Experimental and Numerical study of Turning Cutting tools Random vibration towards mitigation

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Abstract:

Turning machine vibration is an old problem on manufacturing processes. Unless avoided, vibrations may cause large dynamic loads damaging the machine spindle, cutting tool, or work-piece and leave behind a poor surface finish. This work intended mainly to measure the random vibration in various cutting tool length . Accelometer fixed in different points along the tool-piece to test the effect of distance from the fixed point on random vibration . A USB vibration analyzer and using a specialized program the data obtained analyzed for many random vibrational parameters (acceleration RMS, velocity RMS ,displacement RMS and maximum frequency) .Different speed for the turning process are used (40 ,125,180 and 540 rpm) .Result shows increasing behavior for acceleration , velocity and displacement with decreasing behavior upon decreasing distance from fixation point and decreasing behavior for maximum frequency reached. Also, a Finite element model was suggested using ANSYS 14 to simulate the cutting tool displacement and von-Miss stress distribution .

Keywords: ***tool-Piece, work-piec, random vibration, frequency, RMS***

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الخلاصة :

يعد الاهتزاز في ماكينات الخراطة مشكلة تصنيعية قديمة جدا . يمكن ان يؤدي الاهتزاز في هذه المكائن الى توليد حمل ديناميكي يتلف الجزء الدوار واداة القطع او قطعة التشغيل وتترك خلفها انهاء للسطح ضعيف. هذا البحث يهدف بشكل رئيسي الى قياس الاهتزاز العشوائي على طول اداة القطع . وضع متحسس الاهتزاز في نقاط مختلفة على طول اداة القطع لاختبار تأثير المسافة من نقطة التثبيت على الاهتزاز العشوائي . باستخدام جهاز تحليل الاهتزاز ذو وصلة (يواس بي) مع برنامج متخصص تم تحليل البيانات لمتغيرات الاهتزاز العشوائي مثل (التعجيل والسرعة والازاحة وكذلك التردد) . تم اختيار سرع مختلفة لماكنة الخراطة هي (40 و125 و180 وكذلك 540 دورة/دقيقة) . النتائج اظهرت سلوك متزايد للتعجيل وللسرعة و الازاحة بزيادة المسافة من نقطة التثبيت مع تناقص في قيمة التردد العظمى. تم اقتراح نموذج بطريقة العناصر المحددة باستخدام برنامج (ANSYS 14) لمحاكات توزيع الازاحات والاجهادات .

كلمات دليلة: اداة قطع ، اداة تشغيل ، اهتزاز عشوائي ، تردد ، RMS

1. Introduction

Cutting is a complicated process where in performance depends upon a number of cutting and tooling conditions. Today the standard procedure to avoid vibration during machining is by careful planning of the cutting parameters. Machining vibration exists throughout the cutting process. While influenced by many sources, such as machine structure, tool type, work material, etc., the composition of the machining vibration is complicated. However, at least two types of vibrations, forced vibration and self excited vibration, were identified as machining vibrations. Forced vibration is a result of certain periodical forces that exist within the machine. The source of these forces can be bad gear drives, unbalanced machine-tool components, misalignment, or motors and pumps, etc. Self-excited vibration, which is also known as chatter, is caused by the interaction of the chip removal process and the structure of the machine tool, which results in disturbances in the cutting zone. Chatter always indicates defects on the machined surface; vibration especially self-excited vibration is associated with the machined surface roughness [1].

Erol Turkes et al [2] chatter prediction was investigated for orthogonal cutting in turning operations. The linear analysis of the single degree of freedom (SDOF) model was performed by applying oriented transfer function (OTF) and decomposition form to Nyquist criteria. Machine chatter frequency predictions obtained from both forms were compared with modal analysis and cutting tests.

Armando I. S. A. et al[3] studied the influence of the tool entering angle on the stability of the process and on tool life based on a time and frequency domain analysis of the cutting forces. The results show that lower entering angles may provide stabler cutting, as indicated by the regular tool wear instead of the microchipping resulting from the use of a higher value of this angle.

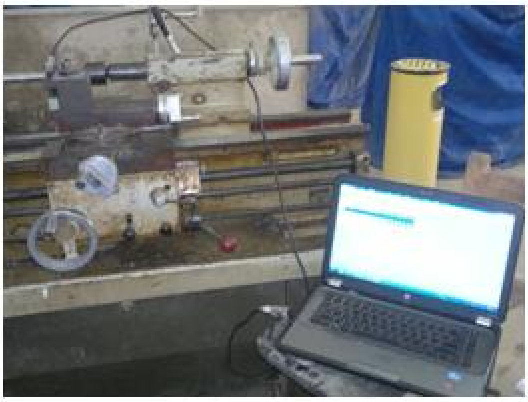
Although cutting forces are larger at lower entering angles, the tool life is much longer, since most of this load is associated with low frequencies, at which the tool behaves like a rigid body.

Francis C. Moon1 and Tamas Kalmar Nagy[4] reviews the prediction of complex, unsteady and chaotic dynamics associated with material-cutting processes through nonlinear dynamical models. The status of bifurcation phenomena such as subcritical (Hopf) instabilities is assessed. A new model using hysteresis in the cutting force is presented, which is shown to exhibit complex quasi-periodic solutions. In addition, further evidence for chaotic dynamics in non-regenerative cutting of polycarbonate plastic is reviewed. Raviraj Shetty et al [5] discusses experimental work and finite element analysis to investigate the mechanism of chip formation during machining of DRACs. Focus of this paper is on understanding the influence of different cutting parameters on mechanism of machining. Chips generated experimentally and by finite element modeling during orthogonal machining of DRACs were used for this purpose. Brandon C. Gegg et al [6] Gives a parameter study of a machine-tool with interrupted cutting is completed for eccentricity frequency and amplitude. The effects with respect to chip length are also incorporated, such that comparisons of the parameter maps can be accomplished. Specific areas within the parameter maps are studied to explain the complicated motions within. In such a case, the switching characteristics are shown with respect to eccentricity frequency. The complexity of the periodic solution structure is discussed regarding the stability, in relation to the vector fields and mapping quantities.

[7-13]Considerable research efforts have been put into controlling or reducing the extent of the damaging vibration in machining systems by using various vibration control or attenuation methods. These methods include both process parameter control to avoid chatter conditions and structural modifications to improve dynamic stiffness of the elastic structure of machining systems. [14] M. Thomas and Y. Beauchamp optimized cutting parameters be selected in controlling the quality required for surface finishes. They focuses on the collection and analysis of cutting-force, tool-vibration and tool-modal-parameter data generated by lathe dry turning of mild carbon steel samples at different speeds, feeds, depths of cut, tool nose radii, tool lengths and workpiece lengths. A full factorial experimental design(288 experiments) that takes into consideration the two-level interactions between the independent variables has been performed.

2. Experimental work

The Experimental work done on a turning machine with twelve different speed **Figure.(1)a** .The length of cutting tool is 15 cm (high carbon steel) fixed as a cantilever beam with 10 cm length gives the ability to attach the high magnetic base accelometer along its length with variable interval as shown in **Figure.(1)b**



(a)

(b)

Fig. (1) The turning machine used with accelometer

The measured data transferred from the acelometer through USB interface with PC through a special program (EI-Calc- Erbessd instruments ®) used to get various vibrational parameters **Figure(2).**

Fig. (2) The USB vibration analyzer used

This measured data converted to acceleration ,velocity and displacement with time and Transformed later by using Fast Fourier analysis (FFT) to measure the frequency attended . Four rotational speed are selected used namely (40,125,180 and 540 rpm) .The feed rate used are constant through the experimental work and was (0.1mm/rev) . Some variables used are listed in **Table 1**

Table 1 Cutting tool and work piece variable used

Variable	Level	Variable	Level
Cutting speed (S)	40,125,180 and 540	Work piece length (L)	40 cm
Feed rate (f)	0.1 mm /rev	Work piece radius (R)	8 cm
Tool nose dimension	1.5 mm	Rack angle (α)	30^{0}
Tool length(T)	15 cm		

3. Results and Discussions :

The results obtained utilizing a time duration for reading data 30 second . A 10 sec sample for 40 rpm turning velocity shown in **Figure(3)** . The gradual cutting process vibration obvious for the first seconds and gives indication for the feed rate used .The Sample rate (11025hz). Assuming the vibration of the turning machine reached to the cutting tool considered constant and small for each reading .

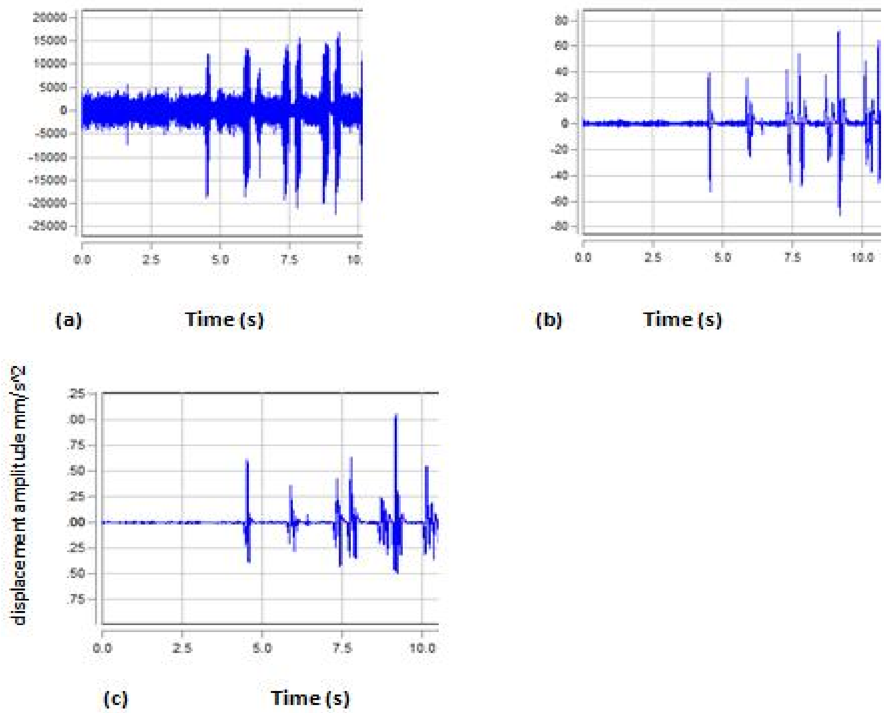


Fig. (3) sample data for 40 rpm turning velocity for 10 sec

a) Investigation of distance of the accelometer from fixed end

The point of accelometer position are selected to range from (20-70) cm and the random vibration variable measured. **Figures .(4,5,6)** represent the behavior of the displacement RMS , Velocity RMS and acceleration RMS . These figures shows the increasing trend for the different vibration parameters with the distance of point measuring increasing . On the contrary we see the behavior is decreasing for frequency measured this is because the length of the cantilever beam become larger where the points of measuring is near the fixed end and so the stiffness is larger hence the frequency since frequency is function of stiffness of cutting tool .

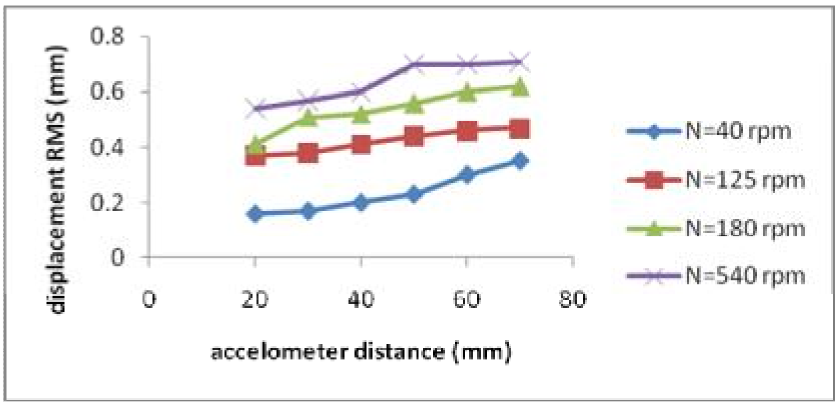


Fig.(4)The displacement RMS vs accelerometer distance

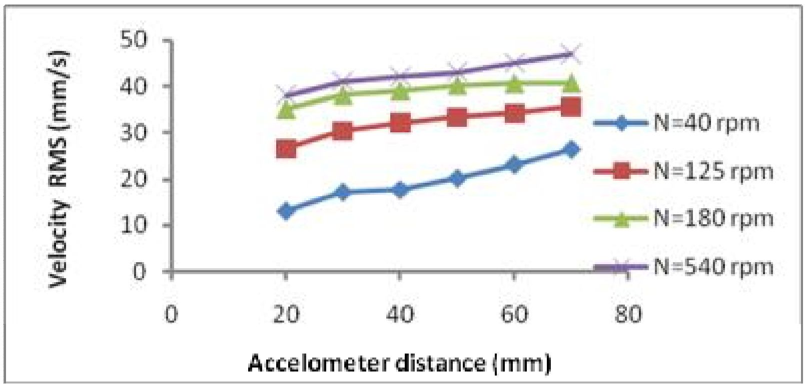


Fig.(5)The Velocity RMS vs accelerometer distance

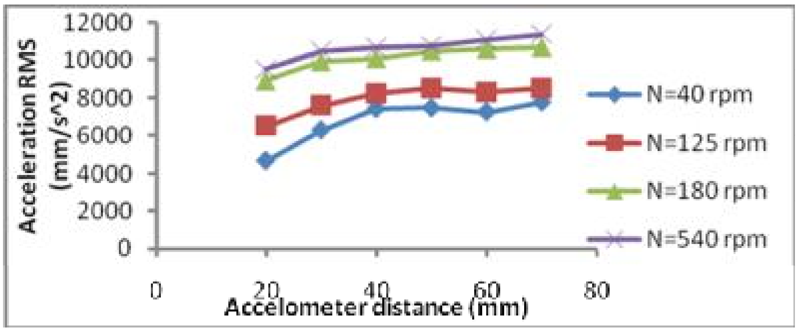


Fig.(6)The acceleration RMS vs accelerometer distance

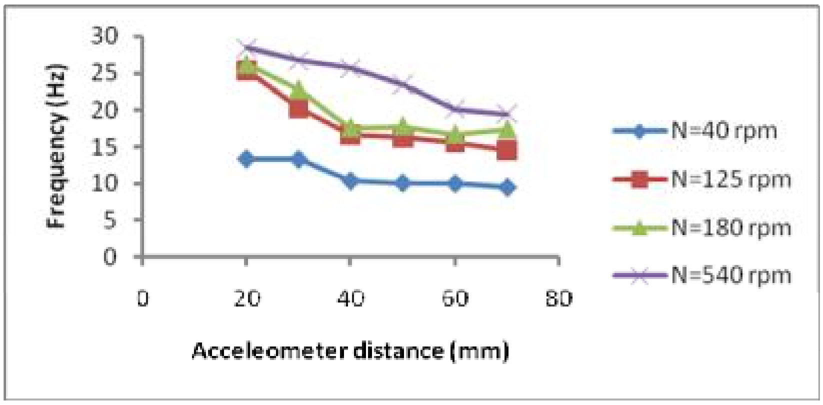


Fig.(4)The Maximum frequency vs accelerometer distance

b) Investigation of stresses and deformation due to random excitation

The experimental PSD (acceleration Power spectrum density) are input to a suggested 3d Finite element model **Figure .(5)** using Ansys 14 to study the effect of vibration on deformation and stresses of cutting tool with different lathe machine speed . We assume that the cutting tool tip is the same material of the cutting tool and considered as one piece . Sample deformation and stress in the cutting tool are shown in **Figure.(6 a,b,c).**

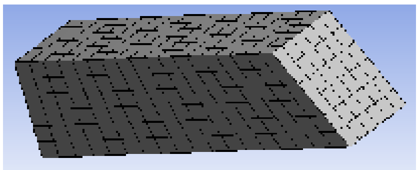
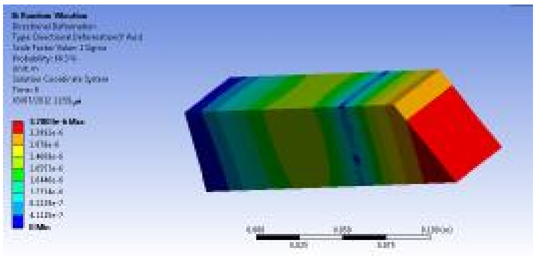
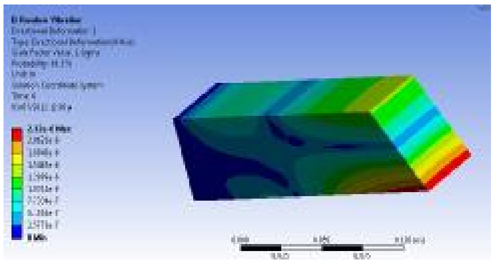


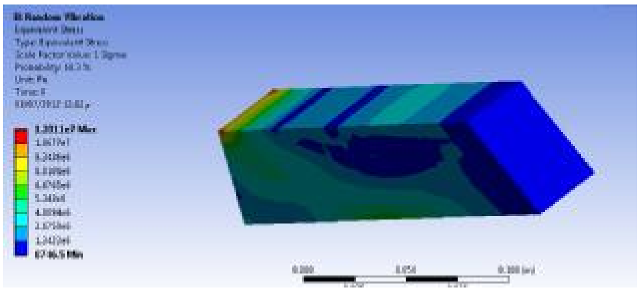
Fig.(5) Finite element mesh used to model the cutting tool



(a)



(b)



(c)

Fig.(6) (a)Directional deformation in y-direction in 40rpm
(b) Directional deformation in x-direction in 40 rpm
(c) Equivalent Von-Mises stresses distribution in the cutting tool in 40 rpm

Table 2 Maximum Deformation and Von –Mises stresses in the cutting tool

N (rpm)	Max. Y-deformation (m)	Max. X-deformation (m)	Von Mises(Mpa)	Stress Percent increase
40	3.7e-6	2.37e-6	1.2	0.2
125	5.6e-6	3.1e-6	1.5	
180	7.2e-6	4.2e-6	2.01	0.25
540	9.1e-6	6.5e-6	3.23	0.36

The experimental PSD trend are input to each case of the lathe speed to get the displacement and stress as shown in table 2. The stress and the deformation are increasing with cutting speed and the deformation in x-direction and z-direction are symmetric.

4. Conclusions

The random vibration characteristic influence on cutting tool during turning process on lathe machine is investigated. A major conclusions are drawn from this study :

1. The acceleration RMS , velocity RMS and displacement RMS shows increasing trend with regard to point of accelometer position from the fixed point of cutting tool.
2. Frequency attended in the cutting tool shows a decreasing behavior ,gives indication to reduce the vibration induced by manipulating the free distance of cutting tool from the fixed point and consider it superior than other parameters .
3. The stress and the deformation are increasing with cutting speed and the deformation in x-direction and z-direction are symmetric for e.g.(von mises stress percentage increase 20% for speed 40-125 rpm , 25% for speed 125-180 rpm and 36% for speed 180-540 rpm) .

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