Determining the Roughness Angles of Surfaces Using Laser Scanners

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SUMMARY

Terrestrial laser scanners are measuring instruments providing the detailed 3D object geometry directly and fastly. The most important advantage that laser scanners provide is the ability of getting the detailed 3D model of the complex objects very quickly with respect to other measuring methods. In this study, it is aimed to measure and define mathematically the roughness degree of the surfaces of rock pieces that are obtained as the result of breaking experiment. After the visual inspection of the surfaces, it was decided that the most convenient measuring method is scanning the surfaces in terms of complexity. The aim of the study is to measure the roughness angles, which are used to determine roughness degree effects as an important factor on the cutting resistance, faster and faithful. To achieve this goal; laser scanner was used as the measuring device, because of their ability of providing detailed 3D object geometry directly and fast. Nextengine 3D Desktop Laser Scanner was used in this study. Nextengine 3D Desktop Laser Scanner is a low cost scanning system which provides high precision with fast measuring ability. It is a triangulation based scanner. The objects that were used in this study are two opposed half pieces of a coring. The coring was broken under load test. Each pieces of the coring was laid on the tray of the system, which is approximately 15 cm from the device. This tray has the ability to rotate the object automatically to enable to scan all sides of the object. The acquired point clouds were filtered and noise reduction was applied. After that surface models of the both object were created using triangulated irregular network. Opposed Cross sections were created on both surfaces. New points that can represent these cross sections were generated automatically. These points were split up to cross sections and sorted according to their coordinate values. For each cross section curve equations were generated by using Matlab Curve Fitting Toolbox. Since they could not be mathematically formulated shape preserving fitting was used. After these fitting, slopes for certain intervals were calculated on these curves. Roughness angles were calculated from these slope values. Finally maximum, minimum and average values of negative and positive angles were summarized and roughness degree of the coring was determined.

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1. INTRODUCTION

Terrestrial laser scanners are measuring devices that has the capability of obtaining the detailed 3D object geometry directly and fastly. Laser scanners should not be considered as the replacing technology of the other methods like photogrammetry or classical geodetic measurements by itself, but it is a complementary and effective method when it is used together with the other methods. The most important advantage of laser scanners is the capability of measuring and modeling the complex objects and surfaces as highly detailed with respect to classical methods. In this study, it is aimed to measure the roughness degree of the surfaces of rock pieces and define the roughness angles. After visual inspection of the rock surfaces that were gathered at the end of breaking experiment, it was decided to use laser scanner for modeling the surfaces. Nextengine 3D Desktop scanner was used for the study. Nextengine 3D desktop scanner is a low-cost scanner which provides precise 3D point cloud fastly. This paper is organised as 4 sections. The first part is about the principles and tehcnical features of terrestrial laser scanner used at the study. At the second part, measuring and modeling steps were discussed. The third part covers the followed steps in order to determine the surface roughness angles and results. Finally, results, problems and solution recommendations are discussed at the fouth part.

2. OPTIC LASER SCANNING

In recent years, by the rapid development at computer technology, graphic processors of personal computers has strengthen and as result of this, the use of 3D modelling has grown up in both scientific area and among the end users. Together with the increasing demand to 3D models, high cost of the commercial laser scanners and the difficulty of processing the data from these devices has lead the development of low-cost 3D laser scanning systems. The main principle of optical scanners is triangluation. According to the triangulation principle, it is possible to calculate the 3D object coordinate (c) if the distance between camera and laser source (d) and two angles (α), (β) (**Figure 1:** 3D object scanning by triangulation method) of triangle are known. Magnitude of (γ) angle effects the depth resolution. If the angle increases, depth resolution increases [Zagorchev,2006].

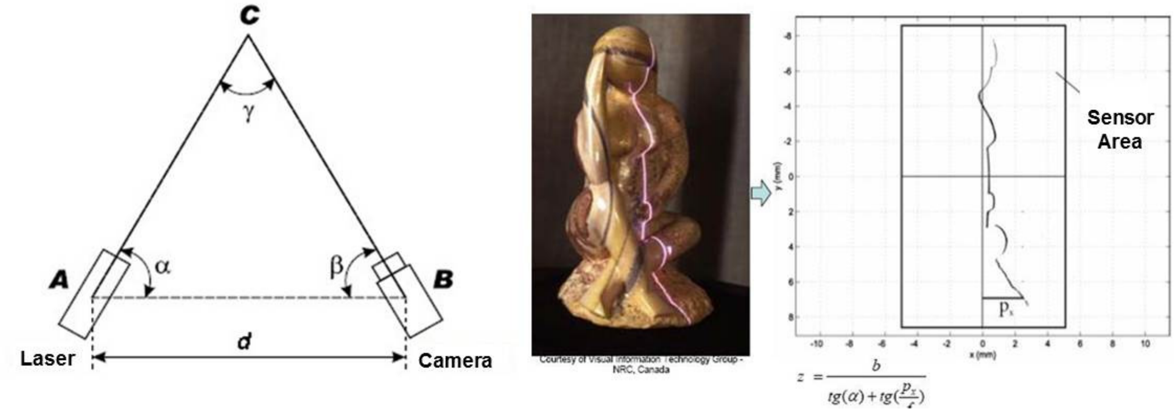

Figure 1: 3D object scanning by triangulation method

In this study, Nextengine 3D Desktop scanner was used (**Figure 2**). Nextengine 3D desktop scanner is a low-cost scanner which provides precise 3D point cloud fastly. Accuracy of the system is specified by the manifacturer as ±0.127 mm for macro mode and ±0.328 mm for wide mode.

3. SCANNING AND MODELLING

The rock pieces were placed on the rotating tray which is about 15cm away from the scanner. It is important that the whole object should place in the view of the camera of the scanner. ScanStudio HD software is used to control the scanner. The tray has the capability of rotating 360^{o} and rotates the object by the predefined angles. The alignment of the point clouds are done automatically by the ScanStudio. It should be taken care of not to change the position of the both scanner and the object. If this situation occurs, the software cannot carry out the automatic alignment process. In this kind of problem, one can align the point clouds manually by using the alignment tool of the software. At the end of the scanning, 3D model of the rock pieces were obtained and saved as vrl and exported to Geomagic Studio software to carry out some filtering processes. First of all, a low-level noise reduction was applied to the model and then point number was reduced by applying curvature sample method.

Figure 2: Nextengine 3D desktop scanner

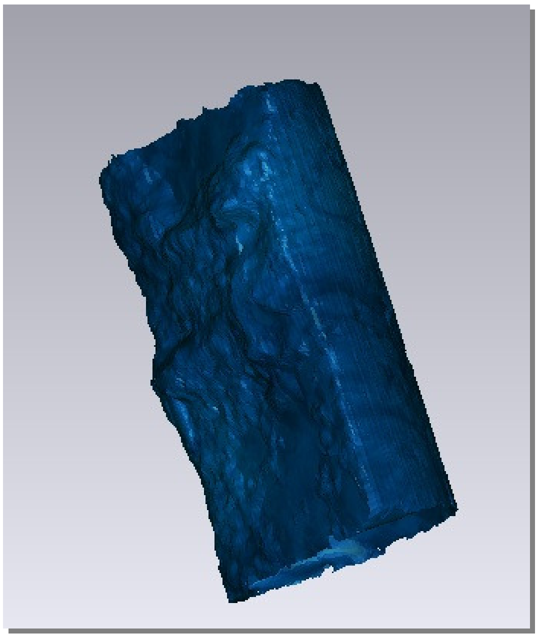

Figure 3: 3D Model

Curvature sample method preserves the detailes by reducing the point number at flat areas while preserving the number of points at non-flat parts. After post-processing steps, mesh model was generated from point cloud. The final model stil had some ocluded areas due to the viewing angle and lack of the light during the scanning. These occluded areas should be filled by choosing the appropriate enterpolation method of the software. Since the roughnesses of the surfaces are matters in this study, curvature-based method was choosen in order to preserve the curves. After getting the full 3D object model, cross-sections on the surface are taken with 2 mm interval in order to obtain the breaking angles (**Figure 3** and **Figure 4**). CAD illustrations of these cross sections are given in **Figure 5**.

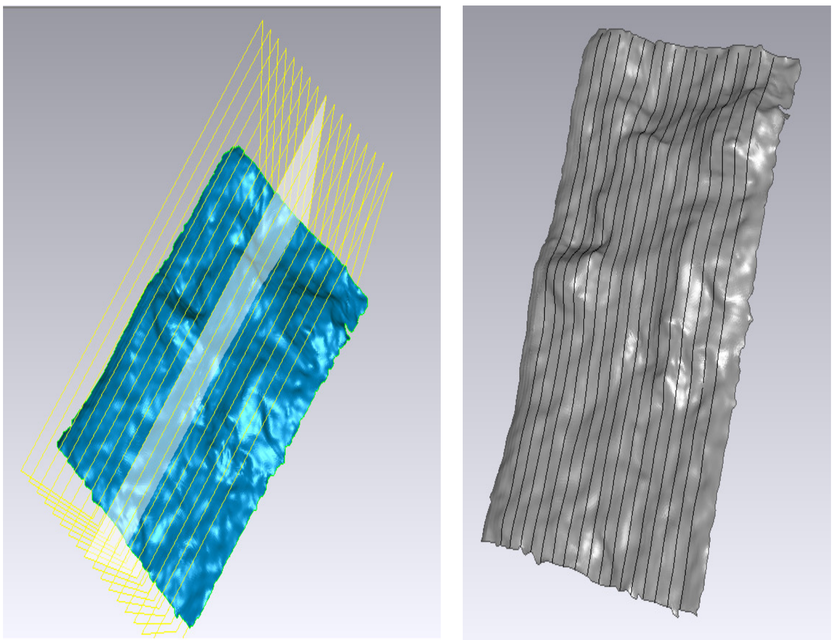

Figure 4: Cross-Sections

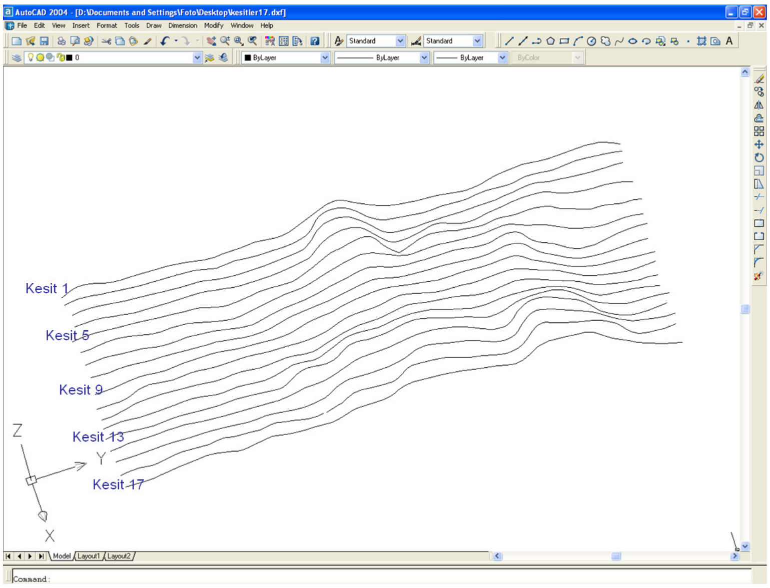

Figure 5: CAD illustration

4. DETERMINING THE SURFACE ROUGHNESS

In this section, calculating the roughness angles on surface was carried out. For this purpose MATLAB software's Curve Fitting Toolbox was used. By using the curve fitting toolbox, the first derivatives with 1 mm interval was calculated on curves. First derivatives give the slope of the curve on that point, so the breaking angle can be calculated as the inverse of the slope. Number of cross sections, number of point on each section and length of sections are given in Table 1. The maximum and minumum angles in both negative and positive and avarage of the angles were calculated and given in Table 2 for the all 17 cross-sections. Cross-Section-Slope Graph of the first cross-section is given in Figure 6.

Table 1: Cross-Sections and Number of Points

Cross section	Number of point	Length (mm)		Cross section	Number of point	Length (mm)		Cross section	Number of point	Length (mm)
1	74	69.3		7	74	69.2		13	74	68.9
2	75	69.2		8	73	68.7		14	76	68.2
3	74	68.6		9	72	68.6		15	76	68.6
4	76	69.9		10	73	69.5		16	75	68.5
5	74	69.6		11	72	68.7		17	75	69.0
6	74	69.3		12	73	68.8				

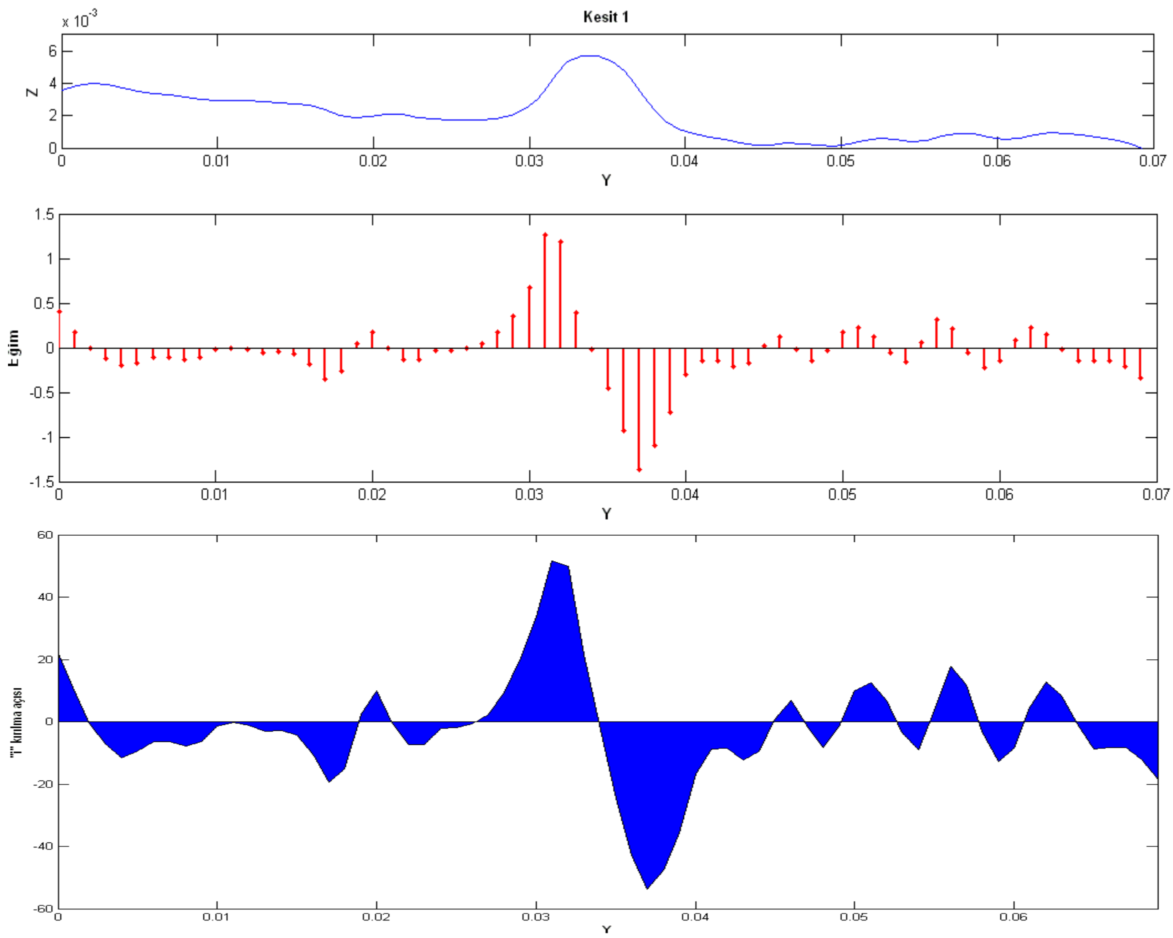

Figure 6: Cross-Section-Slope Graph Cross-Section "i" breaking angle graph

Table 2: Cross sections and breaking angles

Cross-Sec. No	Max Negative	Min Negative	Negative Avarage	Max Positive	Min Positive	Positive Avarage	Absolute Avarage
1	-53.68	-0.34	-10.44	51.76	0.82	14.93	11.85
2	-57.58	-0.15	-10.92	53.85	0.01	9.93	10.51
3	-57.11	-0.25	-13.39	47.05	0.02	12.26	12.89
4	-60.78	-0.58	-14.42	38.10	1.32	14.08	14.28
5	-51.23	-0.38	-15.21	29.96	0.46	12.47	14.23
6	-45.82	-0.47	-15.26	21.25	1.82	10.50	13.22
7	-64.67	0.00	-13.50	21.50	0.06	9.95	11.83
8	-53.57	-0.08	-11.64	19.28	0.06	8.47	10.44
9	-48.30	-0.10	-12.81	20.88	0.09	7.47	10.49
10	-40.34	-0.25	-12.72	30.33	0.00	10.13	11.69
11	-37.26	-0.05	-13.50	24.90	0.06	9.71	11.91
12	-47.57	-0.27	-13.26	36.14	0.04	10.32	11.72
13	-52.10	0.00	-13.70	41.52	0.00	13.08	13.48
14	-55.32	-0.12	-16.91	43.77	0.17	12.62	14.83
15	-54.05	-0.02	-17.53	53.91	0.02	12.48	15.08
16	-48.31	-0.02	-15.39	50.89	0.01	14.06	14.85
17	-58.92	-0.39	-14.82	44.67	0.00	13.57	14.29

Average	-52.10	-0.19	-13.86	40.82	0.33	11.69	12.85

In order to compare the obtained angles with the Description of Discontinuities and JRC standarts, curve fitting and calculation of the breaking angles steps for aforementioned standarts were carried out, as well (Table 3). The geometric relationship between cross sections and DOD standards are illustrated in Figure 7.

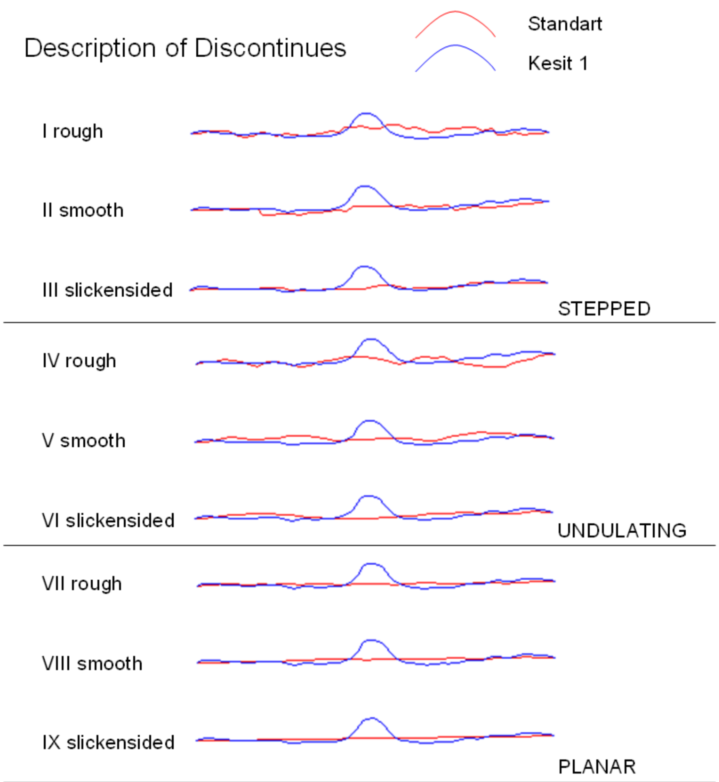

Figure 7: Obtained cross-section for DOD

Table 3: DOD standarts

Cross-Sec. No	Max Negative	Min Negative	Negative Avarage	Max Positive	Min Positive	Positive Avarage	Absolute Avarage
1	-55.32	-1.92	-13.32	52.85	0.29	10.61	11.69
2	-43.05	-0.01	-6.58	48.67	0.97	6.17	6.33
3	-19.86	-0.03	-7.36	31.62	0.06	2.34	2.95
4	-23.27	-0.92	-9.80	35.89	0.49	11.47	10.68
5	-14.60	-0.64	-5.42	17.63	0.10	6.55	6.02
6	-7.81	-0.35	-2.93	8.34	0.02	3.57	3.33
7	-9.22	-0.48	-3.05	10.48	0.01	3.31	3.16
8	-3.66	-0.08	-1.31	6.65	0.06	1.65	1.53
9	-0.65	-0.10	-0.36	1.88	0.10	0.89	0.82

5. RESULTS AND RECOMMENDATIONS

This study presented that terrestrial laser scanners can be effectively used in terms of accuracy and time to precisely calculate roughness angles of surfaces. These kinds of desktop scanners for sample drilling cores are higly suitable, but for the real case studies terrestrial laser scanners should be used. The proposed methodology will give effective and quick results for the period of collecting and processing the data.

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