International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 6, Issue 4, pp 20-29, April-2022

https://doi.org/10.47001/IRJIET/2022.604004

Design, Analysis and Fabrication of Ultrasonic Power Horns Used to Produce Medical (Surgical) Face Mask and Their Supplements

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Abstract - **Due to a wide and rapid spread of Covid-19 virus, the world exposure suffering from the severe shortage not only for those personal protective equipment that are normally used in hospitals but also extended to the care homes, and because the global rollout of the harmful virus around the world, the number of cases of for pandemic covid-19 is rapidly increased in most countries. The motivation of the current work provide a design of an efficient tools that can overcome many issues concerned with the distribution of virus, and therefore to suppress the prevalence of virus through apply the health rules for quarantine and safety. Ultrasound power technique in general, specifically ultrasonic power remains one of the efficient and reliable processes that can be performed in a wide range of applications such as medical, engineering and manufacturing, which it entered directly in processing different kinds of medicals stuff such as manufacturing medical masks and other accessories beside their other applications in most engineering and industrial fields, etc. The advantage of this technique is crucial and essential in produce protect things required for general purposes like medical masks and their supplements. Design an efficient tool that can be works on the principle of ultrasonic power with providing high performance through add slots will directly leads to enhance many criteria which are benefit in producing large numbers of medical accessories such as facial masks with consuming minimum amount of materials, cost and time. This work presents a study based on design a wide block horn have double slots and an exponential stepped profile, which the horn is modelled, analysed, fabricated based on selecting of aluminium type 7075 as horn materials and their vibration characteristics such as natural frequency and displacement are successfully extracted, using finite element model. A correlation between the design variables and characteristics of the proposed block horn is obtained through perform sensitivity analysis and investigation of the horn response surface. The simulation program of commercial code ANSYS was performed successfully to characterize the mode shapes of the selected horn models and their data discussion was confirmed experimentally using Doppler effect of 3D laser vibrometer to extract horn measurements. The correlation between electrical impedance and experimental analysis were successfully identified with minimum percentage recoded a value of 2 % varied from the natural frequency of vibrating horn. Optimizing slots position of the designing block horn have been led to significant enough frequency separation measured accordingly to the exciting axial mode with sufficient uniformity of displacement amplitude and minimum stress identified far away from the horn tip; this is recommended in the field of mass production to allow sufficient ultrasonic energy transferred to the working area. This work concludes that designing an efficient horn will surely reflect on works in acceptable quantity and quality processing parts such as in producing medical masks and their supplements. In comparison with traditional processes, performing ultrasonic power results in fewer additives attain joints material with no holes from sewing, or weak strands, revoke the rise of adhesive cost and lower the glue delivery system. In contrast, the ultrasonic process has pace cycle rate which has capability in reducing of maintenance down time.**

Keywords: Ultrasound power technique, slotted block Horn, Modelling analysis, Experimental analysis, exciting frequency, production of mask.

I. INTRODUCTION

As ultrasonic power technique covers broad fields of applications and encompasses assortment of medical and industrial procedures. It is reasonable to perform this technique to be strongly entered in field of industrial but with medical applications, which means that the technique enter in production and manufacturing of different things such as a surgical masks and other accessories that are rapidly needed to obstacle the separation of pandemic which is spread around the world and then to increase the protection against the increasing percent of infections. Due to a wide and rapid spread of Covid-19 virus, the world exposure suffering from the severe shortage not only for those personal protective equipment that normally used in hospitals but also extended to

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the care homes [1]. The fast spread of harmful pandemic put the supply of medical and their supplements under stressed and result in a huge shortage of personal equipment such as facial masks…. Etc. Generally, this technique has many components but the most important efficient components of ultrasonic system are the working horn, as this component is always be touch to the worked area.

Horns have many shapes and different profiles. Block horn is one of these types that are normally used in welding and cutting. Ideally, the horn should vibrate at least with purely longitudinal mode of vibration and with uniform amplification at working surface. Serious problems found in modal coupling between favourite and un-favourite modes, one of these problems are related to Poisson's effect of transverse coupling initiated through the change in width and thickness. In case of using block horn; the excitation can be obtained when the horn is designed with or without slots, but this directly affects on providing displacement amplitude measured at a horn tip and also the amount of delivering energy to the work. Making slots in block horn will enhance uniformity at working surface, but may also lead to introduce some issues, which can be overcome through careful design. It is compulsory to obtain excitation of the vibrating horn to match and satisfy many criteria for example tuned at operating mode and allow good separation from other unfavorable modes, obtain high displacement uniformity with large gain and low energy losses. Therefore, adding slots lead to enhance horn efficiency and ensure high sufficient energy delivered to the working area, also to improve quality of joints. Literature researches investigate the dynamic and vibrational characteristics of block horn, through focusing on reliability and performance of horn excitation [1-2].

The need to improve the performance of block horn is carried out by part of studies that identified amplitude uniformity at work place and high amplitude value due to proper setting of position for slot geometry [3]. Another improvement for the horn performance is done by using modelling to redesign the tool and to measure its natural frequency [4]. Full factorial design with genetic algorithm is used to design horn and to examine its vibration along exciting mode with proper displacement, which its result are identified [5]. At different horn profiles, the non static performance is examined to extract dynamic properties for both simple and complex manner. The results of finite element improve that the stress induced by the horn is acceptable and due to the limitation of horn yield material [6]. An optimization of slot position is studied for various configurations of slotted block horn, the results of simulation showed that high amplitude with excellent uniformity can be obtained by adding slots to the horn, while low amplitude with non uniformity is observed by horn without slots. The validation is conducted with the aid of using 3D laser Doppler vibrometer [7]. A study on horn parameter optimization for metal welding is revealed based on perform genetic algorithm and use the methodology of response surface. The results show that the output variables can be preformed successfully according to the optimization of input variable [8]. The analyses of the horns are carried out using different techniques such as inspection by interferometry [9], detection by velocimetry [4], design of experiment (DOE) [10]. The current work offers an access to study and analyze a block horn containing slots.

The modelling of horn is successfully designed and optimized by finite element method, while their experimental results are identified by modal analysis of laser effect to identify from the mode of vibration and improve its data correlation. The analyses will help focusing on understand block horn behaviour and to improve its performance. At the end and due to the influence of pandemic on different medical fields and its supplements, a motivation for find a solution to reduce many issues is become mandatory. Therefore, the proposed work aims to provide one of the modern and most powerful techniques that can be applied effectively in design and production things which help to curb the virus spread and to reduce the shortage of personal protective equipment, particularly medical (surgical) face mask and their supplements, in fast and precise manufacturing with low cost and minimum consumed materials.

1.1 Mathematical and analytical approach for designing horn

In ultrasonic system, horn considers one of the most important components because this it is directly dealing with the working piece. Therefore, it is important to derive the mathematical expression and consider the basic propagation of the horn characteristics. The geometry of the horn is considered based on specifying horn geometry such as length, cross-section and displacement and the equation of motion aids with the condition of equilibrium is created based on Newton-Euler assumption for the bar under longitudinal direction. The predominant parameter that controls the change in frequency axially is the length, which the wave equation for the relationships between the length and the frequency in axial mode can be written as:

$$E(\partial^2 u/\partial x^2) = \rho(\partial^2 u/\partial t^2) \text{ or}$$

$$C^2(\partial^2 u/\partial x^2) = \partial^2 u/\partial t^2\ , \quad \rightarrow C = \sqrt{(E/\rho)} \quad [11] \quad (1)$$

Where C, ρ, E is the velocity of sound, density and modulus of elasticity respectively.

$$d^2U/dx^2 + \psi U = 0 \qquad \psi = (\omega/C) = (1/\lambda) \qquad (2)$$

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Where ψ, λ is the wave number and the wave length respectively.

$$\therefore\ \omega_n=(\psi)\sqrt{(E/\rho)}\quad,\ f_n=(\psi/2L)\sqrt{(E/\rho)}\qquad(3)$$

The wave length referred by Greek letter lamda (λ) is like below formula [5].

$$\lambda=(C/f_n)=(2L)\qquad(4)$$

In ultrasonic machines, the vibration transferred across the generator and passed along horn to be imparted at the end to the working tool that is excited in the form of displacement amplitude, this lead to reduce the amount of forces raised during machining and also decrease the friction force contact between the working tool and workpiece, resulting in lower stresses of the workpiece, enhance the uniform surface and cross-section of the products.

In designing of block horn, several factors must be considered such as frequency excitation, frequency mode separation, isolation between excited and non excited mode, high amplification, good uniformity and low stress concentration. The principle of design block horn depends on the multiples of the half wavelength, length, width and thickness. A block horn is derived according to the uniform bar analysis, slot separation and the bridging section that joined bar element to other elements. The horn is excited longitudinally which the resonant horn length is determined based on the derivation of final mathematical expression as shown below:

$$L=(C/2f)+2a-2(C/\omega)\tan^{-1}(W/W-(n+1)$$

$$h\tan(\omega a/C)\qquad(5)$$

Where *f*, *w*, *h* and *a* are the working frequency, wide of block horn, width of slot and length, respectively, as shown in Figure 1. The block horn width is selected according to a dimension of application, while the forth and back mass of the block horn is located by the nodal line and its dimension is measured relative to the wavelength, which is set equal to ($\lambda/4$).

In this study, the horn have two slots, which is designed in such a manner and have a direction parallel to the direction of longitudinal motion. The slot positions are specified to match the producing effect of horn, improve heat dissipation and avoid any un-favourable spots that initiated during operation [12].

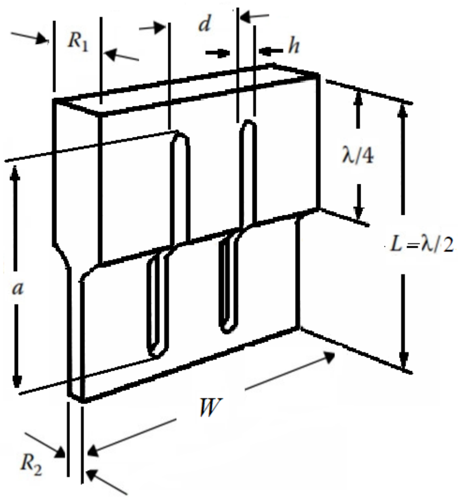

Figure 1: Sketch and layout of horn with double slots

The geometry of modeling horn was selected to be identified by the geometry of components (length and width) to be worked, for example medical masks (shown in Figure 2). Therefore, the breadth and width of the block horn are measured to match the geometry of the masks and to permit between the natural frequency and resonant frequency to be much closer.

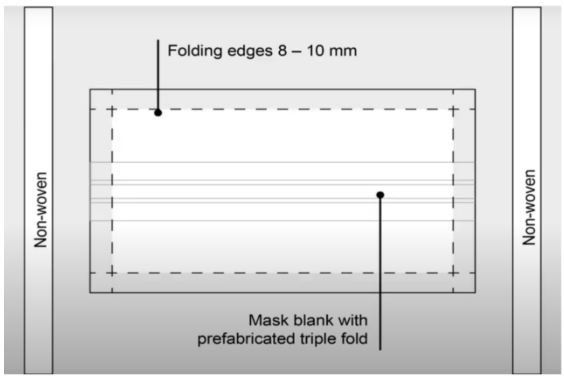

Figure 2: Layout of the surgical mask (Courtesy Picture)

The modeling analysis based on finite element method was built to examine vibration amplitude distribution of a block horn, which it cross-sectional profiles are examined and the propagation of acoustic wave is described analytically based on the assumption of Navier's equations (6) [13].

$$\begin{aligned}&(\Omega+\Psi)(\partial^2X/\partial x^2+\partial^2Y/\partial x\partial y+\partial^2Z/\partial x\partial z)+\\&\Psi\Delta^2X+\eta F_x=\eta(\partial^2X/\partial t^2)\\[1em]&(\Omega+\Psi)(\partial^2X/\partial x\partial y+\partial^2Y/\partial y^2+\partial^2Z/\partial y\partial z)\\&+\Psi\Delta^2Y+\eta F_y=\eta(\partial^2X/\partial t^2)\\[1em]&(\Omega+\Psi)(\partial^2X/\partial x\partial z+\partial^2Y/\partial y\partial z+\partial^2Z/\partial z^2)+\\&\Psi\Delta^2Z+\eta F_z=\eta(\partial^2X/\partial t^2)\end{aligned}\qquad(6)$$

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Where X, Y and Z are denoted to the displacement of the horn particles in the three directions of x, y and z axes, respectively. Ω and Ψ are referred to the constant; while body forces relative to the mass are denoted by the direction of three force (F_x, F_y and F_z) directly along x, y and z axes respectively. The finite element method is required to confirm matching between the geometry of the working parts and the dimensions of the working tools with high accuracy and good consistency.

II. THE PROCEDURES OF DESIGNING BLOCK HORN

In designing of block horn, the procedures were adopted to ensure that the ability and productivity of producing medical masks ultrasonically. The block horn was selected, specified and optimized according to standard specifications of designing ultrasonic tools, which its variables such as slot shape, slots number and slot position through conduct former analysis of the created model part. As per central design of horn, the non linearity of displacement amplitude was precisely developed using modal and harmonic analysis with integrating response surface methodology (RSM). A genetic algorithm function (GAF) is also used to obtain the geometries of the vibrating horn. The horn geometry was specified to match to the geometries of producing masks (Figure 3). The resonance length of exciting horn was calculated according to the derivative equations, while the width was selected to the same dimension of the mask (Figure 2). Natural frequency of the designed horn is calculated depend on analytical derivation of the wave equation as shown in eq. (4).

Generally, the range of ultrasonic frequency for the exciting block horn in axial mode is set to have a value of 20 KHz; while its material properties were also selected such as elastic properties (75 GPa) and density (2750 kg/m3) were selected according to the type of horn materials, which in this study aluminium type 7075 is chosen as a horn material. The tuning length of the block horn was calculated and has a value of 90 mm, and the reduction of rectangular cross section was suggested to toward the lower face of stepped horn. This is required to obtain high amplification of vibration at the lower face of horn. The double slots divide the horn into three sides; these bars have shorter edges if it compared to the whole edge of the horn. The benefit of creating slots is confirm delivering vibration uniformly at lower face of the horn, as this uniformity is required at working area that the horn touched with work part. In addition, the three side bars were designed to have a thickness that attributes to be greater at middle bar of the upper part compared with other bars having the same thickness at lower part. This difference in thickness between upper and lower parts allows the horn to create uniform vibration. Further, the width of the horn was also designed to ensure uniform vibration at horn edge.

Figure 3: Boundaries of surgical masks that match the geometry (length) of working tool (block horn Tip)

Finite element technique has ability to model any simple or complex structure throughout using mesh convergence technique of connecting elements. The elements have material properties which can be applied to analysis and characterize the behaviour of structure. The form of connection between elements called 'node'. The nodes of element are easily to simulate after applying boundary and loading conditions to calculate the results of analysis [14]. So, the horn was modelled in different conditions using simulation program with benchwork of commercial code ANSYS, the analysis covers the characteristics and convergence of the block horn. The type of element used in finite element analysis is 3D homogeneous and isotropic solid, which the number of elements were developed by modelling parts has 20750 hexahedral elements with element size of 2.9 mm. The model of horn was created, sketched, designed and its mechanical properties were included within material model.

The meshing technique was also preformed in such a manner to identify mesh density of the block horn, the nodes that created by simulation allow the element to have vertex and the number of nodes that construct the grid of points are lead to form the horn mesh. The boundary conditions were set on each element of the horn back and front section, which the displacement of excitation at back section is constrained along the x- and y- axes. Figure 4 shows the behaviour between vibration modes that extracted from using mesh technique. The solution of vibration modes confirm that the finite element program provides accurate results for the frequency domain in accordance with natural frequencies, mode shapes and for tuning ultrasonic components with significant complex geometry. As a horn designed relative to the principle of half wave length or to the multiple of wavelength, it is recommended to examine several factors that are significantly affects on the performance of vibrating horn. Therefore, a slotted block horn should resonate at the same value of operating frequency of generator or transducer, and during operation the coupling of vibration modes must get enough

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form in order to obtain good separation and to provide high amplification with low stress measurement at block horn tip. In simulation program, the modal analysis extract the characterisation, the isolation of both natural frequency and their mode shapes are calculated based on conducting method that calculate the difference between axial frequency with lower and higher mode frequencies, and then later identified from the isolation of first and second frequency [14].

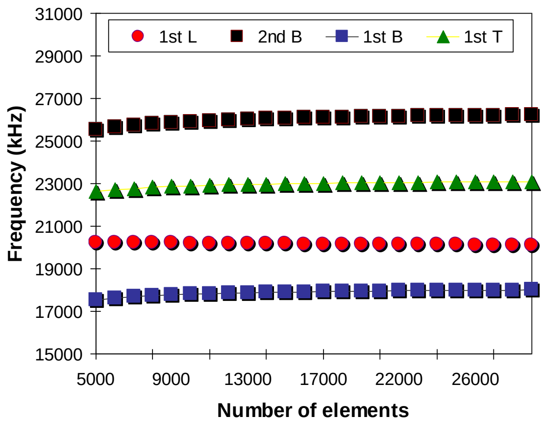
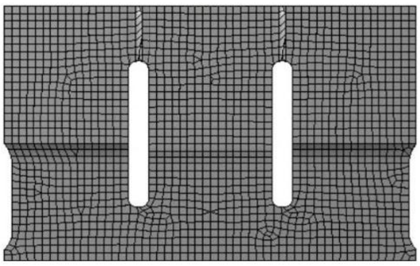
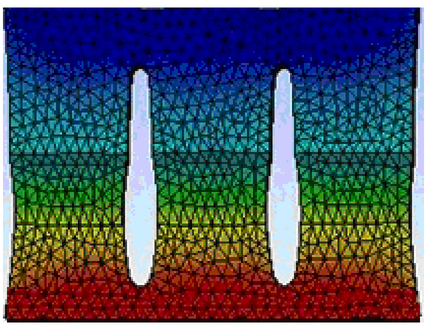


Figure 4: Analysis the mesh convergence of block horn

The modelling provides different configuration of block horn with different slots geometries (slot width, slot height and slot separation). Figure 5 shows the geometry mesh modelled and simulated contour extracted by FE program ANSYS. The analysis of finite element models confirms the successful calculation of natural frequency and mode shapes.



(a)



(b)

Figure 5: Simulation of double slotted block horn (a) mesh model (b) contour model

The most important parameters to characterize ultrasonic resonators are the resonance frequencies and the corresponding vibrational modes. A quick impression of the resonating body can be obtained from the Location of nodal patterns. The harmonic analysis results of this work reveal the features of the block horn such as: maximum (15.90 µm) and minimum (12.30 µm) displacement at the horn face, displacement uniformity (94.0%) and the horn gain (77.3%) respectively.

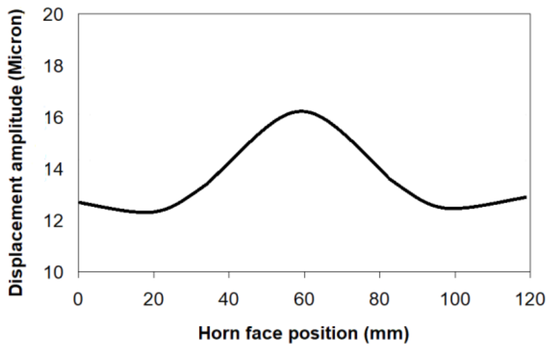


Figure 6: Displacement variations at working face of excited horn

Horn geometry was specified including the geometry of adding slots (height and width), which this work has four design variables were specified to be included in calculation in order to obtain horn with good optimisation, these variables are defined such as slot length (x1), slot width (x2), variation distance between slots (x3) and horn height (x4) as shown in Figure 7.

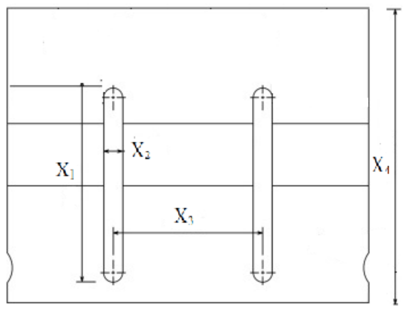


Figure 7: Sketch of the design variables for the slotted block horn

These variables were performed and entered in model and acoustic problem analyses in which a requirement for the combination between them are carried out using response surface methodology [15]. In modeling, a set of various combinations of design variables were carried utilized from the central composition design to obtain natural frequencies of slotted block horn, which the analysis have 20-factorial, 8-centre and 9-axial points. Figure 8 reveals the variation in design variables for arbitrary selection of four different combinations. It was noticed that the frequencies are within the limit of exciting frequency and the significant behaviour of longitudinal vibration confirm high displacement amplitude at

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working area of slotted block horn, which is recommended to the requirements of predicting the production of masks with high consistency and good quality.

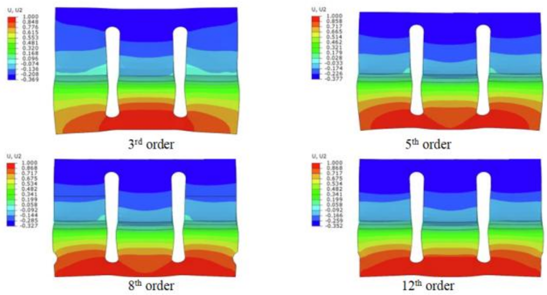

Figure 8: Simulation analyses of different design variables for slotted block horn

The model analysis of the simulation horn was determined to address the amplitude values of displacement at horn working surface, which after that these analysis were considered later for perform the harmonic analysis. Low uniformity was calculated (89%) through the presence of Poisson's effect in axial mode and low frequency separations were expected for the unslotted block horn configurations. While, with adding slot to the horn, good estimation value (96%) of uniformity was obtained, as shown in Figure 9. With obtaining high amplitude values of the horn, the control of uniformity becomes more difficult through any modification of slots dimensions, positions, as well as the change in horn profile [16]. Adding slots are significantly affects on surface uniformity, but improving uniformity may also be obtained through the addition of horn refinement, this in fact depend on particular application. However, slots issue some problems, which can be eliminated by carful design [17]. Analysis of induced stress is another parameter that significantly affect on the performance of exciting horn, which the analysis are harmonically performed to examine stress distribution along the horn body. In modelling, many attempts were carried done due to numbers of horn modifications with slot configuration in order to obtain high amplitude with low stress values. The horn was successfully controlled to obtain purely excitation in one direction, while other movements in transverse and torsional modes are constrained in order to allow it to vibrate in axial mode.

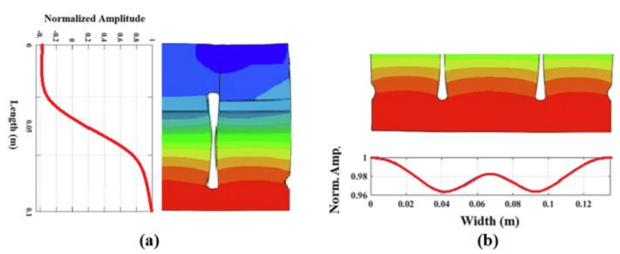

Figure 9: Variations of displacement amplitude along (a) length of the block horn (b) width of the block horn

The Von-Mises stress induced for most attempts were indicates that the maximum values are conducted by small region confined to location of slots, while higher stress induced value at horn working surface were calculated (30 MPa) to show an acceptable level through comparison with fatigue strength of the horn material. This in fact confirms that the horn can be worked in safe and good condition and it easily designed in proper parameters and within metallurgical limit. Figure 10, shows a normalising of stress levels measured across the half wave length of slotted block horn exciting at 20 kHz. It can be shown that the values of stresses which were extracted from calculating of design variables shows significantly lower indication in comparison with initial model; this confirms the effectiveness of using genetic algorithm and performing it to specify horn geometry in proper manner. The non linearity of developing model which is obtained by surface methodology is directly set as an input to a fitness function in GA, to perform optimal condition of designing horn. However, the control of modifications in horn shape and slot configuration is not easy due to the high sensitive to the exciting frequency [18].

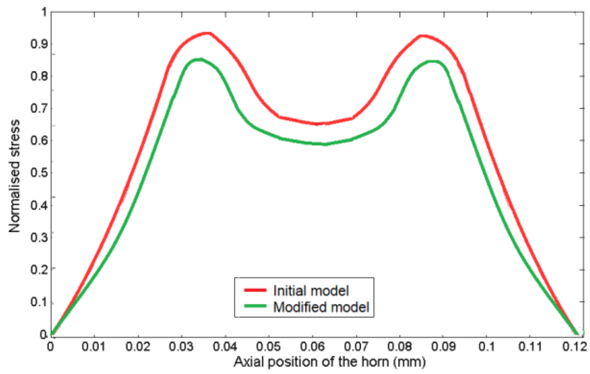

Figure 10: Normalised stress distribution along the half wave length of slotted block horn

Low stress induced through excitation of joint make the process to have more reliable and applicable in producing large number of face masks within consuming short time and minimum energy.

III. EXPERIMENTAL AND VERIFICATION OF THE SLOTTED BLOCK HORN

In this study, the validation was performed to identify from the performance of modelled block horn. This was successfully done using CNC technique process, the fabricated horn with implementing double slots was securely connected to the transducer by means of rounded screw and the connection was securely checked using special fastening tool to any losses or leakage during operation, Figure 11 shows the connection of the horn with transducer.

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Figure 11: Connection of fabricated slotted block horn with transducer

The results were obtained through conducting many experiments that carried out on fabricated block horn using aluminium type 7075. Figure 12 shows a configuration of vibration analysis of exciting block horn, the processes were carried out experimentally to identify from the Eigen frequency and also to characterize the mode shapes and damping ratio. In experiments, ultrasonic components, 3D LDV (3D Laser Doppler vibrometer) and other connections were setup. In experiment test, a random signal is set to verify from the results of numerical analyses, then the ratio of input / output exciting block horn was carried out to examine the Eigen frequency and exciting modes. This was obtained after converting domain from time to frequency through using mathematical transformation of Fast Fourier (FFT).

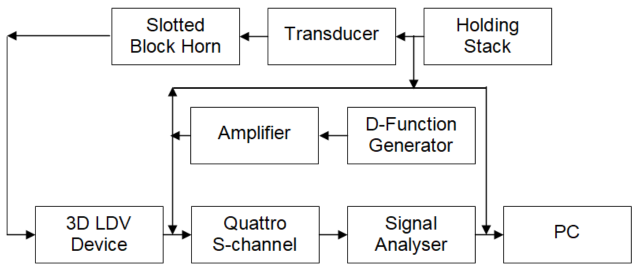

Figure 12: Configuration of vibrating frequency analysis of slotted block horn

The response of vibrating system was analyzed using frequency response function (FRF), which by this function it can be easy measuring of displacement, velocity and acceleration of vibrating horn based on assumption of parameters measurements and output response [19]. Good separation between vibration modes was known by experimental models, which the isolation of modes was recorded to be greater than (1 KHz) from the driving mode (longitudinal mode). This was significantly affects quality of work and to the amount of vibration amplitude and reduces coupling effect [15]. Other measurements such as spectrum and modal peaks of excited block horn were measured by experimental test (Figure 13). The bandwidth of frequency is conducted up to 70 KHz, and the horn was vibrating randomly with highest displacement amplitude at working surface. The data of spectrum analyzer confirms a good separation of vibration non tuned modes regarding to the tuned mode, which the separation were recorded to have at least 2 KHz far from the operating mode (axial mode).

This is required to avoid any coupling modes that significantly affect on proper amplitude and can lowering quality of work. The ratios between longitudinal to bending and between longitudinal to torsional were 14.8 % and 15.87 % respectively. On the other hand, a ratio of less than 10 % was recorded between exciting mode and other surrounded modes [20]. In addition, other tests such as displacement and gain were measured experimentally to verify from the results of the same tests that obtained numerically. This was important to minimize motion distortion, energy dissipation and poor uniformity at working area [21, 22]. The electrical impedance of ultrasonic stack (horn connected with transducer) was measured, to identify from the value of pre-load, which the measurements were set to keep all constituents of transducer in compression during operation. The output of impedance analyzer type (Agilent 4040A) is shown in Figure 14.

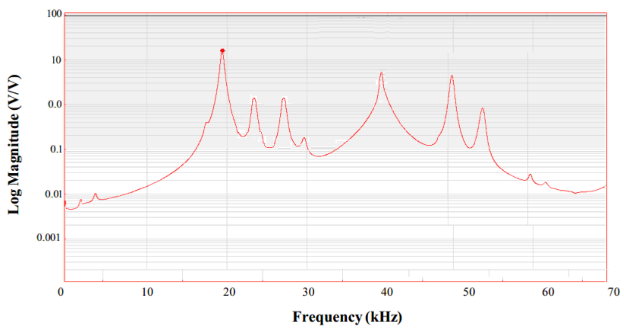

Figure 13: Spectrum and modal peaks of ultrasonic block horn

However, insufficient pre-load may result to high impedance and then make the block horn prone to be unstable and subjected to failure. The magnitudes of electrical impedance are obtained based on frequency range and according to the series of natural frequency, under assumption of equality between series and parallel frequencies. The indication of resonance frequency shows very close to match with that designed frequency, with correlation percentage less than 2%. This was required to obtain sufficient ultrasonic energy transferred to works, and also significantly affects on quality of joint.

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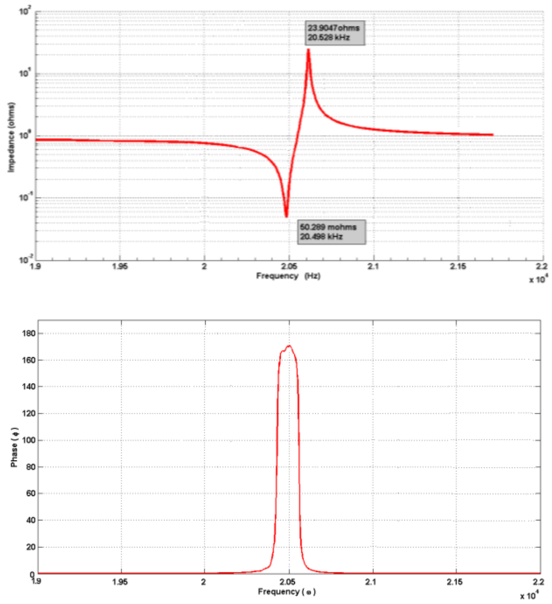

Figure 14: Output of impedance analyzer for measuring electrical impedance of the ultrasonic stack

IV. MASK CONSTRUCTION

The welding stack components were securely connected and encountered on movable hydraulic arm that its movements is going gently and continuously to press the nonwoven layers on to support anvil (specially designed for welding process requirements) where the block horn delivers ultrasonic energy that permanently joint them together, as shown in Figure 15. The vibration produced by ultrasonic welding stack creates friction between intimate surfaces, which the friction leads to rise heat and melts the plastic, and brings the intimate areas in pure condition to weld it in a good manner. More advantageous can be extracted from ultrasonic operation, which can be utilised to convert the nonwoven fabric from large to small or narrow strips by make cutting or slitting process. While, sealed cutting edge is done by using heat that also applied to get quilt of multiple layer material into a form of laminated product such as in the application of facial masks. In addition to bond these layers and binding it into a finished seam to the edge of face mask. Further, to join the tie strap or stretchable ear loop to link it at the edge of mask. The benefits of ultrasonic method with respect to other traditional methods have made it an indispensable technique for process and produce any kind of nonwoven materials like face mask, surgical grab… etc. Applying ultrasonic technique is important to overcome the pandemic effect through providing many benefits such as:

- Remarkable speed and productivity
- Strong, continuous seams and bonds
- Zero consumables or contaminants
- High energy efficiency
- Continuous technical improvement

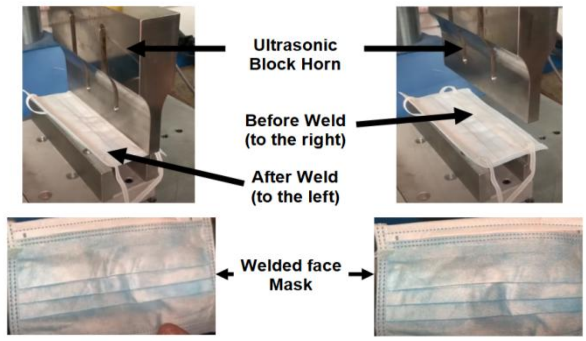

Figure 15: Medical mask constructions and joint it with accessories using ultrasonic block welding technique

V. CONCLUSION

The presented work aims to provide one of the modern and most powerful techniques that can be applied effectively in design and production things which help us to curb the virus spread and to reduce the shortage of personal protective equipment, particularly medical (surgical) face mask and their supplements, in fast and precise manufacturing with low cost and minimum consumed materials. This was completely done by design, simulation and fabrication of the ultrasonic block horn with two slots. The exciting horn remains the most efficient operating tool, as this tool is directly contact to the working area and allows bringing enough energy to complete process quantitative and qualitative. Therefore, to overcome several issues initiated within these applications, optimization of designing horn was successfully done to coincide between exciting frequency with operating frequency of transducer (normally 20 kHz). Many criteria were examined on exciting horn such as the isolation of tuning mode from surrounding modes, check the uniformity amplitude at working surface, increasing of displacement amplitude (amplification) at horn tip and shift back the stresses.

Additionally, the slots added in the direction of exciting horn in longitudinal manner in order to reduce Poisson's effect, through reduce the transverse coupling and to enhance horn performance for the suggested process. A genetic algorithm function (GAF) was performed to obtain the geometries of the block horn. While, the improvement of displacement amplitude was determined using RSM. Adding Slots result to increase the consistency of mask production compared with the other traditional processes which their production has less quality. The assembled welding stack was analysed through using electrical impedance and EMA, which the analyses demonstrate a close correlation between data with minimum percentage of difference (less 2%) for the exciting frequency. In addition, the ultrasonic technique provides fast, clean and no need to consume any flame or pre heat that are essentially required to complete bonding processes. It was concluded that good block horn profile with optimized slots

ISSN (online): 2581-3048
Volume 6, Issue 4, pp 20-29, April-2022
https://doi.org/10.47001/IRJIET/2022.604004

position can vibrates in high sufficient excitation and proper displacement amplitude with low stress at working surface; this is required in mass production of such processes like fabrication surgical masks and other supplements. Finally, producing different kinds of medical masks and other supplements by using ultrasonic power technique will leads obtain products with high quality, less additive, best bond with no hole or voids from sewing process, no weak strands, minimum cost of adhesive and glue delivery system, and reducing the routine of maintenance down time.

ACKNOWLEDGMENT

The authors of this paper thank the University of Mosul for serious follow up and direct support in completing the implementation of this work in an analytical, numerical manner. The author also expresses his desire to appreciate all the efforts that were made on the experiments.

REFERENCES

[1] Oude Vrielink TJC, Meijer JH Using surgical wrapping material for the fabrication of respirator masks. PLOS ONE 15(7): e0236239. https://doi.org/10.1371/journal.pone.0236239. 2020.

[2] M. Lucas, A. Cardoni, E. McCulloach, G. Hunter, and A. MacBeath, "Applications of power ultrasonics in engineering," Applied Mechanics and Materials, vol. 13-14,pp. 11-20, 2008.

[3] H. S. J. Seon Ah Kim, Eun Mi Kim, Dong Sam Park "Vibration analysis of ultrasonic metal welding horn for optimal design " in Proceedings of the 2010 International Conference on Mechanical, Industrial, and Manufacturing Technologies (MIMT 2010) Sanya, China, 2010, p. paper23.

[4] M. Lucas and A. C. Smith, "Redesign of ultrasonic block horns for improved vibration performance," Journal of Vibration and Acoustics, vol. 119, pp. 410-414, 1997.

[5] Dipin Kumar R, Roopa Rani M, Elangovan S (2014) Design and Analysis of Slotted Horn for Ultrasonic Plastic Welding. Applied Mechanics and Materials 592-594: 859-863. https://doi.org/10.4028/www.scientific.net/ AMM.

[6] S Kumar, W Ding, Z Sun, C S Wu, Analysis of the dynamic performance of a complex ultrasonic horn for application in friction stir welding. International Journal of Advanced Manufacturing Technology 97:1269 –1284. https://doi.org/10.1007/s00170-018-2003-0.2018

[7] Ziad Shakeeb Al Sarraf, Majid Midhat Saeed Design and analysis of slotted block horn used for ultrasonic power applications. Journal of southwest jiaotong university 54:1–10. https://doi.org/10.35741/issn.0258-2724.54.5.28.

[8] Elangovan Sooriyamoorthy, Shenton Ponnayya John Henry, Prakasan Kalakkath, Experimental studies on optimization of process parameters and finite element analysis of temperature and stress distribution onjoining of Al–Al and Al–Al2O3 using ultrasonic welding. International Journal of Advanced Manufacturing Technology 55:631–640. https:// DOI 10.1007/s00170-010-3059-7. 2011.

[9] Graham G, Petzing JN, Lucas M, Modal analysis of ultrasonic block horns by ESPI. Ultrasonics 3:149-157. https://doi.org/10.1016 /S0041-624X (98) 00050-X.1999.

[10] Sun-Rak Kim, Jae-Hak Lee, Choong D Yoo, Jun-Yeob Song, Seung S Lee, Design of highly uniform spool and bar horns for ultrasonic bonding. IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control 58:2194-2201. https://doi.org/10.1109/TUFFC.2011.2069.

[11] ZIad Shakeeb Al-Sarraf, Margaret Lucas, Design and simulation of ultrasonic metal welding horn.Al-Rafadain Eng J 2015;23:56–68.

[12] Thanh Hai Nguyen, Quang Thanh Le, Phuong Minh Luu, Huu Loc Nguyen, Manufacturing of Ultrasonic Horn for Bonding Non-Woven Materials. National Conference on Machines and Mechanisms 2015, Ho Chi Minh City.

[13] Dai, Wen-Long; Y.C. Liu; Huang, Jin H. Enhanced Working-Amplitude Distribution of Ultrasonic Wide-Blade Horn With the Use of a Wave tuning plate. 19th International Congress on Acoustics Madrid, 2-7 September, 2007.

[14] Euan McCulloch, Experimental and Finite Element Modelling of Ultrasonic Cutting of Food, PhD. Thesis, University of Glasgow, 2008.

[15] Anand Kumarasamy, Elangovan Sooriyamoorthy, Design and Optimization of Slotted Block Horn Utilized in Ultrasonic Insertion Process Through Rsm-fea-ga Integration Technique, doi: https://doi.org/ 10.21203/rs.3.rs-260954/v1

[16] D. Y. Ming, et al., "A new optimization method for horn designs in ultrasonic welding systems," 2002.

[17] A. Cardoni and M. Lucas, "Enhanced vibration performance of ultrasonic block horns," Ultrasonics, vol. 40, no. 1-8, pp. 365{369, 2002.

[18] Z. S. Al-Sarraf, "A study of ultrasonic metal welding," PhD thesis, University of Glasgow, UK, 2013

[19] Ziad Shakeeb Al Sarraf, Majid Midhat Saeed, Design and Analysis of Slotted Block Horn Used for Ultrasonic Power Applications. Journal pf Southwest

ISSN (online): 2581-3048

Volume 6, Issue 4, pp 20-29, April-2022

https://doi.org/10.47001/IRJIET/2022.604004

Jiaotong University, Vol.54 No.5 Oct. doi10.35741/issn.0258-2724.54.5.28 2019

[20] Li. Li, "A surgical bone biopsy needle using ultrasonic-sonic frequency vibration,". PhD thesis, University of Glasgow, UK, 2017

[21] Sonobond. (2011). Ultrasonics Metal Welding Available: http://www.sonobondultrasonic.com/welders-bonders-metals.asp

[22] B. M. B. A. D. Grewell, "Evaluation of amplitude stepping in ultrasonic welding," Welding Journal, sponsored by the American Welding Society and the Welding Research Council, 2010.

Citation of this Article:

Ziad Shakeeb Al Sarraf, Khalid Elias Hammo, "Design, Analysis and Fabrication of Ultrasonic Power Horns Used to Produce Medical (Surgical) Face Mask and Their Supplements" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 6, Issue 4, pp 20-29, April 2022. Article DOI https://doi.org/10.47001/IRJIET/2022.604004

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