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Computer-controlled Sophisticated Ultrasonic Cleaner

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ABSTRACT

The significant advantage of ultrasonic cleaning technique is the abilities to clean the delicate and complex shape materials without damaging their surfaces quickly. Ultrasonic cleaners have found increasing applications in a variety of industries because these offer an environmentally good alternative to ozone-depleting compounds and hazardous solvents. Also, ultrasonic vibration is one of the methods for chemical synthesis (chemical reaction) and of yield enhancement of chemical engineering process. Consequently, there is a need to develop multipurpose ultrasonic cleaner/vibrator using computer control, which can be used to set the various performance parameter of ultrasonic vibrator such as frequency, duty cycle, continuous/ pulsed mode, duration of operation, and thermal profile of tank during the process. An ultrasonic cleaner was developed using an oscillator circuit and the duration of oscillator circuit functioning can be set through the computer. Computerised ultrasonic cleaner using indigenously made piezoceramic transducers and their advantages over the conventional ultrasonic cleaners are discussed.

Keywords: Ultrasonic cleaning technique, ultrasonic vibrator, piezoceramic-based transducer, PC-based ultrasonic cleaner

1. INTRODUCTION

The ultrasonic energy in the form of vibration has wide range of applications, from cleaning of contaminated small workpieces in the industries to scrap away of the unwanted deposits. The use of ultrasonic cleaning has become increasingly popular due to the restrictions on the use of chlorofluorocarbons such as 1, 1, 1-trichloroethane. Because of these restrictions, many manufacturers and surface treaters are using immersion cleaning technologies rather than solvent-based vapour degreasing. The use of ultrasonic enables the cleaning of intricately shaped parts effectively as compared to the cleaning by vapour degreasing process. Ultrasonic cleaning is a powerful technique to remove tough contaminants without damaging the substrate. It provides excellent penetration and cleaning in the narrowest crevices and between tightly spaced parts in a cleaning tank to remove unwanted particles from an object by exerting mechanical oscillations of high frequency[1,2].

Ultrasonic vibrations are also used in process industries such as leather, chemical, and textile to reduce process time, pollution load, and improvement in the product quality[3-7]. Ultrasonic vibration is considered as one of the methods for chemical synthesis (chemical reaction) and of yield enhancement of chemical engineering process for emulsification, degassing, crystallisation, extraction, etc[8-11].

2. DESIGN

To get stable and smoothly controllable output frequency, IC 3525 as oscillator circuit along with MOSFET IRF630 as push-pull amplifier to amplify the ultrasonic frequency have been used in the present design. An input voltage of 1.5 kV was used to drive the piezoceramic-based transducer. The output voltage from push-pull amplifier was 24 V and this voltage was stepped up using a step-up transformer. This step-up transformer was designed

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to provide 120 W output power with 1.5 kV output voltage. The magnitude of power required for the piezoceramic transducers depends upon the size and capacity of the cleaning tank. As the driving voltage for the transducer was 1.5 kV/80 mA, a ferrite core transformer was used to have compact volume and better efficiency. The cut section of piezoceramic based transducer system is presented in Fig. 1.

The photograph of various components used in the piezoceramic-based transducer system is shown in Fig. 2. The piezoceramic transducer used for generating the ultrasonic vibrations was developed in this laboratory using oxides of lead, zirconium, and titanium by powder metallurgical process.

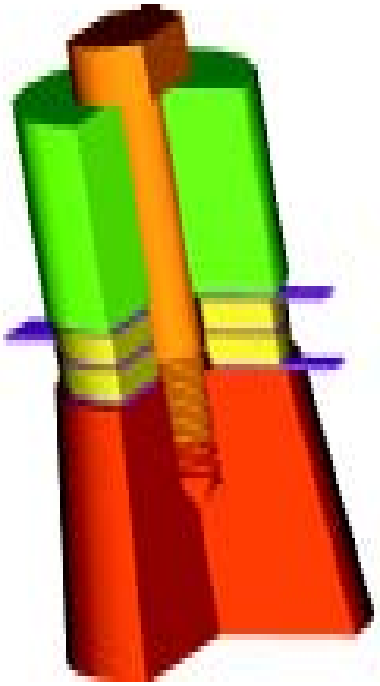

Figure 1. Cut section of piezoceramic-based transducer system.

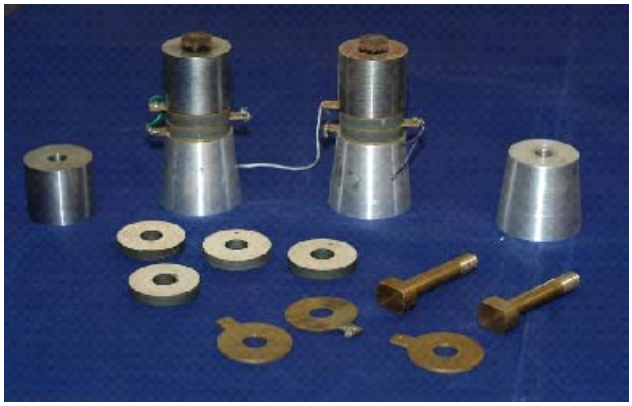

Figure 2. Components used in piezoceramic-based transducer system.

A software program along with parallel port interface was developed to control the shutdown pin of oscillator IC 3525 and to operate the system in pulsed mode. In the present work, the computer code has been developed in visual basic to interface the functioning of ultrasonic clearer through the parallel port. The schematic diagram of PC-based ultrasonic cleaner is shown in Fig. 3.

3. DEMERITS OF CONVENTIONAL CLEANING

Conventional cleaning is carried over by submerging the workpieces in a cleaning solution for a predetermined time, or by pressure flushing with chlorinated fluorocarbon (CFC) solvents such as methylene chloride toluene. CFC solvents are environmentally undesirable, so their use is being reduced[1]. Aqueous and non-CFC solvents are biodegradable, so these are environmentally preferable. However, aqueous solvents are less effective cleaning agents than the CFC solvents.

4. MERITS OF ULTASONIC CLEANING

Ultrasonic cleaners reported here have advantages like: (i) high intensity cleaning action with optimum efficiency, (ii) economical, safe and compact, (iii) rapid and thorough cleaning of small and large components and assemblies, (iv) efficient cleaning of metal, plastic, ceramic, alloys, etc, (v) rigorous cleaning of intricate parts that are normally inaccessible, (vi) stainless housing reduces risk of cross-contamination, and (vii) software program allows to preset the desired cleaning duration. In brief, this ultrasonic cleaner will be a useful tool for many industrial applications.

5. CONCLUSION

In the present study, an ultrasonic cleaner has been developed using variable-time functionable oscillator circuit. The output of the oscillator is amplified using MOSFET coupled with ferrite core transformer to get a signal of 1.5 kV at 40 kHz

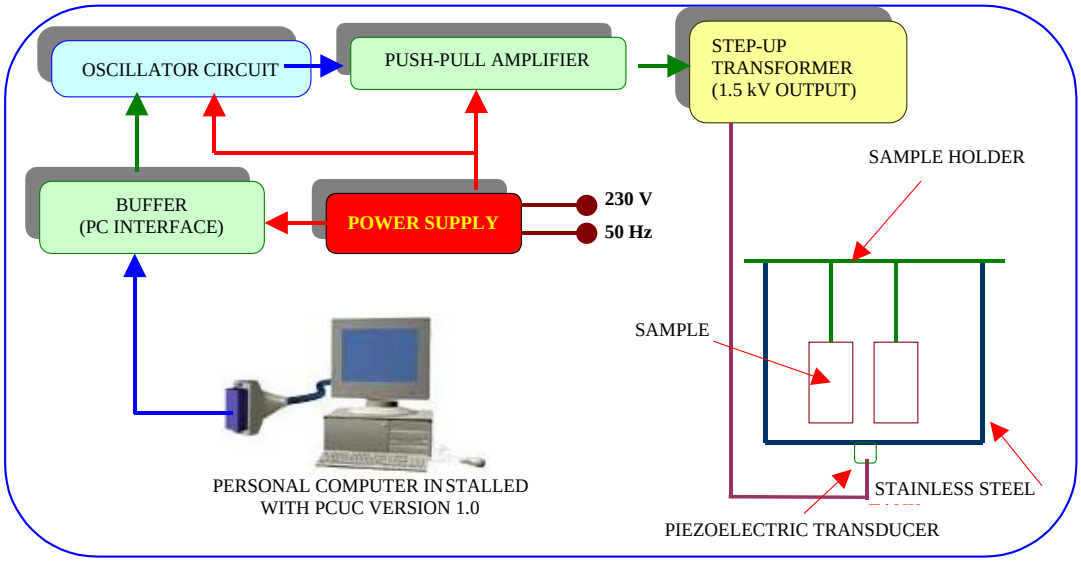

Figure 3. Schematic diagram of PC-based ultrasonic cleaner.

and the entire setup is sealed against harsh external environment. User-friendly software for the overall control of ultrasonic cleaner developed can control the ultrasonic cleaner in both continuous mode and pulsed-mode operations. Both the output frequency and duty cycle are adjustable by the user for all customised applications. These ultrasonic cleaners can be used to remove abrasive dust, grease, blast debris, paint and surface contaminants.

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REFERENCES

1. Kim, Jin O.; Choi, Sunghoon & Kim, Jung Ho. Vibroacoustic characteristics of ultrasonic cleaners. *Applied Acoustics*, 1999, **58**, 211-28.
2. Kumar, R. Can sound help chemical engineers? *Ind. Chem. Engr. J.*, 1994, **36**(1-2), 3-18.
3. Sivakumar, V. & Rao, R.G. Application of power ultrasound in leather processing: An eco-friendly approach. *J. Cleaner Prod.*, 2001, **9**(1), 25-33.
4. Sivakumar, V. & Gangadhar Rao, Paruchuri. Studies on the use of power ultrasound in leather dyeing. *Ultrasonics Sonochemistry*, 2003, **10**, 85-94.
5. Thakore, K.A. Application of ultrasonics in dyeing of cotton fabrics with direct dyes, Part I: Kinetics of dyeing. *Ind. J. Text. Res.*, 1988, **13**, 133-39.
6. Thakore, K.A. Application of ultrasonics in dyeing of cotton fabrics with direct dyes. Part II: Diffusion kinetics of dyeing. *Ind. J. Text. Res.*, 1988, **13**, 208-12.
7. Oner, E.; Baser, I. & Acar, K. Use of ultrasonic energy in reactive dyeing of cellulosic fabrics. *J. Soc. Dyers Col.*, 1995, **111**, 279-81.
8. Contamine, F.; Faid, F.; Wilhelm, A.M. & Berlan, J. Delmas. Chemical reactions under ultrasound. *Chem. Eng. Sci.*, 1994, **49**, 5865-873.
9. Suslick, K.S. Ultrasound - its chemical physical, and biological effects. VCH Publishers, New York, 1988.
10. Lorimer, J.P.; Mason, T.J. & Fiddy, K. Enhancement of chemical reactivity by power ultrasound: An alternative interpretation of the hot spot. *Ultrasonics*, 1991, **23**, 157-69.
11. Hagenson, L.C. & Doraiswamy, L.K. Comparison of the effects of ultrasound and mechanical agitation on a reacting solid-liquid system. *Chem. Eng. Sci.*, 1998, **53**, 131-47.

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