ORIGINAL ARTICLE

Modelling of the Air Current in the Vertical Plane of Hatsuta Agricultural Sprayer

Modelación de la corriente de aire en el plano vertical del pulverizador agrícola Hatsuta

http://opn.to/a/Co96T

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ABSTRACT. The proper use of the air stream in agricultural sprayers is a constant concern of farmers and professionals of Agricultural Engineering. The drift produced by this equipment affects human health and the environment by pollution, in addition to the economic damages they represent to the farmer. In this work, the airflow in the vertical plane of Hatsuta-420, sprayer is studied using modelling by means of the computerized fluid design technique. In the modelling, the FLUENT fluid package ANSYS 16.0 software is used. The results of the modelling are analyzed and compared with experimental measurements of the air velocity made to this sprayer in the plane studied. It is concluded that with modelling of airflow in CFD, airflow studies in the vertical plane of agricultural sprayers with the 0.97 to 0.99 accuracy can be predicted.

***Keywords**:* flow, fluid dynamics, sprayers.

RESUMEN. El uso adecuado de la corriente de aire en los pulverizadores agrícolas, constituye una preocupación constante del agricultor y los profesionales de la Ingeniería Agrícola. La deriva producida por estos equipos afecta a la salud humana y al medio ambiente por la contaminación, además de los daños económicos que representan para el agricultor. En el trabajo se estudia la corriente de aire en el plano vertical del pulverizador Hatsuta utilizando la modelación mediante la técnica de dinámica de los fluidos computarizada. En la modelación se utilizó el paquete de fluidos FLUENT del software ANSYS 16.0. Los resultados de la modelación se analizan y comparan con mediciones experimentales de la velocidad del aire realizadas a este pulverizador en el plano objeto de estudio. Se llega a la conclusión que con la modelación del flujo del aire en CFD se puede predecir los estudios de la corriente de aire en el plano vertical de pulverizadores agrícolas con un 0.97 a 0.99 de precisión.

***Palabras clave**:* flujo, dinámica de los fluidos, pulverizadores.

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Received: 23/06/2017
Approved: 14/03/2018

INTRODUCTION

To ensure the efficient protection of crops with minimal damage to the environment and human health, it is necessary to know the nature of the air stream aerodynamics in agricultural sprayers. Many farmers and researchers have devoted efforts to the knowledge of the air current and have pronounced on the matter (Walklate, 1992; Walklate *et al*., 1996; Cross *et al*., 2003; Delele *et al*., 2007). However, the study of these flow phenomena have been carried out in tunnels and in large-scale laboratories, where measurement errors are introduced by the environmental conditions or lab structures. In recent years, computational fluid dynamics (CFD) has been used in agricultural production systems according to Bartzanas *et al.* (2013), marking a path for the knowledge of fluid aerodynamics (Tsay *et al*., 2004; Herrera *et al*., 2014). In the case of agricultural sprayers with models, it is possible to describe the behaviour of the air stream in different work regimes, and thus to achieve better designs and control the pesticide drift effect in the treatments of shrubs fundamentally (Fujimoto *et al*., 2016). Several researchers have studied the modelling of airflow in agricultural sprayers and have determined relationships between their parameters and sprayer quality (Herrera *et al*., 2005; Han *et al*., 2014; Salcedo *et al*., 2015; Duga *et al*., 2017). The originality of the work lies in achieving a model that describes with the minimum of error the air flow in the vertical plane of an agricultural spray for shrubs.

The objective of the work is to achieve a model through the dynamics of computational fluid that can describe the airflow of Hatsuta sprayer in the vertical plane, where the air velocity vectors are determined at a distance of the fan output of 2.5m and similar height.

METHODS

For the modelling, the FLUENT fluid package of ANSYS 16.0 software was used. The results of the flow modelling are compared with experimental measurements in the laboratory made to the remote sprayer of the fan output of 0.8, 1.6 and 2.4 m (Rodrigues, 2005).

In the realization of these studies, the HATSUTA model SS-420 sprayer was used as an experimental model (Figure 1). This type of hydropneumatic equipment is considered in the category of low airflow and is intended for the application of defensives in plantations of coffee.

FIGURE 1. Hatsuta-420 Sprayer.

In this work the air stream of the sprayer is modeled by CFD in the vertical plane using the FLUENT fluid package of ANSYS 16.0 software, these results are compared with laboratory measurements made to the sprayer referred to in the work of (Rodrigues, 2005). The CFD analysis is carried out based on the velocity profile of the air at the outlet of the diffuser and the geometry of the Hatsuta sprayer, taken from the work of Herrera *et al.* (2005). For the run of the program, a computational domain is created, where the fluid moves (Figure 2) and there, the mesh is performed, defining 6530 nodes and 6377 elements for the development of the program equations.

In the computational domain, the axial sprayer fan is placed with radial exit of diameter 700 mm and the initial speed conditions at the fan outlet, which in this case, average 33 m / s. In the sidewalls of the domain, the environmental pressure is considered, since it represents the calm air where the current is inserted so that the flow develops freely.

The density and viscosity of the air were taken as 1.225 kg/m^3 y 1.7894 e^{-5} kg/m-s, respectively. The model chosen for the run of the program is viscous laminate with a convergence criterion of 1e-7 with 500 interactions. Other authors such as Salcedo *et al.* (2015), use the models with turbulence (k-ε, SST k-ω and Reynolds Stress Model), considering better adjustment, which is due to the fact that they introduce the tree as a porous area in the simulation, and consider the turbulence of the flow.

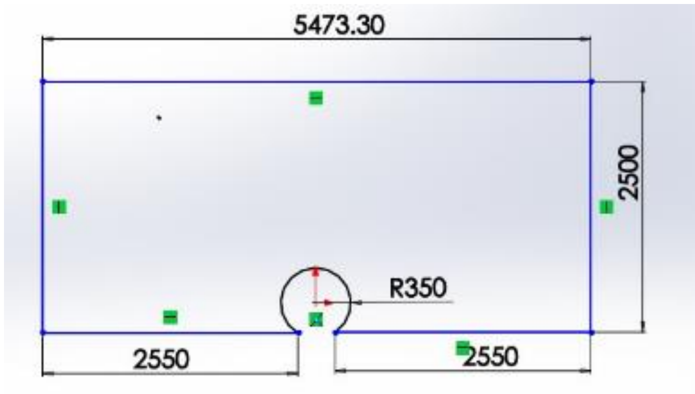

FIGURE 2. Dimensions of the computational domain in mm.

The experimental measurements of air velocity in the vertical plane were obtained from the work of Rodrigues (2005). The measurements were made in a roofed room with sidewalls 15 m away from the sprayer. The temperature and humidity were measured with digital HOMIS equipment with an accuracy of 0.1 ° C and a resolution of 0.01°C for temperature and relative humidity with an accuracy of +/- 3%. The ambient air velocity was measured with a paddle anemometer KESTREL 1000, with an error of ± 3% in the reading and a resolution in the measurement of the air velocity of 0.1m / s, with measuring range of 0.3 at 40 m / s. The speed at the selected points of the airflow was measured with an anemometer with hot wire sensor model AVT / 65, with a measurement range of 0 to 50 m / s and a resolution of 0.1 m / s.

As statistical processing, a regression analysis was performed between the data obtained from the simulation (CFD) and the data measured experimentally. The Determination Coefficient is determined, that gives the variation rate of the variable Y (experimental measurements), which is explained by the variable X (data obtained by CFD modeling), that is the predictor or explanatory variable. The greater the coefficient of determination, the better the prediction will be. If it were equal to 1, the predictor variable would explain all the variation of Y, and the predictions would not have an error.

RESULTS AND DISCUSSION

The graph of Figure 3 shows the result of the airflow modeling in the vertical plane, represented by the air velocity in the computational domain. At the output of the fan diffuser, the highest speed values occur, in the whole periphery values between 28 and 36 m / s are produced, but it is significant that in the lower part of the diffuser there are speeds in the range of 43 to 50 m / s much greater than at the output of the fan. This is because in the sprayers with axial fans and radial outlet, the lower part of the outlet of the diffuser facing the ground is closed and the airflow in this area is forced out through the areas near it, producing a higher flow value and therefore air velocity vectors with higher values. The zone of initial peripheral speed is followed by zones of speed that decrease in magnitude but occupy a greater radius as they move away from the outlet of the fan diffuser, characteristic of the wear of a turbulent free air current, until reaching to values between 0 and 7 m/s (Abramovich *et al.*, 1984).

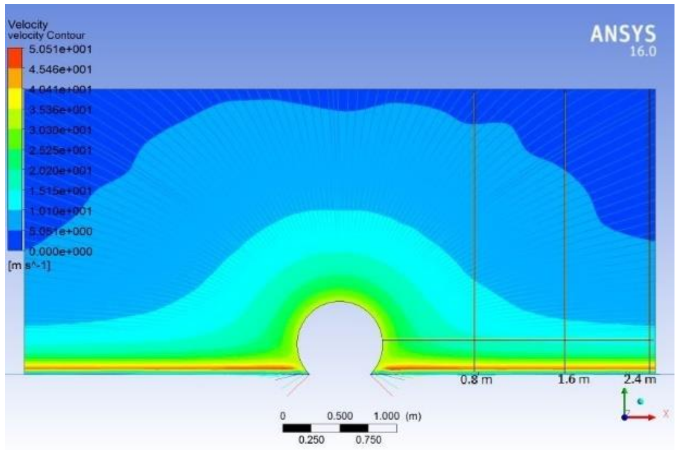

FIGURE 3. Distribution of air velocities in the vertical plane of the Hatsuta-420 sprayer.

The Figure 4 shows the air velocity graphs according to the height and on the X-axis the distance of 0.8, 1.6 and 2.4 m from the outlet of the fan diffuser as indicated by the vertical lines in Figure 3.

In Figure 4, the three curves for the different distances studied are shown, showing a decrease in the magnitude of the air velocity as the height increases. The speed decreases with the increase of the distance in the horizontal plane from 0.8 to 2.4 m. The curve referring to the height at the distance of 0.8 from the fan m is shown with less slope than for 1.6 and 2.4 m distance from the fan. In the case that it is used in a coffee plantation, taking into account the sowing frame and the diameter of the cup, the contact of the flow with the shrub would be approximately at the distance of 0.8 m from the fan, responding to the curve of the greatest speed values according to height.

In Table 1, the results of the regression analysis between experimentally determined data and those obtained in the model by CFD for the three distances at the output selected in the vertical plane are shown.

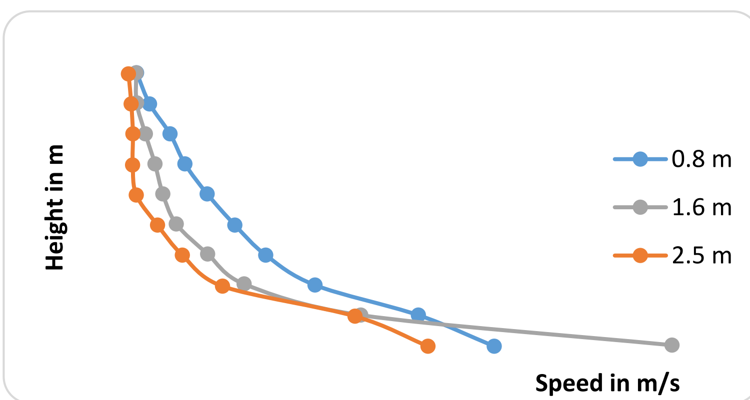

FIGURE 4. Air velocity according to the height at different distances from the output of Hatsuta sprayer.

TABLE 1. Results of the Regression Analysis.

Distance from the Exit in m	Equation	R^2
0.8	$y = 0.973\,x + 0.502$	0.996
1.6	$y = 1.546\,x + 2.09$	0.992
2.4	$y = 0.497\,x + 1.652$	0.976

In Figures 5, 6 and 7, the comparison between the results of the modelling with the data obtained in the laboratory, for each distance from the fan output for analysis is shown. In Figure 5 the air velocity of the modelled variant against the experimental one is compared to the distance of 0.8 m from the fan. A similar behavior of the speed determined in the laboratory with respect to the results of the model is observed. The results of the regression analysis for this variant are shown in table 1, where the adjustment equation and a value of the coefficient of determination of 0.9969 are shown, which corroborates that it is valid through modelling to predict the speed in the air current of the sprayers.

Figure 6 shows the velocity curves at 1.6 m distance from the fan output in the horizontal plane, in this case the curve of the laboratory data maintains the same trend as the data resulting from the modelling, but with values of slightly lower speed. The regression analysis of this variant is observed in Table 1, where the equation and a value of the coefficient of determination of 0.9929 are shown, although it is lower than that obtained at the distance of 0.8 m, it is considered a good correlation value between experimental results and the modulated.

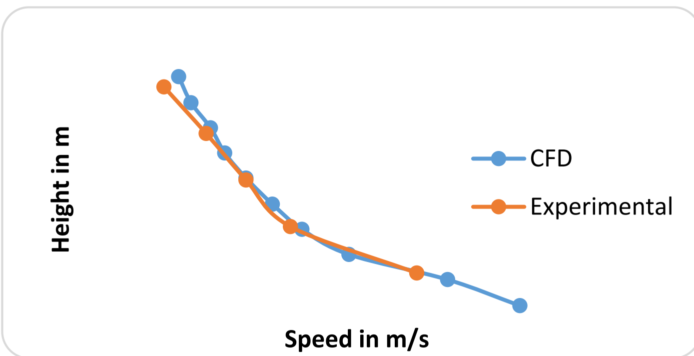

FIGURE 5. Air velocity according to height at 0.8 m distance from fan outlet.

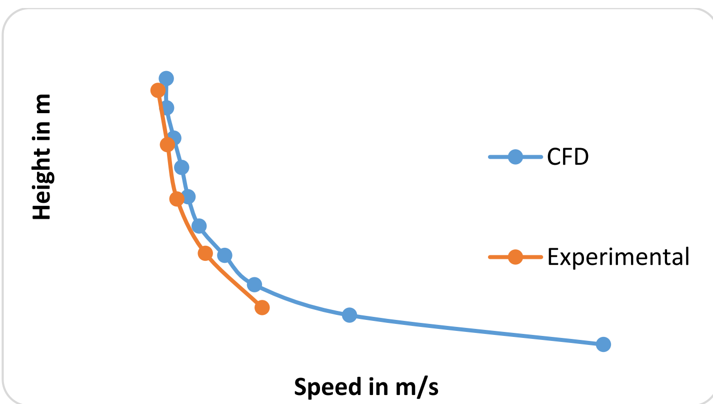

FIGURE 6. Air velocity according to height 1.6 m away from the fan outlet.

In Figure 7, the comparison between the experimental and modelled data at a distance of 2.5 m from the fan output is shown. As in the previous case the trend of the curves is maintained, but with lower speed values in the case of the experimental. The statistical analysis performed considering the linear process is shown in Table 1, in which a coefficient of determination of 0.9766 is observed, although less than the previous ones, they maintain high values of adjustment. On the other hand, it is observed as the distance to the exit of the fan increases, the coefficient of determination decreases although it remains above 0.97.

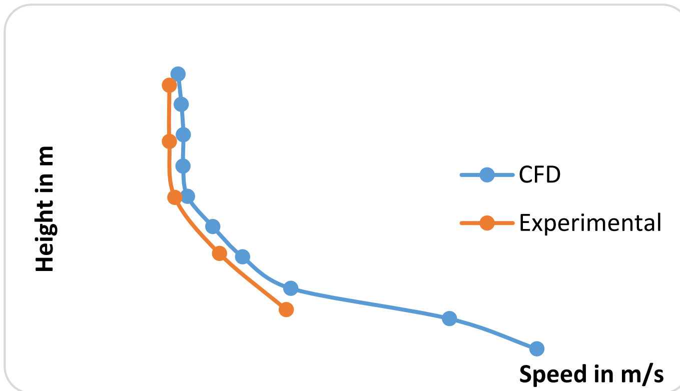

FIGURE 7. Air velocity according to height 2.4 m away from the fan.

In general, at the three distances where the air velocity in the stream was analyzed, a good adjustment was obtained with the experimental results, expressed by the results of the coefficient of determination with errors less than 1% for the distances at the output of 0.8 and 1.6. , and less than 3% at a distance of 2.4 m, which validates the use of the model. reported similar results, in the validation of models with computerized fluid dynamics in 2D Salcedo *et al.* (2015).

CONCLUSIONS

The results of the analysis corroborated that there is a correlation between the laboratory data and those resulting from the model with values of R2 of 0.9969, 0.9929 and 0.9766, so that the model studied, is valid for the study of the air flow of the sprayer in the vertical plane.

In the model results, the velocity of the air in the center of the fan outlet decreases with the increase of the distance to this from 43 to 7.2 m / s and in the lower zone of the output speeds of 43 to 50 m / s, characteristic of axial fans with radial outlet used in agricultural sprayers.

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