An Experimental Study of the Frictionally Induced Vibrations on Rough Textile Fabrics

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1. Introduction

Human beings have the ability to describe the object's shapes and patterns using vision but cannot recognize the specific properties such as the hardness, roughness and friction without touching them. Finger of a human has billions receptors on his hands which makes easy to define the object shapes and textures. In the textile industry, new fabrics are still categorized by experts that evaluate the softness and quality of textiles by sliding the index or thumb fingers over the fabrics. When human finger touches any surface, friction occurs between fingertip and surface due to the induced vibrations. The frequency content in these vibrations are investigated to understand how the mechanoreceptors are functioning in the human fingers [1,2]. The receptors of the touching area acquire and transmit the frequency information to the brain for further processing the information.

2. Motivation

Humans are excellent at recognizing common objects by touch alone and determination of their material properties, shapes, texture etc. Although the textile industry demands the automation for the characterization of the textile quality, there is still lack experimental setups aimed to analyze the frictionally induced vibrations of texture patterns that limits the progress in this area.

3. Experimental Method

The custom build experimental setup consists of two linear motors located perpendicular to each other in order to give the horizontal and vertical motions. A three dimensional piezoelectric force sensor mounted on the vertical linear motor to measure the normal and friction force. The cross-talk of these sensors is checked and minimized with proper calibration. A hemispherical glass sphere with different radius of curvature is attached to the force sensor as an end effector and come into contact with the textile fabrics. The sensor is attached to the vertical motor and a substrate is connected to the shaft of the horizontal motor. A real time normal force (preload) control is performed using two different control algorithm; an adaptive proportional- integral- derivative (A-PID) and sliding mode control (SMC). The adaptive PID controller used in this work is based on gain scheduling. The coefficients of the PID controller are changing with respect to the tracking error. In contrary, SMC is a switching based nonlinear and variable structure control method mostly used for controlling nonlinear systems. The performance of these two controllers is compared for the constant preload control.

4. Results and Summary

Textile fabrics with different texture patterns (roughness values) are tested using different preload, velocities and tip sizes. A sample scanning electron microscopy (SEM) image of the textile sample is shown in Figure 1 (a) with a 0.6 mm repeated pattern in the weft yarn direction. The corresponding friction, normal force and error values are shown in Figure 1 (b-c) where the preload is kept constant at 100 mN. Using a low pass filter and fast fourier transform algorithm (FFT), the friction force signal in time domain is transformed into frequency domain. As shown in Figure 1 (d), the excitation frequency from the texture pattern of the fabric is nearly recognized with the friction amplitude response. Although the experiments are conducted with low speeds using quasi-static assumption, fibers used in textiles are usually viscoelastic nature which shifts the frequency. Purely elastic contact of end effector and patterned steel fiber substrates is also analyzed using the proposed experimental setup.

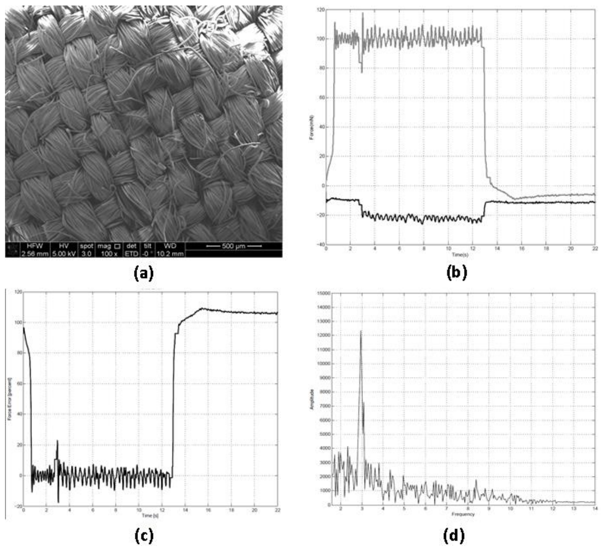

Figure 1: (a) The SEM image of the textile fabric, (b) friction and preload graph in time domain, (c) the force error graph, (d) Frequency response of the friction force.

5. References

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