Kamil ŻUROWSKI[1], Adam PIOSIK[2], Radosław CIECHACKI[1]
[1] Przemysłowy Instytut Maszyn Rolniczych w Poznaniu
ul. Starołęcka 31, 60-963 Poznań
e-mail: zurowski@pimr.poznan.pl
[2] Katedra Protetyki Stomatologicznej Uniwersytetu Medycznego im. Karola Marcinkowskiego w Poznaniu
ul. Bukowska 70, 60-812 Poznań

FDM RAPID PROTOTYPING METHOD IN THE CONSTRUCTION OF PORTABLE TEST STAND

Summary

This study examined possibilities of using Rapid Prototyping technology in the design and construction of specialized test stand for infrared imaging of dental zirconia's ceramic samples. The FDM technology, requirements for carrying out research and a test stand idea is described. The realization of the test stand is presented taking into account the specific research requirements using test stand installed in the dental office. The 3D CAD models and the prototype test stand is presented.
Key words*: rapid prototyping, computer aided design, experimentation, test stand*

WYKORZYSTANIE METODY PRZYROSTOWEJ RAPID PROTOTYPING FDM W BUDOWIE LEKKIEGO STANOWISKA BADAWCZEGO

Streszczenie

W artykule opisano możliwości zastosowania technologii Rapid Prototyping w procesie projektowania i budowy specjalistycznego stanowiska badawczego do obrazowania w podczerwieni procesu skrawania ceramiki cyrkonowej, stosowanej w protetyce stomatologicznej. Opisano technologię FDM, wymagania dotyczące charakteru badań naukowych prowadzonych na projektowanym stanowisku oraz koncepcję budowy. Przedstawiono sposób realizacji budowy stanowiska, uwzględniający specyficzne wymagania dotyczące badań na stanowisku znajdującym się w gabinecie stomatologicznym. Pokazano modele CAD 3D wybranych części oraz prototyp stanowiska.
Słowa kluczowe*: szybkie prototypowanie, komputerowe wspomaganie projektowania, badania, stanowisko badawcze*

1. Introduction

Rapid Prototyping conception defines a set of methods for quick, accurate and reproducible production of elements in the additive technology (eg using stereolithography or 3D printing). The first commercial Rapid Prototyping system was introduced in 1988 [1] and has since been constantly growing number of producers of incremental technologies, and their use spread in different areas of daily life. The undeniable advantages of prototyping technologies are:

- obtaining complex geometry of the product,
- fast prototyping of final model
- the ability to print directly from 3D CAD files.

Incremental methods often give way to conventional methods for creating machine parts, especially when we take into account:

- strength and durability of made components,
- high cost of materials,
- the quality of printed models surface.

The key to the incremental cost-effective use of technology in the design and construction of machines is a thorough analysis of the strengths and weaknesses of RP technologies and the ability to appropriate use of 3D printers at appropriate stages of research and development.

2. Requirements for constructed test stand

Infrared imaging of the machining process of samples made from zirconium oxide required special construction of the test stand. The research problem was the ceramic sample temperature measurement during machining process in terms of influence processing parameters on phase transformations occurring in the samples. To unambiguously determine the temperature distribution on the surface of machined samples (fig. 1) it was necessary to design and build specialized light test stand, which would allow for quick installation in a dental office. Special and primary requirement relating to the proposed test stand was its integration with high speed, turbine dental drill, used widely for the processing of ceramics in dental prosthetics.

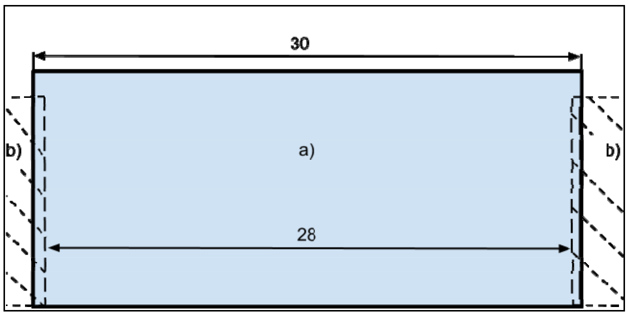

Fig. 1. Test sample (a) and fixing outline (b)
Rys. 1. Próbka badawcza (a) oraz zarys mocowania próbki (b)

The test stand was designed to achieve precise reciprocating motion of test sample with defined way and the frequency and ensure repeatable contact forces with specified value between sample and tool (fig. 2). Specific tasks of the test stand were:

a) elimination of the impact of human factors on key machining parameters, including:

- contact force,
- feedrate,
- machining path,
- machining angle,

b) ability to measure the front and back surface of the sample using infrared imaging camera.

Already at the stage of project development of the test stand, it was found that the thermographic measurement of machining process using liquid cooling may be inaccurate due to the water spray surrounding the drill. For this reason, the possibility of measure of the sample on the rear surface (dry side) was taken into account. The innovative nature of the research project required of the test stand include research methodology of thermography machining process measurement. Considering conditions and surrounding conducted research works the general requirements concerning the built research position were formulated:

– the ability of quick assembly and disassembly,
– flexible design solutions,
– the possibility of transport by one person,
– compact design of the test stand,
– test stand dimensions as small as possible.

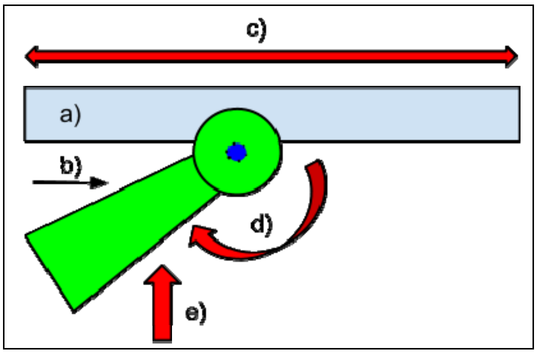

Fig. 2. Kinematic diagram of the test stand – top view: a) machined test sample, b) high-speed handpiece , c) feed direction of the sample, d) rotation direction of the spindle, e) force between tool and sample

Rys. 2. Schemat kinematyczny stanowiska badawczego – widok z góry: a) próbka skrawana, b) wiertarka turbinowa, c) kierunek posuwu próbki, d) kierunek obrotu wrzeciona, e) siła docisku narzędzia do próbki

3. The components used in the construction of the test stand

For the construction of the test stand the following elements were used:

– light linear bearings used in the furniture industry,
– DC 12V motor with integrated planetary gearbox (engine parameters are listed in Table 1),
– electrical components (cables, power supply, case, switch, etc.),
– exhibition aluminum profile system 8 mm,
– temporary mechanical joints elements,
– hydraulic pipe holders,
– FDM elements constructed using 3D printer.

Table 1. Characteristic of the used electric drive [2]

Tabela 1. Zastosowany napęd elektryczny [2]

Manufacturer	Bühler Motor
Type	DC Gear Motor
Model	1.61.077.414
Nominal supply voltage V_N [V]	12
Nominal input current I_N [A]	1.4
Rated torque M_N [N/m]	1
Rated speed n_N [rpm]	40

4. FDM Rapid Prototypng method

Fused Deposition Modeling (FDM) is an incremental method of model building by depositing layers of thermoplastic polymer (ABS). Empty spaces are filled using water soluble support material (fig. 3). For the elements construction the Stratasys Dimension 1200 es SST FDM 3D printer was used, which is installed in the Department of Agricultural Machines Materials Testing and Development in Agricultural Machinery in Industrial Institute of Agricultural Engineering. In the used 3D printer applied layer has a thickness of 0.254 or 0.33 mm, and the size of the built model restricts the cuboid of dimensions 254 x 254 x 305 mm. Components of test stands was built from the ABS material with a tensile strength Rm = 36 MPa. FDM method that uses polymers belonging to the category of engineering plastics is being ranked among the group of Rapid Prototyping / Rapid Manufacturing / Rapid Tooling due to the physico-mechanical properties of the completed parts, similar to the properties of the construction polymers, processed with conventional technology [3].

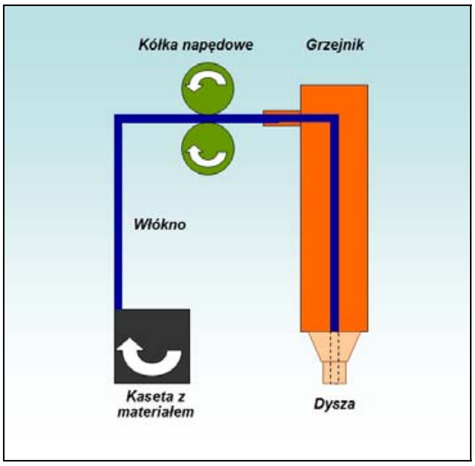

Fig. 3. FDM technology

Rys. 3. Technologia FDM

Fig. 4. 3D Printer Stratasys Dimension 1200es

Rys. 4. Drukarka 3D FDM Stratasys Dimension 1200es

Fig. 5. 3D Printer Stratasys Dimension 1200es – work chamber
Rys. 5. Drukarka 3D FDM Stratasys Dimension 1200es – komora robocza

5. Test sample grip made using FDM method

Due to the work carried out during the test stand task construction of the sample grip should:
- enable a fast and repeatable assembly of the test sample,
- be characterized by minimal contact with the sample surface,
- have a low thermal conductivity,
- have sufficient stiffness in contact forces acting,
- allow observation of the machining process of the front and back of the sample,
- drain coolant stream,
- be mounted on linear bearings.

All of these requirements have been fulfilled (fig. 6 and 7).

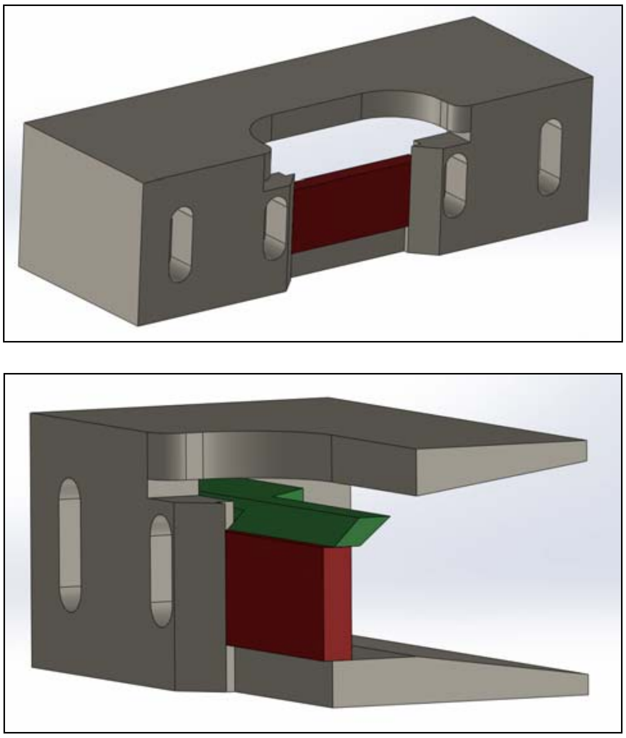

Fig. 6. Test sample mounting with the sample (red) – 3D CAD model
Rys. 6. Uchwyt na próbkę badawczą z próbką (kolor czerwony) – model CAD 3D

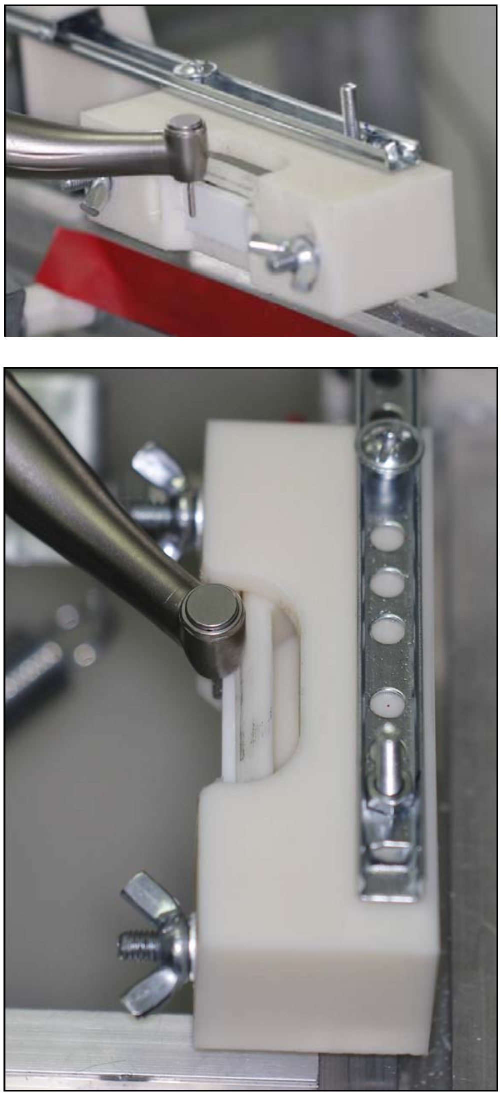

Fig. 7. Test sample mounting with fixed sample prepared for testing
Rys. 7. Uchwyt z zamocowaną próbką przygotowany do badań

6. Combination of 8 mm aluminium profile system with elements made using FDM Rapid Prototyping method

Spatial framework, based on aluminum profile systems, joined by special connectors are lightweight and quick to assemble structures, commonly used in industry and exhibition industry. Successfully are also used as a supporting constructions in industrial automation, mainly due to the ability to quickly and accurately sensors and actuators assembling. In the construction of this test stand lightweight frame structure made of aluminum profile section 32 x 32 mm is used, with a view to achieving maximum flexibility in space framework configuration and the requirement of low weight design. To keep the compact dimensions of the test stand it was decided to insert parts made by FDM, thereby eliminating some temporary mechanical connections. The space frame is equipped with three supports on the location and amount takes into account the center of gravity position and the space under for the coolant collecting container. Crankset were made using FDM method (Fig. 9). It allows the continuous adjustment of the stroke length in the range of 18 to 26 mm. The assembling of the driving mechanism and linear bearings were realized by locking connection. Linear bearings are lubricated with silicone oil for vacuum pumps. Force between tool and sample is realized through the stretched spring. Contact force obtained in the range of 1 to 10 N. Complete test stand, designed and built using rapid prototyping method, is shown in figure 10.

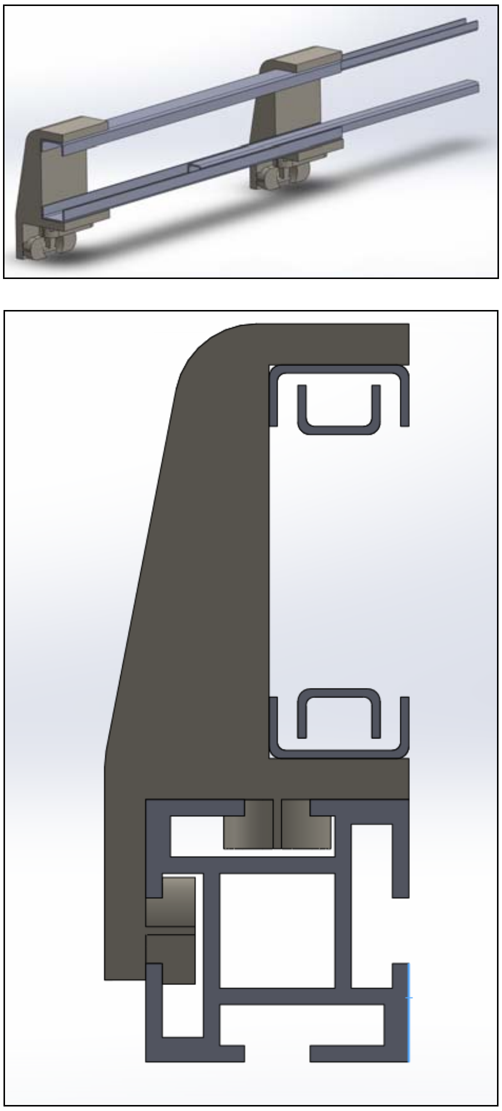

Fig. 8. Linear bearings support produced using elements made using FDM method
Rys. 8. Mocowanie łożysk liniowych przy użyciu elementów wykonanych metodą FDM

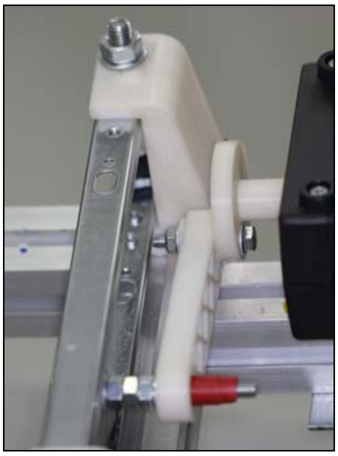

Fig. 9. Crankset view
Rys. 9. Widok układu korbowego

Rys. 10. Stanowisko badawcze z zamontowaną wiertarką turbinową
Fig. 10. Test stand with high-speed handpiece

7. Summary

These test stand will allow in the simple way to infrared imaging the machining process of zirconium oxide for dental prosthetics elements, in terms of determining best machining parameters. Parts made using FDM Rapid Prototyping are characterized by enough stiffness and meet the requirements of responsible parts of the structure. Skilful application of the FDM method in the construction reduces the number of mechanical connections, and hence the degree of complexity, installation time and total weight of test stand. The use of FDM method in the design and construction of experimental test stands partially removes the need to create conventional technical documentation, identify the technological capacity of the prototype contractor and ensure the availability of the blanks to the newly designed machine parts production. Designed test stand fulfills all his requirements, simultaneously is a part of the modern trend of widening spectrum of applications of Rapid Prototyping methods in the engineering. With the increasing strength of structural materials used in the construction of models, rapid prototyping, incremental technology involved in the construction of machines will show an upward trend.

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Test stand construction was realized by Mechatronic Innovation and Implementation Laboratory, acting at the club No. 38 of Poznan Department of Polish Association of Mechanical Engineers and Technicians (SIMP) in the Industrial Institute of Agricultural Engineering in Poznan.