# PARAMETERIZATION OF SAMPLES FOR MODELING OF LASER BURNING

## *Increasing the Lifelikeness of Synthetically Generated Samples*

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Abstract: This paper describes methods for the generation of samples in modeling burning by a laser beam. In the first part, it briefly informs about real data set and the way of approximation of real samples by mathematically described smooth surfaces. In the main part, the paper focuses on methods which can be used for increasing the lifelikeness of the result of the sample generation process for simulation purposes. Finally, the results are summarized and the future plans are outlined.

# 1 INTRODUCTION

The work described in this paper is a part of a larger project that deals with laser burning control and simulation of laser burning process. We are interested in processing the measured data, its visualization and laser burning simulation. For our work, we use real samples burned by a laser and measured by a confocal microscope. The means of data acquisition process is described in (Hájková, 2008).

All measured samples are represented in the form of a height map. As a part of data processing, we are going to find a set of parameters that would define a mathematical function approximating the shape of the pulse optimally and to get a parametrical description of the sample roughness in all its areas. The parametrical description could be used as a part of the sample simulation process. First, we generate the basic shape of the pulse. Than, to get more realistic results, the basic smooth surface can be further adjusted by using methods for a random surface modification described in this paper.

## 1.1 Data Description

As mentioned in the introduction, the description of each measured real sample is stored in the format of a height map. This height map is formed by a matrix of real numbers, which express the heights of intersection points in a uniform rectangular grid. The whole data set consists of samples with a defined number of laser beam pulses burned by a laser into a single point in the material.

To get a better imagination about the appearance of a sample, see

Figure 1, where an example of a sample cross-section is shown. It contains several typical features, which result from the burning process and the character of used material.

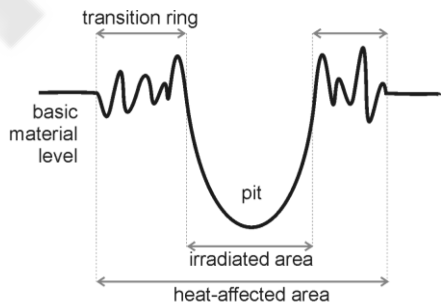


Figure 1: A typical cross-section of a sample.

During the burning process, the surface of the material is exposed to an intense pulsed laser beam that causes a rapid rise in local temperature. The surface is warming up and the material starts to ablate. The material, which is ablated, redeposites around the irradiated area and damages the surrounding material (Dahotre et al., 2008). Finally, at the exposure site, a pit with a transition ring around it is left behind. An example sample (100

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laser pulses burned into a single point in steel) in 3D view can be seen in Figure 3a.

The central part of the pulse (i.e., the area directly irradiated by the laser beam) is smooth and the bottom of the pit is a little bit rougher (Figure 2a). The most ragged surface part is the transition ring. The surface is modulated by some concentric waves that are both regular and irregular (Figure 2b). Sometimes, local defects with a considerable roughness can appear, especially at the outer border of the transition ring (Figure 2c). At the outer border, the roughness declines slowly and fades into the roughness of the bulk material. All these facts should be taken into account if we want to generate a realistically looking surface of a laser-burned sample.

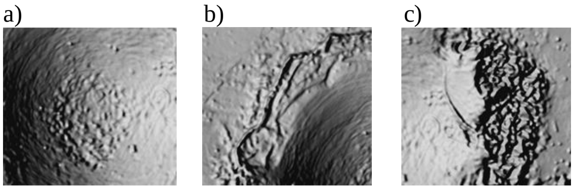


Figure 2: Examples from different parts of a typical sample surface.

## 1.2 Sample Shape Approximation

As described in (Hájková, 2009), the basic shape of a sample can be approximated by a smooth surface defined by mathematical functions which approximate the pulse pit by an elliptical paraboloid, and the pulse transition ring by the top half of a parabolic elliptic torus. An example of a real sample and its approximation can be seen in Figure 3.

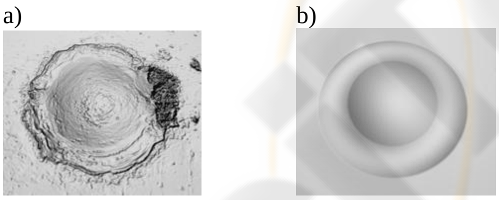


Figure 3: An example of the sample approximation by a smooth surface.

To obtain the most realistically looking sample, surface the generated surface should be further modified and some roughness should be added.

# 2 ROUGHNESS GENERATION

If we burn the same sample twice into different places, it will never be the same, because at least the surface of the basic material differs. That is why we have to enhance the sample generation with random features such as noise or various defects to get more realistic results. These features and the methods how to generate them are described in the following subsections.

## 2.1 Perlin Noise Function

As can be seen in Figure 3, the mathematically generated sample is too smooth in comparison with the real one. That is why it is necessary to modify a generated surface by some kind of artificial defects that would represent the granularity of the material and the roughness of different parts of a real sample.

One of the possible solutions is to use the Perlin noise function (Perlin 1985), (Perlin, 2002). The Perlin noise function has a very wide range of application, not only in the computer graphics, but also in many other areas, where natural appearance is required.

Perlin noise combines a noise function with an interpolation function. The noise is formed by randomly generated values the distance of which is given by some frequency. This frequency is defined as 1/wavelength, where the wavelength represents the distance from one generated value to the next one. The generated values are interpolated using the Hermit interpolation (Žára et al., 2005) to get a smooth interpolating curve (with given amplitude and frequency). If we sum up several curves (called octaves) with various frequencies and amplitudes, we get the final Perlin noise function. An example of 1D octaves can be seen in Figure 4. The frequency ranges from 1 to 32, the amplitude is the same for all octaves.

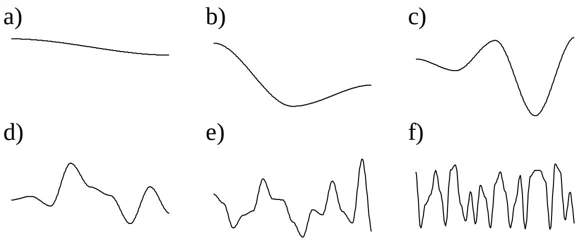


Figure 4: Octaves that are added to the final 1D Perlin noise with the same amplitude and different frequencies: a) 1, b) 2, c) 4, d) 8, e) 16, f) 32.

For the modification of the generated smooth material surface, we need the 2D Perlin noise. A different number of octaves can be added into the final 2D noise or various amplitudes can be used. Several examples of the final 2D Perlin noise are shown in Figure 5.

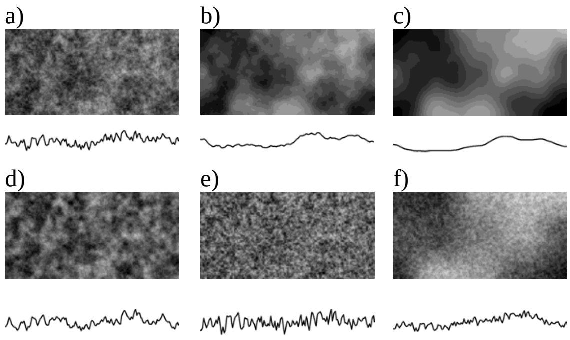

Figure 5: 2D Perlin noise after summing up 6 noise functions with different amplitudes. Amplitude of each following octave is a) the same; b) half; c) quarter the size. d-f) Perlin noise generated according to three different amplitude vectors.

It is evident that the variability of the Perlin noise function is high and so we can use it for the realistically appearing samples generating.

Perlin noise can be used several times during the process of pulse generation. The result depends on the used parameters. The first case, where the Perlin noise can be used, is the generation of the roughness of the pit bottom. The roughness is generated according to the noise amplitude vector. A real sample (100 laser pulses burned into steel) is shown in Figure 6a, an example of the Perlin noise modulated surface of the ideal pit can be seen in Figure 6b.

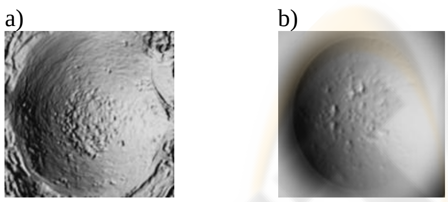

Figure 6: a) The pit of a real sample; b) Perlin noise modulated on the surface of the ideal pit.

Another area where the usage of the Perlin noise is appropriate is generating the transition ring, or to be more precise, some local defects on it. To get a better imagination how the generated surface looks like, compare the 3D surface of the real local defects in two samples in Figure 7a,b and the surface generated by the Perlin noise in Figure 7c.

For the sample generation, we need to form several smaller areas representing the local defects. For this purpose we can also use the Perlin noise. At the beginning, we generate a mask of the transition ring (see Figure 8a). Then, we generate another mask representing the basic shape of the thresholded Perlin noise (Figure 8b). If we make an intersection of both masks, we get the result mask shown in Figure 8c. This result mask serves for the modulation of the Perlin noise described above (Figure 8d). To get a more realistic appearance, the original shape of the transition ring mask could be slightly changed by a distortion.

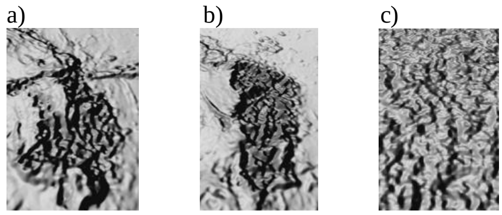

Figure 7: a, b) Local defects in two different samples; c) surface generated by the Perlin noise.

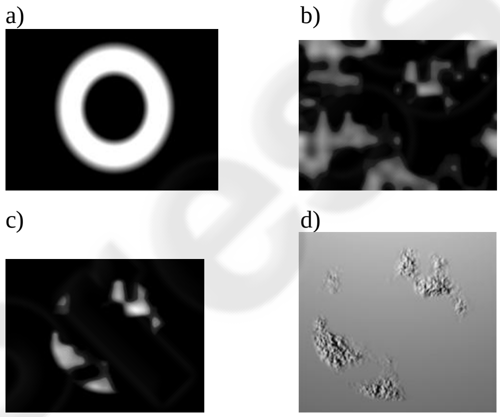

Figure 8: a) Mask of the transition ring; b) mask of the local defect areas; c) intersection of both previous masks; d) final result after the generation of local defects.

## 2.2 Waves Modulation

In the real samples, concentric waves are visible in the area of the transition ring (as shown in Figure 2b). These waves are especially noticeable on the outer border of the ring, they are relatively thin and sometimes even discontinuous. Their shape consists of a number of edges which approximately form an elliptical shape.

If we want to generate a wave, we have to know several parameters for its description, e.g. its diameter, width, height or segmentation. The segmentation is determined with the set of points forming a line segment. All line segments are converted to an arc plane with the given width and height.

In the real samples more than one wave can often be recognized. Examples of 20 and 30 waves modulated on the smooth sample surface can be seen in Figure 9.

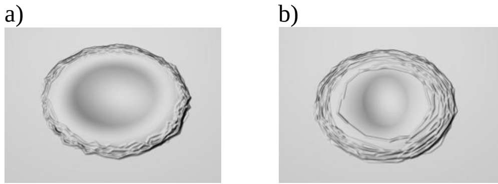


Figure 9: Examples of a) 20 and b) 30 waves modulated on the smooth sample surface.

## 3 RESULTS

If we put all the generated parts together, we obtain the final sample. For the basic material, the surface of the measured real sample is used. Than, the basic shape of the pit is computed and its bottom is modified by the Perlin noise. After that, we can generate the transition ring. Its basic shape is computed, the masks for the ring and the Perlin noise are created and then used for its modification. Results can be seen in Figure 10. The original samples with 10, 50, and 100 laser pulses burned into steel are shown are placed in the left column. They can be compared with the results of the pulse generation, which are placed in the right column.

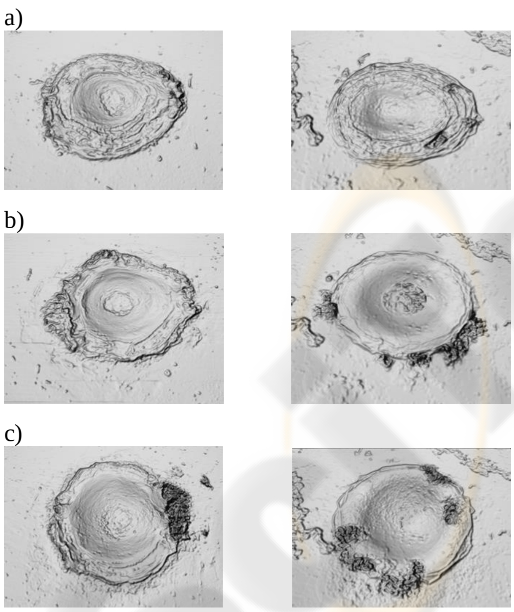


Figure 10: Real and generated samples: a) 10; b) 50; c) 100 laser pulses burned into a single point in steel.

## 4 CONCLUSIONS

This paper describes methods for the roughness and noise generation. They serve for increasing the lifelikeness of samples which are synthetically generated based on the parameters gained from the real measured data. This can be used as a basic approach for the laser burning process simulation.

The set of parameters consists of the parameters describing the pulse basic shape (such as its inner and outer border diameters, its depth or the maximal height of the transition ring) and of several parameters for the roughness description (such as amplitude vectors for the Perlin noise, waves parameters, etc.).

The majority of parameters have to be obtained automatically to ensure the self-contained data processing. Some parameters depend on the used material and the others are typical for a particular number of laser pulses burned into a single point. As can be seen in Figure 10, the present results look very well and the improvement of the generating process automation is one of the tasks we want to work on in the future.

## ACKNOWLEDGEMENTS

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