ROUGHNESS MEASUREMENT VERIFICATION OF THE SURFACE STRUCTURES PRODUCED BY DIFFERENT MANUFACTURING TECHNIQUES USING WAVELET TRANSFORM

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Abstract:

In this study, roughness measurement verification was conducted using wavelet transform for the surface structures produced by different manufacturing techniques. These are surface grinding, front milling and face turning. After manufacturing, the surface roughness values were measured by means of stylus profilometer as contact measurement technique. Then, manufactured surface images were captured and inspected by 3D digital microscope. The captured images were then pre-processed using high pass filter in order to enhance the image before further image analyses conducted. Discrete Wavelet Transform in 2D image processing identifies different frequency components of images. This method was generally used to identify different surface topography produced by different manufacturing processes.

Non-contact (imaging) and contact (stylus profilometer) measurements of surface roughness were compared by employing the image processing method such as Wavelet transform and Ra values taken from stylus profilometer. Ra as 2D roughness parameter is evaluated in order to both determine and verify the roughness values obtained from measurement technique as stylus profilometer.

The values computed with the proposed method were compared with the roughness values obtained from 3D digital microscope. The relationship between wavelet parameters and surface roughness was determined (Stdv: 70.41, 77.22, 89.81 and corresponding Ra: 0.498, 2.382 and 3.984εm for ground, front milled and face turned surfaces, respectively).

Keywords: Computer Vision, Manufacturing techniques, Roughness measurement, Wavelet transform

1. INTRODUCTION

Surface grinding, front milling and face turning are conventional manufacturing techniques producing different surface topography. Surface topography is generally investigated and evaluated using non-contact and contact measurement techniques. These techniques have some advantages and disadvantages with regard to the designing concepts. The determination of surface roughness using computer vision is a rapid, low cost, and reliable non-contact technique.

Advances in software and hardware technology have produced major structural alterations in digital image processing, which is the use of computer algorithms to perform image processing on digital images. One way of estimating the surface roughness from the digital images is discrete wavelet transform. This technique characterizes the surface images in terms of time-frequency components. Several image processing techniques are developed in order to comprehend the surface topographical characterization, since monitoring of the surface images is a vital factor in planning of engineering processes.

Surface roughness, a critical parameter of surface quality, has negative effects on the performance of a machined part, since the fabricated roughness values are difficult and expensive to keep under control with regard to expected tolerances in manufacturing processes. There are several roughness parameters assessing the surface topography. The most well-known of them are average of center line profile (Ra), and average maximum height of roughness profile (Rz). These parameters are commonly measured by a stylus-based measurement system [1ï 3]. 3D Digital Microscopy making a remarkable contribution to the improvement of the field of dimensional measurement [4] is commonly used for measuring these roughness parameters.

Previous researchers have conducted several studies for surface texture evaluation using image processing techniques in the literature [5,6].

Lee and Turng studied the relationships between the feature of the surface image and the actual surface roughness under a variation of turning operations. They used a polynomial network using a self-organizing adaptive modeling method. They found that, the surface roughness of the turned part can be predicted with reasonable accuracy if the image of the turned surface and turning conditions are given [7].

Morala et al. [8] investigated the surface images for unmanned visual quality inspection and surface roughness discrimination in turning using a multiresolution method. They concluded that a texture classification was performed by a multilayer Perceptron artificial neural network. Experimental results show that the proposed approach achieves error rates between 2.59% and 4.17%.

Weckenmann et al. [9] presented the optical multi-sensor measurement system consisting of a shadow-section-system and a light-section-system as well as suitable methods of analysis for in-line inspection. The laboratory results from that study indicated that the measurement uncertainty of better than 0.1 mm at every profile was obtained.

2. FLOW OF THE EXPERIMENT

The evaluation process flow as represented in Fig.1 consists of three main phases, namely the machining of workpieces, the measurement of roughness parameters and computational phases.

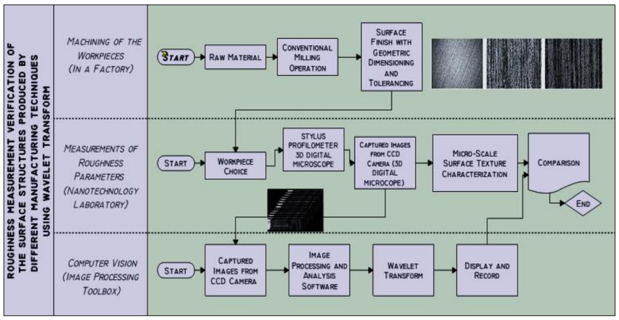

Fig.1: The evaluation process flow for characterization of surface roughness.

3. MATERIALS AND METHODS

3.1 Machining of the Workpieces

The workpieces were manufactured using three different machining processes, which were surface grinding, front milling and face turning. The specimens were manufactured by the three manufacturing processes. The surfaces obtained after these processes presented three different mean roughness values of (R_a) 0.498, 2.382 and 3.984εm. The captured images were illustrated in Fig. 2. These mean values were calculated from ten measurement points which were taken in the same alignment with an increment of 1 mm.

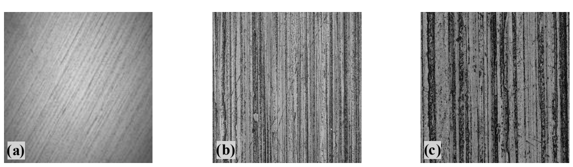

Fig. 2: The images taken from the workpieces a) Ground surface (R_a=0.498εm), b) Front milled surface (Ra=2.382εm) and c) Face turned surface (Ra=3.984εm)

3.2 Measurements of Roughness Parameters

The contact roughness measurement of the machined surfaces was performed by Form Talysurf Intra 50 profilograph with εltra software (FTS Iε) according to the EN ISO 4287 by mapping the readings taken in a direction perpendicular to the direction of lay by calculating of the roughness parameters like Ra and Rz (ISO/DIS 25178-70:2011) from a standard spectrum of roughness. The tactile system has a high resolution, in 1.0 mm range 16nm. It was used 60 mm stylus arm length, 2 µm radius conisphere diamond stylus tip size, 1 mN force (speed = 1 mm/s) and Gaussian filter in all measurements by the stylus instrument.

After carrying out the measurement with Form Talysurf Intra 50 profilograph [11], the evaluation processes were conducted with 3D digital microscope (Keyence VHX-2000) [12] is a high resolution CCD camera based system with a high intensity halogen lamp and image processing capabilities.

In this study, patterns of the machined metal surfaces (Ground, Front Milled and Face Turned) were captured. The size of workpieces was 5x5 mm. The field view of instruments was 21x21 εm.

Each measurement is the average of six scans [10]. 11 roughness parameters were obtained during each measurement and Ra values were used in this study.

3.3 Discrete Wavelet Transform

Several investigations have been performed to inspect surface roughness of a workpiece by using image processing techniques [10,13,14,15]. The same location of each captured image as shown was processed and analyzed using Matlab image processing toolbox. In this study, the procedures for Discrete Wavelet Transformation (DWT) were applied to the images using the algorithms [16, 17].

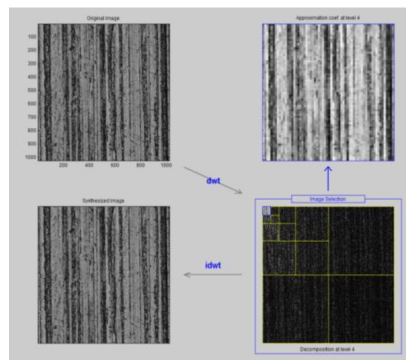

Fig. 3: Wavelet Transform Procedure.

4. RESULTS AND DISCUSSION

4.1 Roughness Measurement by Digital Microscope

The roughness measurement results taken from the stylus profilometer are given in Table 1.

Table 1: Roughness measurement results in terms of Ra.

Type of Manufacturing Techniques		Surface Grinding	Front Milling	Face Turning
Roughness Measurement Results R_a (µm)	**1**	0.485	2.386	3.971
	2	0.493	2.368	3.993
	3	0.479	2.392	3.989
	4	0.502	2.383	3.992
	5	0.508	2.392	3.985
	6	0.497	2.381	3.974
	7	0.506	2.372	3.976
	8	0.499	2.379	3.987
	9	0.501	2.387	3.983
	10	0.508	2.382	3.988
	Mean	**0.498**	**2.382**	**3.984**
	Std.Dev.	**0.010**	**0.008**	**0.008**

Grinding process, the process of surface finish and precision can be several times better than the other processes like milling or turning process (Table 1).

Figures 4, 5, and 6 show the wavelet transform results for the surface images for ground, front milled and face turned.

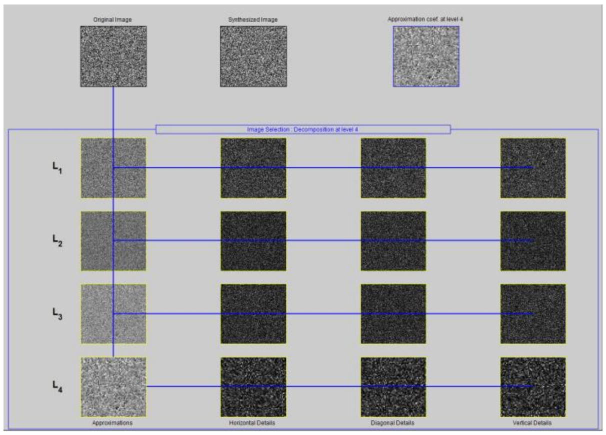

Fig. 4: Wavelet Transform for the ground surface.

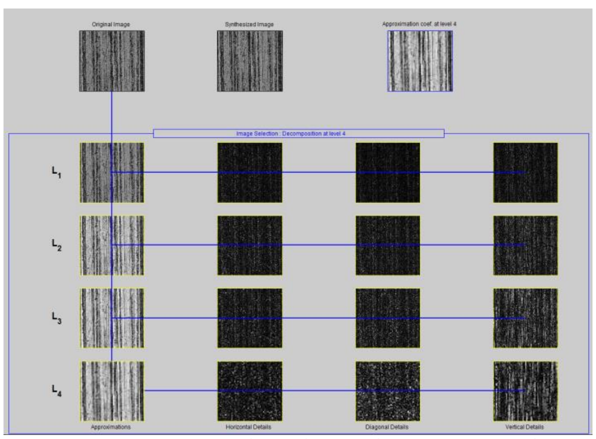

Fig. 5: Wavelet Transform for the front milled surface

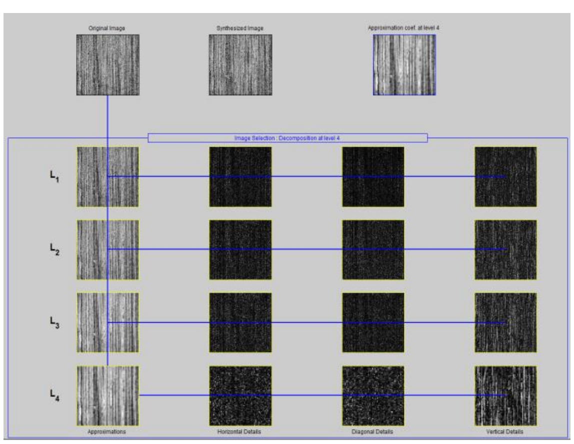

Fig. 6: Wavelet transform for the face turned surface

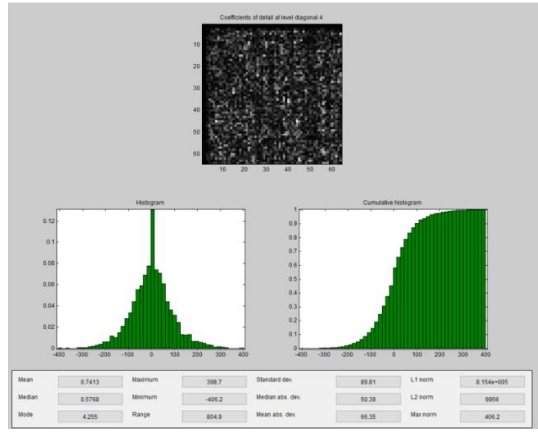

Fig. 6: Wavelet Transform for the face turned surface

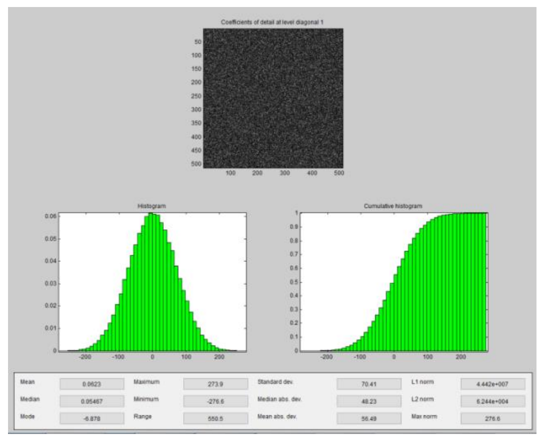

Fig. 7: Statistical results from wavelet transform for the ground surface

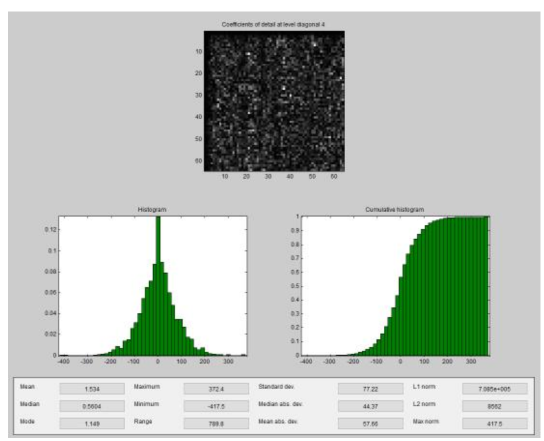

Fig. 8: Statistical results from wavelet transform for the front milled surface

Statistical results from DWT analysis indicated that standard deviations derived from the images decomposed at level 4 had significant relationship with Ra values for ground, front milled and face turned surfaces, respectively (Stdv: 70.41, 77.22, 89.81 and Ra: 0.498, 2.382 and 3.984εm).

5. CONCLUSIONS

This paper investigated the surface characteristics of the micro-scaled manufactured samples not only in measuring their surface roughness but also analyzing their surfaces using image processing techniques. Results of discrete wavelet transform based on image processing evaluation can help to enhance basis for the quality improvement and optimization of surface texture characterisation of technical structures for the future.

This study showed that computer vision has a great potential in the determination of the surface roughness parameters as the noncontact measurement. DWT image processing and analyses results explicitly imply that this technique is useful in the determination of surface roughness.

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