Application of coordination measuring methods for assessing the performance properties of polymer gears

(Rapid communication)

Tomasz Dziubek[1)]

DOI: dx.doi.org/10.14314/polimery.2018.1.8

Abstract: The research related to the use of coordinate measuring methods for assessing the performance properties of polymer gears has been performed. Presented work is a continuation of work on the accuracy of geometry of gears manufactured using Rapid Prototyping Methods (RP) [1]. Deformations were assessed for research models made with 3-Dimensional Printing methods PolyJet, FDM (Fused Deposition Modeling) and SLS (Selective Laser Sintering), especially for geometric deviations and shrinkage. Geometrical accuracy verification of models was performed using the ATOS II Triple Scan touchless optical system.

Keywords: polymer materials, optical scanner, geometrical accuracy, gears models.

Zastosowanie współrzędnościowych metod pomiarowych do oceny właściwości użytkowych polimerowych kół zębatych

Streszczenie: Właściwości użytkowe polimerowych kół zębatych badano z zastosowaniem współrzędnościowych metod pomiarowych. Opracowanie stanowi kontynuację prac nad dokładnością geometrii kół wytwarzanych metodami szybkiego prototypowania (*Rapid Prototyping* – RP). Deformacje oceniono w odniesieniu do modeli badawczych wytwarzanych metodami przyrostowymi PolyJet, FDM (ang. *Fused Deposition Modeling*) oraz SLS (selektywne spiekanie laserowe, ang. *Selective Laser Sintering*), zwłaszcza pod względem odchyłek geometrii oraz występowania zjawiska skurczu. Weryfikację geometrii modeli wykonano z wykorzystaniem bezstykowego systemu optycznego ATOS II Triple Scan.

Słowa kluczowe: materiały polimerowe, skaner optyczny, dokładność geometryczna, modele kół zębatych.

The accuracy of prototype gear models manufactured by Rapid Prototyping (RP), determined using coordinate measuring method, enables rapid and reliable geometric error control. The integration of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM/RP) and Coordinated Measuring Method (CMM) methods allows for a significant acceleration of the manufacturing process of high quality gear components [2–5]. Due to the accuracy of the RP devices and the assumptions concerning the digitization of the complete geometry of the research models, it is important to develop and apply the appropriate assessment methodology, as described in publications in this field [6–10], in order to shorten the assessment process.

EXPERIMENTAL PART

Materials

Materials used for the preparation of gears prototypes, respectively for the method:

1) PolyJet – FullCure720 RGD720 photopolymer resin,
2) FDM – ABSplus thermoplastic material,
3) SLS – Precimid 1170 polyamide powder.

Materials used in manufacturing processes, apart from mechanical parameters, surface structure [11] and shrinkage level, differ in terms of transparency and anti-reflective properties. The latter have a significant impact on the assessment process as well as on the preparation of assessed models.

Analysis was performed for gears, wherein the geometric parameters are: module – m = 3.5 mm, number of teeth – z = 14, pitch diameter – d = 49 mm, addendum diameter – d_a = 56 mm, face width – b = 10 mm, hole diameter – φ = 20 mm.

Coordinate measurements of gears prototypes

Prototype models, made using these additive manufacturing methods, were assessed using the touchless ATOS II Triple Scan optical system (Fig. 1).

1) Rzeszow University of Technology, Faculty of Mechanical Engineering and Aeronautics, al. Powstańców Warszawy 8, 35-959 Rzeszów, Poland, e-mail: tdziubek@prz.edu.pl

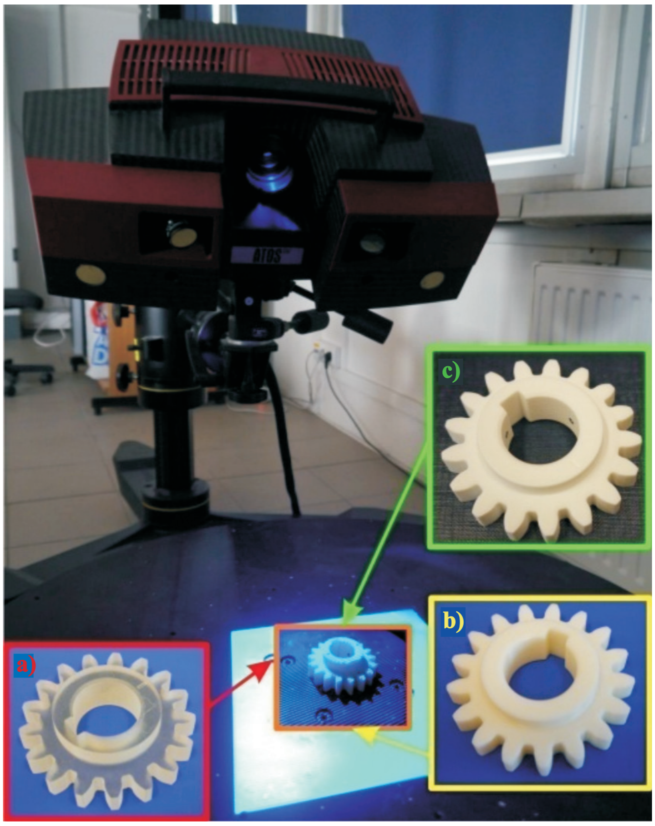

Fig. 1. Scanning gears with ATOS II Triple Scan: a) PolyJet, b) FDM, c) SLS

This process was preceded by the preparation of the assessed gears, based on the appropriate alignment of the markers on the gear geometry, in accordance with the adopted assessment strategy [3] and the elimination of light reflections made by applying the anti-reflective layer on the assessed geometry. Due to the specific structure of the surface obtained using the analyzed methods, it was necessary to apply the anti-reflective layer to the gears manufactured with FDM and PolyJet methods.

The characteristic feature of the SLS method and the Precimid 1170 material used in the process is that such components do not require anti-reflective layer. Because of the specificity of the material and the surface structure obtained, the assessment error resulting from the thickness of the applied layer is eliminated for accuracy. This also shortens the preparation time of the model to be assessed.

RESULTS AND DISCUSSION

Prototype gears obtained using additive manufacturing methods of PolyJet, FDM and SLS were subjected to the research.

The analysis of the gears manufacturing accuracy was performed using the GOM Inspect V7.5 program in the form of detailed dimensional deviations at selected points on the gear surface (Fig. 2a) and specific cross-section profiles of the gear (Fig. 2b). Due to the large volume of detailed assessment reports, only selected figures are presented here.

In the first stage, the accuracy of the PolyJet method was analyzed. On the basis of the comparison of gears made from the FullCure720 RGD720 photopolymer resin with 3D-CAD nominal models, significant dimensional differences (Figs. 2a, 2b) ranging from -0.064 to +0.069 mm can be observed.

In the next stage, the dimensional accuracy of the gears made from ABSplus thermoplastic material was assessed. In the case of gears manufactured with the FDM method, no adverse effect of the shrinkage process on the flat hub surfaces was observed (Fig. 3a). However, it was found that the gear profile geometry errors were different from those of the nominal model (Fig. 3b), which may be due to the inaccuracy of the device used.

The greatest difference in geometry accuracy was observed for the prototype gears made from Precimid 1170

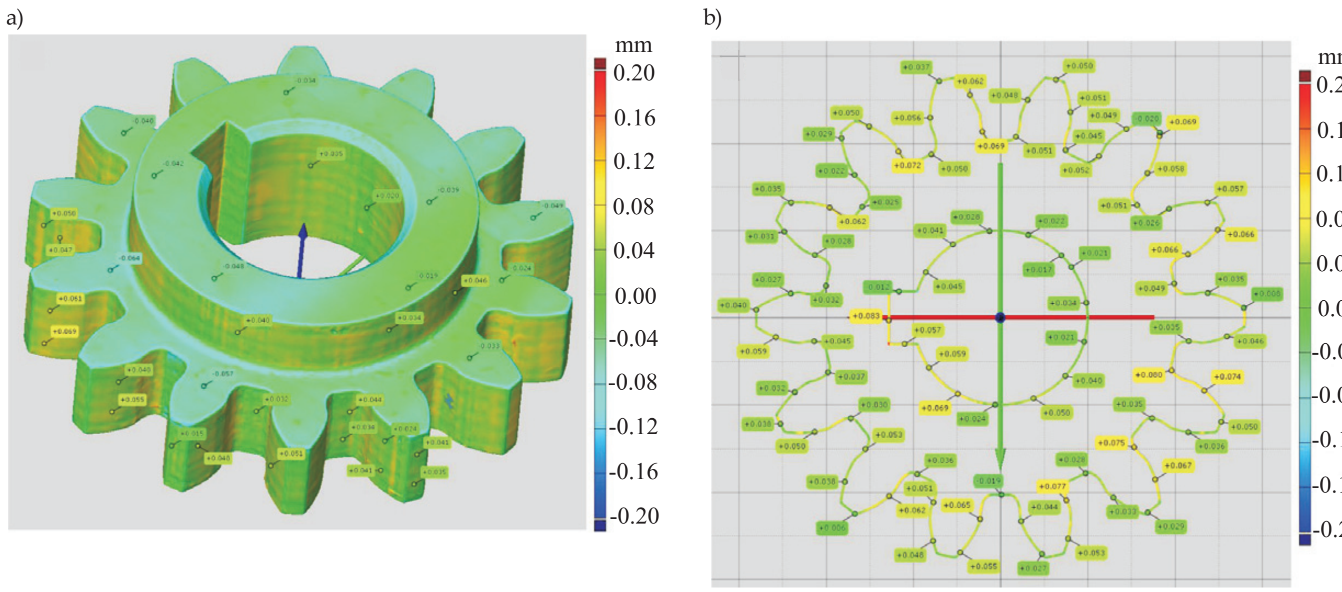

Fig. 2. Dimensional deviations of: a) gear made from FullCure720 RGD720 material, b) the profile of gear

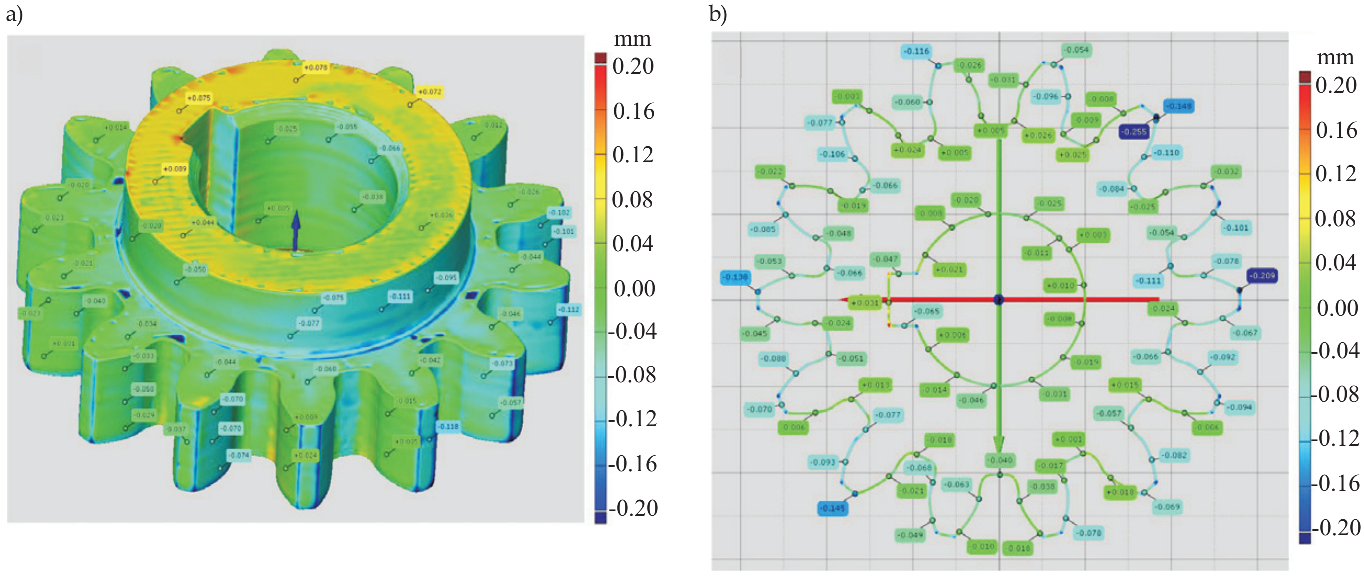

Fig. 3. Dimensional deviations of: a) gear made from ABSplus material, b) the profile of gear

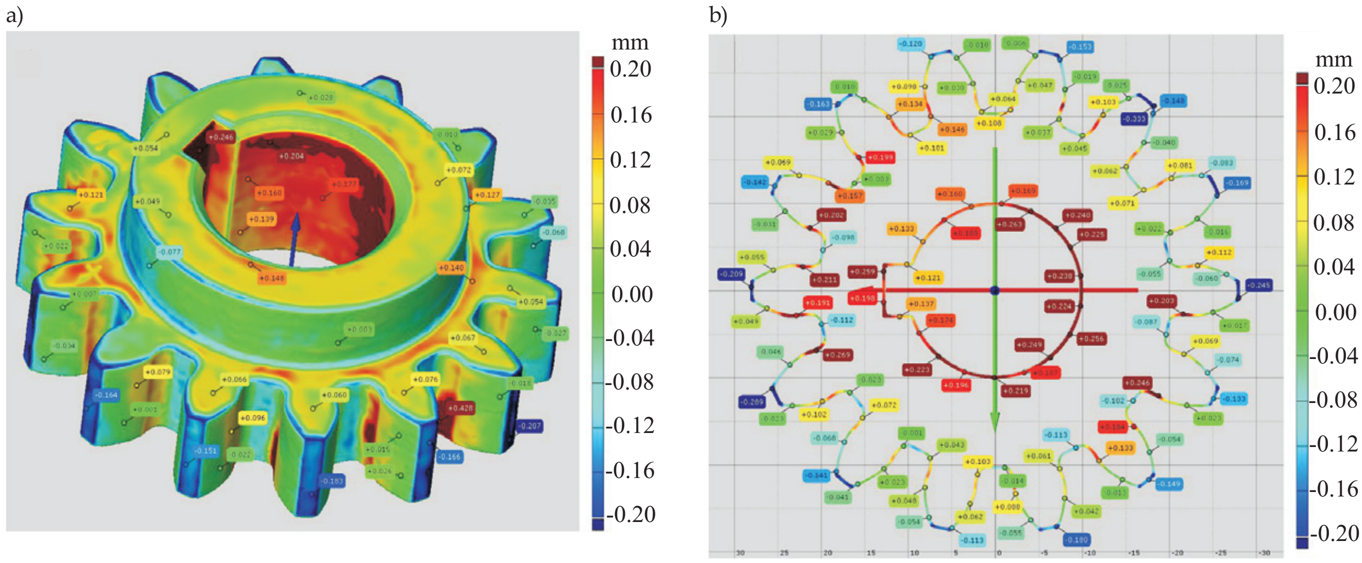

Fig. 4. Dimensional deviations of: a) gear made from Precimid 1170 material, b) the profile of gear

powder used in the additive SLS manufacturing method (Figs. 4a, 4b). They are the result of processing shrinkage of uneven removal of the powder layer in the post-processing stage. The geometry deviation range for this method is from -0.333 to +0.428 mm.

CONCLUSIONS

According to the research, FullCure720 RGD720 material used in the PolyJet method is characterized by the least distortion of geometry. Owing to their properties, the gears produced by this technique can serve as functional models or for casting molds. The occurrence of discrepancies in the dimensions of the upper surface of the hub and the teeth of the tested gears may result from the flow of the material. The effect on the differences in the dimensions of the research wheels was primarily the shrinkage of the resin used.

In the case of gears manufactured with the FDM method, obtained results indicate that the manufactured models can be used successfully at the stage of technological tests of new products.

The biggest geometry errors have been demonstrated by the prototype gear obtained from Precimid 1170 powder used in SLS. Still, its advantage is that there is no need to cover the measured geometry with anti-reflective layer, which reduces the preparation time of the model for assessment and increases its accuracy. The results show that prototypes made with such precision can be used predominantly as demonstrators.

Obtaining the improved dimensional compatibility of gears prototypes and the 3D-CAD nominal model is possible by removing the top layer of the material more precisely and introducing geometric correction factors for the shrinkage minimizing process. This will be the subject of further research.

REFERENCES

[1] Dziubek T., Oleksy M.: *Polimery* **2017**, *62*, 44. http://dx.doi.org/10.14314/polimery.2017.044
[2] Budzik G.: *Archives of Foundry Engineering* **2007**, *7* (2), 83.
[3] Budzik G., Dziubek T.: *Diagnostyka* **2015**, *16* (*1*), 51.
[4] Goch G.: *CIRP of Annals – Manufacturing Technology* **2003**, *52*, 659.
[5] Łazarz B., Wojnar G., Czech P.: *Eksploatacja i Niezawodność – Maintenance And Reliability* **2011**, *1* (*49*), 68.
[6] Neumann H.J.: "Industrial Coordinate Metrology", Verlag Moderne Industrie, Landsberg/Lech 2000.
[7] Ratajczyk E.: „Współrzędnościowa technika pomiarowa", Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2005.
[8] Budzik G.: „Dokładność geometryczna łopatek turbin silników lotniczych", Oficyna Wydawnicza Politechniki Rzeszowskiej, Rzeszów 2013.
[9] Budzik G., Grzelka M., Markowski T., Oleksy M.: *Pomiary, Automatyka, Kontrola* **2010**, *56* (*1*), 18.
[10] Dziubek T.: „Analiza współrzędnościowych systemów pomiarowych kół zębatych", Rozprawa doktorska, Politechnika Rzeszowska, Rzeszów 2012.
[11] Królczyk G., Raos P., Legutko S.: *Tehnicki Vjesnik-Technical Gazette* **2014**, *21*, 217.

Received 5 VII 2017.