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Generation of triangle mesh softgauges and AM material measures for surface texture characterization

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Abstract

Several material measure data files (softgauges) have been designed with specific structures and periodical patterns. The softgauges, available as a triangle mesh, were exported and used to manufacture physical material measured in metal using 3D printers. The whole project aims at scanning samples with an XCT scanner, then reconstructing the surface, characterizing the patterns and comparing them to the initial design. In order to separate deviations due to the additive manufacturing from those due to CT scans and reconstruction, the same samples were also measured using optical profilers. This paper focuses on the design of the softgauges and the constraints imposed by 3D printers or XCT scanners resolution and ranges.

Keywords: additive manufacturing, surface quality, triangle mesh, X-ray computerized tomography, surface texture, softgauges

1. Introduction

Many industrial products now contain mechanical components produced by additive manufacturing (AM), using metallic powder (SLM – Selective Laser Melting). If AM techniques offer many advantages over traditional subtractive techniques (design flexibility, weight gain, complex internal parts, …), several drawbacks need to be addressed. One of the main problems is the low surface finish quality, which has a direct influence on the surface function. AM components exhibit very rough surfaces, with all sorts of marks (welding tracts, particles, cracks, cavities, etc.) that are difficult to characterize, due to the surface complexity. Moreover, internal surfaces and undercuts cannot be measured by classical surface profilers, and this is the reason why the use of X-ray computerized tomography (XCT) is becoming more frequent.

Within the scope of the RAPID FreeVox project, Digital Surf and Digisens have developed a consistent chain for the measurement and analysis of AM sample using CT scans (see **Figure 1**). The surface extracted from the voxel cube, using DigiXCT® [1], is sent to MountainsMap® 9.1 [2] as a triangle mesh (called a Shell), where it is analysed with specific tools, in particular surface texture parameters calculated directly on the shell. These parameters have been developed in collaboration with the Center of Precision Technologies of the University of Hudderfield [3, 4].

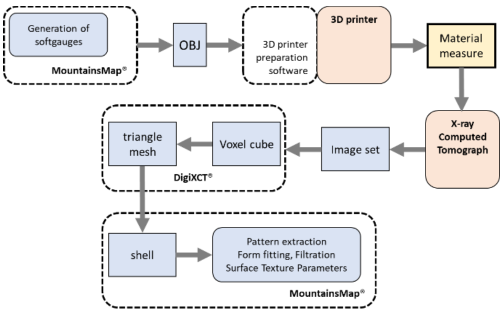

Figure 1. manufacture and verification chain

As this chain is aimed at providing tools for additive manufacturing applications, test samples have been designed in order to be manufactured and then measured and analysed.

2. Design constraints

Surfaces made by metal AM processes have a very rough texture. Due to the size of the laser spot and the resolution of the scanner, most 3D printers are not able to reproduce correctly patterns below 50 to 100 µm in lateral and 10 to 30 µm in height. However, surface texture is usually characterized by lateral wavelengths of less than 100 micrometres and amplitudes of 20 micrometres or less. A compromise had to be found in terms of scales, and also in order to avoid too big files with too many points. The size of these samples cannot be too large, to be compatible with high resolution XCT instruments. Patterns on the samples must be big enough to ensure that they are printed correctly, but fine enough to be compatible with surface texture.

3. Softgauge design

Two categories of softgauges have been designed: a square plate of 30 mm of size and 3 mm thickness, with patterns on the top surface, and a cube of 30 mm of size, with patterns on three faces (top, left and front), the three remaining faces being flat.

Three different designs of textured surface were generated to provide a wide variety of test structures. A software generator was developed and each model of patterns can be generated either as a plate or a cube, and sent directly to MountainsMap® 9 for visualization and analysis. These softgauges are generated as triangle meshes and can be saved as STL, OBJ or PLY file formats. In addition, the patterns can also be generated as normal surfaces, i.e. the classical 2.5D surfaces that can be saved in SUR or SDF file formats. They are used to assess the deviations due to the conversion as shells.

3.1. First softgauge

The first softgauge design contains several geometric patterns, similar to those found on material measures defined in ISO 25178-70 [5]. Several patterns are designed as profiles replicated on a two-millimetre band, and reproduced once along the X-axis and once along the Y-axis. These patterns include: a triangle profile (type PPT) with a period of 6 mm and an amplitude of +/- 300 µm; a profile made by the superposition of four sine waves of various periods and amplitudes in order to create a complex profile on which parameters can be verified; a set of rectangular grooves (type PGR) with varying width to test the lateral fidelity of the 3D printing; and another set of rectangular grooves with varying depth for the vertical fidelity. At the centre of the plate, a circular sine wave (type ARS) with a period of 3 mm and an amplitude of +/- 200 µm (see **Figure 2**).

Figure 2. First sample reproduced on the top face of a plate (left) and on three faces of a cube (middle) and extruded inside (right)

The geometrical patterns can be used to calculate the true value of some parameters using mathematical integration. The true value can then be compared to the value calculated on the generated and sampled file or the measured file, and assess the effect of sampling or other factors. This method, based on mathematical softgauges is the only method that is independent from any implementation, contrary to reference software or algorithms [6].

3.2. Second softgauge

The second sample is a simple skin surface (see **Figure 3** left) reproduced from a real measurement but amplified ten times in heights. This pattern will be used to check areal surface texture parameters on the extracted surface and assess their dispersion depending on the face orientation.

3.3. Third softgauge

The third softgauges design contains two bidirectional chirp patterns, one sinusoidal and one rectangular, and two spherical caps (type APS), one convex and one concave (see **Figure 3** right). The two chirps can be used to evaluate the spacing fidelity. The two spherical caps will be used to check form deviations in function of the face orientation.

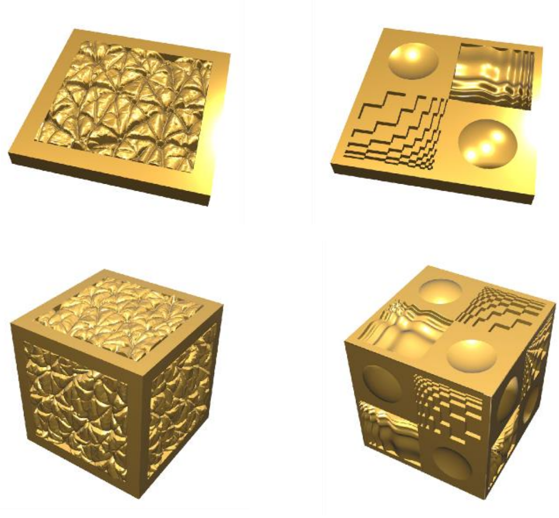

Figure 3. Second softgauges (left) with a skin surface. Third softgauge (right) with chirp patterns

4. Experiment

Once printed, the samples are then measured with an XCT instrument that produces a set of images around the sample. These images are then used to reconstruct a voxel volume, using DigiXCT® from Digisens. This software also extracts the iso-surface separating the material from the surrounding medium, leading to a triangle mesh. It is then sent to MountainsMap® where verifications are carried-out.

Acknowledgments

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References

[1] https://www.digisens3d.com
[2] https://www.digitalsurf.com/software-solutions/profilometry/
[3] https://research.hud.ac.uk/institutes-centres/cpt/
[4] Pagani L, Townsend A, Zeng W, Lou S, Blunt L, Jiang XQ and Scott PJ, 2019, Towards a new definition of areal surface texture parameters on freeform surface: Re-entrant features and functional parameters, *Measurement* **141**
[5] ISO 25178-70:2014, GPS – Surface texture: Areal – Part 70: Material measures
[6] Todhunter L, Leach RK, Lawes S, Harris P and Blateyron F, 2020, Mathematical approach to the validation of field surface texture parameter software, *Surf. Topogr.: Metrol. Prop.* **8**