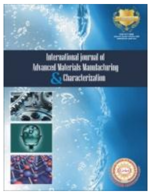

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Finite Element Analysis of Ultrasonic Vibratory tool and Experimental Study In Ultrasonic Vibration-assisted Turning (UVT)

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In the modern day's applications of hard materials in different industries, like aero-technical, defense and petrochemicals sectors etc. have been increased remarkably. The machining of these hard materials is very difficult in conventional turning process. Ultrasonic assisted turning is a suitable and advanced process for machining hard and brittle material because of its intermittent cutting mechanism. In the present work, Designed the experimental set-up and Experimental study have been carried out to find the difference between ultrasonic-assisted and conventional turning at different cutting condition taking Stainless steel (SS-304) (a general purpose engineering material) as a work piece material. FEA has been used for more than 40 years to various structural, thermal and acoustic problems. In this present problem ANSYS® software package is used to analyze dynamic analysis of ultrasonic vibratory tool. Both modal and harmonic analysis of UVT are carried out to calculate the natural frequency and amplitude of tool.

Introduction

Metal cutting by using ultrasonic frequencies vibrations is more suitable technique, comparison with traditional cutting method[1]. The present research is particularly focused on ultrasonic vibration-assisted turning. Ultrasonic-vibration assisted turning is a cutting technique in which a certain frequency (in ultrasonic range) of vibration is applied to the cutting tool or the work-piece (besides the original relative motion between these two) to achieve better cutting performance[2]. A number of experimental setup has been proposed to make the process simpler, but the tendency is to apply the process to a wide range of materials and to study the effect of machining parameters. Many researchers have reported significant improvements in noise reduction, tool wear reduction, surface finish, etc[3,4].Tangential direction: Vc=πND < Vt=2πaf Where V is the cutting speed during turning operation, N is the rotational speed of work-piece, Vt is the tip velocity, f is the frequency of vibration and a is the amplitude of vibration[6]. The experiments confirmed an evident reduction in the cutting force for ultrasonic cutting with vibration in tangential direction (f =20kHz, a=10μm). It was also reported that cutting force reduction was less at higher cutting speeds and, with a cutting speeds exceeding a certain level (Vt > a, where ω is the angular frequency), vibration did not affect the cutting force[7].

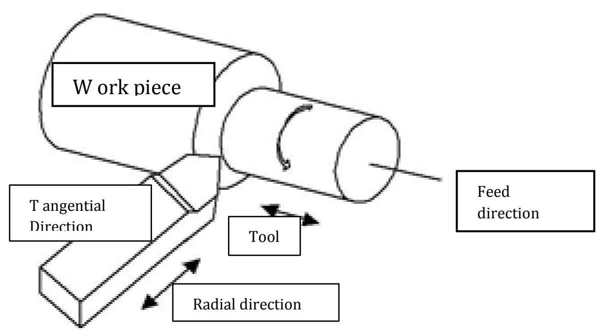

Figure1. Principal vibration directions during ultrasonically assisted turning[5].

When the ultrasonic vibrations applied in Tangentional direction the following restrictions are imposed:

$$\text{Tangential direction: } V_c = \pi ND < V_t = 2\pi a f$$

Where V_c is the cutting speed during turning operation, N is the rotational speed of work-piece, V_t is the tip velocity, f is the frequency of vibration and a is the amplitude of vibration[6].

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Design of experimental set up

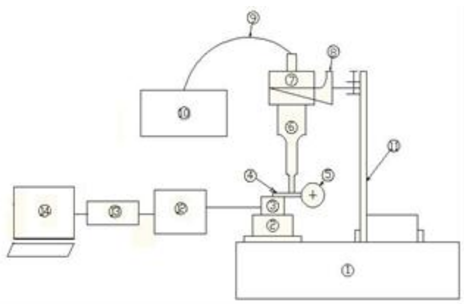

Figure2. 2-D Schematic diagram of ultrasonic assisted turning System.

1. HMT Model NH 26 Lathe.
2. Compound plate
3. Dynamometer (Kistler model 9272)
4. Tool (treated as a cantilever)
5. Work-piece
6. Ultrasonic vibratory tool (UVT)
7. Booster/converter
8. Bracket
9. H.F.Cable with 4 pin coaxially (M) to (F) connector connects 20 kHz high voltage to converter.

10 Generator
11.L-type holder
12 Charge amplifier model 5070A
13 DAQ
14 PC (CONTROL UNIT)

Table1. Specifications Ultrasonic systems[8]

Line voltage	**220V/230V AC Single phase**
Input frequency	**50Hz**
Current consumption	**220V, 50Hz.-6A**
Output frequency	**20kHz**
Amplitude	**8µm**
Output power	**2kW**
Output control	**Auto tuning with load output power range 30 to 100% of nominal converter amplitude.**
Operational mode	**Continuous mode:-on/off & timer mode.**
Tuning	**Auto tuning operation in normal mode. Also manual tuning facility.**
Converter weight with horn	**Approx 1 Kg**
Generator weight	**Approx 3 Kg**

The work-piece(SS304) is clamped by the three jaw chuck of „HMT model NH 26" lathe.The commercial piezoelectric transducer (unloaded 20±0.5 kHz frequency) provides vibration to the ultrasonic vibratory tool (UVT). The tip of UVT is placed vertically on the cutting tool. The cutting tool is treated as a cantilever beam, which is fixed on Kistler model 9272 dynamometer. The UVT placed perpendicularly to the work-piece in the horizontal plane allows the cutting tool to make the ultrasonic vibration movement in the cutting velocity direction. The amplitude of vibration is 16µm at cutting tool tip as calculated, which the working amplitude for all experiments

Table2. Specification of single point cutting tool

Material	Tool steel
Geometry (D_1-W-L)	5mm-5mm-20mm
Young's modulus (E)	210GPa
Poisson's ratio (γ)	0.30
Density (ρ)	8150
Natural frequency (f)	19653

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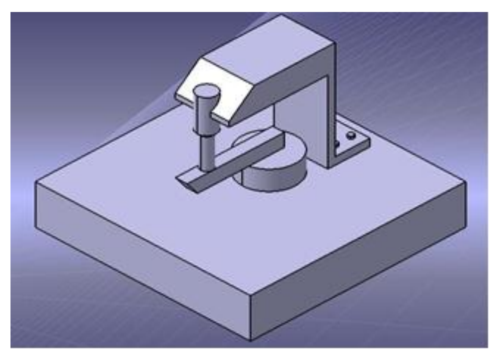

Figure3. 3-D view of experimental set up (Cutting tool treated as cantilever beam).

Figure.3 shows the Isometric view of ultrasonic assisted turning (UAT) set-up. The ultrasonic transducer is clamped at its nodal point by a light weight bracket and the bracket is fixed by sliding mechanism with special designed L-shape holder. This L-shaped holder maintained the height of the ultrasonic transducer, which is fixed on cross slide of the lathe. The UVT is connected to generator by H.F. Cable with 4 pin coaxially (M) to (F). The generator is generating high frequency around 20±0.5kHz with 2.0kW (max) power from the input mains voltage 230V AC, 50Hz frequency.

Experimental procedure

Cutting condition

Table3. Cutting condition used in experiment

Work-piece material	S(m/min)	D(mm)	f(mm/rev)	d(mm)
Stainless steel(SS304)	57	45	0.04	0.1
	74	45	0.05	0.15
	96	45	0.06	0.2
	125	45	0.07	0.25

The work-piece is cylindrical and faces are machined prior to the experiments. A finishing cut with a very small depth of cut is performed using the same cutting tool to be used in the experiments, in order to eliminate any leftover eccentricity. In the experimental run, first cut is made conventional and as soon as the tool travelled by 10mm (depends upon the time) the vibration is switched on thus allowing the second cut to proceed under same cutting condition but with ultrasonic vibration.

Figure4. Work piece preparation in UAT using lathe (HMT Model NH 26).

Work piece preparation and processing

After finishing one experiment as shown in Figure 4, it is marked for identification. So, every experiment is divided into two parts, the first part is convention turning (CT) and second one is ultrasonic assisted turning (UAT). Each experiment was done at different cutting condition and the same procedure is applied in different experiments shown in Figure5.

Figure5. Work piece after the experiment.

'TALISURF' equpment is used to Measure the surface roughness on the Stainless steel Workpiece in Ultrasonic Assisted Turning (UAT) as well as conventional turning(CT). By using Kistler model 9272 dynamometer and control unit measuring the cutting forces on both CT and UAT.

Results and Discussion

Based on the experimental data UAT improved the surface roughness by 15.0–40.0%. It proves that UAT can obtain smoother surface in comparison with conventional turning. It proves that UAT can obtain smoother surface. Because of the unstable turning process in CT, the surface can easily produce some defects such as burrs, tearing and so on, so the quality of surface becomes poor. While the UAT can reduce the influence of deformation and built-up-edge formation because of high frequency reciprocating movement between the contacting surfaces of the tool and the work piece, so as to make the turning process more stable. The test results show that the cutting force for the UAT method decreases by 25.0–35.0 % in comparison with CT. In UAT, feed rate has considerable influence on surface roughness while the influence of depth of cut and cutting speed on surface roughness become less intense than others parameters. The experimental results clearly shows that, the ultrasonic-vibration assisted turning is more sutable than Conventional turning. The UAT method has been found to be a suitable technique to achieve high-quality surfaces finish and lower cutting force requirement not only for hard material but also for general purpose engineering material, like stainless steel etc.

Conclusion and Recommendation

In this present work the experimental study has been carried out to find the difference between UAT and CT. Discuss the experimental set-up and procedure. Cutting force and surface roughness measures on stainless steel workpiece. The results have been compared with Ultrasonic assisted turning(UAT) and conventional turning(CT) process. More study is essential to know the effect of vibration parameters (amplitude, frequency, direction of vibration) on cutting performance in UAT. It is being suggested to make use of various cutting tools and various types of work-piece materials have to be to use in experimental procedure.

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