RESEARCH ON NUMERICAL SIMULATION FOR VELOCITY DISTRIBUTION OF SWIRLING TURBULENT JETS IN SPRAY IRRIGATION TECHNOLOGY

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ABSTRACT: *In spray irrigation technology, the change of the basic parameters of the flowfield has relationship directly with the coefficient of swirling intensity coefficient S, with each value of swirling coefficient differently then the distribution of parameters in flow field also variedly. Remarkably change when the coefficient of swirl intensity changes through the variables as axial velocity u, tangential velocity w; the change of radial velocity v related to turbulent intensity.*

Keywords: *Numerical simulation, swirling turbulent jets, irrigation technology*

1 INTRODUCTION

The dramatic effects of swirling turbulent flows in inert and reacting flow systems have been known and appreciated for many years. In fact, swirling turbulent flows occur in a very wide range of applications in both with and without combustion. In non-reacting cases, applications include, for example, vortex amplifiers and reactors, cyclone separators, Ranque-Hilsch tubes, whirlpools, agricultural spraying machines, heat exchangers, jet pumps… In combustion systems, the strong favorable effects of applying swirl to injected air and fuel are extensively used as an aid to stabilization of the high intensity combustion process and efficient clean combustion in a variety of practical situations: gasoline engines, diesel engines, gas turbines, industrial furnaces and many other practical heating devices [2].

Swirling turbulent flows result from the application of a spiraling motion, a swirl velocity component (tangential velocity component) being imparted to the flow by the use of swirl vanes, by the use of axial-plus-tangential entry swirl generators or by direct tangential entry into the chamber [1].

Therefore, studying the impact of swirling effect to the velocity distribution of swirling turbulent spray jets is necessary to establish completely for mathematical and numerical models of the spray jets.

2 SET UP A MATHEMATICAL MODEL TO PERFORM FOR SWIRLING TURBULENT JETS

Mathematical model for the swirling turbulent jets in spray irrigation technology is established through by developing conservative laws in the two-phase swirling turbulent jets, considering characters of the equipment, combining with some related expressions and boundary conditions. Thence we define the complete system equations for the two-phase swirling turbulent jets for homogeneous two-phase case.

When considering to characteristic of spray irrigation equipment, the system of basic equations for swirling turbulent jets in cylindrical polar coordinate (x, r, θ), including 8 of the differential equations with 8 unknown identified need to (u, v, w, C, p, k, ε and K_C), is written in the term of general as:

$$a_\varphi\left[\frac{\partial}{\partial x}\left(\varphi\frac{\partial\psi}{\partial r}\right)-\frac{\partial}{\partial r}\left(\varphi\frac{\partial\psi}{\partial x}\right)\right]-\frac{\partial}{\partial x}\left[b_\varphi r\frac{\partial(c_\varphi\varphi)}{\partial x}\right]-\frac{\partial}{\partial r}\left[b_\varphi r\frac{\partial(c_\varphi\varphi)}{\partial r}\right]+rd_\varphi=0 \quad (1)$$

in which $\varphi \equiv \psi$ (u, v), w, k, ε, K_C, p or C

a_φ, b_φ, c_φ ≡coefficients associated with variable φ

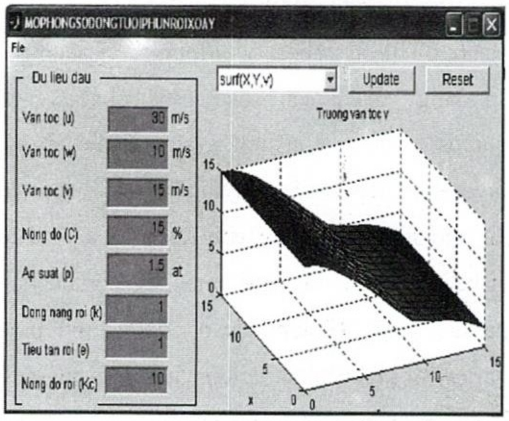
General equation (1) will resolved by finite volume method [3]. The calculation was conducted on the computer; the programs were built through the support of the Matlab 6.5 software. In which values of basic parameters u, v, w, C, p, k, ε and K_C are the values at the different grid points in the resolutive process of the system of basic differential equations for swirling turbulent jets in spray irrigation technology.

We can simulate the distribution of the parameters and build the software interface to simulate of the distributive field of the parameters by using calculated results (figure 1) [4].

3.APPLICATION OF NUMERICAL SIMULATION FOR DISTRIBUTION OF SPRAY VELOCITY

3.1 Distribution of axial velocity

Figure 2 ÷ 7 illustrate the distribution in 3D space and the distribution in the vertical axis along the cut surface spray line of axial velocity with the multiplier swirling coefficient different [4]. Axial velocity profile changes in the progression from the nozzle exit to locations farther flow. Maximum velocity reaches at the nozzle exit, the farther, from nozzle exit, the location is, the less the velocity is. At weak swirl (S = 0 and S = 0.3), the maximum velocity on the axis of the jet reaches, and at high swirl (S = 0.6), the maximum velocity is not on the axis of the jet. Increasing swirling coefficient will increase rate of decay of axial velocity.



Du lieu dau

Van toc (u) 30 m/s

Van toc (w) 10 m/s

Van toc (v) 15 m/s

Nong do (C) 15 %

Ap suat (p) 1.5 at

Dong nang roi (k) 1

Tieu tan roi (e) 1

Nong do roi (Kc) 10

surf(X,Y,v)

Figure 1 Numerical simulation interface of swirling turbulent jets in spray irrigation technology

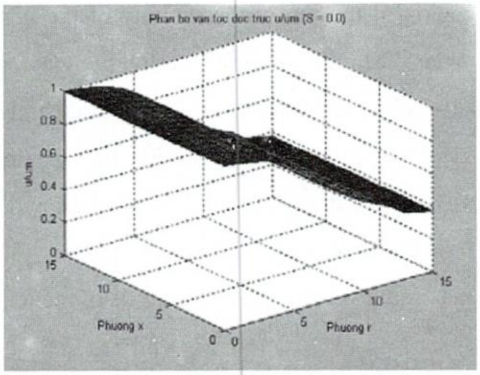


Figure 2 Distributive field of axial velocity u/u_m when S = 0.0

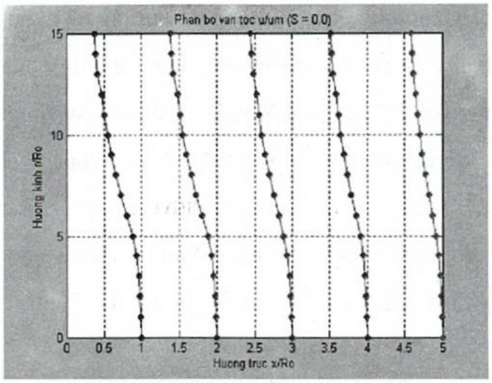


Figure 3 Axial velocity distribution u/u_m when S = 0.0

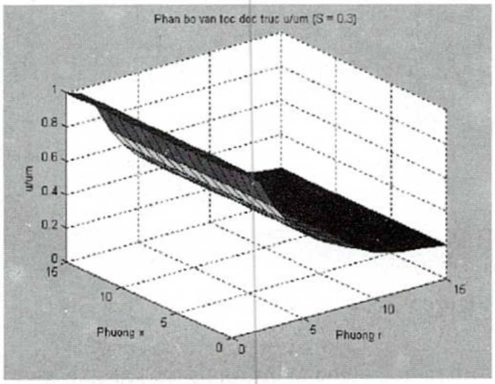


Figure 4 Distributive field of axial velocity u/u_m when S = 0.3

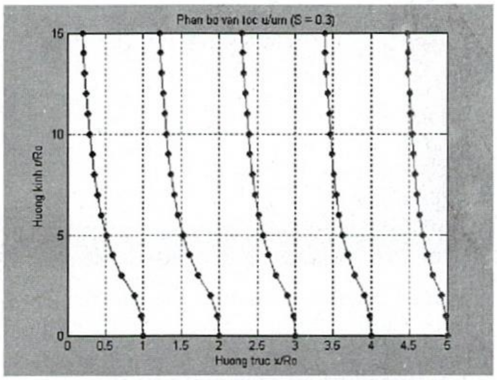


Figure 5 Axial velocity distribution u/u_m when S = 0.3

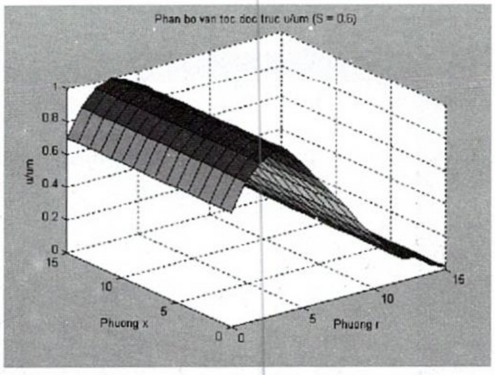


Figure 6 Distributive field of axial velocity u/u_m when S = 0.6

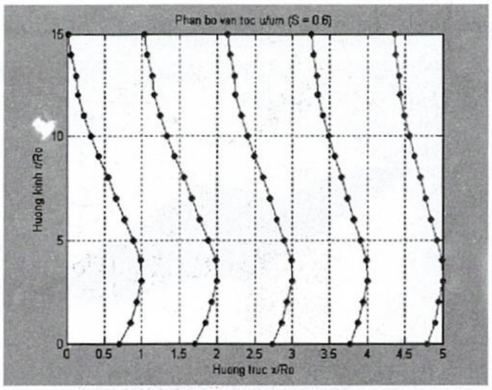


Figure 7 Axial velocity distribution u/u_m when S = 0.6

Figure 8 illustrates the distribution of maximum axial velocity when the swirling coefficient changes (long axis) [4]. Diagram shows that, when increasing the swirling coefficient than decay of the axial velocity occurs more quickly, this is explained by the increase of the flow distance horizontally. Figure 9 illustrates the radial distribution of axial velocity with different swirling coefficient (at x/d = 4). When swirling coefficient increased, the distribution of axial velocity is small and spread horizontally (the radius of spray jet increases). When swirling coefficient obtains critical degree (S = 0.6), the forces due to the axial adverse pressure gradient exceed the forward kinetic forces and the flow reverses its direction in the central region of the jet, in the vicinity of the nozzle. After central region, velocity decreased gradually. Diagram also shows that, at weak swirl (S = 0 and S = 0.3), the maximum velocity on the axis of the jet reaches; and S = 0.6 by appearing to central region should maximum velocity not on the axis of the jet.

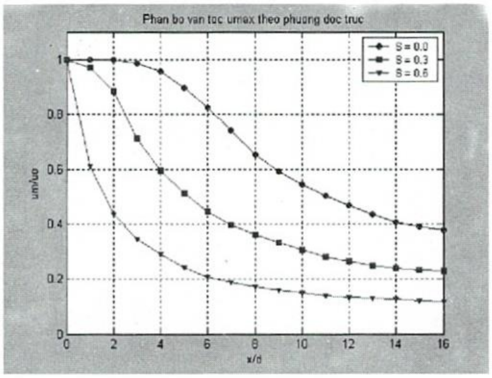


Figure 8 Maximum axial velocity distribution u_m/u_0 with different swirling coefficients

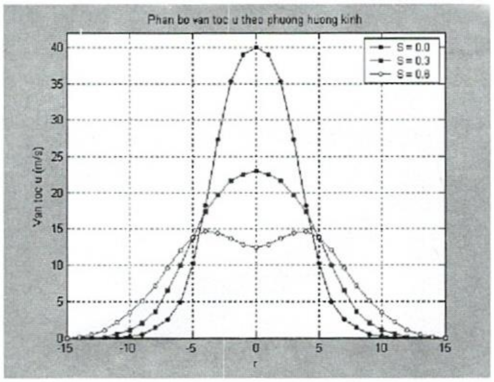


Figure 9 Radial distribution of axial velocity (x/d = 4)

3.2 Distribution of radial velocity

Figure 10 illustrates the distribution in 3D space and figure 11 illustrates the distribution of radial velocity in along cut as the swirling coefficient S = 0 [4].

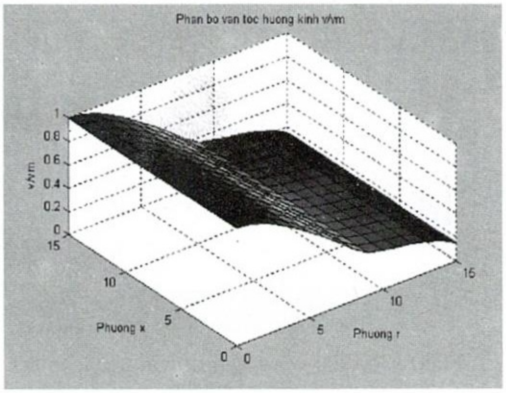


Figure 10 Distributive field of radial velocity v/v_m when S = 0.0

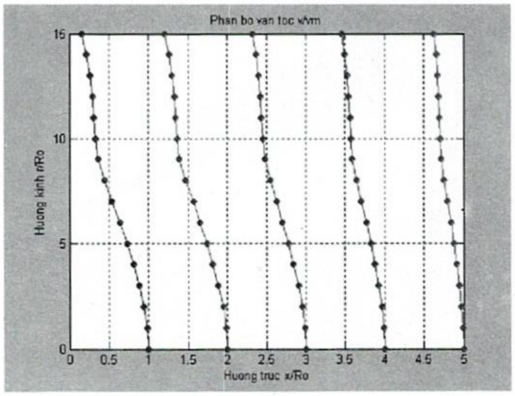


Figure 11 Radial velocity distribution v/v_m when S = 0.0

Diagrams show that, maximum radial velocity is at the nozzle exit; the farther , from nozzle exit, the location is, the less the velocity is. Radial velocity profile changes in the progression from the nozzle exit to locations which are farther flowfield. In summary, radial velocity component depends on many turbulent characteristics of flow.

3.3 Distribution of tangential velocity

When swirling coefficient S = 0, there is no tangential velocity field, or w = 0. Figure 12 and figure 13 illustrate the tangential velocity field in 3D space and the distribution of tangential velocity in a long cut as the swirling coefficient S = 0.6 [4]. Maximum tangential velocity which is established at near the nozzle exit depended on the intensity of swirling coefficient, and then decayed.

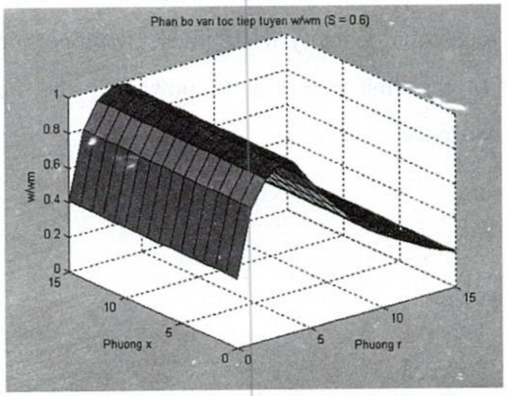


Figure 12 Distributive field of tangential velocity w/w_m when S = 0.6

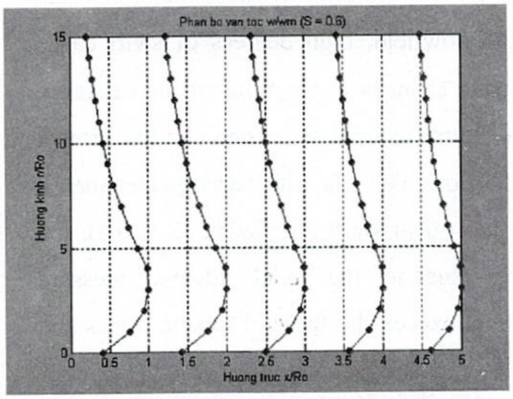


Figure 13 Tangential velocity distribution w/w_m when = 0.6

Figure 14 illustrates the axial distribution of maximum tangential velocity when the swirling coefficient S = 0.6 [4].

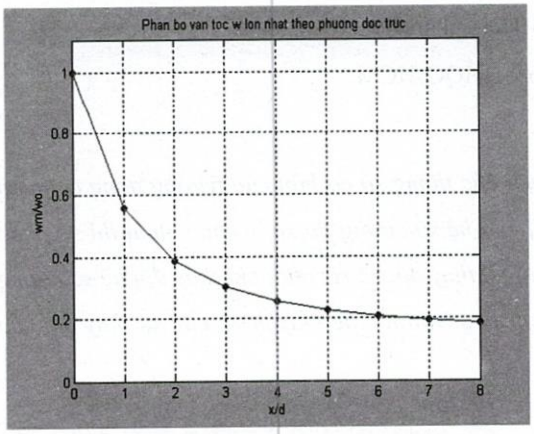


Figure 14 Axial distributive of maximum tangential velocity w/w_0 when S = 0.6

Diagram shows that, the value of tangential velocity decreases rapidly near the nozzle exit and **as the away from the it decreases is from**. Because the swirl increases will increase the angle of dispersed, so tangential velocity profile will change in the progression from the nozzle exit to locations which are farther from flowfield. Intensity of the tangential velocity as high swirl (S = 0.6) to make the motion and mix with surrounding fluid sets up adverse axial pressure gradient and thus the central recirculation zone is created.

4 CONCLUSIONS

The numerical simulation for distribution of swirling turbulence jets in spray irrigation technology shows that the distributive profile of velocity components depends on the swirling coefficient imparted to the flow. When swirl is weak, the maximum velocity on the axis of the jet reaches. As the swirl coefficient is increased, the radial spread of the jet increases. This is interested in the applications for spray irrigation technology, because it makes range of rain-drop bigger, increases effective use of water; in addition ability to irrigation water with cooling for the crop, improving the micro-climate.

Low degrees of swirl cause minor changes to the flowfield, high degrees of swirl cause dramatic changes in the form of the existence of a central recirculation zone and the growth of the flow. For jets with swirl greater than a certain critical swirl coefficient (S = 0.6), the forces due to the axial adverse pressure gradient exceed the forward kinetic forces and the flow reverses its direction in the central region of the jet, in the vicinity of the nozzle.

Simulation results for maximum axial and tangential velocity distribution along axis show that, perfect fit with the research results of experimental by A. K. Gupta, D. G. Lilley, N. Syred [1], is the decay of axial velocity u, tangential velocity w are inversely proportional to the first and second power of the flow distance.

NGHIÊN CỨU MÔ PHỎNG SỐ PHÂN BỐ VẬN TỐC CỦA DÒNG PHUN RỐI XOÁY TRONG KỸ THUẬT TƯỚI PHUN

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TÓM TẮT: *Trong kỹ thuật tưới phun, sự thay đổi các thông số cơ bản của trường dòng có quan hệ trực tiếp với hệ số cường độ xoáy S, với mỗi giá trị của hệ số cường độ xoáy khác nhau thì sự phân bố của các thông số trong trường dòng cũng khác nhau. Sự thay đổi rõ rệt nhất khi thay đổi hệ số cường độ xoáy được thể hiện thông qua các biến vận tốc dọc trục u, vận tốc tiếp tuyến w; còn sự thay đổi của vận tốc hướng kính v có liên quan tới cường độ rối*

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