Journal of KONES Powertrain and Transport, Vol.14, No. 2 2007

SURFACE ROUGHNESS OF AIRCRAFT ENGINE BLADE MODELS PRODUCED WITH VARIOUS METHODS OF RAPID PROTOTYPING

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Abstract

Results of the study of surface roughness of the aircraft engine blade model, produced with various methods of rapid prototyping are presented. Blade models were made with two incremental methods of rapid prototyping: stereo lithography (SLA-250 device) and three-dimensional printing (Z510 Spectrum printer). In incremental methods of rapid prototyping a model is formed by hardening of consecutive layers of the base material. Model position in the equipment work area has a significant influence on surfaces quality of a prototype, especially in stereo lithography method. It is essential in case of elements with curvilinear surfaces like aircraft engine blades. A CAD blade has been exported to the STL format within surface precision of 0,001 mm. Afterwards, it was duplicated and set up in various positions of the virtual work area of the 3D Light year programme dedicated to the SLA-250 device. Data prepared in this way have been used for producing physical models. Roughness surveys were carried out with the Talyscan150 device, manufactured by Taylor Hobson Precision. The measurements permitted making three-dimensional maps of surfaces of blade prototypes. Thanks to that, it was possible to determine optimum position of blade in the work area of RP devices in respect to prototype surface quality.

Keywords: *combustion engine, rapid prototyping systems, surface roughness, impeller blade*

1. Introduction

Models of aircraft engine blades can be made by various techniques of rapid prototyping, depending on prototype use and the required precision [4]. The incremental techniques of rapid prototyping are characterized by their typical stepped surface structure, typical for a laminar structure of the model. It is visible particularly on elements with complicated surface shapes, as aircraft engine blades, among others. Surface roughness of models produced with laminar incremental systems of rapid prototyping depends on many factors, including:

a) shape of model surface,
b) position of model surface in respect to work surface,
c) surface precision of virtual model,
d) precision of the method,
e) the type of initial material.

Taking the above factors into account it permits obtaining of prototypes with optimum surface roughness [1, 5, 8].

2. Producing of blade prototypes

There are many methods of rapid prototyping including, among others: Stereolithography (SL), Three-Dimensional Printing (3DP), Fused Deposition Modeling (FDM), Laminated Object Manufacturing (LOM), Selective Laser Sintering (SLS) [6].

In an analysis of all methods in respect of producing the prototypes of aircraft engine blades, only those most precise ones should be short listed. For research reasons, two rapid prototyping methods i.e. stereolithography (SL) and three-dimensional printing (3DP) were selected [1, 7]. Blades prototypes were produced on the base of the same CAD model, which was exported to the STL format with precision to the nearest 0,001 mm [1, 2, 3]. Blade models were positioned on the work platform of the SLA 250 device in two positions: vertical (Fig. 1a) and at a slant (Fig. 1b). It permitted defining the effect of prototype position, in relation to the work plane (*X,Y*), on its surface roughness.

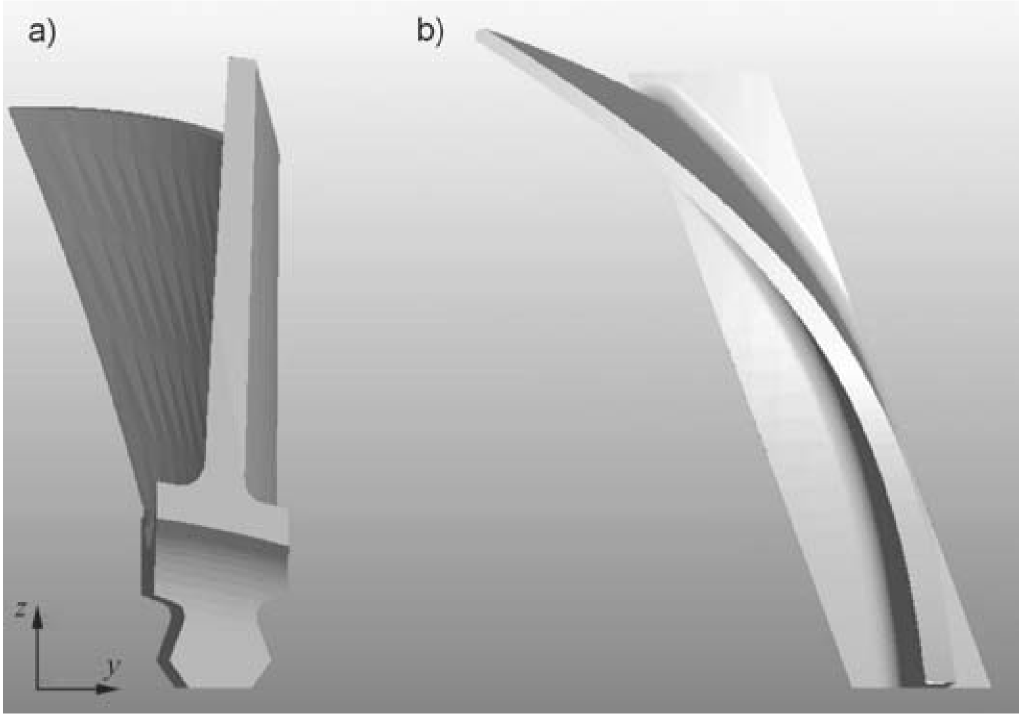

Fig.1. Blade positioning on work platform: a) vertical, b) slanted

3. Blade roughness measurements

Surface roughness measurements were carried out with the Talyscan150 instrument produced by Taylor Hobson Precision (fig. 2) and the TalyMap 3D software package used for surface analysis. The measurements were carried out on a sampling area of 1 mm x 2 mm with the sampling step of 10 μm and the three-time replication [9, 10].

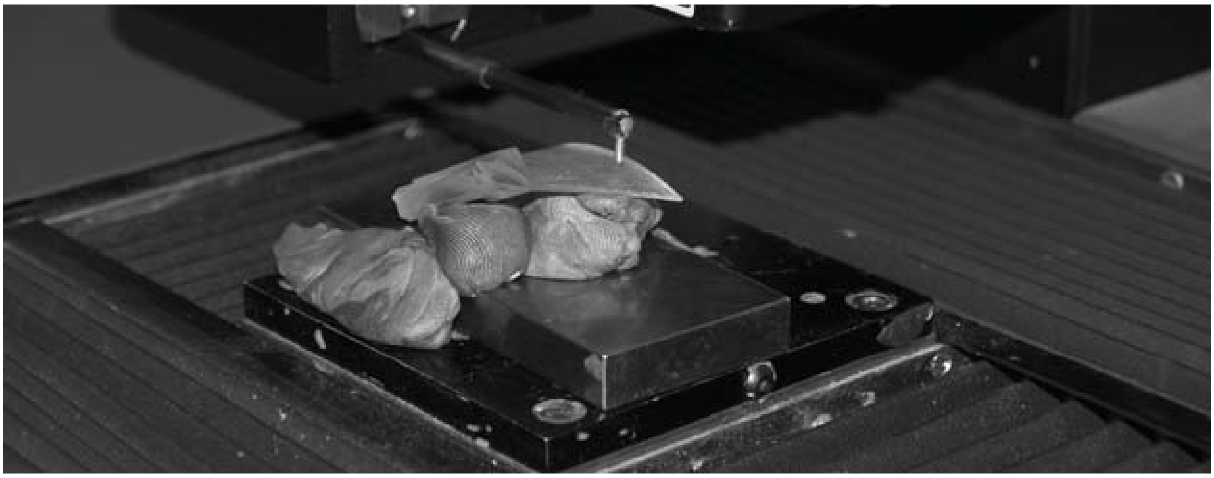

Fig. 2. Blade surface roughness measurement with Talyscan 150 instrument

3.1. Sample # 1 – SLA model in vertical position

The first sample was a stereolithographic model of blade, made with the SLA-250 unit manufactured by the 3D Systems, in vertical position on the platform. As a result of program processing of the measurements the following 2D- and 3D-diagrams were plotted (see fig. 3 and 4).

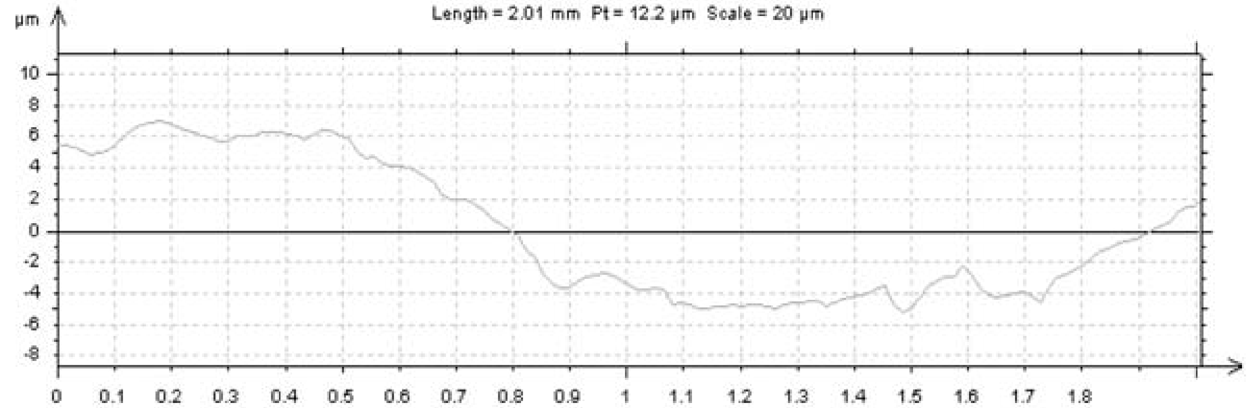

Fig. 3. Surface profile of the studied sample

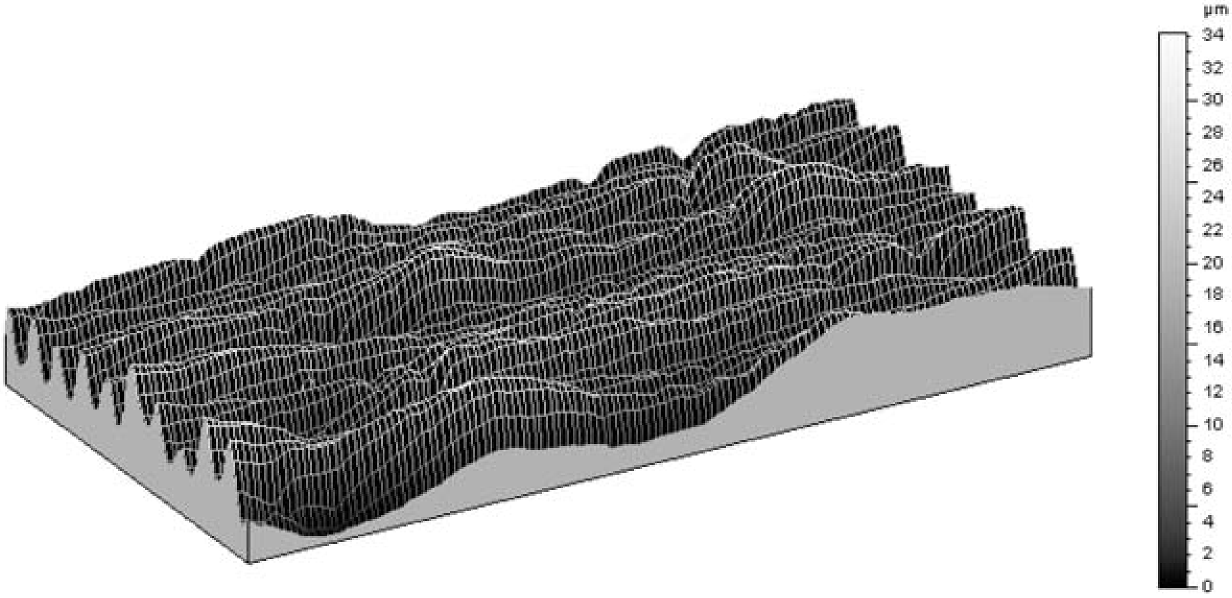

Fig. 4. Isometric view of the surface of the studied sample

Table 1 presents the values of selected 2D- and 3D-parameters of surface roughness of blade prototype.

Tab. 1. Selected surface roughness parameters

2D-Parameter	Value [µm]	3D-Parameter	Value [µm]
Ra	0,40	*Sa*	4,92
Rq	0,60	*Sq*	5,90
Rp	0,81	*Sp*	10,0
Rv	1,88	*Sv*	16,2
Rt	3,31	*St*	34,2
Rz	2,69	*Sz*	27,6

3.2. Sample # 2 – SLA model in slanted position

This second sample is a stereolithographic model of blade produced with the SLA-250 unit, made by 3D Systems, in a slanted position on the platform. As a result of program processing of the measurements the following 2D- and 3D-diagrams were plotted (see fig. 5 and 6).

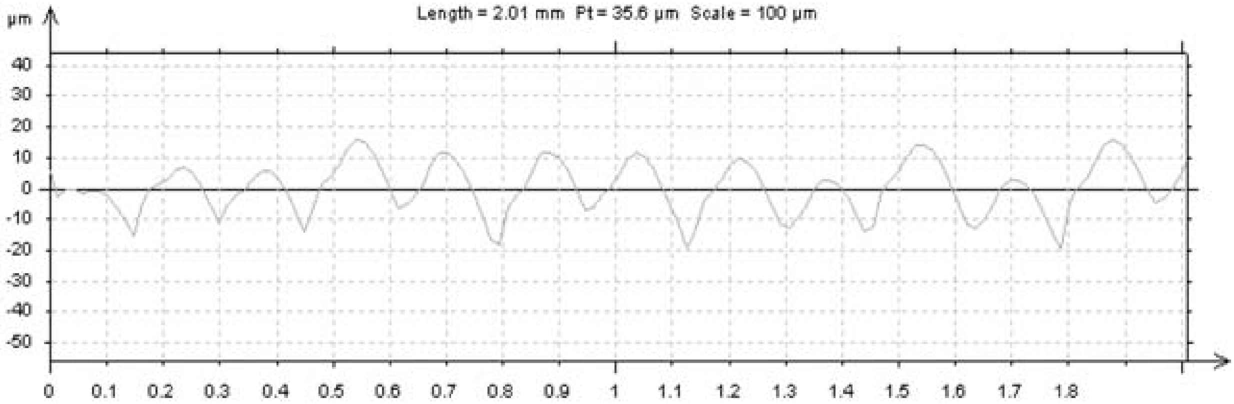

Fig. 5. Surface profile of the studied sample

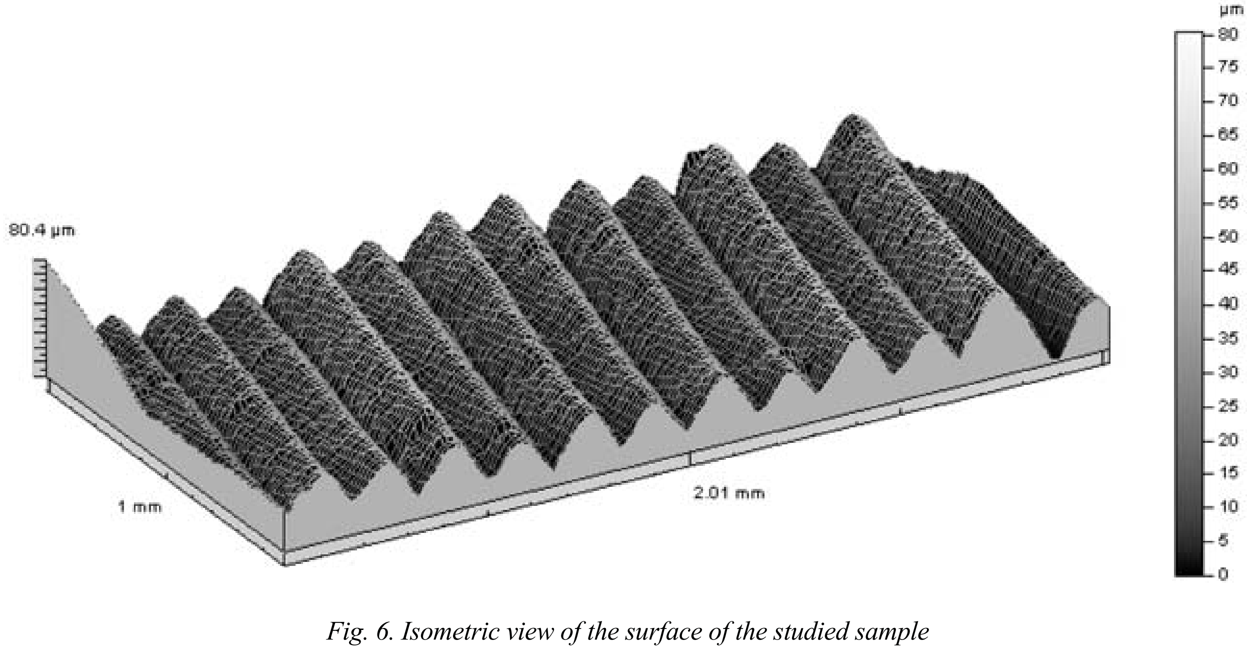

Fig. 6. Isometric view of the surface of the studied sample

Table 2 presents the values of selected 2D- and 3D-parameters of surface roughness of blade prototype.

Tab. 2. Selected surface roughness parameters

2D-Parameter	Value [µm]	3D-Parameter	Value [µm]
Ra	7,05	*Sa*	7,62
Rq	8,45	*Sq*	9,21
Rp	12,7	*Sp*	48,9
Rv	19,6	*Sv*	31,5
Rt	33,7	*St*	80,4
Rz	32,3	*Sz*	41,8

3.3. Sample # 3 – 3DP model

The first sample is the model of blade produced with the use of 3D-printing on Z510 Spectrum, made by ZCorporation, in vertical position. As a result of program processing of the measurements the following 2D- and 3D-diagrams were plotted (see fig. 7 and 8).

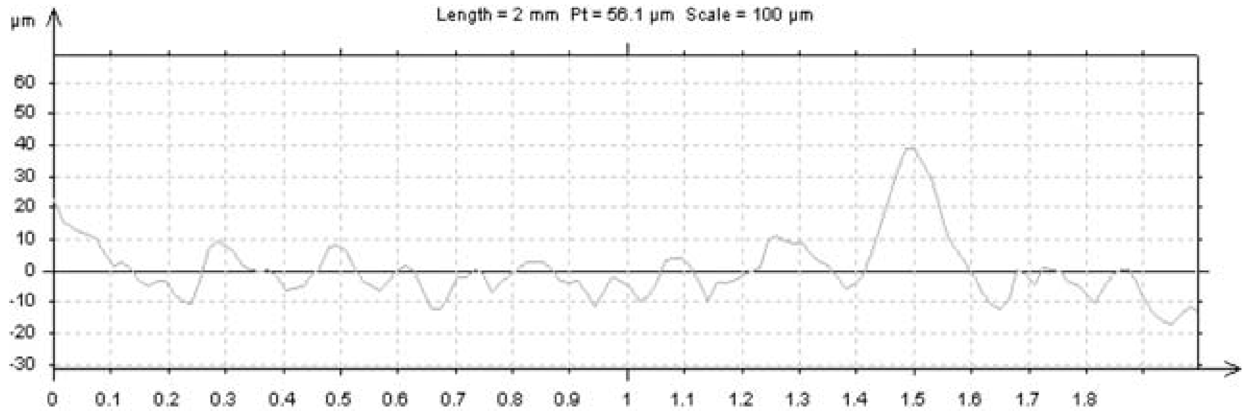

Fig. 7. Surface profile of the studied sample

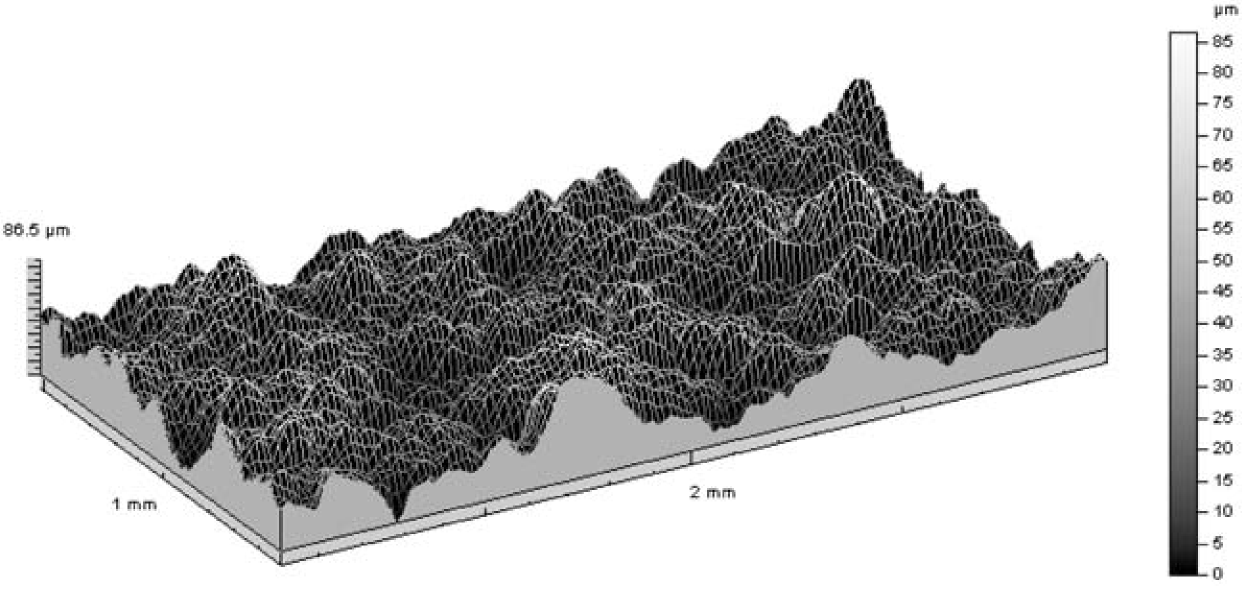

Fig. 8. Isometric view of the surface of the studied sample

Table 3 presents the values of selected 2D- and 3D-parameters of surface roughness of a blade prototype.

Tab. 3. Selected surface roughness parameters

2D-Parameter	Value [µm]	3D-Parameter	Value [µm]
Ra	4,01	*Sa*	9,56
Rq	4,90	*Sq*	12,0
Rp	3,72	*Sp*	49,7
Rv	10,8	*Sv*	36,8
Rt	41,4	*St*	86,5
Rz	19,5	*Sz*	68,7

4. Conclusions

The incremental methods of rapid prototyping have a surface structure characteristic for laminar structure of the model. If models have curvilinear surfaces (blades, impellers), a stepped structure is an inherent feature.

Surface parameters depend on the position of the model on the platform of rapid prototyping machine. Vertical positioning of a blade on the platform permits achieving the best precision of the geometric structure of its surface. In case of impellers, the rotational axis of a impeller should be parallel to the vertical axis (or z axis of the machine). Such positioning ensures uniformity of manufacturing parameters of all impeller blades.

Surface roughness of the model is also affected the rapid-prototyping method itself. The best surface roughness parameters are ensured by the stereolithography method.

If a smooth prototype surface is required, an allowance of material should be left for finishing. A coating may also be applied on the model prior to finishing.

Machined model may serve as a master to produce a silicon matrix. Castings or moldings from such tool have a surface structure that matches the matrix, and thus it matches the machined model as well.

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