# A Review on Research Aspects and Trends in Ultrasonic Machining


**Karun Kant, Prashant Gupta, Shrikant Vidya, Lavepreet Singh, and Anurag Shanu**

## 1 Introduction

Ultrasonic machining is a mechanical sort non-customary machining measure with boundless use in machining of amazingly hard-fragile materials. This material is generally created by powder metallurgy. USM could be a reasonable option for machining of wide range of WC–Co materials, as the cycle is liberated from numerous issues related with warm base machining. USM has been differently named ultrasonic penetrating, ultrasonic cutting, ultrasonic rough machining, and slurry boring. USM is a non-customary powered substantial evacuation measure. Both electrically conductive and non-metallic materials can be machined through this tool. In USM, high recurrence electric oomph is changed over into mechanical sensations through a transducer supporter mix, which are then sent to an energy centering just as intensifying gadget known as horn or sonotrode. Machining of hard and fragile materials is acquiring significance because of its developing usage in numerous ventures like hardware, optical, and bio-clinical fields. Ultrasonic-helped processing (UAM) joins the material evacuation system of granulating, processing kinematics, and ultrasonic help.

### *1.1 Principle of Ultrasonic Machining*

It deals with a similar guideline of ultrasonic welding. This machining utilizes ultrasonic waves to create high recurrence power of low plentifulness, which goes about as main impetus of grating. Ultrasonic machine creates high recurrence vibrating wave of recurrence around 20,000 to 30,000 Hz and adequacy around 25–50 μm.

K. Kant · P. Gupta · S. Vidya (✉) · L. Singh · A. Shanu
Department of Mechanical Engineering, Galgotias University, Greater Noida, Uttar Pradesh, India



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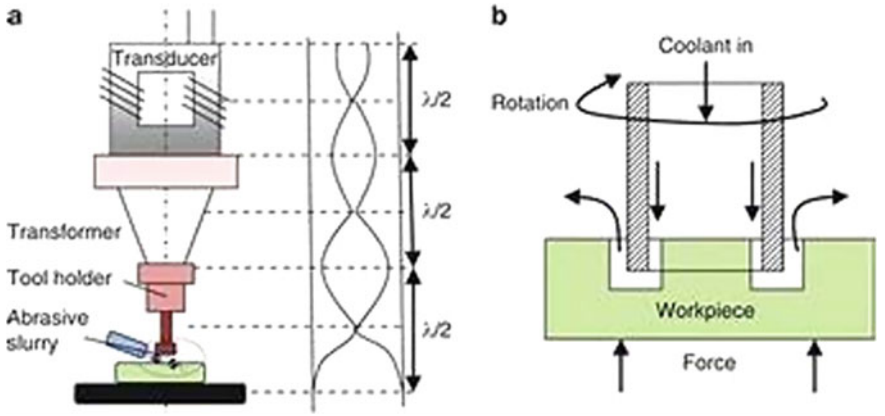


**Fig. 1** Ultrasonic machining process [1]

This high recurrence vibration move to rough molecule contains in grating slurry. This leads space of grating molecule to fragile workpiece and eliminates metal from the contact surface (Fig. 1).

## *1.2 Applications*

- This machining is utilized to machine hard and fragile material like carbide, earthenware, glass, and so on.
- This is utilized in machining of pass on and apparatus of drill, wire drawing machine, and so forth.
- Used in creation of silicon nitrite turbine sharp edge.
- It is utilized to cut jewel fit as a fiddle.
- It is utilized machining of machining non-conductive hard material which can't be machined by ECM or EDM because of helpless conductivity.

## *1.3 Advantages*

- Hard material can be effectively machined by this strategy.
- No heat produced in work so there is no issue of work solidifying or change in construction of workpiece.
- Non-conductive metals or non-metals, which can't be machined by ECM of EDM can be machined by it.
- It doesn't shape chips of huge size.

## 2 Reviews on Ultrasonic Machining

Abdo et al. [2] defined that pocket processing has been viewed as quite possibly the most generally utilized tasks in machining. The target of this exploration was to examine the impact of the device covering boundaries on a superficial level unpleasantness, exterior sound structure as well as the machined pocket profiles. The trial results give proof that the surface harshness and MRR have been altogether as a consequence of the considered device covering and the device way approaches. In this examination, the impacts of the device covering and the instrument way procedures were tentatively investigated on a superficial level harshness using RUM, MRR, and profiles of pouches machined on alumina ($Al_2O_3$) clay were calculated.

Saqib Anwar et al. [3] elaborated the rotating ultrasonic machining (RUM) that has demonstrated its abilities in a few assembly applications, specifically for the fabrication of large highlights on fired material. Surface cracking and edge chipping, on the other hand, are the most common issues encountered throughout the RUM of artistic materials. The exhibition estimates such as surface unpleasantness, surface sound structure, and apparatus dress are dissected to assess machinability. Furthermore, the sidewalls of channels have a coarse machined section close to the top control and a relatively flat region of machined surface active near the bed of channel. Using RUM interaction to the bio lox specialty material, fantastic surface completion of $R_a = 0.21$ m and $R_t = 2.3$ m can be achieved. To improve the surface unpleasantness of micro-channels, lower feed rates and cut depths are optional, while higher degrees of shaft rapidity and vibration sufficiency with acceptable vibration recurrence estimation should be nominated.

Jagadish et al. [4] concluded that the feed rate affects the material expulsion rate, while the slurry affects the form point and over-cut focus.

Cong et al. [5] examined the power utilization in rotary ultrasonic machining of CFRP. It outlines an analysis of the effects of information factors (ultrasonic force, apparatus turn speed, and CFRP type) on the power utilization of each portion including the ultrasonic force supply, axle motor, air blower and coolant siphon and the whole system. It was reported that the power utilization of the coolant pump was consistently the best.

Kai Ding et al. [6] conclude that the penetrating power and force for RUM were diminished by 23%, 47.6% individually of those for CD. The reduction in boring power and force diminished step by step with speeding up, while they changed somewhat with expanding feed rate. Nonetheless, it is reported that contrasted with CD, rotary ultrasonic machining can deliver lesser surface roughness of openings under comparable working conditions and the most extreme decrease rate is 23%.

Yasmine El-Taybany et al. [7] stated that the ultrasonic-helped processing of pop glass is researched and contrasted with regular processing (CM). It shows a decrease of hub cutting power and second at higher shaft speed and lesser feed rate and profundity of cut. Subsequently, the effect of UAM boundaries has been concentrated to decide their impact on the pivotal cutting power and the occasion.

Pabla et al. [8] elaborated that present examination is pointed toward considering the effect of various exploratory condition (by shifting thickness of the workpiece, cobalt material, instrument profile, apparatus material, rough coarseness size, and force rating) on reactions of premium (material expulsion rate and device wear rate) in ultrasonic penetrating of WC–Co composite material. The key boundaries for machining attributes were found to be force rating, rough coarseness scale, and apparatus content (MRR and TWR). The best material evacuation rate was achieved by combining a high-power rating with a coarse coarseness size.

Ravinder Kataria et al. [9] mentioned that the lower CR of a composite material (WC–Co) with a higher cobalt satisfied (24%) was due to a higher estimate of break resilience, which counteracts the turn of events and proliferation of breaks. In terms of CR, the silver steel instrument performed the highest. As far as CR was concerned, machines with no measurement bore unrivaled execution. Force rating and rough coarseness size were discovered to be the main boundaries for CR.

Yun-Hyuck Hong et al. [10] concluded that test was performed regarding machining boundaries, like crushing velocity, feed rate, and so forth, to contemplate impact of ultrasonic vibration in pounding. For an ideal state of ultrasonic-assisted crushing, which can restrict the pounding services, the design of experiment method was used. The major machining factors in DOE were ultrasonic sufficiency strength, feed rate, and shaft revolution speed. The ultrasonic crushing decreased the granulating power to 23% than the customary pounding and this could diminish the device wear.

Jatinder Kumar [11] concluded that ultrasonic machining is perhaps the most broadly utilized non-customary cycles, particularly for business machining of hard, weak, and delicate materials. There is colossal extension aimed at use of USM for setting up savvy machining answers for moderately extreme and malleable metals like titanium, nickel compounds. The quality and nature of USM measurements are based on the work material properties like crack sturdiness, hardness as well as the instrument properties (hardness, sway strength, and finish). The impediments of USM, holes saw from the writing survey, and the headings for future examination have likewise been introduced.

Yan Wang et al. [12] discussed the fiber-supported earthenware framework composite has been generally utilized in aviation and other high-innovation fields because of their brilliant mechanical and actual properties. Be that as it may, FRCMC is a sort of commonplace material with inhomogeneous and anisotropic design; in this manner, it is hard to ensure the exactness and surface quality utilizing customary machining. Contrasted and CG, the pounding power can be decreased somewhat, there is more uniformity in surface microstructure, all the more short-fiber chips are framed, the profundity of the cutting notch is all around conveyed, little surface unpleasantness has been accomplished, and the improvement in crushing quality can be done using UAG which is a viable technique for the machining of fiber-supported earthenware framework composite.

Treadwell et al. [13] discussed that paper revealed the correlations between turning ultrasonic machining (RUM) and pounding of CFRP interestingly. Five yield factors were looked at, including cutting power, force, surface unpleasantness, opening

distance across, and material expulsion rate (MRR). Rotational ultrasonic machining, a half-breed machining measure consolidating ultrasonic machining and crushing, has likewise been effectively utilized in penetrating of CFRP mixtures.

Vineet et al. [14] discussed the impact of interaction boundaries, specifically release flow, beat on schedule, and electrical release machining with ultrasonic-assisted cryogenically cooled cathode, has been concentrated on duty cycle and hole voltage, on terminal wear proportion, material evacuation rate, and surface unpleasantness. On M2-grade HSS workpiece material, the UACEDM test was successfully completed. In UACEDM, measurable models for predicting MRR, EWR, and surface roughness have been created connecting the info boundaries, specifically release current, beat on schedule, obligation cycle, and hole voltage.

Shaolei Wang et al. [15] illustrated that the pounding powers and ground surfaces are analyzed among CG and UAG methods. Upgrades in granulating powers and quality of surface might be ascribed to the high recurrence and huge abundancy variety in the elements of the crushing cycle. Ultrasonic vibration creates sway loads, more modest single grain track covering, surface of contact, and inter-granular track covering prompts change in pounding powers and quality of surface. The impacts of framework coordinating on pounding power and surface unpleasantness are concentrated tentatively. The plan of analyses and trial gear are portrayed in detail. A five-variable and four-level partial factorial plan is utilized here to lead tests.

Hao Shen et al. [16] elaborated that turning RUM is a well-known and effective tool for assembling openings in weak materials. Improved material evacuation speeds, decreased cutting forces, and smaller edge piece sizes at the opening way out are all signs of RUM. Intriguingly, a basic feed rate was accounted for in order to ensure the viability of the RUM contact. When the forage rate is at a relatively low level, the ultrasonic force/adequacy diminishes and the hurtful power increments step by step with an expanding feed rate.

Jianjian Wang et al. [17] elaborated that ultrasonic shuddering is thought to be steady or unchanged through the cycle of turning ultrasonic machining (RUM) on fragile supplies, ignoring the impacts of various handling boundaries. Be that as it may, no test proof has been accounted for to approve this supposition. The impacts of thermomechanical stacking happening in the solidness of ultrasonic abundance through RUM cycle were examined in probes quartz crystal and cobalt. The consistency of ultrasonic vibration during the machining cycle was tested using ultrasonic force.

Ravinder Kataria et al. [18] stated that the edge chipping was seen at the leave side of the opening because of extreme corruption of the instrument face for longer machining activity. In any case, the edge of the bored opening showed great surface quality.

PKSC Fernando et al. [19] concluded that the revolving ultrasonic machining can bore openings of top caliber on rocks of various hardness with a much lower cutting power and at an entrance pace of around multiple times quicker than percussive drilling. Instrument pivot ultrasonic power, pace, and feed rate insignificantly affected outward irregularity.

Palamandadige Fernando et al. [20] concluded that the rotational ultrasonic machining (RUM) is a non-traditional besides financially savvy machining strategy for tough and weak resources, like pottery, complex things, etc. RUM is a half-breed measure that consolidates the substantial evacuation instruments of precious stone grating pounding and ultrasonic machining. A trial examination of turning ultrasonic machining of K9 glass utilizing both irregular and conti PKSC Fernan.

Ping Zou et al. [21] elaborated the tests for turning the workpiece of ASS 304 are led with and without ultrasonic vibration utilizing the planned MS-UAT, and afterward the 3D morphology assessment boundaries $S_a$ and $S_q$ are applied to portray and examine the machined surface. A point by test examination is introduced for the impacts of ultrasonic abundance, profundity of cut, and cutting velocity on the machined surface quality in UAT of ASS 304 with solidified carbide-covered cutting apparatus.

Weiming Zeng et al. [22] discussed the rotating ultrasonic machining (RUM) has pulled in ample consideration and around are various distributions on the interaction. Notwithstanding, not many examinations on device costume in the RUM cycle have been accounted for. This daily, without precedent used for writing, presents a test perception on apparatus wear in RUM of alumina.

Hang Gao et al. [23] discussed the revolving ultrasonic machining (RUM) of KDP. Information of a few yield boundaries (like crushing power and force, surface harshness, and edge chipping) were gathered and investigated. As an examination, precious stone boring (without ultrasonic vibration) was additionally tried. It very well may be seen that the force in RUM had a higher most extreme worth than that in precious stone boring, and had a bigger variety as well. In the writing, there could be no different reports on force in RUM for any materials.

Wang et al. [24] proposed a mechanistic model for rotation-based ultrasonic machining of CFRP composites utilizing elliptical ultrasonic vibration, calculated effective cutting time, and also investigated MRR. It was reported that the projected values of cutting forces are in line with the experimental value of results.

In a nutshell, most of the literatures dealt with the parametric optimization, better tool design as well as support addition at the hole exit while the novel method of rotary ultrasonic elliptical machining is promising area of research and development in the quality machining of brittle materials.

## 3 Conclusion

Ultrasonic machining is quite possibly the maximum generally utilized non-customary cycles, particularly for business machining of hard, weak, and delicate materials settings (input power, static burden, plentifulness, and recurrence of vibration). The factual expulsion USM takes remained discovered near happen through proliferation then crossing point of middle then sidelong breaks that remain initiated because of rehashed effects of grating grains. Plan of the instrument is a pivotal reason influencing the profitability of USM measure. Apparatuses with higher frame

will in general smother the adequacy of vibration along these lines lessening the machining rate. Instruments with extreme tip distance will in general experience mishappening and miniature breaking during machining. Exhaustion disappointment of the instrument happens if there's a small misalignment between the two, apparatus and the horn. WC–Co, a composite substance with a higher cobalt content (24 percent) displayed lesser machining percentage because of greater estimation of break strength that opposed turn of events and spread of breaks. The most noteworthy material expulsion rate was gotten at mix of high strength assessment and abrasive coarseness size.

## References


1. Joshi SS (2016) Ultrasonic machining. In: Bhushan B (eds) Encyclopedia of nanotecnology. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-9780-1_366
2. Abdo BMA, El-Tamimi A, Nasr EA (2020) Rotary ultrasonic machining of alumina ceramic: an experimental investigation of tool path and tool overlapping. Appl Sci 10:1667. https://doi.org/10.3390/app10051667
3. Abdo BMA, Anwar S, El-Tamimi A (2019) Machinability study of biolox forte ceramic by milling microchannels using rotary ultrasonic machining. J Manuf Process 43(Part A):175–191. ISSN 1526–6125. https://doi.org/10.1016/j.jmapro.2019.05.031
4. Biswas JH, Jagadish, Ray A (2019) Experimental investigation and optimisation of ultrasonic machining parameters on zirconia composite. Int J Mach Mach Mater 21(1–2):115–137
5. Cong WL, Pei ZJ, Deines TW, Srivastava A, Riley L, Treadwell C (2012) Rotary ultrasonic machining of CFRP composites: a study on power consumption. Ultrasonics 52(8):1030–1037. ISSN 0041–624X. https://doi.org/10.1016/j.ultras.2012.08.007
6. Ding K, Fu Y, Su H, Chen Y, Yu X, Ding G (2014) Experimental studies on drilling tool load and machining quality of C/SiC composites in rotary ultraso ic machining. J Mater Process Technol 214(12):2900–2907. ISSN 0924–0136. https://doi.org/10.1016/j.jmatprotec.2014.06.015
7. El-Taybany Y, Hossam M, El-Hofy H (2017) Experimental investigation of ultrasonic-assisted milling of soda glass using factorial design of experiments. Procedia CIRP 58:381–386. ISSN 2212–8271. https://doi.org/10.1016/j.procir.2017.03.238
8. Kataria R, Kumar J, Pabla BS (2015) Experimental investigation into the hole quality in ultrasonic machining of WC-Co composite. Mater Manuf Process 30(7):921–933. https://doi.org/10.1080/10426914.2014.995052
9. Kataria R, Kumar J, Pabla BS (2016) Experimental investigation and optimization of machining characteristics in ultrasonic machining of WC–Co composite using GRA method. Mater Manuf Process 31(5):685–693. https://doi.org/10.1080/10426914.2015.1037910
10. Kim KT, Hong YH, Park KH, Choi YJ, Lee SW, Choi HJ (2012) An experimental investigation of ultrasonic assisted grinding in DOE approach. Adv Mater Res 565:129–134. https://doi.org/10.4028/www.scientific.net/amr.565.12
11. Kumar J (2013) Ultrasonic machining—a comprehensive review. Mach Sci Technol 17(3):325–379. https://doi.org/10.1080/10910344.2013.806093
12. Li H, Lin B, Wan S, Wang Y, Zhang X (2016) An experimental investigation on ultrasonic vibration-assisted grinding of SiO2f/SiO2 composites. Mater Manuf Process 31(7):887–895. https://doi.org/10.1080/10426914.2015.1090586
13. Ning FD, Cong WL, Pei ZJ, Treadwell C (2016) Rotary ultrasonic machining of CFRP: a comparison with grinding. Ultrasonics 66:125–132. ISSN 0041–624X. https://doi.org/10.1016/j.ultras.2015.11.002

14. Srivastava V, Pandey PM (2013) Experimental investigation on electrical discharge machining process with ultrasonic-assisted cryogenically cooled electrode. Proc Inst Mech Eng Part B J Eng Manuf 227(2):301–314. https://doi.org/10.1177/0954405412469487
15. Wang Y, Lin B, Cao X, Wang S (2014) An experimental investigation of system matching in ultrasonic vibration assisted grinding for titanium. J Mater Process Technol 214(9):1871–1878. ISSN 0924–0136. https://doi.org/10.1016/j.jmatprotec.2014.04.001
16. Wang J, Feng P, Zhang J, Shen H (2017) Experimental investigation on the effects of thermo-mechanical loading on the vibrational stability during rotary ultrasonic machining. Mach Sci Technol 21(2):239–256. https://doi.org/10.1080/10910344.2017.1283962
17. Wang J, Feng P, Zhang J, Cai W, Shen H (2017) Investigations on the critical feed rate guaranteeing the effectiveness of rotary ultrasonic machining. Ultrasonics 74:81–88. ISSN 0041–624X. https://doi.org/10.1016/j.ultras.2016.10.003
18. Kataria R, Kumar J, Pabla B (2017) Ultrasonic machining of WC–Co composite material: experimental investigation and optimization using statistical techniques. Proc Inst Mech Eng Part B J Eng Manuf 231(5):867–880. https://doi.org/10.1177/0954405416629586
19. Fernando PK, Zhang M, Pei Z (2018) Rotary ultrasonic machining of rocks: an experimental investigation
20. Fernando P, Zhang M, Pei Z, Cong W (2017) Intermittent and continuous rotary ultrasonic machining of K9 glass: an experimental investigation. J Manuf Mater Process 1:20. https://doi.org/10.3390/jmmp1020020
21. Zou P, Xu Y, He Y et al (2015) Experimental investigation of ultrasonic vibration assisted turning of 304 austenitic stainless steel. Shock Vibrat 501:817598
22. Zeng WM, Xu XP, Pei ZJ (2009) Experimental investigation of tool wear in rotary ultrasonic machining of alumina. Key Eng Mater 416:182–186. https://doi.org/10.4028/www.scientific.net/kem.416.182
23. Wang Q, Pei ZJ, Gao H, Churi NJ, Kang R (2009) Rotary ultrasonic machining of potassium dihydrogen phosphate (KDP) crystal: an experimental investigation. Int J Mechatron Manuf Syst 2(4):414–426
24. Wang H, Pei ZJ, Cong W (2020) A feeding-directional cutting force model for end surface grinding of CFRP composites using rotary ultrasonic machining with elliptical u trasonic vibration. Int J Mach Tools Manuf 152:103540. ISSN 0890–6955. https://doi.org/10.1016/j.ijmachtools.2020.103540