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THE IMPACT OF MULTI-PURPOSE NOZZLE DESIGN ON MOSQUITO FOGGING SPRAY CHARACTERISTICS

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Abstract
Nozzle design affects fogging flow velocity patterns and acoustic characteristics, aiming to enhance mosquito control strategies essential for reducing diseases like dengue fever. Achieving optimal smoke dispersal through dense foliage and narrow spaces necessitates careful selection of nozzle types and diameters. The research focuses on the impact of audible sound on mosquito fogging spray properties in the presence of smoke and fog, examining the effect of nozzle design on fogging flow velocity patterns and characteristics, and the frequency response of noise distribution using different nozzle configurations. Utilizing CATIA V5, ANSYS Mechanical 2022 R2, and MATLAB software, various nozzle designs—including cone flat, square-flat, and cone-square-triangle—were analyzed. Results indicate that cone nozzles achieve the highest velocity thrust, outperforming flat, square, and triangle nozzles. The flat-cone nozzle excelled in smoke dispersal, maintaining high sound pressure levels (SPL) and acoustic pressure, particularly at a resonant frequency of 1700Hz, ensuring effective smoke penetration and distribution in dense foliage and narrow spaces. Wavelet analysis revealed that flat-cone and cone-square-triangle nozzles produce higher and denser wavelet pockets, enhancing turbulence and mixing for improved smoke distribution. These findings underscore the effectiveness of the flat-cone nozzle for comprehensive fogging coverage. The study recommends future research on integrating artificial intelligence (AI) and sensors into nozzle designs to develop smart nozzles that adjust spray patterns in real-time based on mosquito activity. This integration would maximize efficiency, minimize environmental impact, and optimize pesticide use by focusing resources on areas with high mosquito activity while reducing unnecessary applications. Such advancements could lead to more efficient mosquito control, minimizing the negative effects on the environment and non-target organisms.
Keywords: Nozzle design, smoke dispersion, velocity patterns, acoustic characteristics, noise distribution, wavelet analysis.

1. INTRODUCTION

The existence of adult mosquitoes plays an important role in many problems, especially the spread of diseases such as dengue fever. This is crucial to remove adult mosquitoes in selected affected areas so as effectively control of larvae breeding. Concurrent treatments for both the adult and larval stages serve as an effective approach in mosquito vector management programs that lower down overall numbers of insects, therefore interrupting disease transmission. Selecting the nozzle with the right shape and diameter is crucial for effectively reaching narrow spaces and penetrating deep into foliage. The application of pesticides through space spraying is a complex undertaking, influenced by several crucial factors, including equipment divergence, fogging type, spraying methodology, fluid density, spray volume, and the critical consideration of velocity fluctuations, which are paramount for optimizing space spray application [1]. The velocity pattern and operating pressure significantly affect the effectiveness of the fogging process, influencing spray dispersion and its adaptability to diverse conditions. Smoke dispersion is also influenced by nozzle size, liquid properties, and pressure [2]. The operating pressure of the sprayer has a direct impact on smoke spread, higher pressure results in smaller droplet sizes. All these parameters need careful consideration, especially in scenarios involving narrow areas, to effectively reduce the adult mosquito population. Therefore, this study aims to examine and investigate how nozzle configuration affects flow velocity patterns and frequency response in terms of its velocity fluctuations, ultimately contributing to the control of adult mosquitoes [3].

2. CATIA NOZZLE DESIGNS

According to analysis and research on the many nozzle types used in the mosquito fogging industry, circular nozzles like cones, flats, and non-circular nozzles like squares and triangles, are the most commonly utilised nozzle types. The analysis is now focused on the ability to design a nozzle that combines three-way hose with a Y joiner and W joiner. Different type of functional nozzles which is to increase the effectiveness in kill the mosquito. The 4 types of the nozzle configuration is Y joint (Cone Nozzle and Flat Nozzle), Y joint (Square Nozzle and Flat Nozzle) and W joint (Cone Nozzle, Square Nozzle and Triangle Nozzle). The which comprise both circular and non-circular nozzles and account for the majority of fogging machines. Currently, CATIA V5 software is used to create the four primary types of nozzle combinations, all of which have the identical dimensions and diameters. The nozzles employed in the majority of thermal and cold fogging systems in mosquito fog systems have diameters of 20 mm, which fits to these dimensions for all nozzle inlets [27]. There will be some inaccuracy in the nozzle shape even though the diameter is fixed at 20 mm. For example, certain nozzle shapes, such square and triangle, have unique shape features that cause the diameter or area of the nozzle inlet to vary slightly depending on the shape [27]. However, this simulation of a combination of many nozzle types with varying sizes is required since it helps in evaluating the impact of nozzle configurations on flow velocity pattern, which achieves the project's primary goal. However, because it has no effect on the nozzles' diameter or data output from the inlet, the length of each nozzle is adjusted to be between 100 and 250 mm depending on its construction and shape [27]. It is not necessary for all nozzles to have the same length..

3. SIMULATION PARAMETERS

The quantity and quality of material input are specified according to the type of fluid used. In this investigation, air is employed as the gas. All these parameters will be considered to achieve accurate results and outputs from the created nozzle. In this analysis air is used as the gas, and the relevant properties are detailed in achieve the desired output.

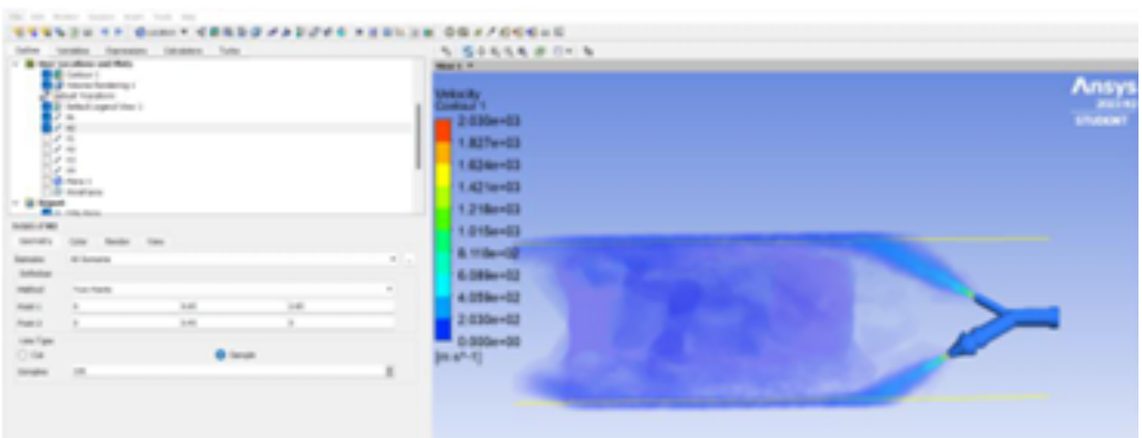
4. ACOUSTIC POINT

In acoustics, a point source in Figure 3-47 is a theoretical concept representing a sound-emitting object as a single point in space. This simplification aids mathematical analysis by allowing the use of fundamental principles like the inverse square law. Point sources are assumed to emit sound uniformly in all directions, forming spherical wavefronts. While this model is a valuable simplification for understanding basic principles of sound propagation, it has limitations, and more detailed models may be necessary in certain situations.

5. ANYSYS ANALYSIS

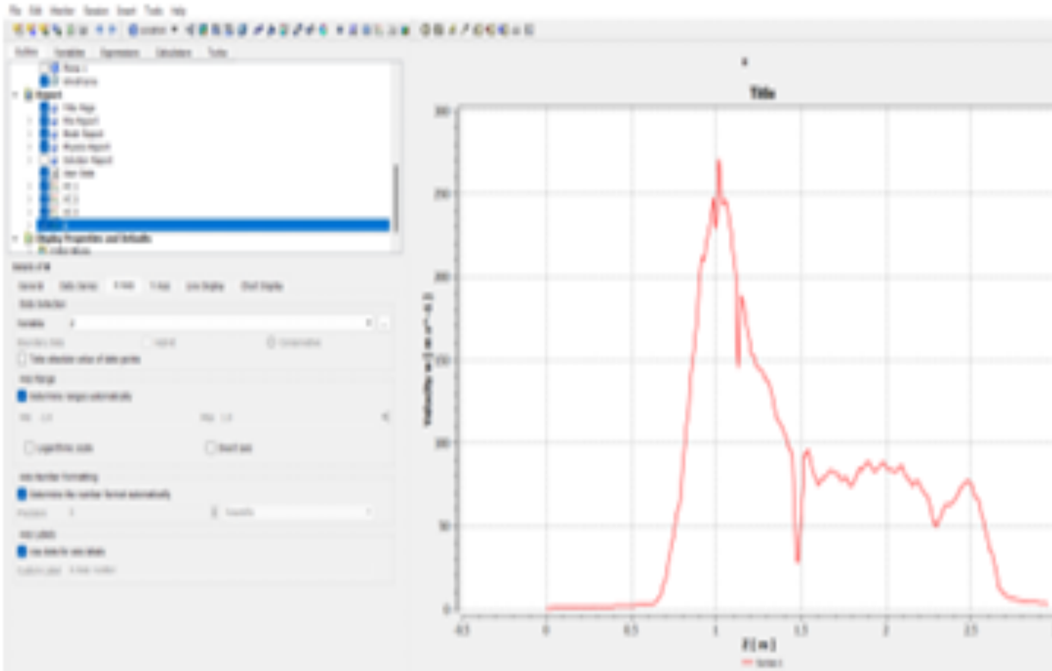
ANYSYS comprehensive analytical capabilities covering various engineering and physics areas. The process of designing geometry, the meshing process, boundary setup, and simulation results are a few of the important analyses that may be carried out with ANSYS. All the procedures, from accurate data entry and extraction to the outcomes of each nozzle test, are essential. During this process, Y joints and W joints nozzles are tested. We can determine the differences between each nozzle with this characteristic and ability because all of these nozzles have been examined using comparable data and boundaries.

6. VELOCITY PLOT



The velocity chart, which plots Y distance (m) vs. X velocity (m/s) to show each line section as previously said from X1 to X4, will be shown in the last phase. Major Velocity, Velocity U, Velocity V, and Velocity W are the variables that have been selected for the velocity chart. All these velocity profiles and components are required since they aid in comparing and displaying the velocity flow pattern for each of the four nozzles that were used, which also fulfils the first goal. Additionally, the horizontal centre line will show the centre streamline's velocity flow pattern in terms of Y Velocity (m/s) vs. X distance 99 (m), with just Velocity W being evaluated because it provides a more accurate figure for nozzle-to-nozzle comparisons. The four tested velocity components in X1 are displayed as an example and the tested velocity W, which represents the centre streamline, is displayed in figure above.

7. LINE SECTION AND STREAMLINE DIMENSION



The smoke display is divided into four vertical sections to study the velocity profiles and components; these four lines have equal distances between each line to collect velocity data at each line section. Table shows each line section as previously mentioned from, along with their differences between each line and point. Every single one of these velocity profiles and component is necessary since it aids in comparing and demonstrating the velocity flow pattern for each of the four different nozzles used, which also fulfils the first goal. To gather streamline data, two horizontal line is also generated. To improve data accuracy and facilitate data comparison with other nozzles, the bisection line for each nozzle is maintained at the same distance..

8. PROBE LOCATIONS

A few steps are needed to obtain the velocity variations at 11 probes positions as shown in Figure 3-74 in ANSYS under the setup workbench. To extract the data variations from the targeted point, there are essentially five key processes that need to be followed: point creation, acoustic receivers, input surface report definitions (average), custom field function, input surface report definitions (RMSE), and calculation execution. The following are the steps probes can be produced under same surface definition report.

9. ACOUSTIC RECEIVERS

The FW-H equation is used to determine the pressure at each place. In computational aeroacoustics, the Ffowcs Williams and Hawkings (FW-H) equation is an essential tool for predicting the sound waves generated in the far field by moving surfaces in unstable flows. This formula provides a clear and complex relationship between the acoustic pressure that a surface produces at a specific distance and the aerodynamic disturbances that occur nearby [35]. Based on the produced points, Figure abive displays the number of receivers and their coordinates. Custom Field Function Calculator (CFFC). With the use of Fluent, a versatile tool, users may create custom field variables beyond the ones the software comes with. These adaptable variables, also known as "field functions," may be changed to satisfy needs in simulations, enhancing the capacity for analysis and visualisation. Apply the same method as in step 2 to compute the RMSE velocity fluctuations but choose the custom field function formula that has been created in different places in the field variable box. The report definition for calculating velocity fluctuation at different places as shown in figure above. The MATLAB software with design built-in coding was used to further post-process all of the simulation process data in order to generate the final output and analyse the flow velocity pattern and frequency response, where both objectives could be achieved. The methodology, in its most basic form, describes the procedures and techniques that are employed in this study to accomplish our two objectives. To build the form of the nozzle with the specific measurements and dimensions, which stand from cone flat nozzle, square flat nozzle, and cone square triangle, CATIA V5 numerical setup design software is applied. Next, the main programme used to do this simulation analysis of smoke flow is Mechanical 2022 R2 ANSYS, where several key steps, including geometry, mesh, setup simulation, line section, and probe structures, are completed and discussed. All the actions taken are crucial because, after the ANSYS simulation is finished, they help us accomplish the project's two goals. Using the built-in design code, all the data obtained from the simulation process were post-processed in MATLAB as a last step. All the methods and software mentioned above enable us to successfully complete the two goals of this project, which are to investigate how different nozzle configurations affect flow velocity patterns and analyse the frequency response of noise distribution. CATIA V5 software is used to create nozzle designs, and Mechanical 2022 R2 ANSYS and MATLAB software are used to analyse flow velocity patterns and velocity fluctuation.

10. FOG NOZZLES DESIGN ANDCONFIGURATIONS

To get the design of the four primary nozzles for the simulation, several key processes were carried out in CATIA V5, which are covered in depth in Chapter 3. All four nozzles are created with appropriate measured dimensions. The final results of creating the four different shapes of fog nozzles Y joint (Cone Nozzle and Flat Nozzle), Y joint (Square Nozzle and Flat Nozzle), and W joint (Cone Nozzle, Square Nozzle and Triangle Nozzle) are displayed, respectively. After that, each of these nozzle files was exported into an STL file, which was then integrated into the ANSYS simulation programme. These STL files essentially use a group of connected triangles to represent the surface geometry of a three-dimensional object. Each triangle's normal vector, which shows which way the triangle is facing, is also included in the file.

11. CONTOUR PLOT

The contour flow diagram for each of the four nozzles involved is the first result of the simulation. The distribution of a particular variable over a geometric domain might be easier to understand with the use of contour plots, which are graphical representations of scalar or vector numbers [35]. Contour plots can be employed to illustrate which link points with the same value to one another, to provide a graphical representation of the data. Contour plots in ANSYS are primarily used to depict and analyse a wide range of physical properties, such as displacement, velocity, electric potential, stress, temperature, pressure, and so on. These kinds of plots may be created for many other types of analysis, such as electromagnetic, thermal, fluid, and structural simulations [35]. Volume rendering computations must be started before the contour flow diagram can be created. This will aid with the presentation and analysis of volumetric data from the nozzle's output. It provides a clear and precise illustration of volumetric data, allowing us to draw conclusions and base decisions on that knowledge. Additionally, it enables the visualisation of internal volume structures, such as stress gradients, material distributions, or fluid flow patterns, which will serve as the output data prior to the creation of contour flow diagrams [35]. A few key parameters have been analysed in terms of velocities, including the velocities in the x, y, and z directions as well as the Root Mean Square (RMS) velocity in the x, y, and z directions, to get a clear and thorough analysis on the contour plot diagram. Because it presents information on the severity of the fluctuations, the RMS value is frequently used for comparing CFD simulations to experimental data or assessing 112 velocity and turbulence levels. This makes it possible to compare several simulation scenarios and measure the variability of the flow field. To determine the impact of nozzles on the flow velocity pattern, maximum distance of the velocity thrust, and energy involved throughout the nozzle's outlet, all four involved nozzles have been compared in all kinds of velocity characteristics mentioned above.

12. CONCLUSION

Future research actions that may focus on utilizing integrated technology in relation to fog nozzles. Research into the incorporation of cutting-edge technology, such artificial intelligence and sensors, will contribute to the development of smart nozzles that may automatically modify spray patterns or intensities in response to mosquito activity. In doing so, needless pesticide use would be decreased, and efficacy would be maximized. Artificial intelligence (AI) and sensor integration in nozzle designs can result in smart nozzles that can detect insect activity and modify spray patterns or strength appropriately. This is particularly useful for controlling mosquito populations. The three major components of this approach are sensors, AI algorithms, and smart sensors with automatic adjustment. Smart nozzles that integrate AI and sensors can monitor mosquito activity in real time, enabling effective and targeted insect control. With the use of technology, this method guarantees optimal use of pesticides, cutting down on needless applications in low-mosquito activity regions and concentrating resources where they are most required. Consequently, the efficiency of controlling mosquitoes is enhanced while 131 reducing the negative effects on the environment and the exposure of non-target creatures to pesticides..

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