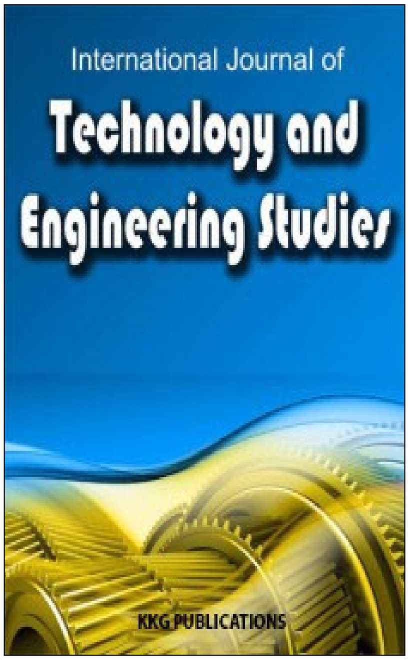
This article was downloaded by:
Publisher: KKG Publications



Key Knowledge Generation
Publication details, including instructions for author and subscription information:
http://kkgpublications.com/technology/

Computational Fluid Dynamic Simulation of Pipeline Irrigation System Based on Ansys

BAHRUDIN [1], HILMAN SYAEFUL ALAM [2], TRIYA HAIYUNNISA [3]

[1, 2, 3] Technical Implementation Unit for Instrumentation Development, Indonesian Institute of Sciences, Bandung, Indonesia

Published online: 13 December 2016

To cite this article: Bahrudin, H. S. Alam and T. Haiyunnisa "Computational fluid dynamic simulation of pipeline irrigation system based on ansys," *International Journal of Technology and Engineering Studies,* vol. 2, no. 6, pp. 189-193, 2016.
DOI: https://dx.doi.org/10.20469/ijtes.2.40005-6

To link to this article: http://kkgpublications.com/wp-content/uploads/2016/2/Volume2/IJTES-40005-6.pdf

PLEASE SCROLL DOWN FOR ARTICLE

KKG Publications makes every effort to ascertain the precision of all the information (the "Content") contained in the publications on our platform. However, KKG Publications, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the content. All opinions and views stated in this publication are not endorsed by KKG Publications. These are purely the opinions and views of authors. The accuracy of the content should not be relied upon and primary sources of information should be considered for any verification. KKG Publications shall not be liable for any costs, expenses, proceedings, loss, actions, demands, damages, expenses and other liabilities directly or indirectly caused in connection with given content.

This article may be utilized for research, edifying, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly verboten.

KKG PUBLICATIONS

International Journal of Technology and Engineering Studies
vol. 2, no. 6, pp. 189-193, 2016

IJTES

COMPUTATIONAL FLUID DYNAMIC SIMULATION OF PIPELINE IRRIGATION SYSTEM BASED ON ANSYS

BAHRUDIN [1*], HILMAN SYAEFUL ALAM [2], TRIYA HAIYUNNISA [3]

[1, 2, 3] Technical Implementation Unit for Instrumentation Development, Indonesian Institute of Sciences, Bandung, Indonesia

Keywords:
Strawberry Plants
Drip Irrigation
Pressure
CFD

Received: 18 June 2016
Accepted: 15 September 2016
Published: 13 December 2016

Abstract. In this study, drip irrigation modeling will be conducted using the existing CFD methods in ANSYS. The purpose of modeling is to get the water pressure needed to circulate water in a strawberry field with a flow rate of 0.95 l/h at each outlet of the irrigation drip. Strawberry plants (Fragaria × ananassa Duch) are one commodity that has great economic value. Strawberries are grown in cold regions in Indonesia, such as Malang, Ciwidey, and Garut. Besides a cold location, strawberry plants also need adequate water and proper irrigation methods. The drip irrigation (DI) method can conserve water and reduce the risk of illness in the strawberry due to pollution by dirty water. This simulation modeling will be used to irrigate 600 strawberry plants in 320 m2 of the total area. From the simulation results obtained, 600 strawberry plants require pressure to be maintained at the pressure tank of 1.019 bar. The simulation of irrigation on strawberry plantation using CFD methods can save time and reduce the error factor analysis of piping design for drip irrigation design on a strawberry plantation.

INTRODUCTION

The cultivated strawberry (Fragaria × ananassa Duch) is one of the fruits that have economic value and contain many health benefits [1]. According to [1], [2], [3], [4], the cultivation of strawberry requires irrigation. New leaf production, stomatal conductance, and photosynthetic rate were significantly reduced under limited water which can inhibit plant growth compared with well-watered. Generally, there are three methods of irrigation like surface, overhead and drip irrigation. However based on [4], the illness of strawberry plants can be caused by water used for crop irrigation that is contaminated with indicator and pathogenic microorganisms and may be affected by many parameters such as irrigation methods. From their report, the drip irrigation (DI) method can reduce the risk of illness in the strawberry lower than overhead method because it can reduce the persistence of the bacteria. According to [5], DI method can save about 51% of irrigation water and can give 19% higher fruit yield as compared with surface irrigation method.

In Indonesia, strawberry can only grow in mountainous areas with an altitude of more than 1000 m above sea level and can be harvested up to five times a year in which the highest production occurred in July and August depending on the circumstances and environment. The data on the number of strawberry production in Indonesia have not been well documented, however, according to data from the Indonesian Central Bureau of Statistics, the imported fresh strawberries in Indonesia reached 210 tons in 2011 [6], [7]. It shows that the strawberry consumption needs of the Indonesian people are greater than the amount of production. In order to boost the production, it needs the technology that can improve the quality and quantity of strawberry cultivation in Indonesia.

Designing a proper irrigation method requires fairly complicated calculations. By using software-based engineering finite element method, we can get the results of the analysis that are approaching so do not need to do calculations manually. ANSYS software can be used to calculate the fluid moving in a pipeline using Computational Fluid Dynamics. If linked with the needs analysis that uses the irrigation piping system then the software is very appropriate because already modern GUI is there so users will be easier to set up some of their parameters. ANSYS CFX simulation results are easier to analyze because many parameters can be displayed, such as flow rate, mass flow, pressure, etc.

COMPUTATIONAL MODEL

Basic Principle of Closed Flow

Based on Bernoulli's law for a closed flow [8], the pressure in the inlet pipe could be calculated for irrigation analytical modeling. The parameter that is needed to obtain the pressure on the inlet pipe is a total head between the inlet and outlet pipes and pipe diameter to be used [8].

$$p_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = p_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2 \quad (1)$$

*Corresponding author: Bahrudin
†Email: bahr003@lipi.go.id

© 2016 The Author(s). Published by KKG Publications. This is an Open Access article distributed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

According to head loss in piping installation [8], measurement of pressure is needed to be done not only from total head and diameter of the pipe but also from the difference of head loss which is divided into major and minor head loss. Major head loss due to the flow of a fluid flowing in a pipe is affected by fluid viscosity, speed, roughness, and the geometry of the pipe. While the minor head loss is caused by the installation piping such as a connection, pipe valve reduction, etc. Analytical calculation of inlet pressure requirement on irrigation piping can be seen in the following discussion:

Head loss mayor, loss of friction with the pipe wall

$$H_L = f\frac{L}{D}\frac{V^2}{2g} \quad (2)$$

Where f is friction factor, L is Length of Pipe, V is average fluid velocity, D is Diameter of Pipe, and g is acceleration of gravity

$$f = \frac{64}{Re} \quad (3)$$

Head loss minor losses due to valve and fitting

$$H_L = K(\frac{V^2}{2g}) \quad (4)$$

K is Head loss factor Pressure from the difference in elevation and speed

$$p_1 = p_2 + \rho g(h_2 - h_1) + \frac{1}{2}p(v_2^2 - v_1^2) \quad (5)$$

Basic Principle of CFD

Finite Element Method (FEM) is a modern analysis method that has been applied to many engineering applications. In principle computation, FEM is a numerical computational method that breaks down a large system that is not up into small elements. Mathematical modeling itself can be made for one -dimensional (1D), two-dimensional (2D) or three-dimensional (3D). However, the model is a model widely adopted 2D or 3D. FEM has become an important step in the design or the modeling of physical phenomena in a variety of engineering disciplines. A physical phenomenon usually occurs in the continuum of matter (solid, liquid, or gas) which involves some of the environmental variables. The variables that come from the environment vary from point to point, so it has an infinite number of solutions in the domain [11].

The fluid flow problem is defined by the laws of conservation of mass, momentum, and energy. These laws are expressed in terms of partial differential equations which are discretized with a finite element-based technique.

Conservation of mass law comes to continuity equation [9][10]:

$$\frac{\partial\rho}{\partial t} + \frac{\partial(\rho v_x)}{\partial x} + \frac{\partial(\rho v_y)}{\partial y} + \frac{\partial(\rho v_z)}{\partial z} = 0 \quad (6)$$

Where Vx,Vy,Vz are components of the vector in the x, y and z directions. ρ is density and t is time.

$$\tau_{ij} = -P\delta_{ij} + \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) + \partial_{ij}\lambda\frac{\partial u_i}{\partial u_i} \quad (7)$$

$$\frac{\partial(\rho C_pT)}{\partial t} + \frac{\partial}{\partial x}(\rho V_xC_pT) + \frac{\partial}{\partial y}(\rho V_yC_pT) + \frac{\partial}{\partial z}(\rho V_zC_pT) = \frac{\partial}{\partial x}\left(K\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(K\frac{\partial T}{\partial y}\right) + \frac{\partial}{\partial z}\left(K\frac{\partial T}{\partial z}\right) + Q_v \quad (8)$$

Computational Domain

The overall design of the system is created in the 3D model so that latter can be used simultaneously for calculation and simulation using ANSYS CFX. Strawberry plantation in Garut would be watered by using drip irrigation method, in which energy was supplied by renewable energy. The main drawback to using independent sources of renewable energy is the unavailability of sources of energy all the time. The combination of PV and wind energy can overcome this. So that when one resource fails, the other will take care of generations. [12].

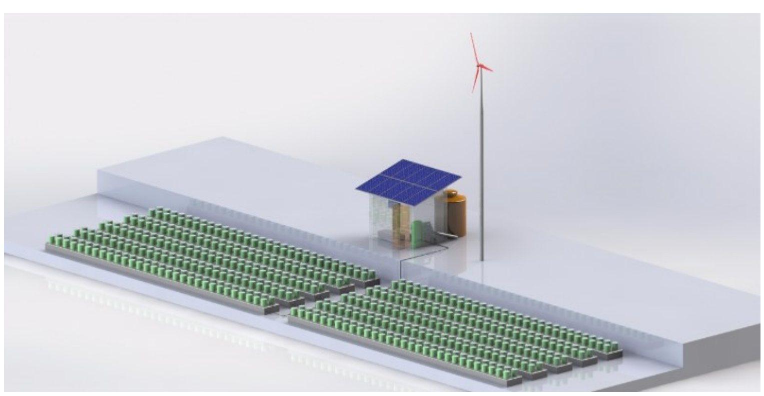


Fig. 1. Design of pipeline irrigation system

In this study, focused on the needs assessment to obtain pressure at the inlet of the main pipeline to be distributed on each of the distribution pipes.

Boundary Condition

Boundary conditions are determined in accordance with the geometry modeling of piping that will be applied to irrigation strawberries with drip method. Boundary conditions setup is using water and gravity force on Y axis, assuming 9.8 m/s^2. Boundary conditions are also determining the inlet, outlet and the wall of the pipe geometry used.

Inlet

Flow at the inlet gets from pressure tank that is controlled to get right mass flow. Flow is set according to the number of plants as many as 600 plants. Each plant needs water as much as 1.8 liters per day. By using drip irrigation method, it is necessary that the speed setting watering drip system is achieved. Flow rate on the strawberry crop drip irrigation method is 0.95 l/h. The amount of water needed for each strawberry plant is also affected by moisture and soil temperature. In this area, the flow rate provided is a strawberry plant need that amounts to 600 plants. So flow rate which should be given at this boundary is 570 l / h.

Outlet

Outlet on a drip irrigation system is using 2.5 mm2 hosen. On this side will be monitored for the mass flow of drip irrigation according to crop needs. Flow rate of water at this boundary must be stable at 0.95 l/h.

Wall

The solid boundaries in all computational domain are viscous walls with no-slip wall boundary condition.

RESULTS AND DISCUSSION

The most important thing in using engineering software based on the finite element method is an element discretization, better known by meshing. In the present study, meshing is not used by default because most of the major elements that have vastly different sizes. Therefore, it is necessary mapping element-element that has different sizes that will be a distinguished setting for meshing process.

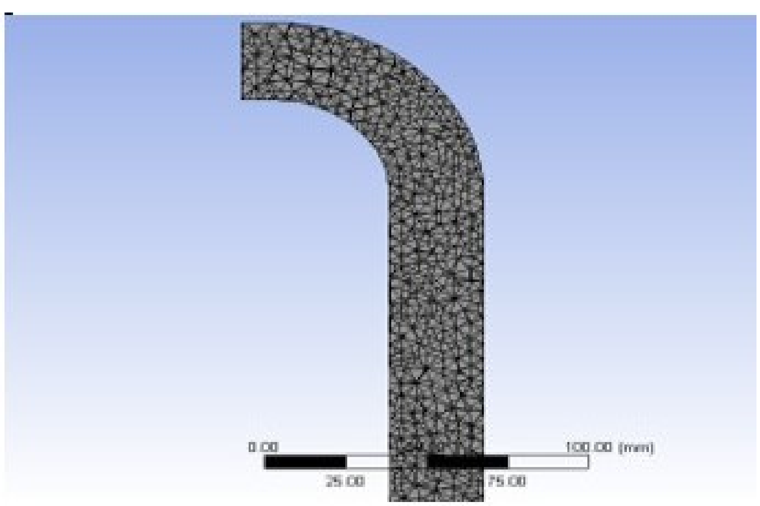


Fig. 2. Meshing for piping

Fig. 2 shows arrangements for pipe sizes using the automatic size of ANSYS meshing. This is because the pipe diameter is large enough so as to reduce the time meshing process and the final calculation is done automatically. At this simulation, the diameter of the pipe is 76.2 mm with inside diameter of 70.2 mm. For part of the hose, setting of meshing is done specifically. In this section use the settings with the distribution of smaller elements than in any part of the pipeline. On the hose, meshing size is limited to 1.5 mm. This is because if the meshing uses the automatic setting of ANSYS, the result of meshing would be destroyed at the end of the hose that eventually the boundary condition setup cannot be performed. At this simulation, diameter inside of hose is 2.5 mm.

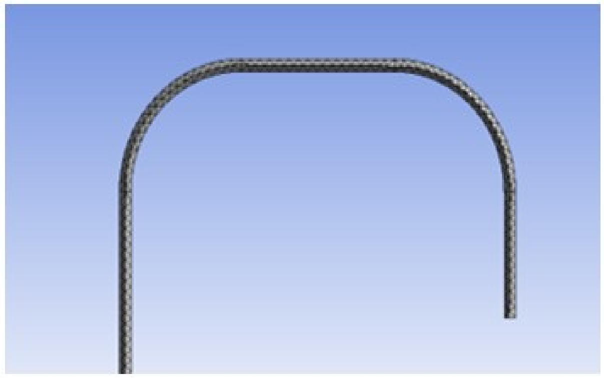


Fig. 3. Meshing for hose

CFD simulation results conducted by the method of finite volume can be seen in Fig. 4. The analysis uses ANSYS CFX software in order to show the contours of the speed and the pressure on the piping irrigation where flow restriction is analyzed at a flow rate inlet 4 l/h. Methods of numerical simulations using ANSYS are used to analyze fluid flow characteristics through parameters such as speed, and pressure and turbulence. In addition, we can visually display these parameters in contour, vector and streamline the flow presented in 3D.

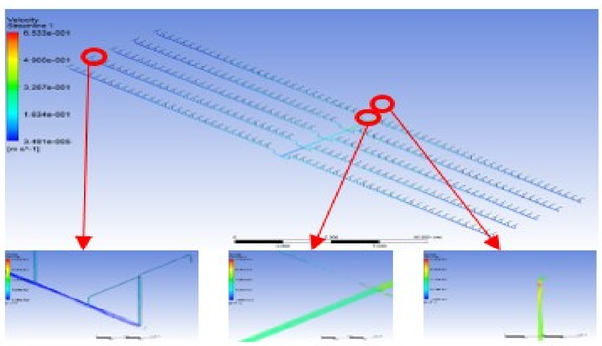


Fig. 4. Velocity at piping area in DI system

Fig. 4 shows the pattern of fluid flow along the piping. The velocity vector shows in detail the direction of fluid motion. In detail, the nature of the flow can be visualized more accurately with 3D streamlined method that describes the nature of the fluid flow to form a string of yarn flow model. Streamlined flow shapes can be seen in Fig. 4.

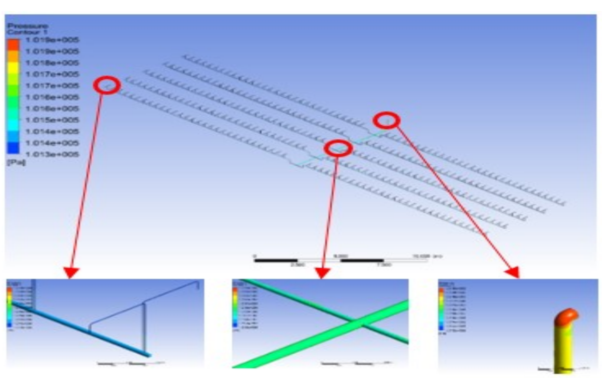


Fig. 5. Pressure at piping in DI system

Fig. 5 shows the contour of simulation results of water flow at the inlet pipe used for drip irrigation with 600 strawberry plants that require a pressure of 101900 Pa or 1.019 bar. These results can be used as a reference for the technical implementation of the design and manufacturing of drip irrigation systems in the strawberry farm. Apart from that, we can see in detail the overall pressure or we can analyze the section of pipe that is experiencing pressure drop.

CONCLUSION AND RECOMMENDATIONS

The simulation of irrigation on strawberry plantation using CFD methods can save time and reduce the error factor analysis of piping design for the design manufacturer of drip irrigation on a strawberry plantation. In addition, the CFD method is able to provide a detailed picture of the flow, such as speed, vector, and pressure along the pipeline. The simulation results of water flow at the inlet pipe used for drip irrigation with 600 strawberry plants require a pressure of 101900 pascals or about 1.019 bars. Hence, this method must be utilized in future. Moroever, researchers are encouraged to explore this domain further and extend this body of knowledge.

Declaration of Conflicting Interests

There are no competing interest.

Acknowledgement

The author wishes to thank Technical Implementation Unit for Instrumentation Development, Indonesian Institute of Sciences which has provided a financial support through LIPI Competitive Activity in 2014 (DIPA-079.01.2.438004/2015). And thanks to the Electric Power and Mechatronics Research Centre, LIPI which has provided laboratory research facilities to design drip irrigation using ANSYS software.

REFERENCES

[1] S. Kumar and P. Dey, "Effects of different mulches and irrigation methods on root growth, nutrient uptake, water-use efficiency and yield of strawberry," *Scientia Horticulturae,* vol. 127, no. 3, pp. 318-324, 2011.

[2] O. M. Grant, M. J. Davies, A. W. Johnson and D. W. Simpson, "Physiological and growth responses to water deficits in cultivated strawberry (Fragaria × ananassa) and in one of its progenitors, Fragaria chiloensis," *Environmental and Experimental Botany,* vol. 83, pp. 23-32, 2012.

[3] O. M. Grant, M. J. Davies, C. M. James, A. W. Johnson, I. Leinonen and D. W. Simpson, "Thermal imaging and carbon isotope composition indicate variation amongst strawberry (Fragaria × ananassa) cultivars in stomatal conductance and water use efficiency," *Environmental and Experimental Botany,* vol. 76, pp. 7-15, 2012.

[4] D. B. Kovacevic, P. Putnik, V. Dragovic-Uzelac, N. Vahcic, M. S. Babojelic and B. Levaj, "Influences of organically and conventionally grown strawberry cultivars on anthocyanins content and color in purees and low-sugar jams," *Food Chemistry,* vol. 181, pp. 94-100, 2015.

[5] M. Genereux, M. Grenier and C. Cote, "Persistence of Escherichia coli following irrigation of strawberry grown under four production systems: Field experiment," *Food Control,* vol. 47, pp. 103-107, 2015.

[6] H. S. Alam, T. Haiyunnisa and Bahrudin, "Comparative analysis of P, Pi, and PID controller optimized bygenetic algorithm on controlling drip irrigation system," *International Journal of Technology and Engineering Studies,* vol. 1, no. 4, pp. 117-122, 2015.

[7] Z. Hanif, H. Ashari, B. P. T. Jeruk and B. Subtropika. (2013). *Distribution Strawberries (Fragaria × ananassa) in Indonesia* [online]. Available: https://goo.gl/jDu7pu

[8] E. W. McAllister, *Pipeline Rules of Thumb Handbook-Quick and Accurate Solutions to Your Everyday Pipeline Engineering Problems.* Amsterdam, Netherlands: Elsevier, 2009.

[9] P. Kohnke, Ed., *ANSYS Theory Reference Release 5.7.* Canonsburg, PA: Ansys Inc., 2001.

[10] D. J. Acheson, *Elementary Fluid Dynamics*. Oxford, UK: Clarendon Press, 1990.

[11] E. Madenci and I. Guven, *The Finite Element Method and Applications in Engineering using ANSYS,* New York, NY: Springer, 2015.

[12] A. S. Ingole and B. S. Rakhonde, "Hybrid power generation system using wind energy and solar energy," *International Journal of Scientific and Research Publications,* vol. 5, no. 3, 2015.

— This article does not have any appendix. —