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Theoretical and Experimental Prediction of Optimal Process Variables for Enhanced Metal Removal Rate During Turning on CNC lathe

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Abstract: In the present work, vibration signals are attained using a microphone during turning operation and treated with signal processing techniques. The Chatter Index has been used to examine the demodulated signals from different signal processing techniques (CI). According to the investigation, Wavelet Denoising and Local Mean Decomposition (WDLMD) is an effective method for online tool chatter monitoring in turning.

Keywords: LMD; EMD; WDLMD; CNC

1. Introduction

Regenerative chatter is a self-excited vibration of cutting tool resulting due to inhomogeneity of the workpiece[1,2]. This inhomogeneity leads to an uneven cut surface on the workpiece[3,4]. This uneven waviness of the surface is exaggerated with the successive turning passes [5]. The representation of the wavy profile has been shown in Fig. 1. In schematic diagram, m is the mass of tool, k is spring constant and c is damping coefficient. Schematic representation of wavy profile is shown in Fig. 1. Thus, chatter detection, monitoring and its detection is challenging task in turning[6,7,8].

Mathematical modeling of the turning system enables us to understand the chatter phenomenon. Moreover, using this developed model, turning process has been simulated. The mathematical model has been developed considering orthogonal turning operation having a single degree of freedom (sDoF)[9,10]. During turning modulated chip thickness are produced as shown in Fig. 1. The dynamic equation of turning on the lathe comprises of cutting, inertial, damping and spring force[11,12,13,14].

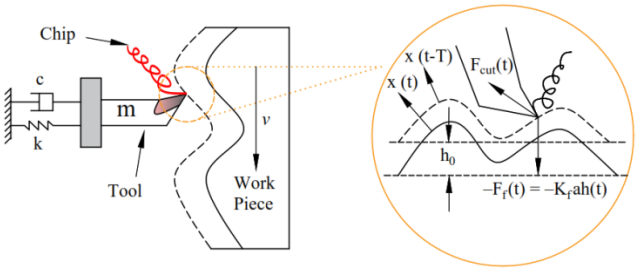


Fig 1: Schematic representation of wavy profile

Due to the fact that tool failure and replacement account for 15% of downtime in the manufacturing sector, condition monitoring has gained significant traction in this sector. To reduce downtime, certain industries have converted to automatic tool changeover systems15,16,17). This decreases downtime and boosts productivity18,19). The issue of unexpected tool failure, however, has not yet been resolved. Later, it was claimed by a number of academics that the regenerating chatter is what caused the tool's unexpected failure. Additionally brought on by this self-excited event include poor surface finish and high cutting force20,21). Sensors were developed to monitor the state of tools and workpieces in order to solve these issues 22,23,24).

The necessary sensor is mounted close to the tool or another adjacent acceptable area in order to monitor the tool's condition. The kind of procedure and features that need to be extracted determine the sensor to use. In this work, the microphone has been used, and signal processing techniques have been used to remove noise contaminations from the obtained data. Many researchers

have investigated various methods, including WT, LMD, and EMD (Zhang et al., 2016) 25, 26). Authors have investigated various strategies in this work and have also suggested a brand-new technique, WDLMD. The obtained signals from the turning action have been processed utilising several signal processing methods, as well as the proposed WDLMD method. Analysis and comparison have shown that WDLMD produces superior results.

2. Methodology

The outlay of proposed methodology has been represented as shown in Fig 2.

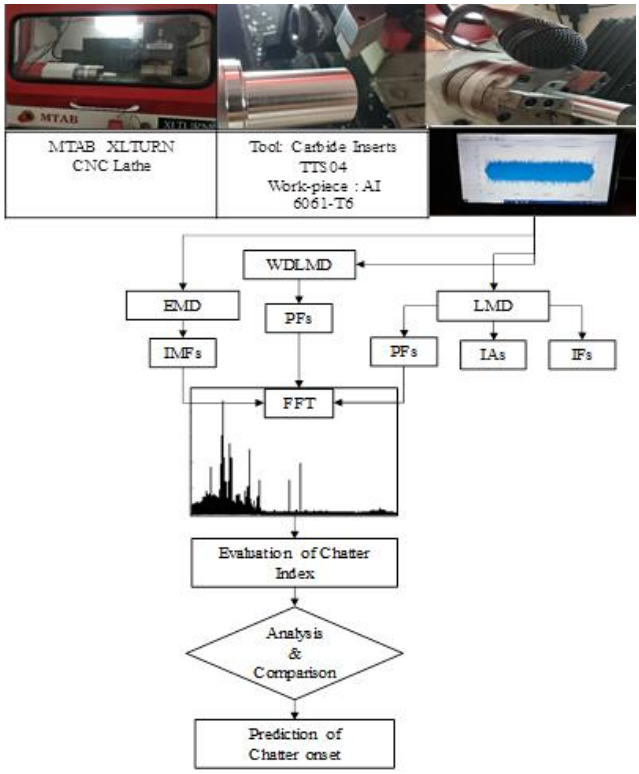


Fig. 2. Outlay of methodology

2.1. Experimentation

Experimentation is done for recording the chatter signals on MTAB trainer lathelathe using TTS04 as tool insert and Al-6061 as workpiece, for cutting combinations d= (0.2, 0.3, 0.4) in mm, n= (1000, 1500 , 2000) in rpm, and f = (30, 35, 40) in mm/min.

2.2. Processing of attained signal using EMD

The intrinsic physical characteristics of a non-stationary signal are extracted by EMD 8. Signals were divided up into a number of IMFs using EMD19). Fast Fourier transform (FFT) was used to further process these IMFs, and this result is likewise displayed in Fig. 3.

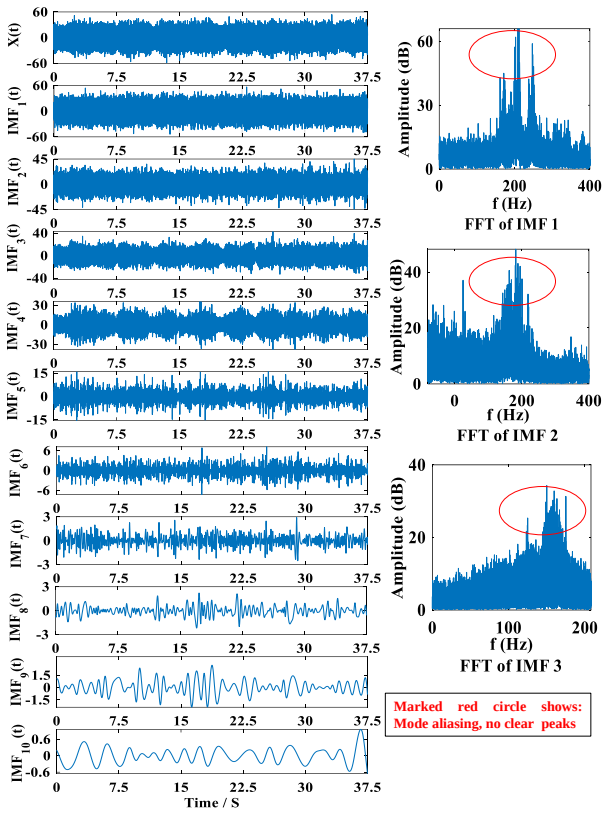


Fig. 3. IMFs and FFTs of attained signal

2.3. Processing of attained signal using LMD

LMD technique is shown in Fig. 4. It decomposes signal into number of product function (PFs). One of the decomposed signals is shown in Fig. 5.

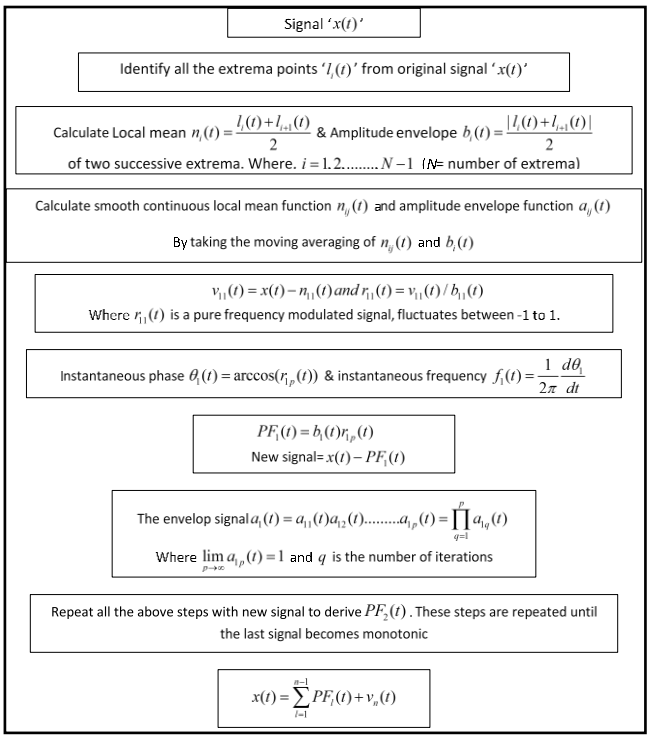


Fig. 4. Flowchart of LMD technique

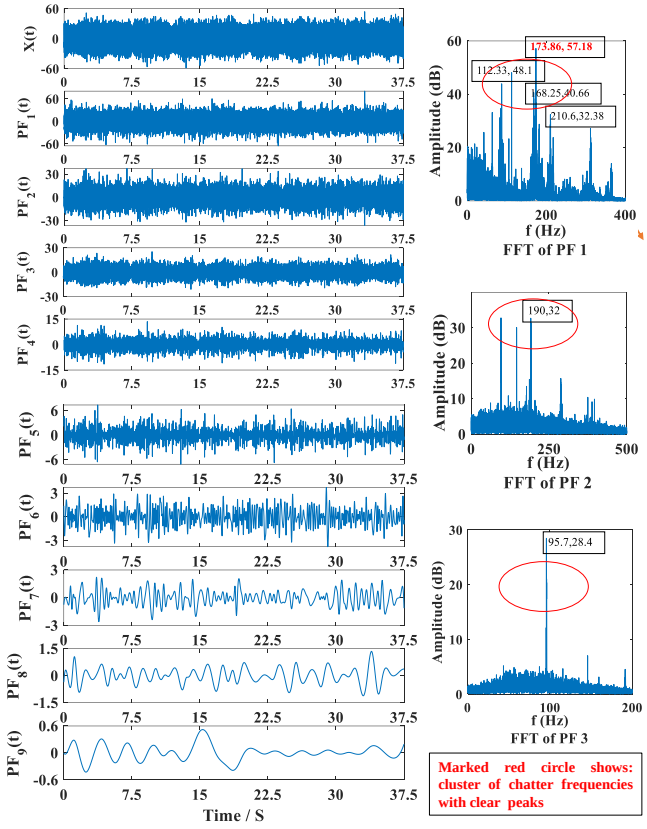


Fig. 5. PFs and FFTs of attained signal

2.4. Processing of attained signal using WDLMD

Chatter signals are inaccurate as a result of the added noise source. As a result, obtained chatter signals must be cleaned up by first denoising them using the wavelet approach, as shown in Fig. 6. The denoised signal was later converted into a number of PFs using LMD. It entails all the procedures necessary to transform the captured chatter signal into knowledge that can be applied to decision-making. After the background noise has been eliminated, the Fast Factorial Transform (FFT) has been used to further analyse the data and assess the chatter frequency in order to produce useful information.

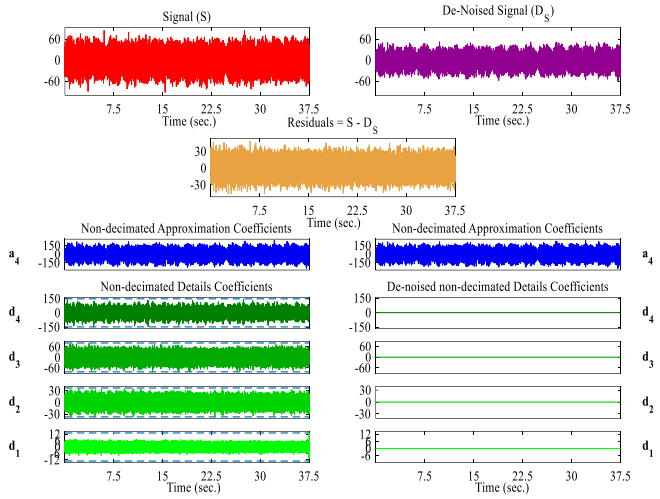


Fig. 6. Wavelet denoising

Further, LMD decomposes denoised signal into PFs as shown in Fig. 7 and using correlation coefficient the signals is reconstructed to get the chatter information and further, FFT has been applied for spectrum analysis as shown in Fig. 8.

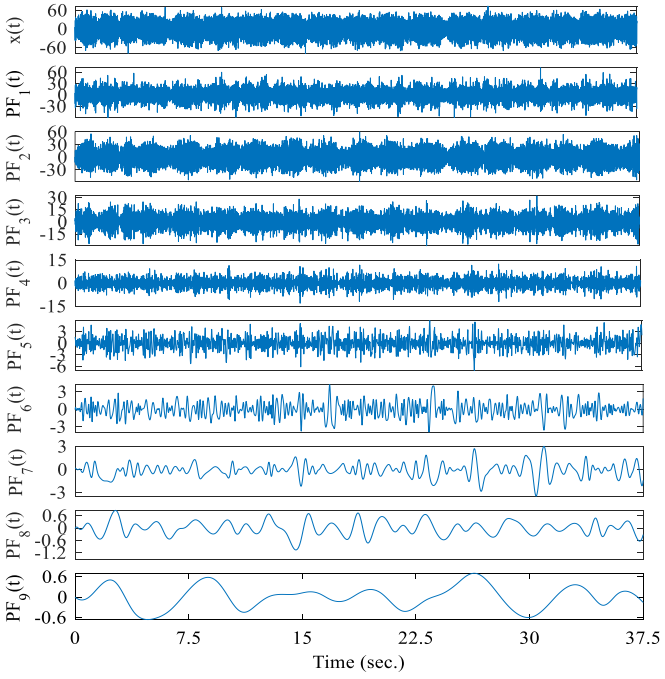
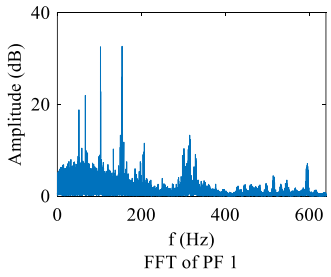
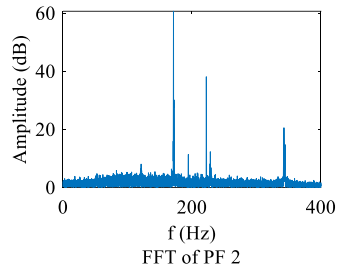


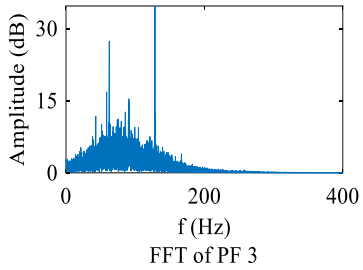
Fig. 7. Signal decomposition of denoised signal



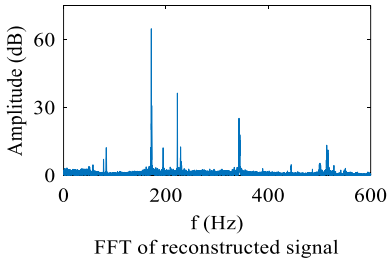
(a)



(b)



(c)



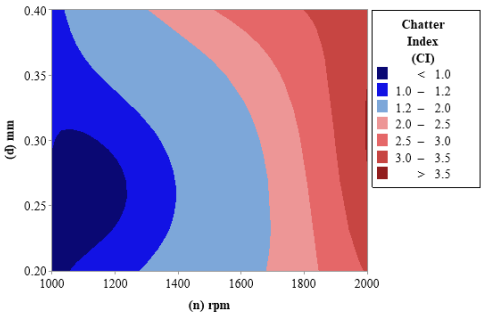
(d)

Fig. 8. FFT of PFs and reconstructed signal

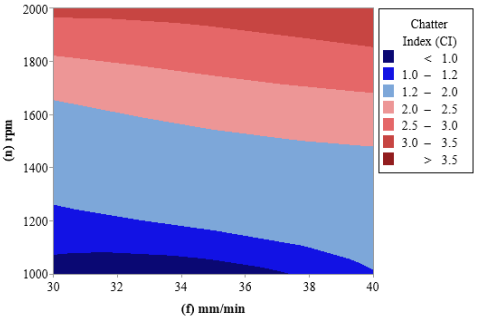
3. Results and Discussion

Sensors gather data in a variety of ways. It's possible that this information won't make sense to us or that it contains noise. As an illustration, a sensor could listen for noise coming from a machine shop. Voices from operators may be heard in the oral sound captured by the microphone sensors. All noises coming from neighbouring machinery in the factory. Signal mistakes are brought on by the additional source of noise. As a result, the noise should be removed from the sound, the basic signal. The cleaned, noise-free signal can be utilised for pattern verification by comparing the present noise-free signals with earlier recorded signal data sets after the noise from the original recorder signal has been removed.

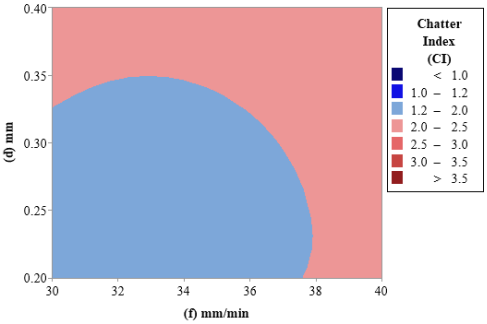
First, signal processing entails all the steps that must be taken to transform the signal gathered and the source into knowledge that can be applied to decision-making. This can entail cleaning up the previously acquired signal to remove noise and processing the data to provide information that can be put to use. In Fig. 9, the contour plot is displayed. Additionally, a consistent range of n= 1000–1280 rpm, d= 0.2-0.34 mm, and f= 30-37.8 mm/min has been noted.



(a)



(b)



(c)

Fig.9. Contour plot on CI w.r.t.: (a) d & n, (b) n & f, (c) d & f

4. Conclusions

Analysis has shown that the EMD, LMD, and WDLMD approaches can effectively filter chatter signals.

Compared to EMD, LMD has the added benefit of being able to predict chatter's onset more precisely because it pays attention to the signal's beginning amplitude changes, however there is still some mode aliasing.

The proposed WDLMD technique proposed by authors is efficient technique for the chatter signal's analysis and to extract information. The conclusion drawn for stable limit is that the CI value should be below 1.2, and for unstable limit the CI value should be above 3.01. The CI value in between 1.2 to 3.01 will result moderate chatter.

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