ISSN 2395-695X (Print)
ISSN 2395-695X (Online)
International Journal of Advanced Research in Biology Engineering Science and Technology (IJARBEST)
Vol. 2, Special Issue 14, May 2016

Computational Analysis of Blunt Trailing Edge NACA 0012 Airfoil

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Abstract — **Blunt trailing edge airfoil shown that compromise between aerodynamic performance and structural benefits can be achieved. A detailed numerical study of blunt trailing edge NACA0012 airfoil with various angles of attack was carried out in the present study. The results obtained shows that increase in lift coefficient, the delayed stall and increment in coefficient of drag. By using modified trailing edge airfoils stalling angle of attack can be increased. The blunt trailing edge airfoils do have the disadvantage of generating drag as a result of low-pressure steady or periodic flow in the near-wake of blunt trailing edge. This paper describes the performance characteristics of NACA 0012 airfoil with and without modification for various angle of attack at mach number 0.1.Two dimensional computational analysis is carried out on NACA 0012 airfoil with and without modification by using ANSYS software.**

I. INTRODUCTION

In the past, many investigations have been carried on blunt trailing edge airfoils with some of the earliest work by indicating that the maximum lift-to-drag ratio of thick airfoils could be increased by incorporating a blunt trailing edge, and suggesting application in the blade root region of rotors such as propellers. Most of these studies simply truncates the trailing edge to achieve the required blunt trailing edge shape.

Instead, the shape of these blunt airfoils seems to be optimal when the trailing edge is thickened as demonstrated. This results in a reduced adverse pressure gradient on the suction side thereby creating more lift and mitigating flow separation due to premature boundary-layer transition. Unfortunately, this trailing-edge shape also creates a steady or periodic low-pressure flow in the near-wake of the airfoil that gives rise to a drag penalty and this explains why blunt trailing edges have been largely avoided in the design of subsonic airfoils. Solutions to minimize the base drag penalty have been investigated for many years and include trailing-edge splitter plates, trailing-edge serrations, base cavities, and trailing edge fairing or wedges.

The primary purpose of this project is to investigate and summarize the effect of blunt trailing edge on the NACA0012 airfoil which is carried out by GAMBIT and FLUENT software. Here cutting off method is used to modify the trailing edge. In case of wind turbine blades, with the increase of wind turbine's size, the design of inboard parts of wind turbine blades involves more factors such as aerodynamic performance, manufacturing costs, structure demands, compatibility and so on. For aerodynamic performance, though the inboard part of large wind turbine blades contributes less to the overall torque generated by the entire blade than the outboard part due to relatively small arm of force, the improvement of aerodynamic performance for the inboard part can still increase the total power output of wind turbines. For structure demands, the inboard parts of the blade bear larger bending moment, so the structural characteristics of airfoils used in this part should be strong enough to bear the load.

II. LITERATURE REVIEW

2.1 CFD ANALYSIS OF BLUNT TRAILING EDGE AIRFOILS OBTAINED WITH SEVERAL MODIFICATION METHODS BY JUAN MURCIA:

Two modification methods are studied this paper. They are cutting off method and added thickness method. Two dimensional simulations were obtained in ANSYS CFX for r typical Reynolds number 3.2 million. A Taguchi method experiment is conducted for the study of four digit NACA airfoil family with the proposed modification methods. A detailed study for the NACA 4421 modified with several trailing edge thickness value was completed. The result obtained show that increase in maximum lift coefficient, the delayed stall and the drag coefficient increase are common to all modification methods studied, whereas it is proven that for cutting off method the lift coefficient curve displacements to higher angle of attack is caused by the loss of camber. Finally it was proved that the added thickness method produces larger maximum lift coefficients and larger critical angle of attack than the cutting of method.

2.2 DRAG REDUCTION IN FLOW OVER A TWO-DIMENSIONAL BLUFF BODY WITH A BLUNT TRAILING EDGE USING A NEW PASSIVE DEVICE:

This paper describes about presenting a new passive control device for form-drag reduction in flow over a two-dimensional bluff body with a blunt trailing edge. The device consists of small tabs attached to the upper and lower trailing edges of a bluff body to effectively perturb a two-dimensional wake. Both a wind-tunnel experiment and large-eddy simulation are carried out to examine its drag-reduction performance. Extensive parametric studies are performed experimentally by varying the height and width of the tab and the span wise spacing between the adjacent tabs at three Reynolds numbers of Re =20 000, 40 000 and 80 000, where u infinity is the free-stream velocity and h is the body height. For a wide parameter range, the base pressure increases (i.e. drag reduces) at all three Reynolds numbers. Furthermore, a significant increase in the base pressure by more than 30% is obtained for the optimum tab configuration. Numerical simulations are performed at much lower Reynolds numbers of Re {=} 320 and 4200 to investigate the mechanism responsible for the base-pressure increase by the tab. Results from the velocity measurement and numerical simulations show that the tab introduces the span wise mismatch in the vortex-shedding process, resulting in a substantial reduction of the vortex strength in the wake and significant increases in the vortex formation length and wake width.

2.3 TRAILING EDGE MODIFICATION FOR FLAT BACK AIRFOILS BY DANIEL L.KAHN:

Blunt trailing edge airfoils are of interest in the engineering of large wind turbine blades because they allow for a strong structure with a high aerodynamic lift to structural weight ratio. However, these airfoils also have a high drag because of the low pressures in the wake acting on the blunt trailing edge. The goal of the present research effort is to find the most effective way of reducing the base drag while retaining the favorable characteristics of the airfoil that make it of interest for application in the inboard region of large wind turbine blades.

Most studies discuss the use of a splitter plate to increase the base pressure and, hence, to reduce the base drag. This is the simplest method and it has been utilized and researched more than any other base drag mitigation device. The nominally optimum dimension is one that has a length the same as the height of the trailing edge. This simply causes the once large vortex system behind the airfoil to be split into two smaller ones. With the two smaller vortices directly behind the base, the rest of the flow over the airfoil forms into the shape of a sharp trailing edge, therefore causing an increase of base pressure without loss of lift. Although simple, it does not quite generate the amount of base drag reduction that can be achieved with other, more complex devices.

Based on the above findings, we propose to test and compare the effects of the following trailing edge configurations on the lift and drag of a blunt trailing edge airfoil:

1. Splitter plate
2. Trailing edge wedge
3. Ventilated cavity
4. M-shaped serrations

The literature on these trailing-edge modifications shows that substantially decreases in the base drag can be achieved with these devices and the proposed wind tunnel test will allow us to evaluate their effect on the aerodynamic performance characteristics of the type of blunt trailing edge airfoils considered for the inboard regions of large wind turbine blades.

III.COMPUTATIONAL WORKS

3.1 METHOD:

The CFD simulation were carried out using GAMBIT and FLUENT 6.3.26.The two dimensional domain is modeled using gambit software.

COMPUTATIONAL MODEL:

3.2 PREPROCESSING:

The design of the model is created along with the specification of the different boundaries, their nature and fluid types for the particular problem. GAMBIT is a pre-processing program developed by FLUENT Inc. primarily for generating a mesh structure for different kinds of geometries. In this study, GAMBIT 2.3 is used for mesh generation. In this study NACA 0012 airfoil vertex data imported in GAMBIT and modeled using the software. Structured mesh was created around the model by creating grid for various angle of attacks, such as -5,-12,0, 5, 12, 15 degrees. If the mesh characteristics and growth are not controlled, then highly skewed elements might be formed that can adversely affect numerical computations of resultant mesh. Hence to tackle such problems, GAMBIT features an option called “Size functions” that can be used to specify the rate at which volume mesh elements change in size proximity to a specified boundary. The number of total elements used here is approximately 200000.

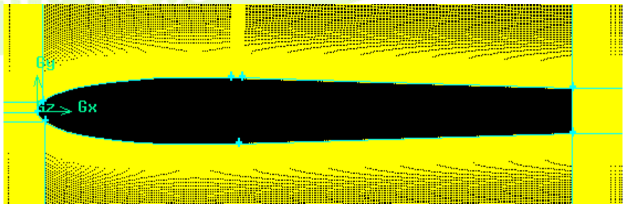


Fig 3.1: Mesh example for the modified NACA 0012 with a trailing edge thickness 0.08m using cutting off method.

The turbulent model used was the two equation K-epsilon model. The model provides highly accurate prediction of separated flows from a smooth surface where adverse pressure gradients are found.

3.3 *MODIFICATION METHOD:*

The present numerical analysis uses cutting off method to modify the NACA 0012 airfoil. The cutting off or 'truncating' method consists of removing a segment from the rear portion of the baseline airfoil and then rescaling the airfoil to its original chord length. The amount of airfoil cutoff is interpolated in order to obtain desired trailing edge thickness. Here 0.08m thickness is used in the trailing edge.

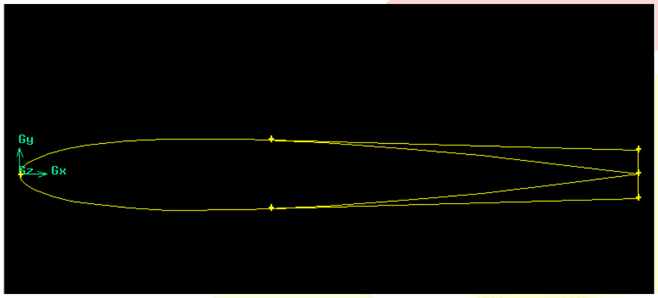


Fig 3.2: NACA 0012 airfoil with a trailing edge thickness 0.08m using cutting off method

3.4 *PROCESSING*:

The simulation is initiated and the PDEs are solved as a steady state or as an unsteady flow problem, as required. In this study, the problem is taken as a unsteady state. The boundary conditions given for the simulation are,

FACE	**BOUNDARY CONDITIONS**
Model	Wall
V in	Velocity Inlet
P out	Pressure Outlet

3.5 *CASE SETUP & SOLVING*

The solution of the problem was solved using the following analysis scheme:

Version**:** 2ddp
Solver: Pressure based
Formulation**:** Implicit
Time: Unsteady
Viscous: K-Epsilon(2 equation)
Material definition**:** air| Density :ideal-gas
Inlet Mach number: 0.1
Flow direction**:** +x-axis
Solution control: Discretization: Pressure: Standard | Density: First Order Upwind |Momentum: First order Upwind | | Energy: First Order Upwind

3.6 *POST – PROCESSING*:

The results thus obtained is then analyzed, generally by exporting the data for further calculation. The coefficient of lift,drag and pressure coefficient distribution around blunt trailing edge airfoils are obtained by the analysis.

IV. RESULTS AND DISCUSSION

The design of blunt trailing edge airfoil and unmodified airfoil for various angle of attack is done with the help of GAMBIT software. The results shows that maximum lift coefficient is increased because of trailing edge thickness. The flow separation is delayed because of adverse pressure gradient decrease in upper surface of the airfoil.

4.1. PRESSURE CONTOURS FOR BLUNT TRAILING EDGE AIRFOIL:

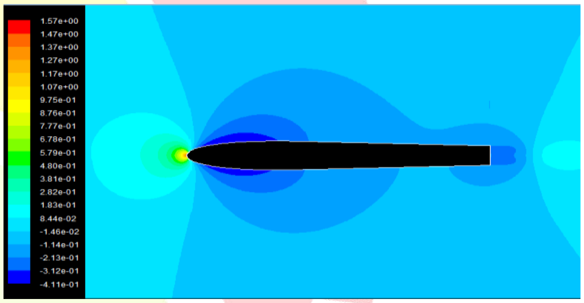


Fig 4.1 Pressure contour for Blunt trailing edge airfoil at 0 degree angle of attack

The figure illustrates pressure distribution over upper and lower surface of modified airfoil at zero degree angle of attack,shows the same pressure on upper and lower surface of the airfoil.

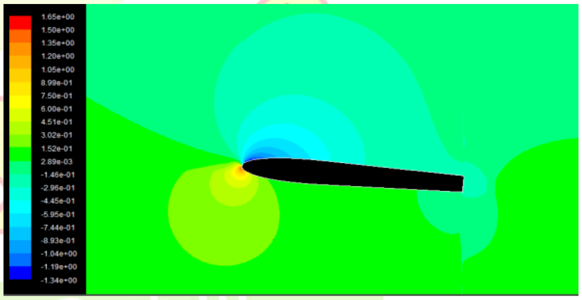


Fig 4.2 Pressure contour for Blunt trailing edge airfoil at 5 degree angle of attack

The figure illustrates pressure distribution over upper and lower surface of modified airfoil at five degree angle of attack,which shows difference in pressure on upper and lower surface of the airfoil.

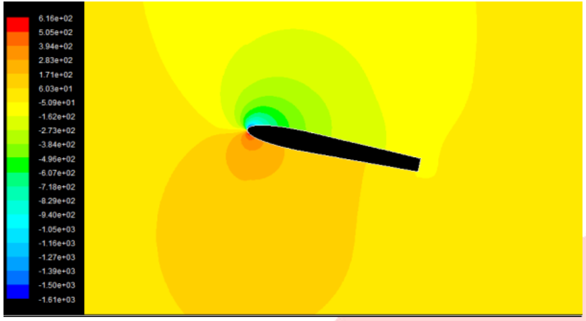


Fig 4.3 Pressure contour for Blunt trailing edge airfoil at 12 degree angle of attack

The figure illustrates pressure distribution over upper and lower surface of modified airfoil at twelve degree angle of attack,which shows low pressure on upper suface and high pressure on lower surface of the airfoil.

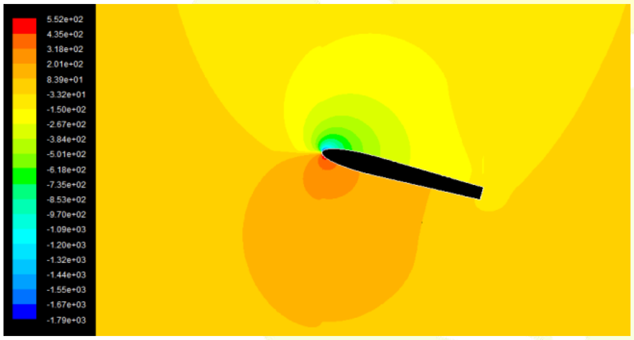


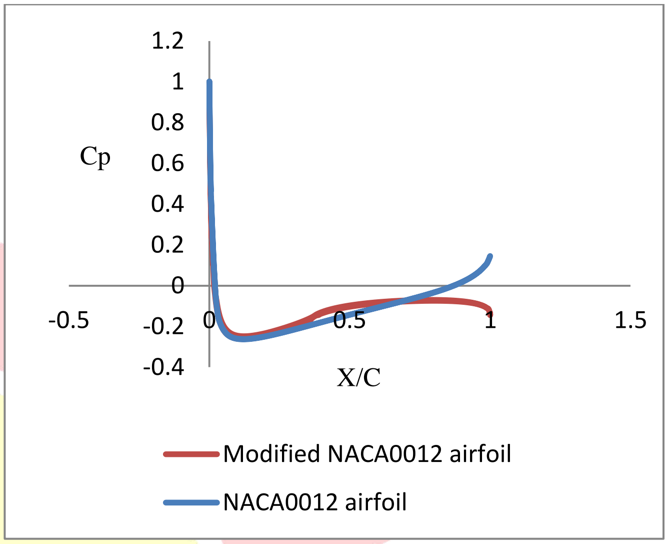
Fig 4.4 Pressure contour for Blunt trailing edge airfoil at 15 degree angle of attack

The figure illustrates pressure distribution over upper and lower surface of modified airfoil at fifteen degree angle of attack,which shows low pressure on upper suface and high pressure on lower surface of the airfoil.

From the above contours ,we can get a clear picture of blunt trailing edge aifoil pessure distribution at various angle of attack such as,0,5,12,15 degrees.

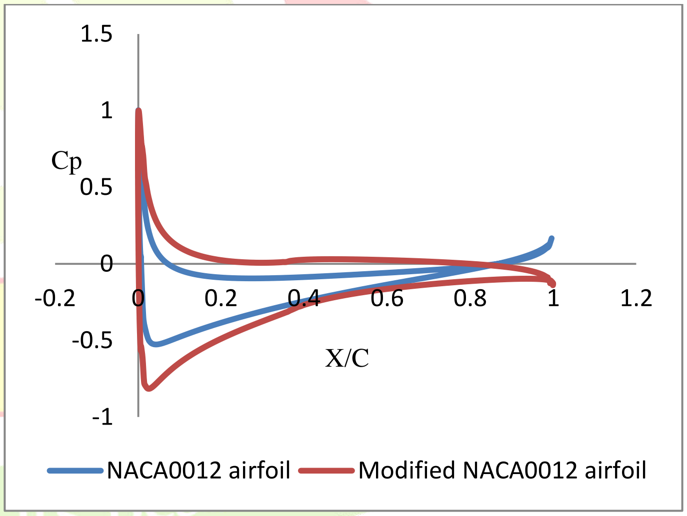
4.2 COMPARISON GRAPHS:

Coefficient of pressure Vs X/C have been plotted for the angle of attack such as 0,5,12,15 degrees.



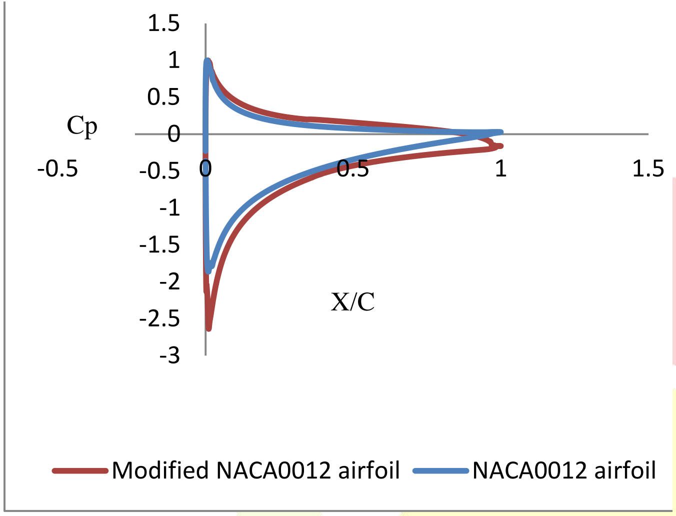
Graph 4.1: Cp Vs X/C at 0 degree AOA

The above graph shows Coefficient of pressure Vs X/C plot at zero degree angle of attack, whereas coefficient of pressure values for modified airfoil is decreased compared to unmodified airfoils.



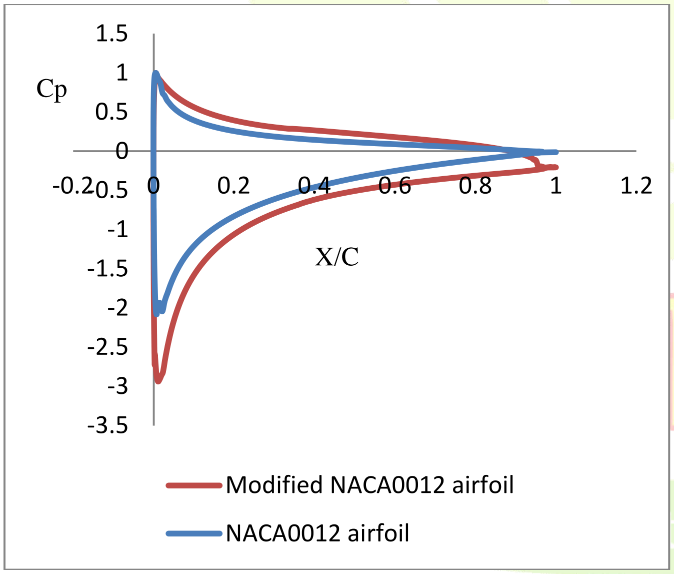
Graph 4.2: Cp Vs X/C at 5 degree AOA

The above graph shows Coefficient of pressure Vs X/C plot at five degree angle of attack, whereas coefficient of pressure values for modified airfoil is changed compared to unmodified airfoils. Maximum suction pressure coefficient is increased.



Graph 4.3: Cp Vs X/C at 12 degree AOA

The above graph shows Coefficient of pressure Vs X/C plot at twelve degree angle of attack, whereas coefficient of pressure values for modified airfoil is changed compared to unmodified airfoils. Maximum suction pressure coefficient is increased.



Graph 4.5: Cp Vs X/C at 15 degree AOA

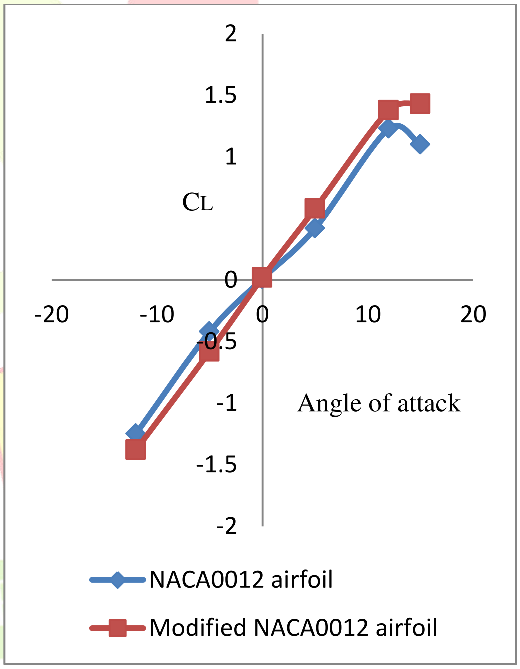
The above graph shows Coefficient of pressure Vs X/C plot at fifteen degree angle of attack, whereas coefficient of pressure values for modified airfoil is changed compared to unmodified airfoils. Maximum suction pressure coefficient is increased. Cp value of lower surface is decreased near the trailing edge of the modified airfoil.

V. CONCLUSION

CFD analysis study of blunt trailing edge airfoil and unmodified airfoil is carried out by using software and the result shows that the maximum lift coefficient increases by using blunt trailing edge airfoil, thereby it also increases stalling angle of attack.

Here the pressure coefficient distribution is altered by the geometric differences, increasing the maximum suction pressure coefficient. The decreased adverse pressure gradient near to the trailing edge delays the flow separation. Here for unmodified airfoil flow separation takes place at 0.5m chord length. But for blunt trailing edge airfoils flow separation takes place at 0.8m chord length. This shows that maximum lift coefficient increases because of the trailing edge thickness.

The following graph indicates the coefficient of lift and coefficient of drag for various angle of attacks. By using blunt trailing edge airfoil 22% of maximum lift coefficient is increased and critical angle of attack is also increased. The base drag can be decreased by using splitter plates as previous methods.

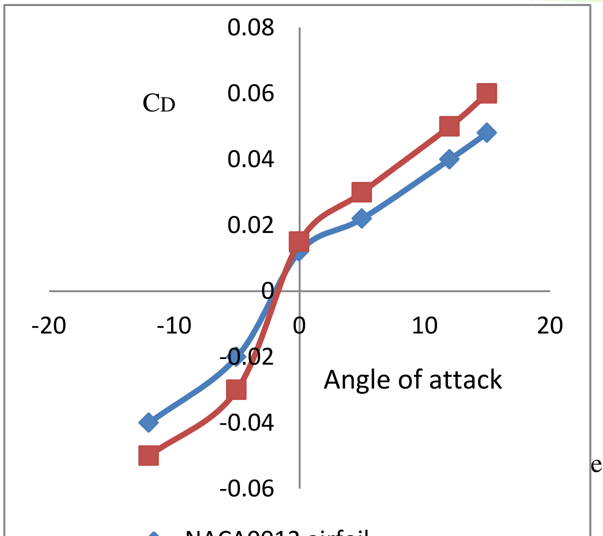


Graph 5.1: CL Vs Angle of attack

The above graph shows Coefficient of lift values at various angles of attack. From the graph, it can be clearly seen that stalling angle of attack is increased from 12 degree to 15 degree for modified NACA0012 airfoil.

ANGLE OF ATTACK (DEGREES)	CD (UNMODIFIED AIRFOIL)	CD (MODIFIED AIRFOIL)
0	0.01	0.023
5	0.022	0.031
12	0.038	0.045
15	0.047	0.058

ANGLE OF ATTACK (DEGREES)	CL (UNMODIFIED AIRFOIL)	CL (MODIFIED AIRFOIL)
0	0.001	0.005
5	0.43	0.58
12	1.23	1.36
15	1.18	1.45



Graph 5.2: CD Vs Angle of attack

The blunt trailing edge method using cutting off method is typically considered in the paper. Thus the improvement in lift coefficient of blunt trailing edge airfoil was studied, as they have a larger maximum lift coefficient and a larger stalling angle of attack than the unmodified airfoils.

Table 4.1: CL for modified and unmodified airfoil

Table 4.2: CD for modified and unmodified airfoil

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