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Cfd Analysis of Flow over Backward Facing Step at Different Inclination Angle

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Abstract:
CFD analysis of single backward facing step is done in this paper. The impact of step point and extension proportion on partition length is contemplated and contrasted and test results revealed in writing [1]. The progression edges considered are 15^0, 30^0, 45^0, and 90^0, while the development proportions considered are 1.5 and 2.0. The geometrical modeling is carried out in ICEM and the numerical simulation & post processing was carried out in commercial CFD code- ANSYS Fluent 15. A two-dimensional isolated renormalized gathering k-Ɛ model is utilized for doing reattachment. The examination of the outcomes indicated that with the increment in step edge and extension proportion, the reattachment length (Lr) increments. Impact of Reynolds number (Re) is likewise examined by shifting it between 15500 to 64500 and it additionally indicated that Lr increments with an expansion of the Re.

***Keywords**: CFD, Backward Step, Reynolds number, Expansion ratio.*

INTRODUCTION

Stream with detachment and reattachment has for quite some time been a subject of essential liquid elements inquire about. The nearness of an isolated stream, together with a reattaching stream, offers ascend to expanded shakiness, pressure vacillations, structure vibrations and clamor, as it likewise shows a flimsy structure with an enormous scale vortex in the isolated viscous layer Troutt et al. (1984) [2] and low-recurrence movement near Lr district with vacillation of a momentary Lr point (Eaton and Johnston 1980). The stream over a solitary side in reverse confronting step gives an exemplary case of above said stream field. The basic geometry and the effectively feasible two dimensionality predestinate the progression geometry to contemplate division wonder. Furuichi et al. [3] contemplated a 2-dimensional in reverse confronting step and estimated the speed changes by utilizing a multi-point LDV and associate the moving way of vortex shedding and speed variance. Hoi Hun Choi et al. carried out numerical investigation of such type of problem over a wide range of Reynolds number and expansion ratio using RANS model and LES model and they found good agreement with both these models [4].

In reverse Facing Step stream is one agent partition stream model, which is of essentialness in both hypothetical and building advancement. Different applications for BFS stream can be found in our day by day life, for example, the airfoils everywhere assault edge, the spoiler streams, partition stream behind a vehicle, channel burrow stream of motor or inside a condenser/combustor, and furthermore the stream around a pontoon or a structure as shown in fig. 1. [5-10, 12]

Some examples of these applications are flow over aerofoil, in a channel whose area suddenly increases and in heat transfer and gas turbine devices.

In any case, in past, just 90^0 advances has regularly been examined, the stream over the slanted advance pulled in less consideration. Ruck and Makiola [1] performed investigates slanted strides

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for various Reynolds no. furthermore, development proportion and concentrated its impact on the reattachment length. Their examination inferred that by expanding the zone proportion or tendency point reattachment length increments for a specific Reynolds no [13].

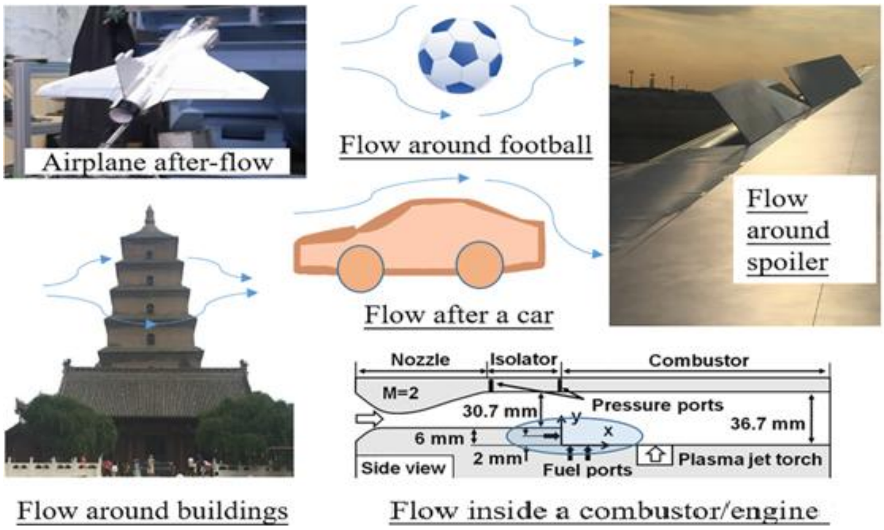

Fig. 1. Applications of Backward Facing Steps [11]

The reason for this examination is to give computational plan to illuminating a stream field in 2D in reverse confronting step and to consider the impact of step tendency on the Lr of the isolated stream, see figure. 2.

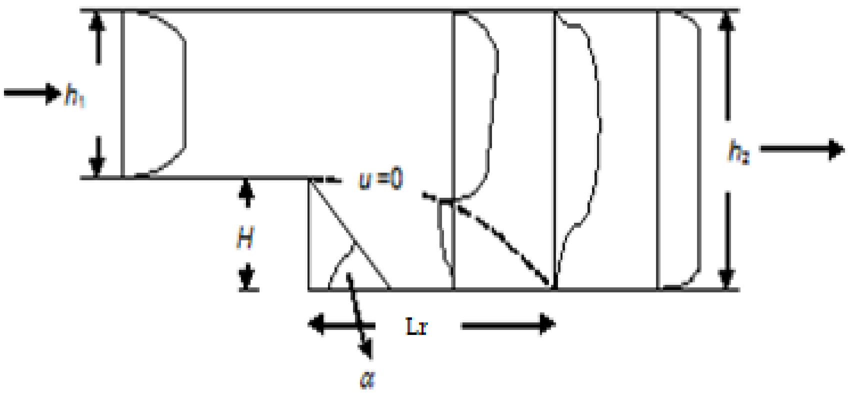

Fig. 2. Backward step with various inclination angles

GOVERNING EQUATIONS

Continuity Equations

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}=0 \tag{1}$$

Momentum Equations

$$\frac{Du}{Dt}=X-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{\mu}{\rho}\left[\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right] \tag{2}$$

$$\frac{Dv}{Dt}=Y-\frac{1}{\rho}\frac{\partial p}{\partial y}+\frac{\mu}{\rho}\left[\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right] \tag{3}$$

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K- Ɛ Equation

$$\frac{\partial \rho \kappa}{\partial t} + div(\rho u \kappa) = div\left[\left(\mu_t + \frac{\rho \mu_t}{\sigma_\kappa}\right) grad\kappa\right] + \rho \mu_t G - \rho \varepsilon \tag{4}$$

$$\frac{\partial \rho \varepsilon}{\partial t} + div(\rho u \varepsilon) = div\left[\left(\mu_t + \frac{\rho \mu_t}{\sigma_\varepsilon}\right) grad\varepsilon\right] + C_{1\varepsilon} \rho \mu_t \left(\frac{\varepsilon}{\kappa}\right) - C_{2\varepsilon} \rho \frac{\varepsilon^2}{\kappa} \tag{5}$$

COMPUTATIONAL METHODOLOGY

For the present investigation, every one of the problems taken is abridged in table no 1. At first the demonstrating is done in ICEM displaying instrument for the previously mentioned geometries. Unadulterated quadrilateral lattice is done to get organized work with all out number of 135000 cells as appeared in figure 2.

Table – 1 Designs taken in Present work

ER (h2/h1)	Re	u (m/s)	Step angle (α)			
1.5	15500	2.20	15	30	45	90
	47000	6.87	15	30	45	90
	64500	10.0	15	30	45	90
2.0	15500	2.20	15	30	45	90
	47000	6.87	15	30	45	90
	64500	10.0	15	30	45	90

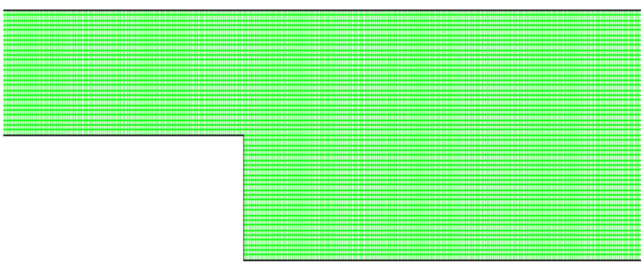

Fig. 3. Quad Mesh of Backward Facing Step

A consistent state based understood solver is utilized to accomplish assembly. Second-request upwind plan was utilized for the discretization of the considerable number of conditions to accomplish higher precision in results [14-15]. Speed pressure coupling is set up by pressure-speed connection utilizing a SIMPLE calculation. Under-unwinding factors are utilized for all condition to fulfill Scarborough condition [4]. Residuals are ceaselessly checked for progression, x-speed, y-speed, z-speed, k, and ω. Intermingling of the arrangement is expected when the estimations of all residuals goes beneath 106. Standard divider work is utilized to explain for the close to divider treatment, as y+ is more than 35 in the entire area.

RESULTS AND DISCUSSION

The economically accessible code ANSYS-Fluent 15 is approved utilizing the trial information announced by Ruck and Makiola [1]. Figure. 3 speaks to the variety of dimensionless connection length (Lr) with Re for test and numerical study. It tends to be seen that the numerical outcome intently same as the exploratory pattern.

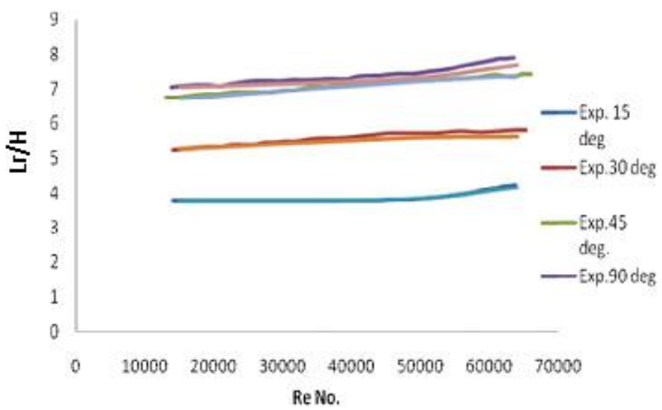

Fig. 4. Validation of Experimental Result of Lr/h with Re for different step angles, ER=1.5

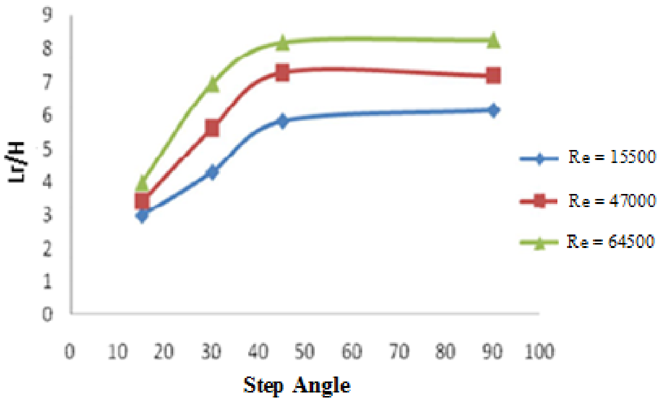

Fig. 5. Assortment of Lr with α, for ER =2 at different Re

The stream can be good pictured in type of imaginary streamline as appeared in Figure. 6. It might be seen that there is a specific helper stream in the confined zone near the corner. The increment of the oblique angle from 25° to 45° is responsible for a notable increase in the pressure drop with increasing Reynolds number under single-phase modeling [16-18].

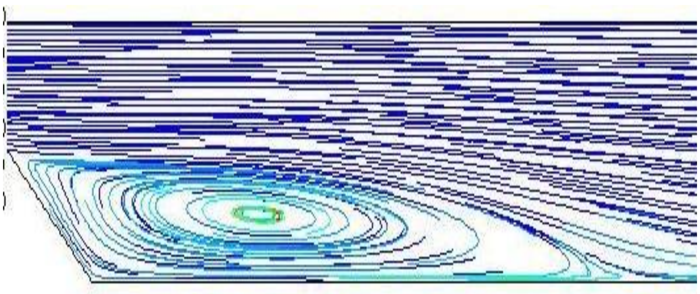

Fig. 6. Streamline Depicting Secondary Flow

CONCLUSIONS

The stream qualities over a 2D in reverse confronting step have been numerically reenacted. The examination of the outcomes shows that:

- The non-dimensional reattachment length (Lr/H) increments from 3.79 for a 150 stage edge to 7.1 for a 900 stage point, at Re = 15500.
- The dimensionless Lr additionally increments from 7.1 to 7.8 as Reynolds number increments from 15500 to 64500 for a 900 stage point.
- With increment in extension proportion from 1.5 to 2, the Lr diminishes for decreasing Re = 15500 however increments for increasing Re.
- For a specific Re, the Lr increments at first till 450 and from that point, remains practically steady.

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1. ANSYS-Fluent 15 User Manual.

Nomenclature

ρ: Density of fluid flowing (kg/m^3)
u: Velocity of flow in *x*-direction (m/sec.)
v: Velocity of flow in *y*-direction (m/sec.)
p: Pressure in the direction of flow (N/m^2)
X:Body force in *x*-direction (N)
Y:Body force in *y*-direction (N)
T: Temperature of Fluid (K)
μ_t: Eddy Viscosity
κ: Turbulent Kinetic Energy

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ε:	Turbulent Dissipation Rate
G:	Turbulent Generation Rate
σ_κ:	Constant
σ_ε:	Constant
$C_{1\varepsilon}$:	Constant
$C_{2\varepsilon}$:	Constant
h:	Heat Transfer Coefficient (W/m^2-K)
T_∞:	Ambient air temperature (K)
ER:	Expansion ratio ($ER = h_2/h_1$) dimensionless
h_1:	Inlet width (mm)
h_2:	Outlet width (mm)
H:	Step height (mm)
Re	Reynolds number
u^*:	Friction velocity at the nearest wall
Lr:	Reattachment length
y:	distance to the nearest wall (mm)
y^+:	dimensionless wall distance ($y^+ = u^* y/\upsilon$)
υ:	kinematic viscosity (m^2/s)
τ_w:	wall shear stress (N/m^2)