MODAL ANALYSIS OF ULTRASONIC STACK ASSEMBLY USING FINITE ELEMENT METHOD

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Abstract: ***In this paper, modal analysis is done for ultrasonic stack assembly. This ultrasonic stack assembly is used in Ultrasonic Assisted Pulse Electrochemical Machining (USAPECM). Geometric modeling of ultrasonic stack assembly is done on Solidworks 2013 and modal analysis is carried out in ANSYS 18.2. In modal analysis, fine meshing is permitted on horn. Frequencies for given modes are contracted in tabular format. Frequency at longitudinal mode direction (Y-axis) is nearer to desired natural frequency of this stack assembly.***

Keywords – Modal analysis, Ultrasonic stack assembly, Finite element method, Ultrasonic Assisted Pulse Electro Chemical Machining.

I. INTRODUCTION

Ultrasonic stack assembly is part of the UAPECM. The main functions for assisting the ultrasonic vibration to USAECM are decreasing surface roughness value and amplitude of ultrasonic vibration must be in micron which is reasonable for small inter-electrode gap. Mainly ultrasonic refers as frequencies beyond the range of human hearing which is above 18 kHz. Mostly, for industrial application chosen range from 20-50 kHz frequencies [1].

Ultrasonic stack assembly is part of ultrasonic assisted electrochemical machining. Ultrasonic stack assembly is capable by translating high frequency electrical signal into high frequency mechanical vibration. Standard 60 Hertz AC with 230 V is supplied to the generator (power supply) and converted to 15,000 or 30,000 Hertz AC with 1000 V electrical energy. This high frequency electrical energy is connected to a piezoelectric transducer which changes the electrical energy into the mechanical vibrations. [5]

These vibrations, when applied to a booster to reduce amplitude of frequency. This mechanical vibration, along with pre-force, generates frictional heat at the end horn (tool) so the metal of work-piece will melt and flushes out with electrolyte.

The elementary ultrasonic stack assembly contains largely of four core components:

- Generator (power supply)
- Transducer (converter)
- Boosters
- Sonotrode

A press to community the converter-boosters-sonotrode stack and a feature to hold coupling parts are desired to comprehensive the ultrasonic stack assembly system, but these mechanisms will be talk over later.

The generator converts typical electrical control (120 – 240 V, 50/60 Hz) into electrical signal at the frequency at which the structure is designed to work. Even though numerous different functioning frequencies are trendy use all over the world, the extreme collective frequencies used in industrial manufacture are 15, 20, 30, and 40 kHz.

The frequency of electrical signal formed by generator is engaged through the cable toward the transducer, which changes the electrical motion into perpendicular, small amplitude mechanical vibrations.

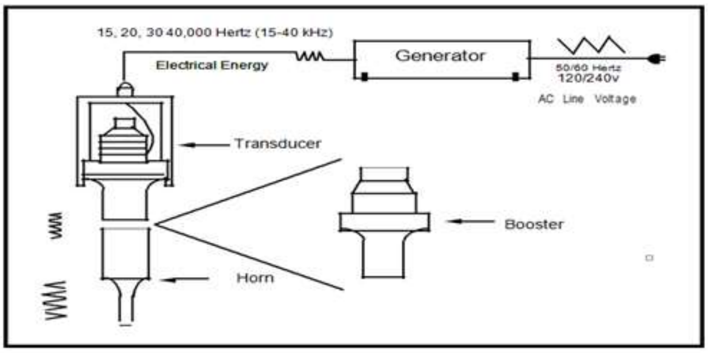


Figure 1 Components of ultrasonic stack assembly.

II. Construction for ultrasonic stack assembly

Ultrasonic generator is used to convert the normal electrical signal to required ultrasonic frequency (28 kHz with voltage 1000V).

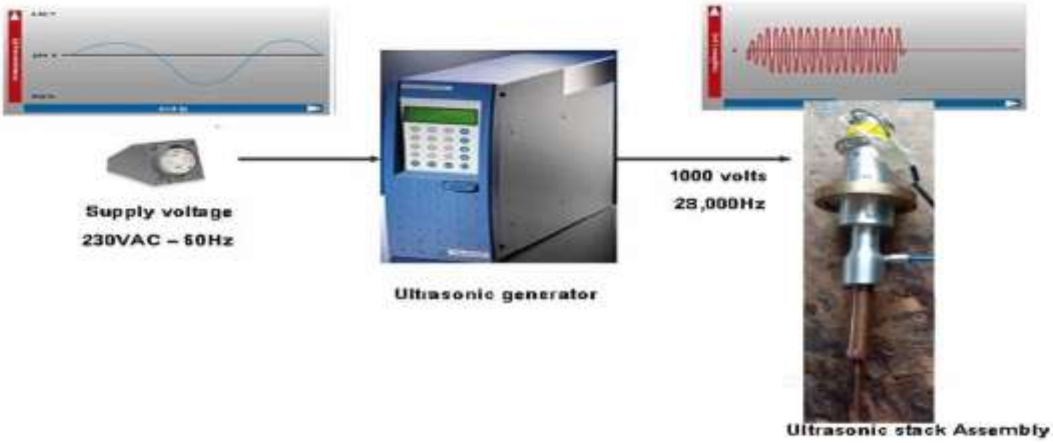


Figure 2 28 kHz frequency Ultrasonic Generator. [5]

Transducer-booster-horn assembly is manufactured by Johnson's Plastosonic Company using the half wavelength techniques. Here, we used the piezoelectric ceramic crystal of material polarized PZT which sandwiched between two metal cylinders which is lower and upper transducer body made from aluminum alloy. And that whole assembly is hold together by bolt. Mostly used to design the ultrasonic stack assembly is half wavelength method for cylindrical stack assembly. Here, there are two PZT crystal shaped disk are used in between the transducer's body and bolt used for kept all components are under compression. The polarization is provided for PZT ceramic disks like the same polarity is faced to each other (positive-positive terminals are faced to each other and also same for negative terminal) [2].

At the end of transducer we connected unity booster which is gives same vibrations are got at the transducer end. The unity booster provide in my case because for USAPECM the horn/tool is made from copper alloy which is soft than other horn materials (generally horn material are Al, Ti and steel because of their unique properties like high surface hardness and fatigue strength) that required minimum vibration. And another booster is used for minimizing amplitude of vibrations.

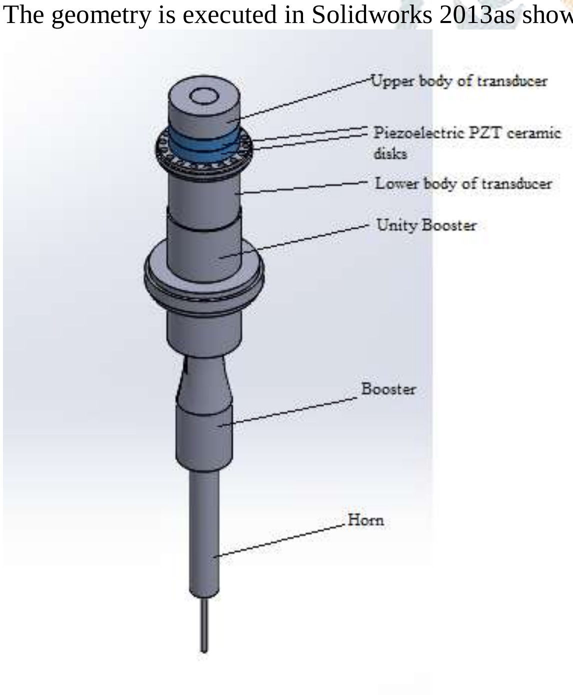
Total length of stack assembly is mainly depends on wavelength (L=Wavelength/2) using half wavelength method.

III. Modal analysis of stack assembly

Modal analysis of the ultrasonic stack assembly was prepared in subsequent steps:

3.1 Geometry

The geometry is executed in Solidworks 2013as shown in figure 3 and all dimensions of individual parts are shown in below figure 4



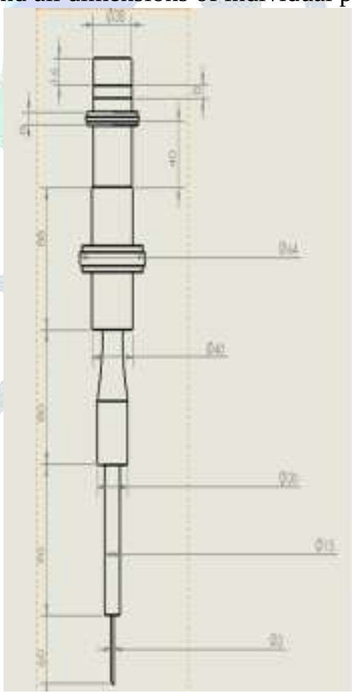


Figure 3 and 4 Design and dimensioning of ultrasonic assembly

3.2 Mesh Generations

Meshing is implemented in ANSYs mesh Pre-processer. Mesh is prepared with Hex dominant method. The whole assembly is meshed into Quad elements. The body sizing for transducer, piezoelectric disk and booster are 2mm and for horn it is 0.75mm. The assembly is meshed with number of nodes and elements 228926 and 58004 respectively shown in figure 5 and 6.

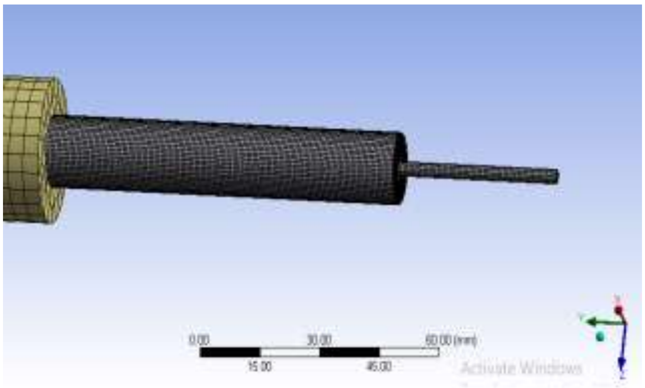


Figure 5 and 6 Meshing of ultrasonic stack assembly.

3.3 Input And Boundary Conditions

The fixed support is given at the upper surface of transducer as shown in figure 7 and the voltage (1000 V) is applied at top of each disks and zero (grounded) at bottom surface of PZT ceramic disks. In analysis setting, the mode numbers and frequency limits is shown in below table 1.

Table 1 Modal analysis settings

Maximum modes to find	25
Limit search to range	Yes
Range minimum	15000 Hz
Range maximum	30000 Hz
Solver unit	Manual
Solver unit system	mks

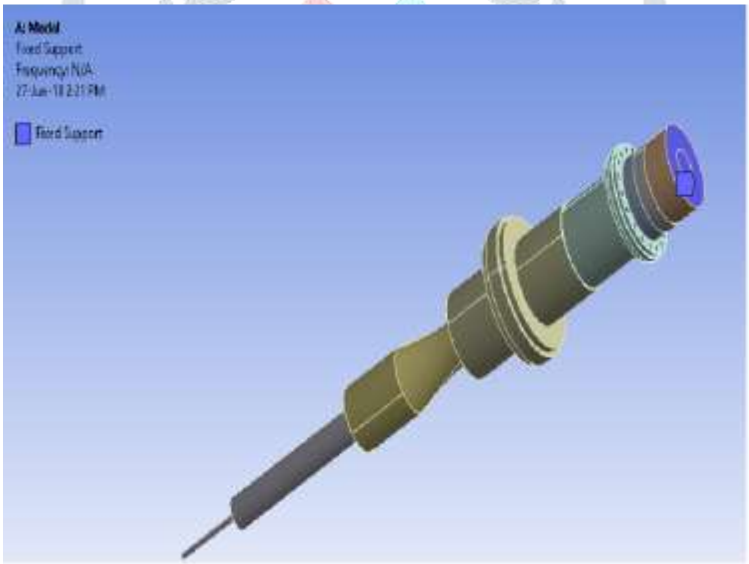
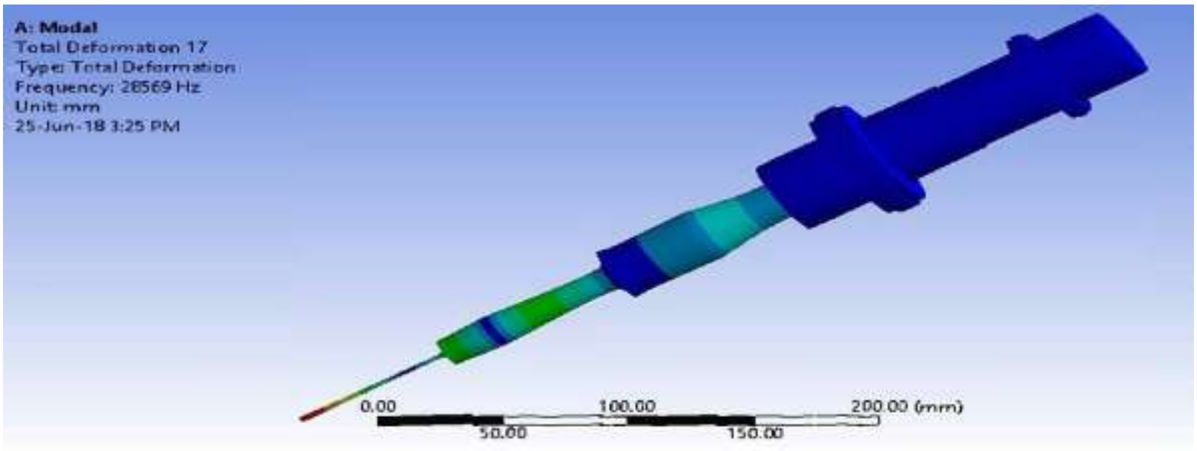


Figure 7 Boundary Conditions**.**

IV. Modal Analysis of Results

At the 17th mode number the frequency is 28569Hz in longitudinal Y- direction within frequency range 15000-30000Hz in ANSYS Modal analysis.



All frequencies at given mode numbers is tabulated

Mode	Frequency
1	15200
2	15223
3	16369
4	16376
5	17967
6	19676
7	19723
8	21273
9	21844
10	22867
11	22888
12	23143
13	25358
14	26014
15	26039
16	28459
17	28569
18	29664
19	29689

V. CONCLUSION

Desired natural frequency is getting at longitudinal direction along Y-axis at 17^{th} number mode. The frequency value at next mode is along axial direction which is negligible and away from desired natural frequency. Modal analysis gives value 28569 Hz which is nearer from excited value (28 KHz).

Margin of separation of resonant frequency is

$$\text{Margin of separation} = \frac{28659 - 28000}{28000} * 100 = +2.35\%$$

VI. ACKNOWLEDGEMENT

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REFERENCES

[1] A.S. Harel, P. V. Jadhav, D.S, Bilgi, J. L. Minanse "Design of ultrasonic Assisted PECM Tool using finite element Analysis" College of Engineering, Pune 2011 .

[2] Sebastian Skoczypiec, "Research on ultrasonically assisted electrochemical machining process", International Journal of Advanced Manufacturing Technology, 2011

[3] Bilgi D.S., Jadhav P.V., Experimental Investigation of Ultrasonic assisted pulse electrochemical drilling for INCONEL 718 with rotary tool, Int. J. Manufacturing Technology and Management, 2014.

[4] K. H.W. Seah, Y.S. Wong and L.C. Lee, "Design of tool holders for Ultrasonic machining using FEM", Journal of Materials Processing Technology, 1993.

[5] Christopher Paul Hampton, "Failure Analysis Of A 30khz Ultrasonic Welding Transducer", University of Illinois at Urbana-Champaign, 2010