (0.5 mm). To control the actual value of the parameter X, the Mitutoyo digital tentacle with a measuring range of 20 mm and an accuracy of 0.01 mm was used.

In the case of 40 mm × 40 mm samples, with connections placed in the middle, 3D measurements of the shape and geometry were made using the GOM ATOS IIe optical scanner (Figure 4). It works on the basis of triangulation. Two cameras of the device record the course of the bands displayed on the measured part, and the software calculates with high accuracy the coordinates of the point for each pixel. The measuring area is 150 mm × 150 mm, resolution - 5 million pixels, and measurement accuracy - 0.0002 mm.

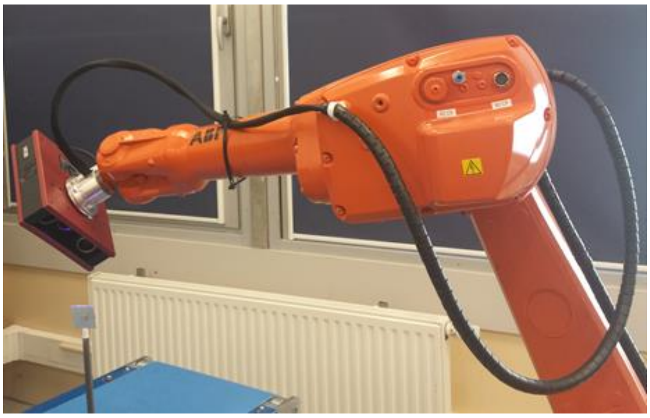

Fig. 4. Measurement of the outline of the embossment using the optical method

Fig. 5 presents the results of optical measurements of CL connections formed with parameter X equal to 0.4 mm and 0.5 mm. In the case of a uniform die, the change of the minimum thickness of the bottom of the embossing does not significantly affect the extent and size of the deformation of the overpressure profile in the upper sheet.

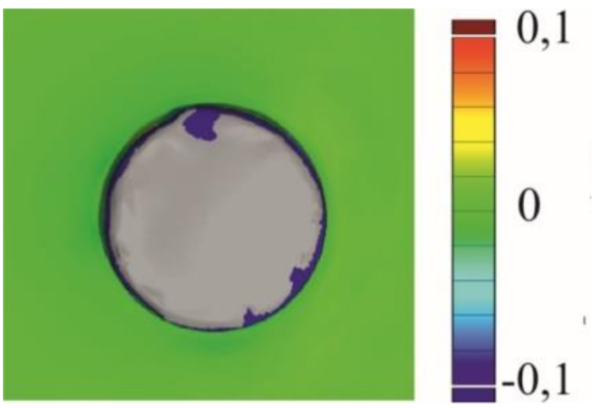

Fig. 5. Deviation from the surface of the upper plate of the CL connector for the parameter X equal to 0.4 and 0.5 mm (punch diameter d = 5.6 mm, material DX51D)

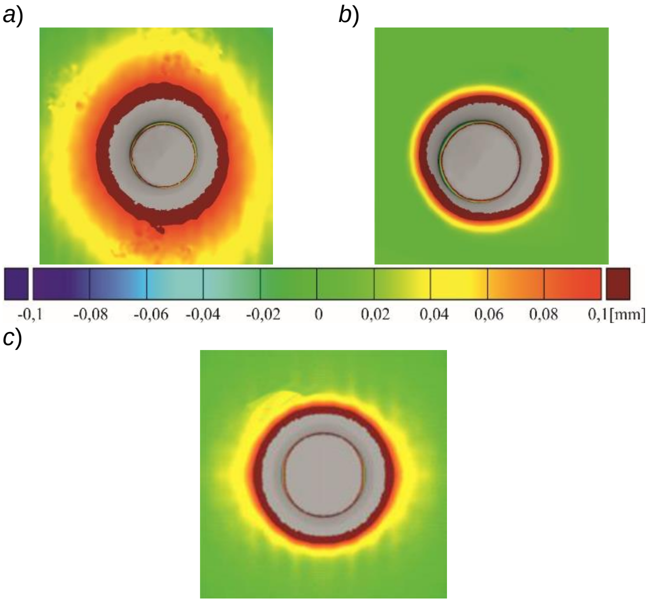

Fig. 6. Deviation of the surface of the upper sheet of the CL joint formed with divisible dies (punch diameter d = 5.6 mm, die cut depth h = 1.4 mm, X = 0.5 mm): a) two-segment, b) three-segment, c) four-segment - in relation to a single-matrix matrix (d = 5.6 mm, h = 1.6 mm, X = 0.5 mm)

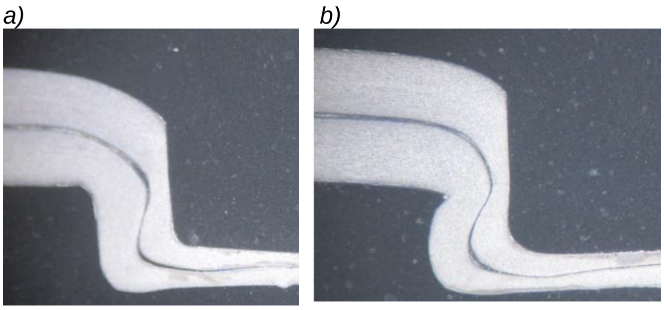

Fig. 7. The deformation shape of the upper plate for the matrix: a) uniform, b) two-segment

The change of the contour deformation area can be obtained by using split matrices (fig. 6 and fig. 7).

The matrix segments in the initial phase block the free flow of material to the blank, which prevents significant deformation of the top sheet. The diameter of the matrix die in the initial forming phase is the same as the die diameter of the die. Increasing the pressure of the forming die causes radial movement of the segments, whereby the material of the joined plates fills the space between the die stamp and the segments and the spaces between the segments. The inner diameter of the scraper was smaller than the diameter of the uniform matrix die. The pressure of the sheet metal sleeve during the forming of the matrix is carried out on the surface of the segments.

Increasing the number of segments changes the shape of the deformation area of joined plates from elliptical (for two segments) to circular (for four segments) - as in the case of a fixed matrix. This is due to the smaller volume of material filling the space between the segments.

Conclusions

The deformation of the top sheet in the area of the consolidation depends on the type of die used to form the clinching joints. For a uniform die with a constant punch diameter d = 5.6 mm, the change in the minimum depth of the transfer floor does not affect the extent of deformation. Segment matrices in the initial forming phase of the joint allow the sheet material to flow only along the extrusion axis. Increasing the forming force causes the radial movement of the segments and the filling of the space between the segments and between the segments and the die stamp. The greater the number of moving segments, the deformation of the top sheet near the scanning is more reminiscent of the shape obtained for the uniform matrix.

REFERENCES

1. Barnes T.A., Pashby I.R. "Joining techniques for aluminium spaceframes used in automobiles: Part II — adhesive bonding and mechanical fasteners". *Journal of Materials Processing Technology.* 99, 1–3 (2000): s. 72–79.
2. Dilthey U., Stein L. "Challenges of joining at automotive industry because of new materials". *Science and Technology of Welding and Joining.* 11, 2 (2006): s. 135–142.
3. Dost I., Khan S.A., Aziz M. "Mechanical evaluation of joining methodologies in multi material car body". *International Journal of Advances in Engineering & Technology.* 5, 1 (2012): s. 259–268.
4. Groche P., Wohletz S., Brenneis M., Pabst C., Resch F. "Joining by forming – A review on joint mechanisms, applications and future trends". *Journal of Materials Processing Technology.* 214 (2014): s. 1972–1994.
5. Kudła K., Wojsyk K., Adamus K. „Własności złączy zgrzewanych punktowo metodą zgrzewania tarciowego z przemieszaniem FSSW i RFSSW". *Obróbka Plastyczna Metali.* XXIV, 3 (2013): s. 193–203.
6. Kluz R., Kubit A., Wydrzyński D. „Zgrzewanie punktowe blach ze stopu aluminium 7075-T6". *Technologia i Automatyzacja Montażu.* 2 (2017): s. 56–60.
7. Behrens B-A., Bouguecha A., Eckold C-P., Peshekhodov I. "A new clinching process especially for thin metal sheets and foils". *Key Engineering Materials.* 504–506 (2012): s. 783–788.
8. Busse S., Merklein M., Roll K., Ruther M., Zürn M. "Development of a mechanical joining process for automotive body-in-white production". *International Journal of Material Forming.* 3, 1 (2010): s. 1059–1062.
9. Kascak L., Mucha J., Slota J., Spisak E. "*Application of modern joining methods in car production*". Rzeszów: Oficyna Wydawnicza Politechniki Rzeszowskiej, 2013.
10. Mucha J. „Współczesne techniki łączenia cienkich blach – zaciskanie przez wytłaczanie (clinching)". *Mechanik.* 11 (2007): s. 932–939.
11. Mucha J., Witkowski W. „Możliwości łączenia przetłaczaniem blachy stalowej o grubości poniżej 1 mm". *Technologia i Automatyzacja Montażu.* 75, 1 (2012): s. 46–49.
12. Jomaa M., Billardon R. "Numerical analysis of the resistance to shear test of clinched assemblies of thin metal sheets". *Materials Processing and Design; Modeling, Simulation and Applications.* 908 (2007): s. 1123–1128.
13. Lambiase F. "Influence of process parameters in mechanical clinching with extensible dies". *International Journal of Advanced Manufacturing Technology.* 77 (2015): s. 1295–1304.
14. Mucha J., Witkowski W. "The clinching joints strength analysis in the aspects of changes in the forming technology and load conditions". *Thin-Walled Structures*. 82 (2014): s. 55–66.
15. Neugebauer R., Todtermuschke M., Mauermann R., Riedel F. "Overview on the state of development and the application potential of dieless mechanical joining processes". *Archives of Civil and Mechanical Engineering*. VIII, 4 (2008): s. 51–60.
16. Cai W., Wang P.C., Yang W. "Assembly dimensional prediction for self-piercing riveted aluminum panels". *International Journal of Machine Tools & Manufacture.* 45 (2005): s. 695–704.
17. Eckert A., Israel M., Neugebauer R., Rössinger M., Wahl M., Schulz F. "Local-global approach using experimental and/or simulated data to predict distortion caused by mechanical joining technologies". *Production Engineering Research and Development.* 7, 2 (2013): s. 339–349.
18. Coppieters S., Cooreman S., Lava P. Sol H., Van Houtte P., Debruyne D. "Reproducing the experimental pull-out and shear strength of clinching sheet metal connections using FEA". *International Journal of Material Forming.* 4 (2011): s. 429–440.
19. Bellini P., Bruno I., Nesi P. "A distributed system for computer vision quality control of clinched boards". *Real-Time Imaging*. 10, 3 (2004): s. 161–176.
20. PN-EN 10346:2015-09 Wyroby płaskie stalowe powlekane ogniowo w sposób ciągły do obróbki plastycznej na zimno – Warunki techniczne dostawy.

Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland