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Preface

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2nd Tarumanagara International Conference on the Applications of Technology and Engineering 2019

Preface

On behalf of the organizing committee of 2nd Tarumanagara International Conference on the Applications of Technology and Engineering (TICATE) 2019, I would like to welcome all delegates to Jakarta, Indonesia with great pleasure. Being held from November 21 to 22, 2019 at Campus I- Jl. Letjen. S. Parman No. 1, Jakarta, the international conference is organized by Universitas Tarumanagara (UNTAR) and technically sponsored by IOP Publisher.

TICATE 2019 has attracted many academicians, scientists, engineers, postgraduates and other professionals from many countries. This conference accepted 215 papers from 7 different countries, those are Australia, Taiwan, India, Malaysia, Japan, Peru and Indonesia. The aim of the conference is to promote exchange of ideas among engineers, researchers, and scientists active in the related areas of technology and engineering.

Our special thank goes to our Rector, Prof. Dr. Agustinus Purna Irawan, who has initiate this international conference, to our Plenary Speakers, Dr.-Ing. Joewono Prasetijo from Universiti Tun Hussein Onn, Malaysia, Prof. Dr. Tjokorda Gde Tirta Nindhia from Udayana University, Indonesia, Prof. Dr. Srikantappa A.S. from Cauvery Institute of Technology, India, and Prof. Dr. Mohd. Zulkifli Abdullah from Universiti Sains Malaysia, Malaysia, and Prof. Yasuyuku Nemoto, Ph.D. from Ashikaga University, Japan.

Our special thank also goes to Tarzan Photo and PT. Astaguna Wisesa as our patrons. Also to all individuals and organizations such as the members of international editorial board, the conference organizers, the reviewers and the authors, for their contribution in making TICATE 2019 as a successful international conference and a memorable gathering event. I am also grateful for the support of publication service of IOP Publisher. We hope that the conference could present you wonderful memories to bring home in addition to new insights and friendship congregated during the event.

We truly value your participation and support for the conference. We hope that you will enjoy TICATE 2019 and culture and tradition in Jakarta.

Dr. Hugeng, S.T., M.T. (SMIEEE)

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Dekan Fakultas Teknik Universitas Tarumanagara, dengan ini menugaskan kepada Saudara:

Dr. Steven Darmawan, S.T.,M.T.

Untuk melaksanakan **Mempresentasikan Hasil Penelitian** dengan data sebagai berikut:

Judul Makalah	:	Reynold Number Effects on Swirling Flows Intensity and Reattachment Point Over a Backward-Facing Step Geometry Using STD k-ε turbulence model
Nama Seminar	:	Tarumanagara International Conference on The Application of Technology and Engineering (TICATE) 2019
Penyelenggara	:	Universitas Tarumanagara
Waktu Pelaksanaan	:	21 – 22 November 2019

Demikian Surat Tugas ini dibuat, untuk dilaksanakan dengan sebaik-baiknya dan melaporkan hasil penugasan tersebut kepada Dekan Fakultas Teknik Universitas Tarumanagara.

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Paper Title:
Reynolds number effects on swirling flows intensity and reattachment length over a backward-facing step geometry using STD k-ε turbulence model

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Reynolds number effects on swirling flows intensity and reattachment length over a backward-facing step geometry using STD *k*-*ε* turbulence model

Reynolds number effects on swirling flows intensity and reattachment point over a backward-facing step geometry using STD *k-ε* turbulence model

Steven Darmawan*
Mechanical Engineering Department, Faculty of Engineering
Universitas Tarumanagara

* stevend@ft.untar.ac.id

Abstract.
Swirling flow caused by sudden expansion is a common phenomena in many engineering application. The flow reattachment which follow after the expansion determines the flow condition, including pressure fluctuation especially when heat transfer mechanism is highly considered. In many cases, this swirling flow oftenly decrease the system performance since fluid convection will decrease and the reattachment point can indicate the length of the swirling flow. At this condition, Reynolds number will affect rettachment length. Due to high resources of experimental method, CFD simulation is choosen for it's flexibility to varied numbers of model and cases. This study aims to numerically investigate reattachment length of swirling flow over expansion zone of BFS at varied Reynolds number with CFD method. The Reynolds number gained from the experimental data. The model is 3 dimensional with Step height *(h)* = 41mm, up stream height (*H)* = 81mm, expansion ratio = 1.5, total length (*L*) = 4050 mm and width = 20*h*. The mesh is triangular with 90.293 nodes. Reynolds numbers varied to Re = 4290.39; 6673.94; 7614.23; and 9287.29 which gained from experimental data with working fluid is set to single phase air. The flow condition is assumed transient with time step set of 1 and simulation is done with STD *k-ε* turbulence model. Respectively, reattachment point at Re = 4290.39; Re = 6673.94; Re = 7614.23 and Re = 9287.29 achieved at x/h = 5.75; 7.8; 9.04; 10.7. This phenomena clearly showed that unsteadiness at higher Re contribute to higher reattachment length.
Keywords: swirling flow, BFS geometry, Reynolds number, reattachment point

1. Introduction

Swirling flow caused by sudden expansion is a common phenomena many engineering application. This application appears in ducting, flow around building, automobile body, ocean current, etc.[1]–[6]. The flow reattachment which follow after the expansion determines the flow condition, including pressure fluctuation especially when heat transfer mechanism is highly considered. In many cases, this swirling flow oftenly decrease the system performance since fluid convection will decrease and the reattachment point can indicate the length of the swirling flow. At this condition, Reynolds number will affect rettachment length [7]. Swirling flow itself is a complex, turbulent flow which simply can be visualized with Backward-facing step (BFS) geometry [8]–[11]. Some geometrical aspects also greatly affected the swirling flow, such as step heigh (*h*), and expansion ratio. Geometric values of BFS studied in this paper is based on BFS geometry by Kasagi & Matsunaga [12]. However, the advance experimental tool to gain such flow might be obstacles (e.g. Laser-velocity measurement, Particle Image

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Velocimetry). This circumstances lead to the use Computational Fluid Dynamics (CFD) as an prospevtive method, especially CFD method has the possibility to varied numbers of flow parameters, including the Reynolds number since this parameters greatly affects the flow characteristic [2], [13], [14]. Unlike the experimental investigation which often use large expansion ratio, investigation with CFD method has options to varied the geometrical aspects as well. This study aims to numerically investigate reattachment point of swirling flow over expansion zone of BFS at varied Reynolds number with CFD method. The Reynolds number gained from the experimental data which also been working on.

2. Method and materials

2.1. Computer Added Design

The BFS geometry configuration is stated on *Table 1*, with some of the parameters reffered to the Kasagi & Matsunaga [12]. The BFS configuration and variation of Reynolds number, Re; 4290.39; 6673.94; 7614.23; Re = 9287.29 as well as CAD model showed by Figure *1* and Figure *2* respectively.

Table 1. BFS Geometry

Step Height (*h*) (mm)	Upstream height (*H*) (mm)	Expansion ratio	Total length (L) mm	Width (mm)
41	81	1,5	4050	20*h*

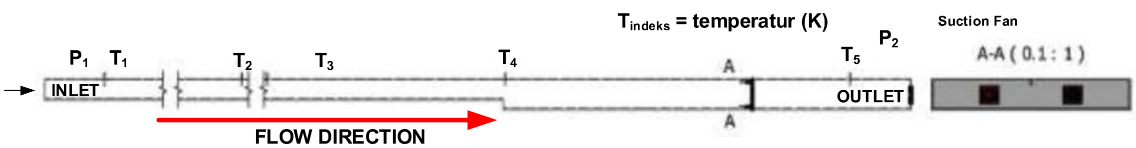

Figure 1. BFS Configuration

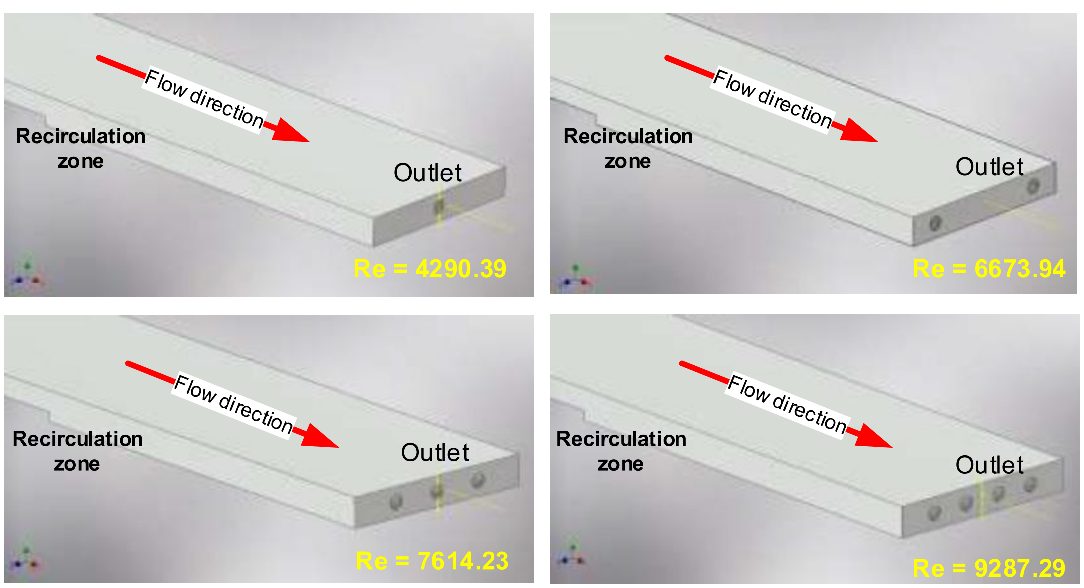

Figure 2. CAD model of BFS

2.2. Method

The BFS model is three dimensional with Step height *(h)* = 41mm, upstream height (*H)* = 81mm, expansion ratio = 1.5, total length (*L*) = 4050 mm and width = 20*h*, similar to the previous study [2], [15]. The mesh is triangular with 90.293 nodes as showed by Figure *3*. Reynolds numbers varied to Re = 4290.39; 6673.94; 7614.23; and 9287.29 which gained from experimental data. Although the swirling flow undoubtly aslo affect the fluid temperature which also gained from the experiment, the thermal parameters is not discussed here. Velocity profile at near wall region governed by von Kármán equation for turbulent fluid flow [16]. Autidesk CFD 2019 (education licensed) was used with computational resources Lennovo Think Pad E440 H1F, Intel Core i7 4702MQ, 12 GB RAM, Windows 8.1 Pro. The working fluid is single phase air, with inlet and outlet temperature also gained from experimental data. The flow condition is assumed transient with time step set of 1. Turbulent model plays an important role in CFD analysis hence the turbulence model choice is necessary. STD *k-ε* turbulence model since it has a good performance in general flow regarding the results and computation resources, including the swirling flow inside a BFS, although the more complex model may needed for larger intensity [2], [8], [17], [18].

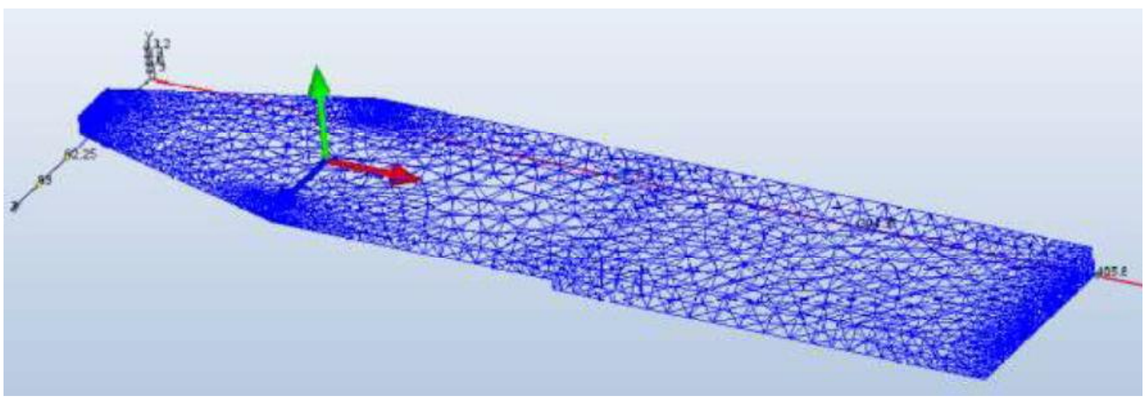

Figure 3. Triangular computational mesh

Governing equations of the turbulent flow used in this study are listed below

Von Kármán law of the wall

$$\frac{U_1}{u_*} = \frac{1}{\kappa}\ln\frac{y u_*}{\nu} + C \quad (1)$$

Mass conservation

$$\frac{\partial \rho}{\partial t} + div(\rho U) = 0 \quad (2)$$

x - momentum equation

$$\rho\frac{DU_x}{Dt} = \frac{\partial(\rho U_x)}{\partial t} + div(\rho U_x U) \quad (3)$$

y-momentum equation

$$\rho\frac{DU_y}{Dt} = \frac{\partial(\rho U_y)}{\partial t} + div(\rho U_y U) \quad (4)$$

z - momentum equation

$$\rho\frac{DU_z}{Dt} = \frac{\partial(\rho U_z)}{\partial t} + div(\rho U_z U) \quad (5)$$

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The STD k-ε turbulence model is a well kown RANS based model which developed by Launder & Spaling (1974), consist of k and ε transport equations [19]. The transport equations are follows:

k transport equation

$$\frac{Dk}{Dt} = \frac{1}{\rho}\frac{\partial}{\partial x_k}\left[\frac{\mu_T}{\sigma_\kappa}\frac{\partial \kappa}{\partial x_k}\right] + \frac{\mu_T}{\rho}\left(\frac{\partial U_i}{\partial x_k} + \frac{\partial U_k}{\partial x_i}\right)\frac{\partial U_i}{\partial x_k} - \varepsilon \tag{6}$$

ε transport equation

$$\frac{D\varepsilon}{Dt} = \frac{1}{\rho}\frac{\partial}{\partial x_k}\left[\frac{\mu_T}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_k}\right] + \frac{C_1\mu_T}{\rho}\frac{\varepsilon}{k}\left(\frac{\partial U_i}{\partial x_k} + \frac{\partial U_k}{\partial x_i}\right)\frac{\partial U_i}{\partial x_k} - C_2\frac{\varepsilon^2}{\kappa} \tag{7}$$

Default constant in STD k-ε turbulence model

C_μ	C_1	C_2	σ_κ	σ_ε
0.09	1.44	1.92	1.0	1.3

3. Results and discussion

CFD simulations are performed to swirling and reattached flow with varied Reynolds number. Swirling flow intensity at recirculation zone of a BFS geometry represented by 2 (two) flow parameters; reattachment length and rasio between reattachment length and step height (*x/h*). Velocity profile at recirculation zone represented by Vx velocity and reattachment point at all the Reynolds number variation showed by Figure 4 - Figure 7. Highest Ux velocity of all variation located in inlet area since the inlet condition is a circular opening similar to the outlet condition as showed by Figure 2. Respectively, lowest variation Re = 4290.39 resulting Ux velocity around 0.2 m/s while highest Re = 9287.29 around 0.4 m/s. The opposite vectors direction at step corner of the Ux represent recirulating flow. A rotating flow at the so-called *lee* also occurred at upper wall of the step [4]. Flow condition at the downstream area asymptotically apprpoaches the fully developed flow [1].

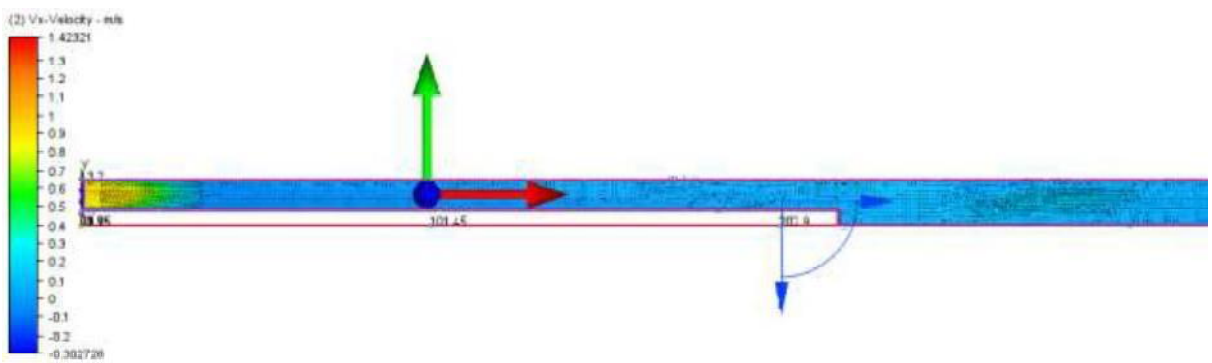

Figure 4. Ux velocity profile at Re = 4290.39

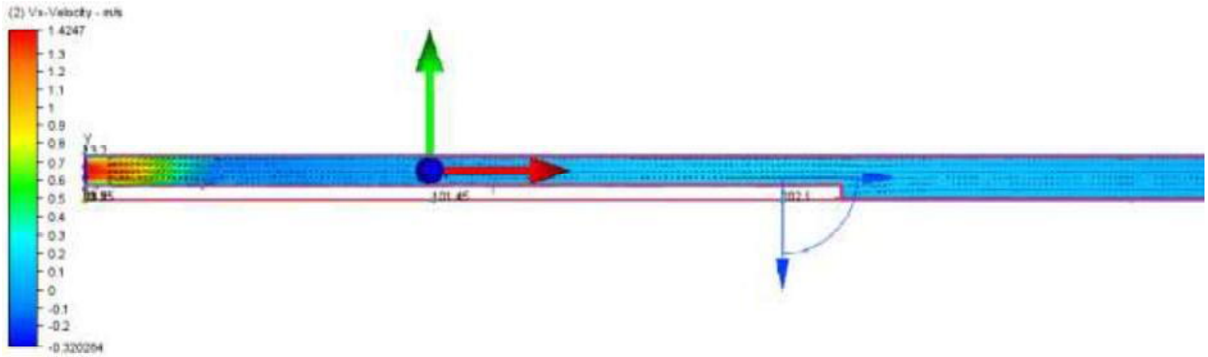

Figure 5. Ux velocity profile at Re = 6673.94

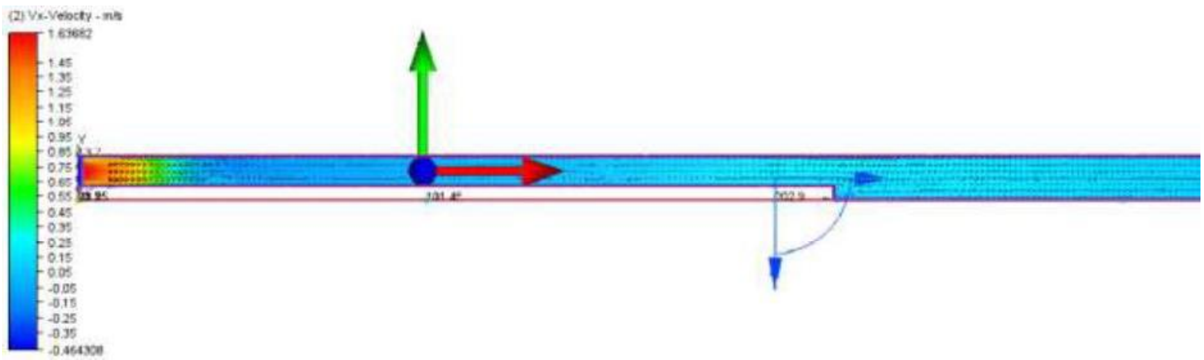

Figure 6. Ux velocity profile at Re = 7614.23

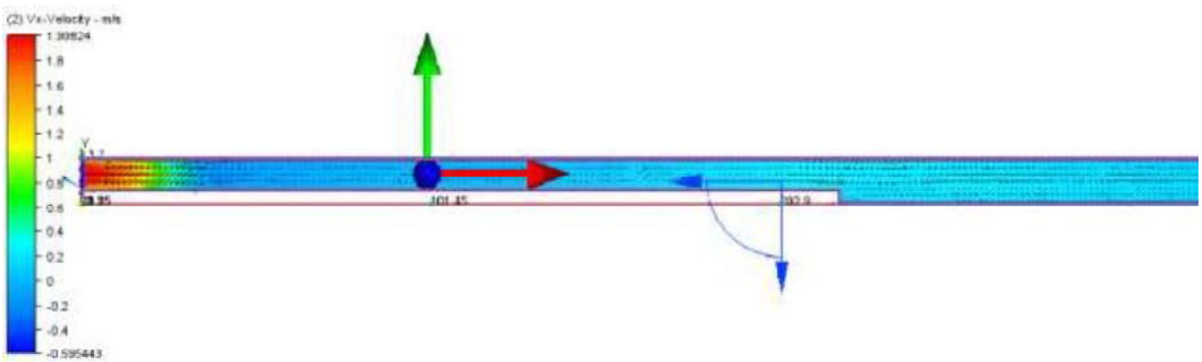

Figure 7. Ux velocity profile at Re = 9287.29

More detailed analysis reprensented by ratio of Vx velocity component and stream velocity to ratio of y-coordinate and step height (h). Arranged into graph at several streamwise location (x)/ step height (h) as showed by Figure *8* - Figure *11*. The reattachment point of swirling flow in a BFS often fixed at single point, therefore a closer look at streamwise location is necessary [20]. Respectively, reattachment point at Re = 4290.39; Re = 6673.94; Re = 7614.23 and Re = 9287.29 achieved at x/h = 5.75; 7.8; 9.04; 10.7. This ratio increased as the Reynolds number increased, inline with the numerical study by [21]. Flow condition after this point tends to has sharper contour that may indicate free flow and can be understood since the reattachment point is caused by flow impingement [22] More well-shaped contour at lower Re indicates that the flow intensity is increased as the Reynolds number increase which also confirmed by the reattachment point achieved by lower Re occur at lower y/h due to the lower momentum supplied by the fluid. Flapping phenomena due to the unsteadiness motion of the shear layer at near-wall may cause this results [20]. The dead zone at the upper side of the step almost not affected by the swirling flow. It is also seen that Reynolds number 4290.39 which has lower x – momentum resulting more stable than higher Reynolds number. In order to gain the more stable results at higher Re, addition of expansion ratio may needed [6].

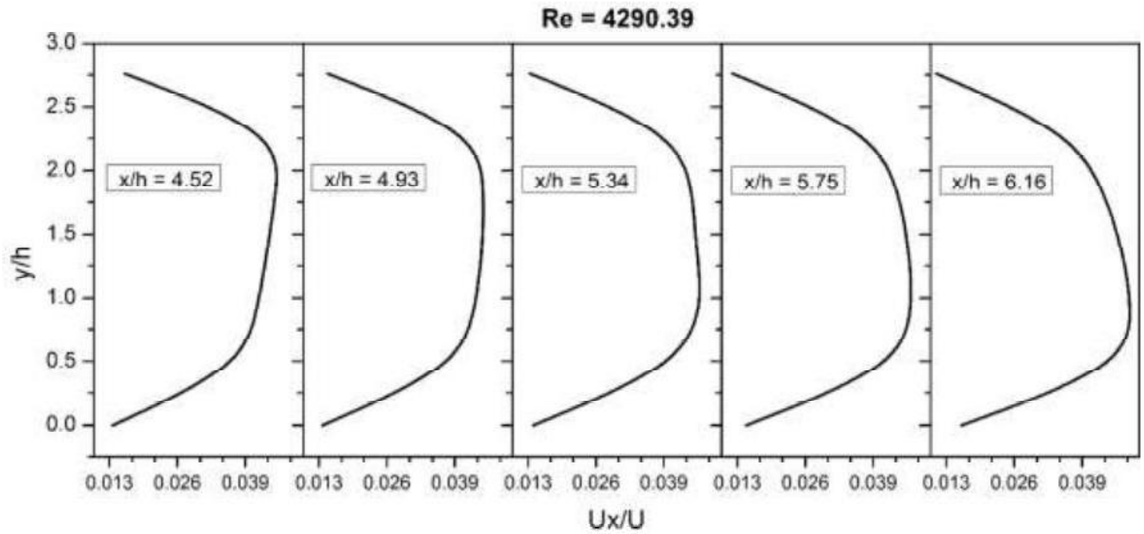

Figure 8. Mean velocity profile at Re = 4290.39

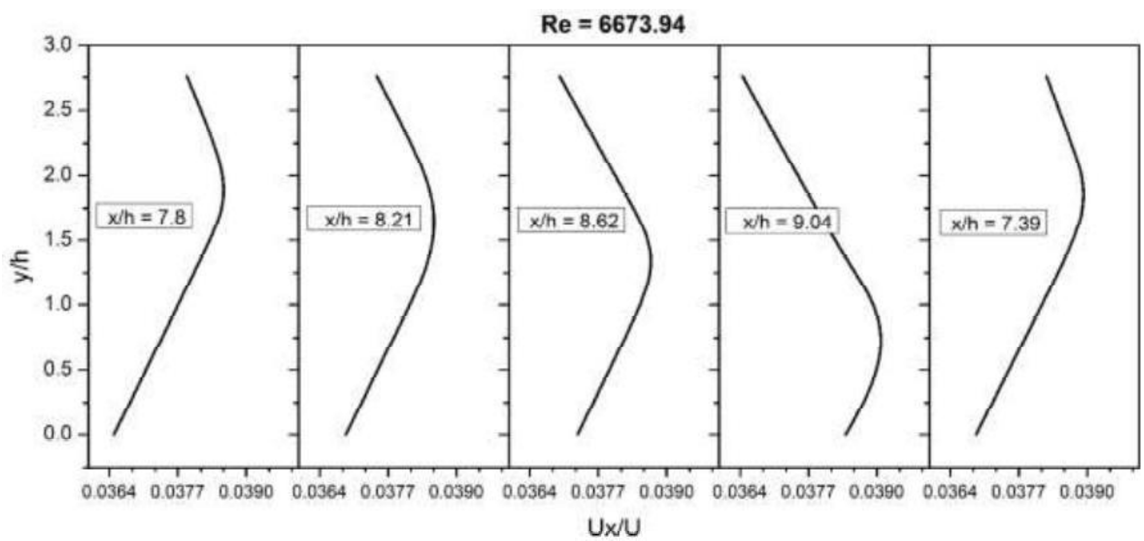

Figure 9. Mean velocity profile at Re = 6673.94

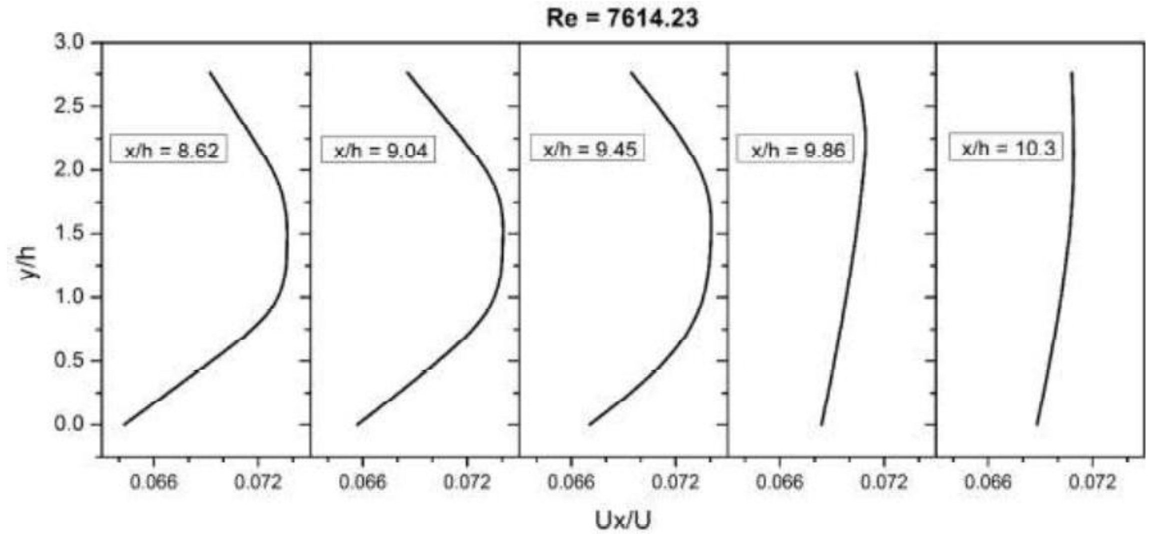

Figure 10. Mean velocity profile at Re = 7614.23

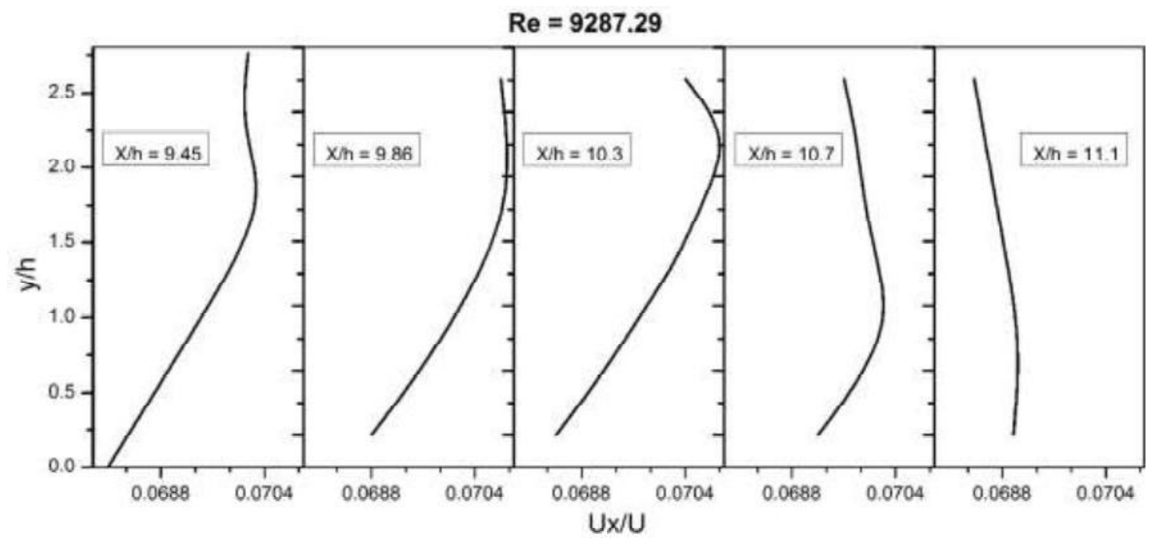

Figure 11. Mean velocity profile at Re = 9287.23

4. Conclusion

CFD simulations have conducted to swirling and reattached flow of a Backward-facing step woth constant step height (h) of 41 mm and expansion ratio of 1.5 with varied Reynolds number: Re = 4290.39; 6673.94; Re = 7614.23; and Re = 9287.29. The CFD simulations are performed three-dimensionaly with 90293 triangular nodes and STD *k-ε* turbulence model. The results indicated that reattachment point achieved farther at higher Reynolds number. Respectively, reattachment point at Re = 4290.39; Re = 6673.94; Re = 7614.23 and Re = 9287.29 achieved at x/h = 5.75; 7.8; 9.04; 10.7 and lower y/h. This phenomena clearly showed that unsteadiness at higher Re contribute to higher reattachment length.

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Jakarta, 18 November 2019

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FULL PAPER ACCEPTANCE NOTIFICATION

Reference Number : TICATE-220

Title : Reynolds number effects on swirling flows intensity and reattachment length over a backward-facing step geometry using STD k-ε turbulence model

Authors : Steven Darmawan

Dear Mr./Madam

Thank you for your paper submission to Tarumanagara International Conference on the Application of Technology and Engineering 2019.

We are pleased to inform you that your submission is accepted for presentation in TICATE 2019. Due to some outstanding reviews for other submissions, however, the review result is not available for viewing yet. We expect to publish the review results will begin on 18 November 2019, you need to register to conference before 19th November 2019.

In the meantime, we recommend that you check your manuscript to minimize obvious errors, such as formatting and grammatical errors.

If you have further questions, please don't hesitate to contact us. We are looking forward to seeing you at UNTAR. Thank you very much for your cooperation.

Sincerely,

Dr. Hugeng, S.T.,M.T.(SMIEEE)

Chairman