Fig. 12. Positions of seats during cooling, from left: L blocked, V free, L free, V blocked

Investigation of cooling process by thermovision

A very important issue for geometrical shape of seats is proper selection of cooling parameters and cooling position. This part of research was made to investigate deformation of a seat due to different storing position during cooling. Cooling was performed in environment conditions. Four cooling positions were investigated. They all are shown on Fig. 12.

The research was aimed to find out which of the position causes the smallest deviation in cold state. Measurement results are shown on the Figs. 13–16. Each of them presents deviations on a view from the top and from the left side.

Basing on these results V free position was chosen for further analysis using thermography.

Temperature distribution with a seat just after opening the mold was shown on Fig. 17 and seat during cooling on Fig. 18.

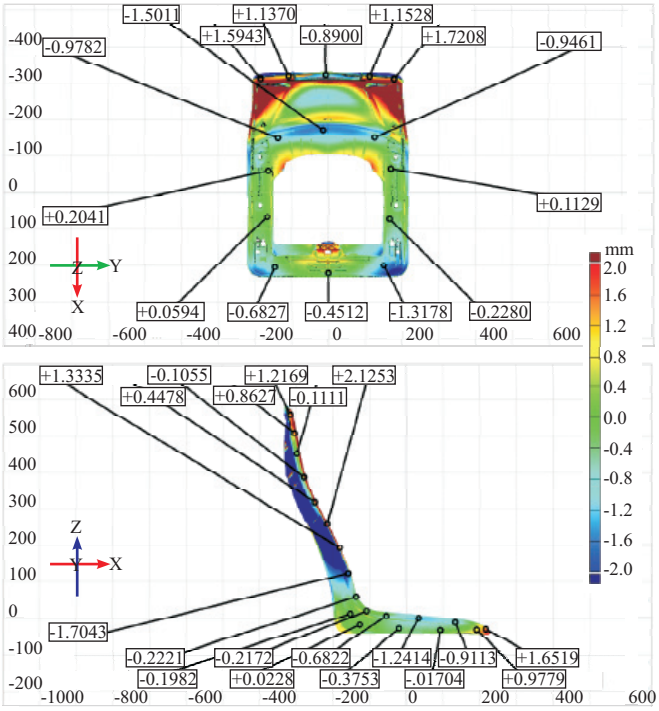

Fig. 13. Seat deviations after cooling in L blocked position

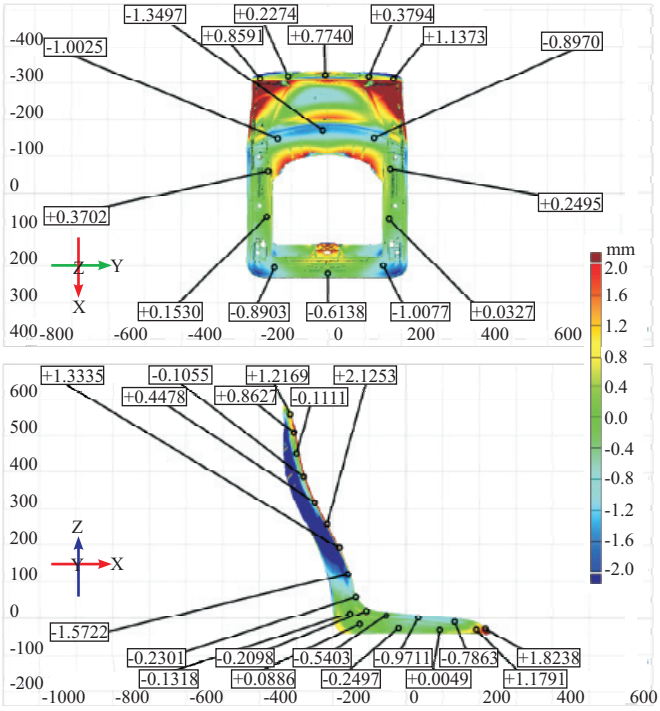

Fig. 14. Seat deviations after cooling in V free position

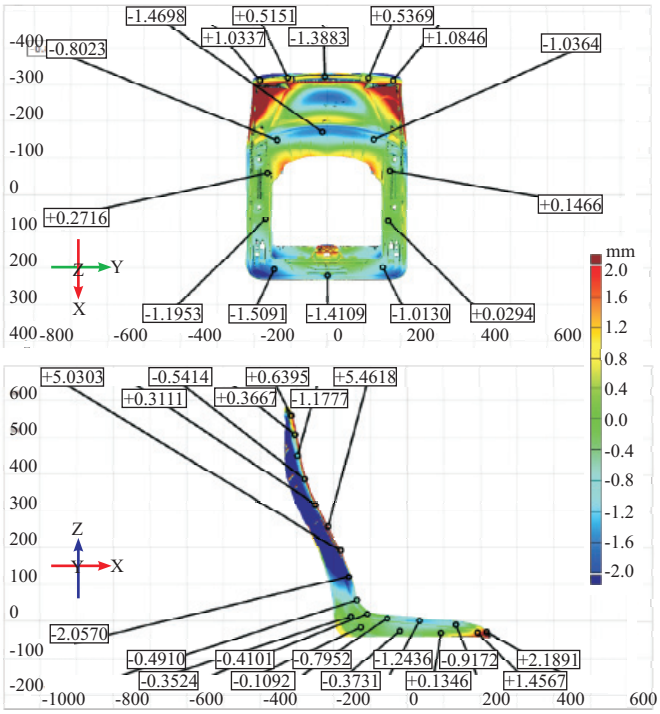

Fig. 15. Seat deviations after cooling in L free position

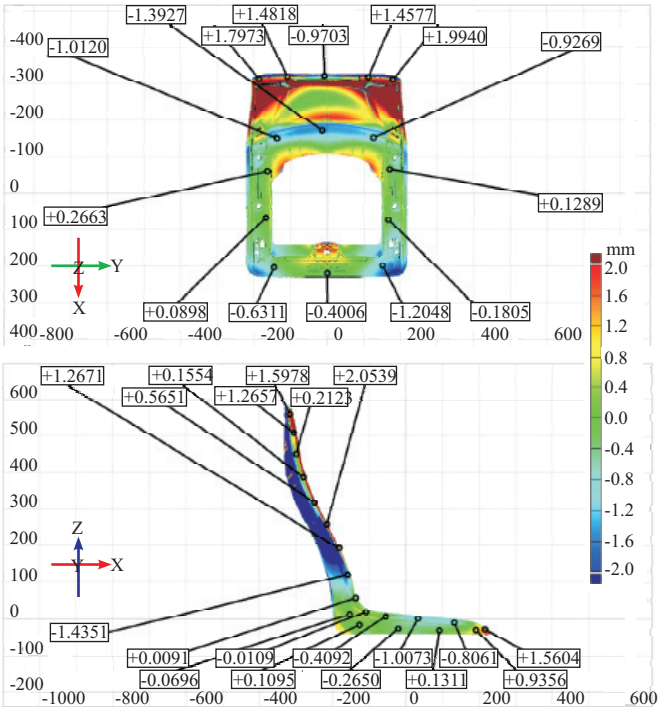

Fig. 16. Seat deviations after cooling in V blocked position

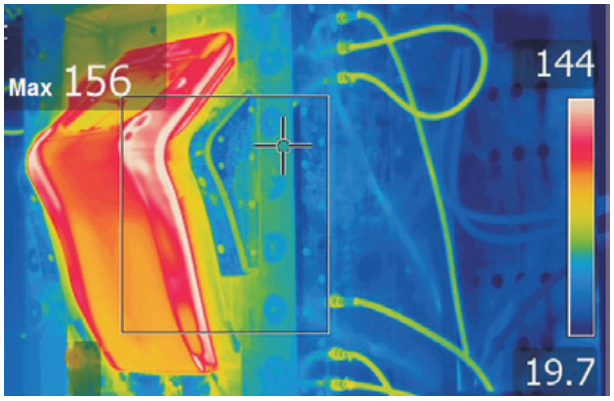

Fig. 17. Thermal analysis of mold with a seat just after opening

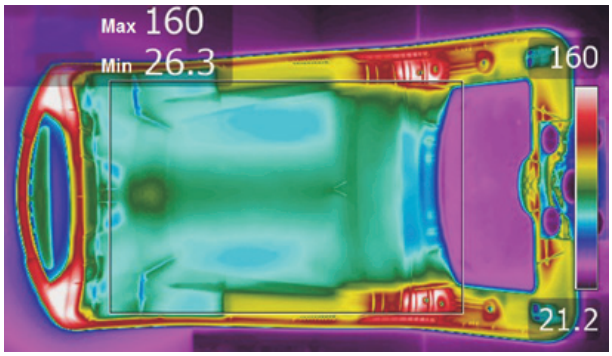

Fig. 18. Seat during cooling

CONCLUSIONS

The research performed on a plastic bus seat after injection showed how modern measurement techniques can improve manufacturing process and a product itself. Application of static and dynamic photogrammetry as examples of coordinate measuring technique gave a lot of data to analyze regarding behavior of machine and geometry of seat. Furthermore, thermography was applied in order to investigate injection and cooling process made it possible to optimize molding and to get more repeatable product and more stable production.

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REFERENCES

[1] Krolczyk G.M., Nieslony P., Maruda R.W., Wojciechowski S.: *Journal of Cleaner Production* **2017**, *142*, 3343. http://dx.doi.org/10.1016/j.jclepro.2016.10.136

[2] Gapiński B., Wieczorowski M., Grzelka M. *et al.*: *Polimery* **2017**, *62*, 53. http://dx.doi.org/10.14314/polimery.2017.053

[3] Gapiński B., Wieczorowski M., Marciniak-Podsadna L. *et al.*: *Procedia Engineering* **2014**, *69*, 255. http://dx.doi.org/10.1016/j.proeng.2014.02.230

[4] "Coordinate Measuring Machines and Systems" (Eds. Hocken R.J., Pereira P.H.), CRC Press, Boca Raton 2012.
[5] Sładek J.A.: "Coordinate Metrology. Accuracy of Systems and Measurements", Springer 2016.
[6] Oliwa R., Oleksy M., Heneczkowski M. *et al*.: *Polimery* **2017**, *62*, 36. http://dx.doi.org/10.14314/polimery.2017.036
[7] Ratajczyk E., Woźniak A.: "Coordinate Measurement Systems", Publishing House of Warsaw University of Technology, Warsaw 2016.
[8] Choi B., Shin H.Y., Yoon Y.I., Lee J.W.: *Computer-Aided Design* **1998**, *20*, 239. http://dx.doi.org/10.1016/0010-4485(88)90069-3
[9] Fang T., Piegl L.: *IEEE Computer Graphics and Applications* **1995**, *15*, 62. http://dx.doi.org/10.1109/38.364966
[10] Campbell R.J., Flynn P.J.: *Computer Vision and Image Understanding* **2001**, *81*, 166. http://dx.doi.org/10.1006/cviu.2000.0889
[11] Brajlih T., Tasic T., Drstvensek I. *et al*.: *Journal of Mechanical Engineering* **2011**, *57*, 826. http://dx.doi.org/10.5545/sv-jme.2010.152
[12] Śliwa R., Oleksy M., Markowska O. *et al*.: *Polimery* **2016**, *62*, 16. http://dx.doi.org/10.14314/polimery.2016.016
[13] Thomas S., Visakh P.M.: "Handbook of Engineering and Speciality Thermoplastics – Nylons", Willey, New York 2012.
[14] Żuchowska D.: „Polimery konstrukcyjne", WNT, Warszawa 1995.
[15] Kelar K., Ciesielska D.: „Fizykochemia polimerów – wybrane zagadnienia", Publishing House of Poznan University of Technology, Poznan 1997.
[16] Wu T.M., Liao C.S.: *Macromolecular Chemistry and Physics* **2000**, *201*, 2820. http://dx.doi.org/10.1002/1521-3935(20001201)201:18%3C2820::AID-MACP2820%3E3.0.CO;2-4
[17] Beuquel Q., Ville J., Crepin-Leblond J. *et al*.: *Applied Clay Science* **2017**, *135*, 253. http://dx.doi.org/10.1016/j.clay.2016.09.034
[18] Wunderlich B.: *Progress in Polymer Science* **2003**, *28*, 383. http://dx.doi.org/10.1016/S0079-6700(02)00085-0
[19] Lee S.S., Phillips P.J.: *European Polymer Journal* **2007**, *43*, 1952. http://dx.doi.org/10.1016/j.eurpolymj.2007.01.056
[20] Lewandowski G., Rytwińska E., Milchert E.: *Polimery* **2006**, *51*, 829.
[21] Li X., Peng Z., Yang C. *et al*.: *Journal of Crystal Growth* **2016**, *450*, 1. http://dx.doi.org./10.1016/j.crysgro.2016.05.040
[22] Murthy N.S.: *Polymer Communications* **1991**, *32*, 301.
[23] Wu T.-M., Wu J.-Y.: *Journal of Macromolecular Science, Part B: Polymer Physics* **2002**, *B41*, 17. http://dx.doi.org/10.1081/MB-120002343
[24] Hang Q., Mo Z., Hang H. *et al*.: *Polymer* **2001**, *42*, 5543. http://dx.doi.org/10.1002/polb.1990.090281315
[25] Kyotani M., Mitsuhashi S.: *Journal of Polymer Science, Part B: Polymer Physics* **1972**, *10*, 1497. http://dx.doi.org/10.1002/pol.1972.160100807
[26] Gendre L., Njuguna J., Abhyankar H., Ermini V.: *Materials and Design* **2015**, *66*, Part B, 486. http://dx.doi.org/10.1016/j.matdes.2014.08.005
[27] Liu M., Li M., Hou H., Li R.: *Polymer* **2015**, *62*, 109. http://dx.doi.org/10.1016/j.polymer.2015.02.031
[28] Khan A.N., Ahmed B.A.: *Polymer Bulletin* **2015**, *72*, 1207. http://dx.doi.org/10.1007/s00289-015-1333-4
[29] Varlet J., Cavaillé J.Y., Perez J., Johari G.P.: *Journal of Polymer Science, Part B: Polymer Physics* **1990**, *28*, 2691. http://dx.doi.org/10.1002/polb.1990.090281315
[30] Abhijit J., Bhowmick A.K.: *Polymer Degradation and Stability* **1998**, *62*, 575.
[31] Campoy I., Arribas J.M., Zaporta M.A. *et al*.: *European Polymer Journal* **1995**, *31*, 475. http://dx.doi.org/10.1016/0014-3057(94)00185-5
[32] Baschek G., Hartwig G., Zahradnik F.: *Polymer* **1999**, *40*, 3433. http://dx.doi.org/10.1016/S0032-3861(98)00560-6
[33] Drozdov A.D., Christiansen J.deC., Gupta R.K., Shah A.P.: *Journal of Polymer Science, Part B: Polymer Physics* **2003**, *41*, 476. http://dx.doi.org/10.1002/polb.10393
[34] Monson L., Braunwarth M., Extrand C.W.: *Journal of Applied Polymer Science* **2008**, *107*, 355. http://dx.doi.org/10.1002/app.27057
[35] Kelar K., Jurkowski B., Mencel K.: *Polimery* **2013**, *58*, 365. http://dx.doi.org/10.14314/polimery.2013.365

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