

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

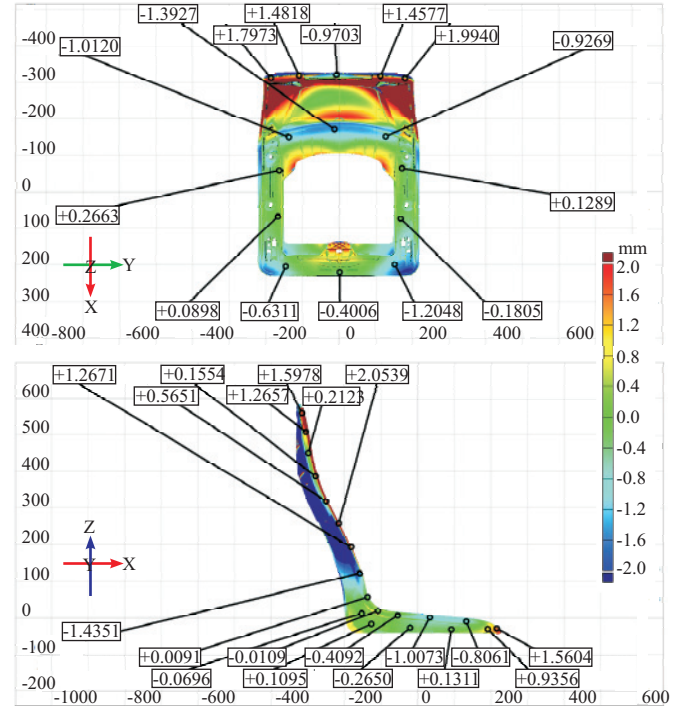


Fig. 16. Seat deviations after cooling in V blocked position

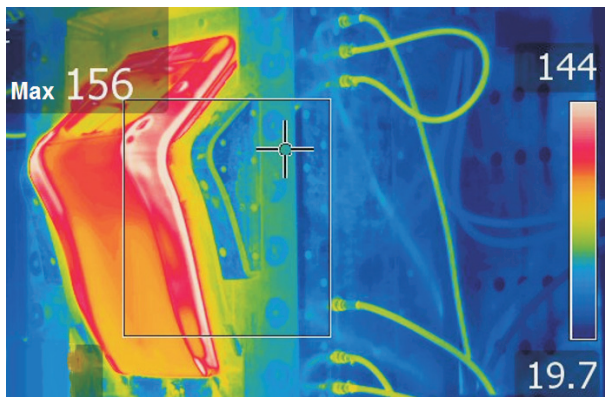


Fig. 17. Thermal analysis of mold with a seat just after opening

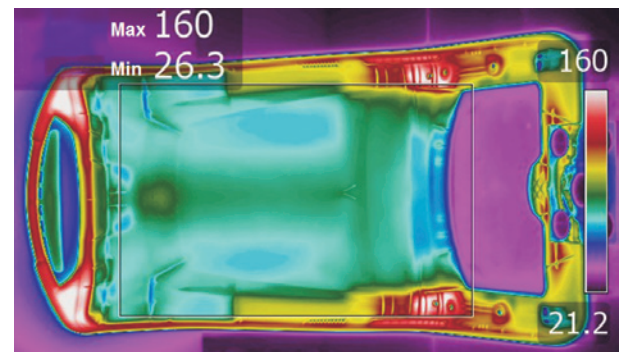


Fig. 18. Seat during cooling

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.

Part of this work was supported by the Polish National Centre of Research and Development (project contract No. Innotech In-Tech K2/IN2/58/182896/NCBR/12; "Elaboration of manu-

facturing technology of new generation ultralight seats for public transportation fulfilling requirements of UE directives, UN regulations and American White Book").

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](http://dx.doi.org/10.1016/0010-4485(88)90069-3)
- [9] Fang T., Piegł 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] Brajlilić T., Tasić 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", Wiley, 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](http://dx.doi.org/10.1002/1521-3935(20001201)201:18%3C2820::AID-MACP2820%3E3.0.CO;2-4)
- [17] Beauquel 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](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., Cavaille 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](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](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., Mencil K.: *Polimery* **2013**, 58, 365.
<http://dx.doi.org/10.14314/polimery.2013.365>

Received 10 VII 2017.