University of Diyala
College of Engineering
Mechanical Engineering Dep
Class: Third Class

lecture-2

Turbomachinery

Blade Theory

By
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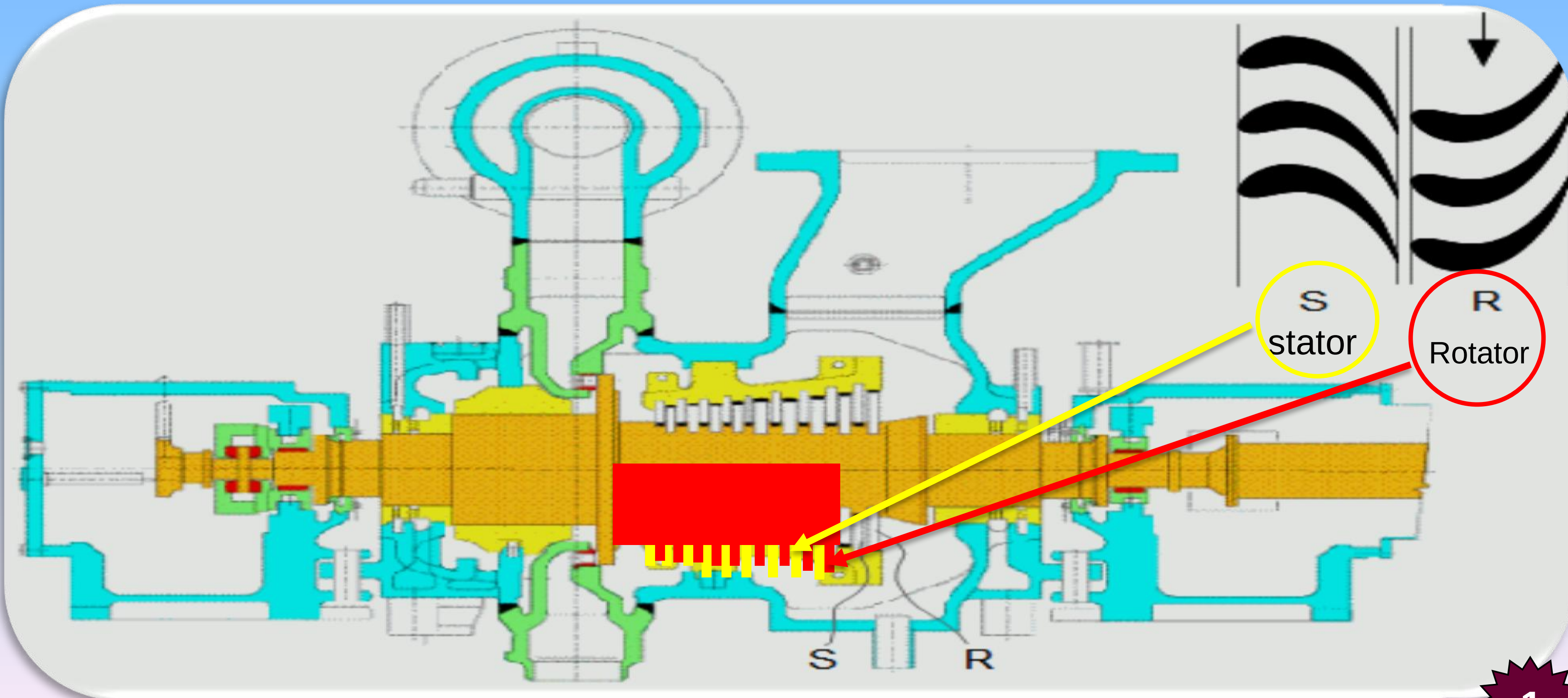
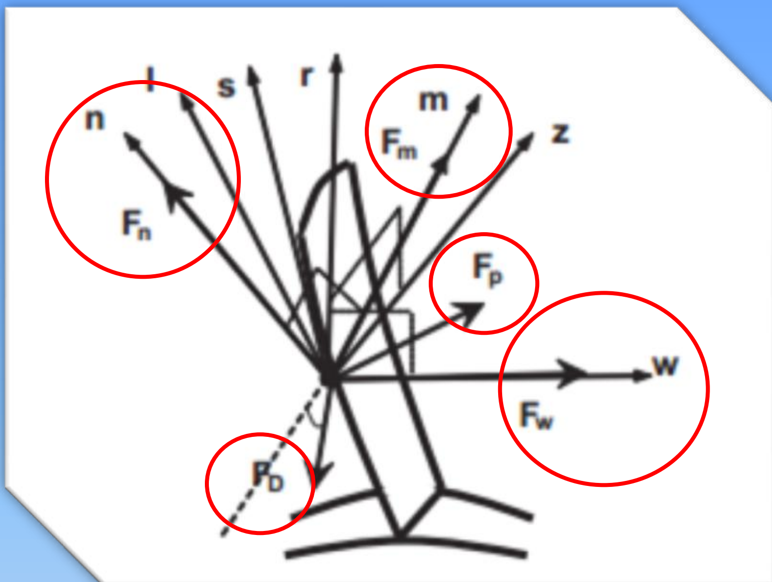
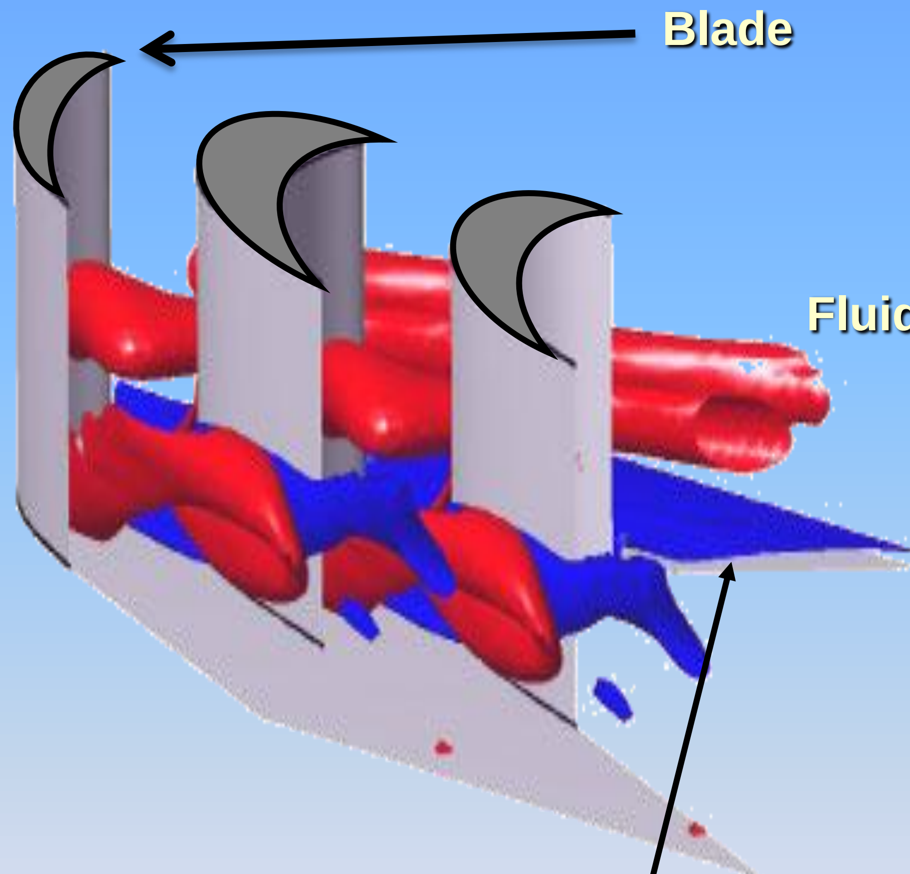
The energy transfer in turbomachines is affected by changing the angular momentum of the fluid. <u>The change in angular momentum is caused by the dynamic action of one or more rotating blade rows.</u>



Sets up forces between the blade row and the fluid





F_p = Pressure Force.

F_n= Normal Direction Force.

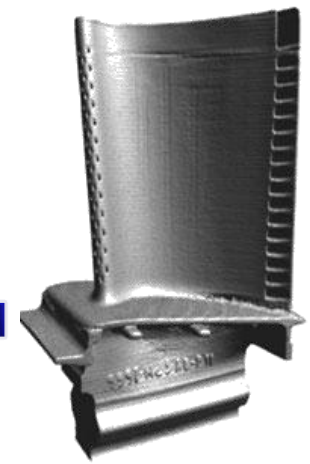
F_w= Velocity Force.

F_m= Meditational Direction Force.

F_D= Drag Force.

Components of these forces in the direction of blade motion give rise to the energy transfer between the blades and fluid

BLADE TERMINOLOGY



1- Base Profile:

It is defined by dividing the major axis into equally spaced stations designated as a percentage of the blade length and specifying the height from axis to profile at each station

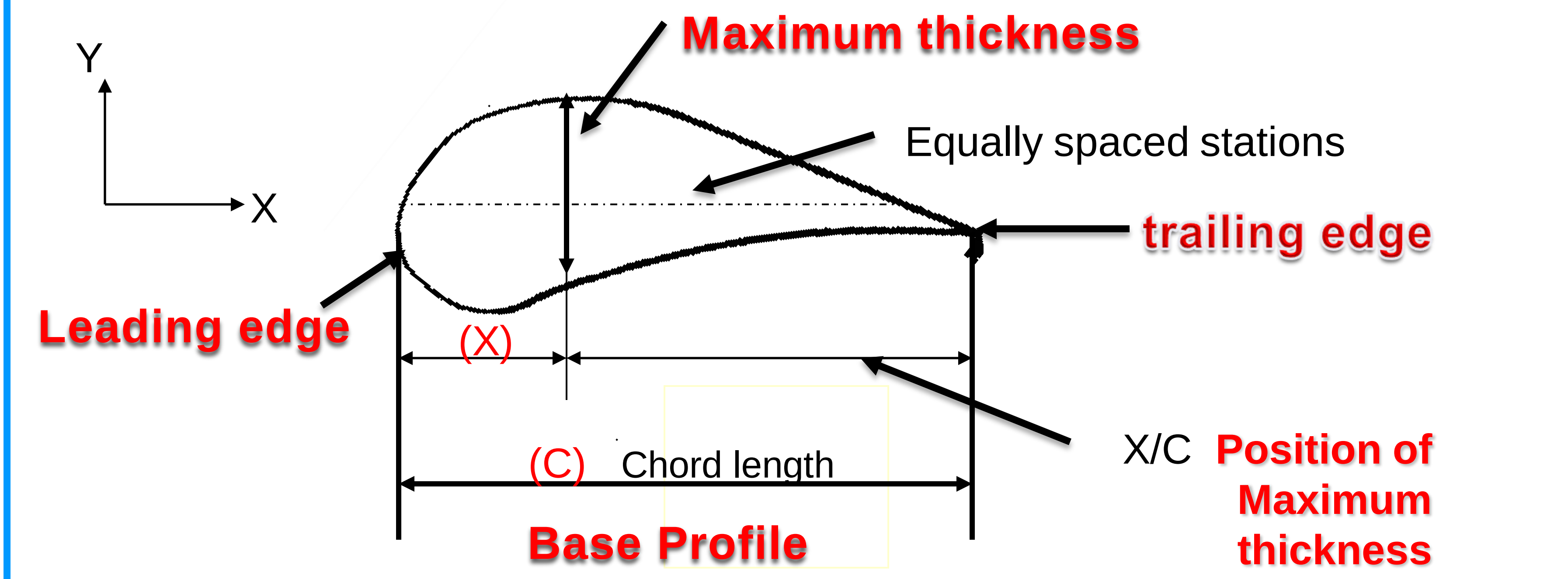


figure show the parameters used in describing blade shapes and configuration of blades

2- Maximum thickness :

It is a useful parameter it is expressed as a percentage of the blade length.

3- Position of maximum thickness :

it is specified as a percentage of the blade length.

4-Leading edge (Nose):

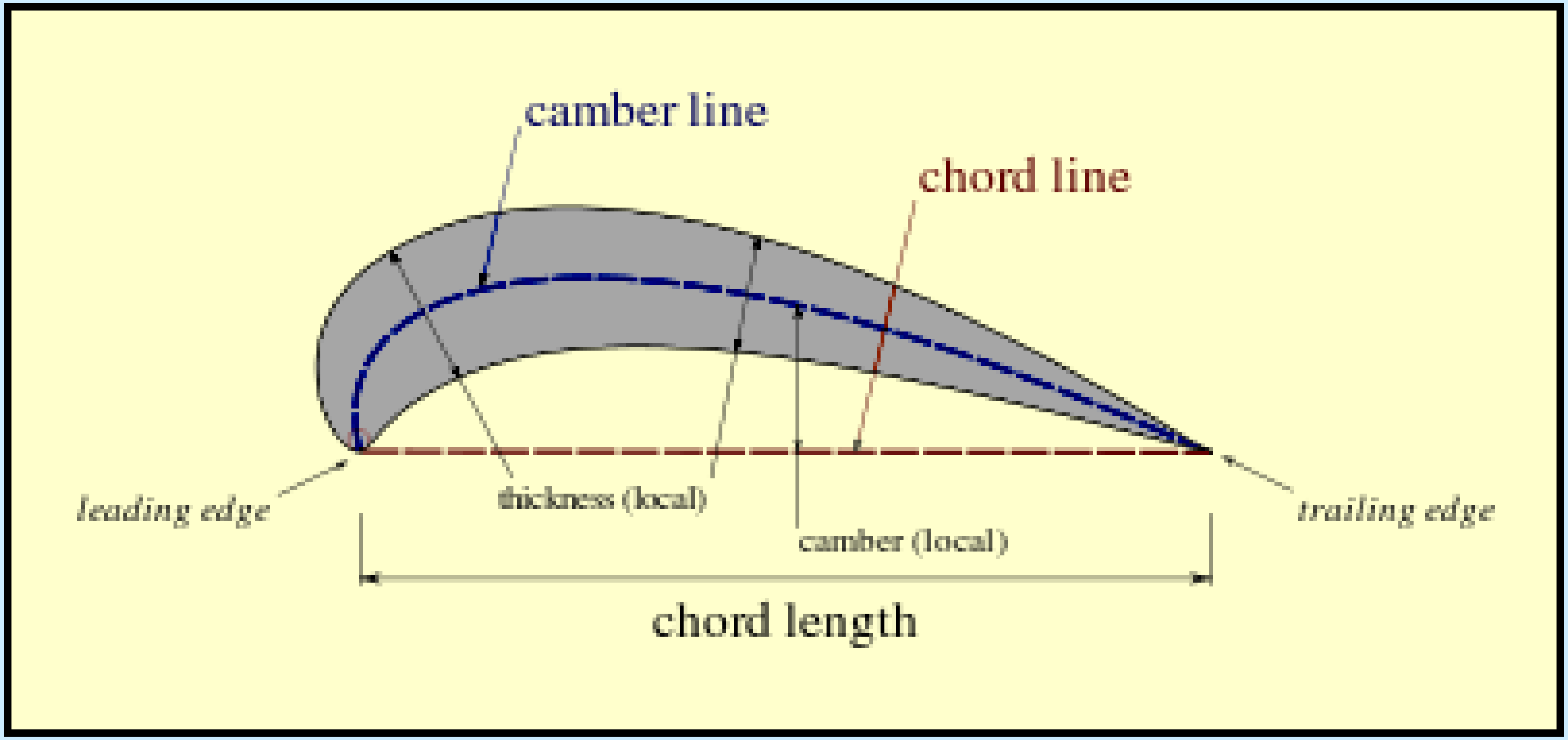
It is usually a circular and specified by radius as a percentage of the maximum thickness.

5-Trailing edge:

It is ideally sharp (zero radius) but as this is impossible . It is circular are specified as percentage of the maximum thickness.

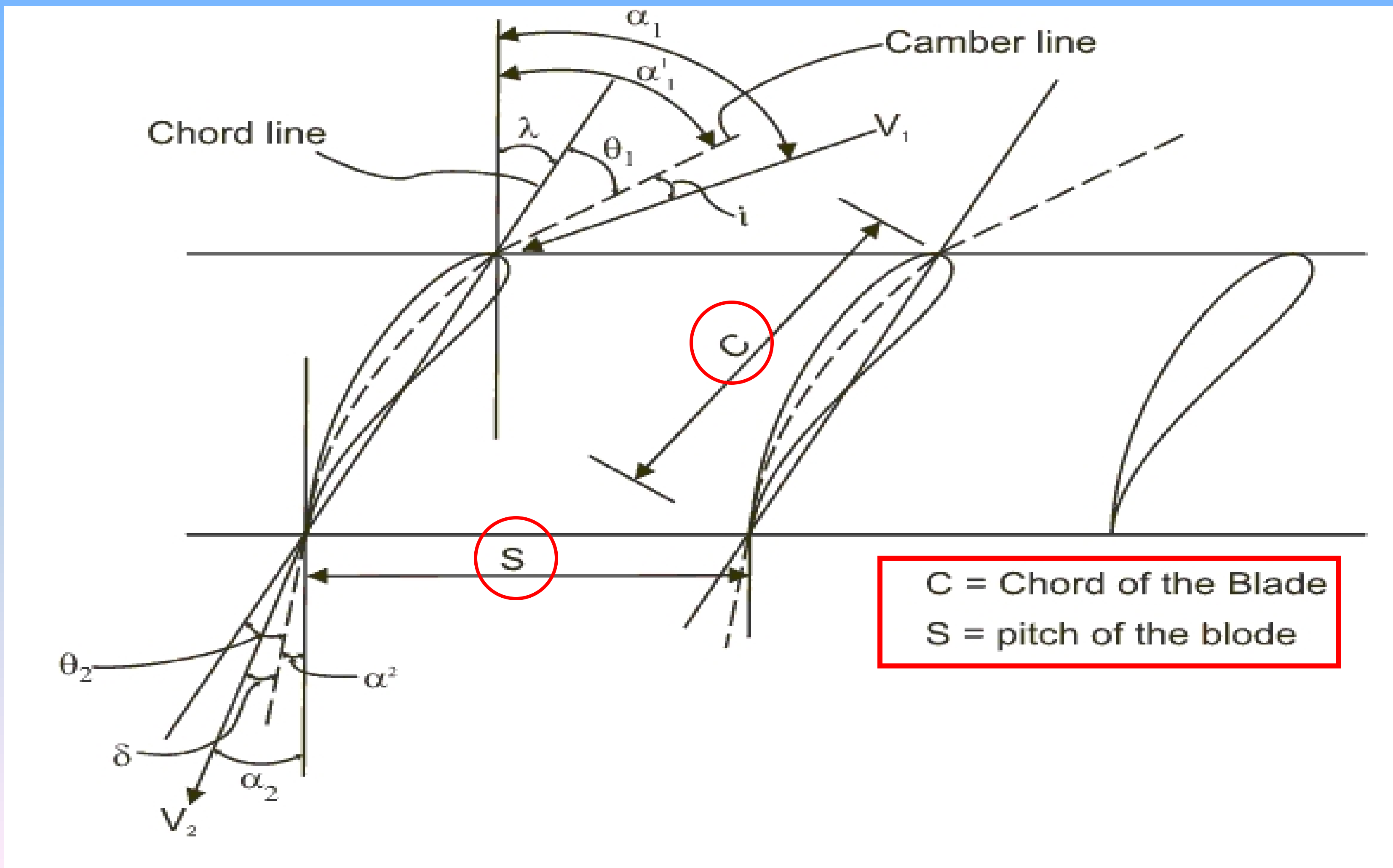
6- Camber line:

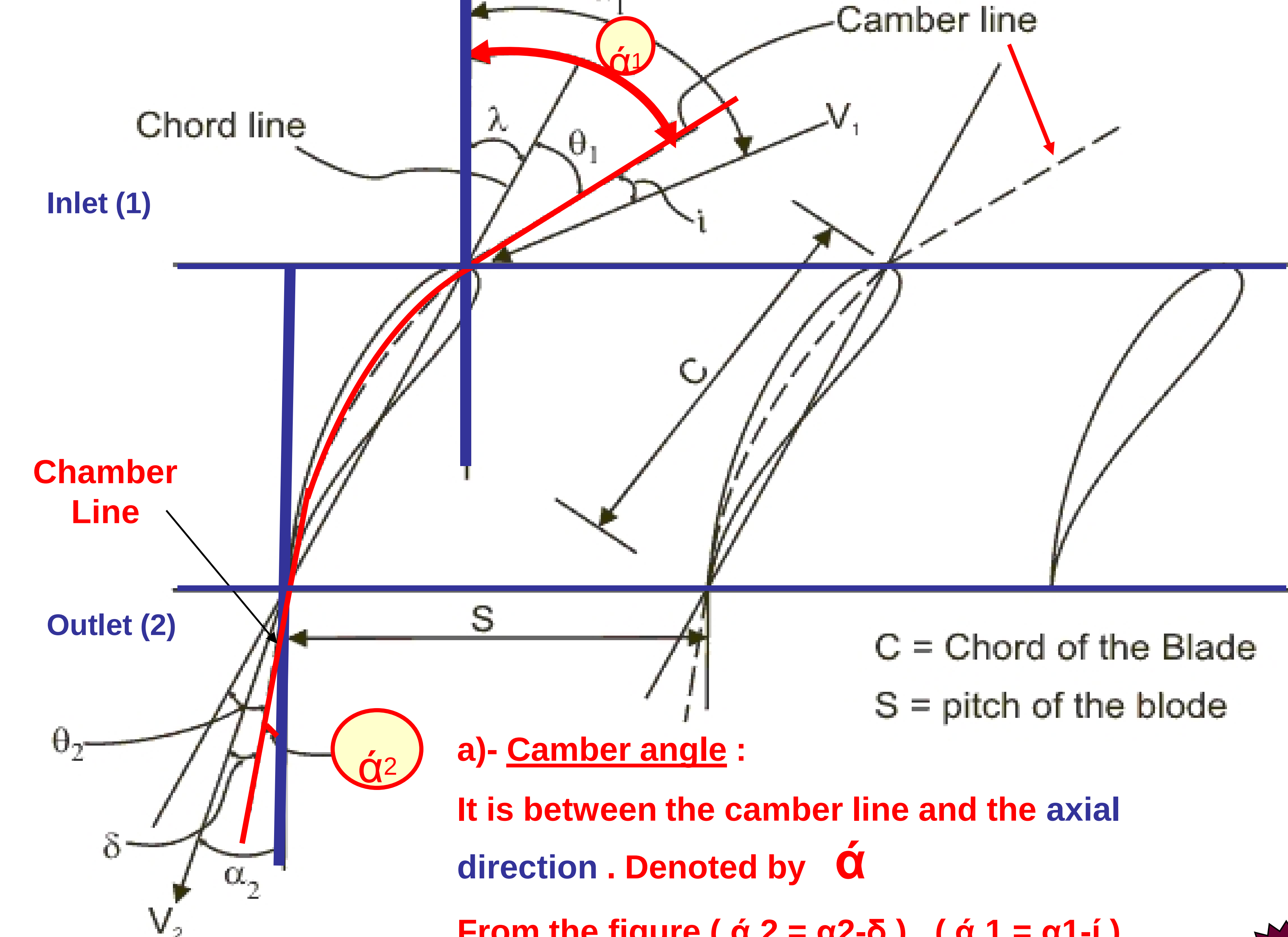
It is formed either by one or more circular arc or one or two parabolic arcs its geometrically simple



Compressor cascade nomenclatures

A <u>cascade</u> is a row of geometrically similar blades arranged at equal distances from each other and aligned to the flow direction

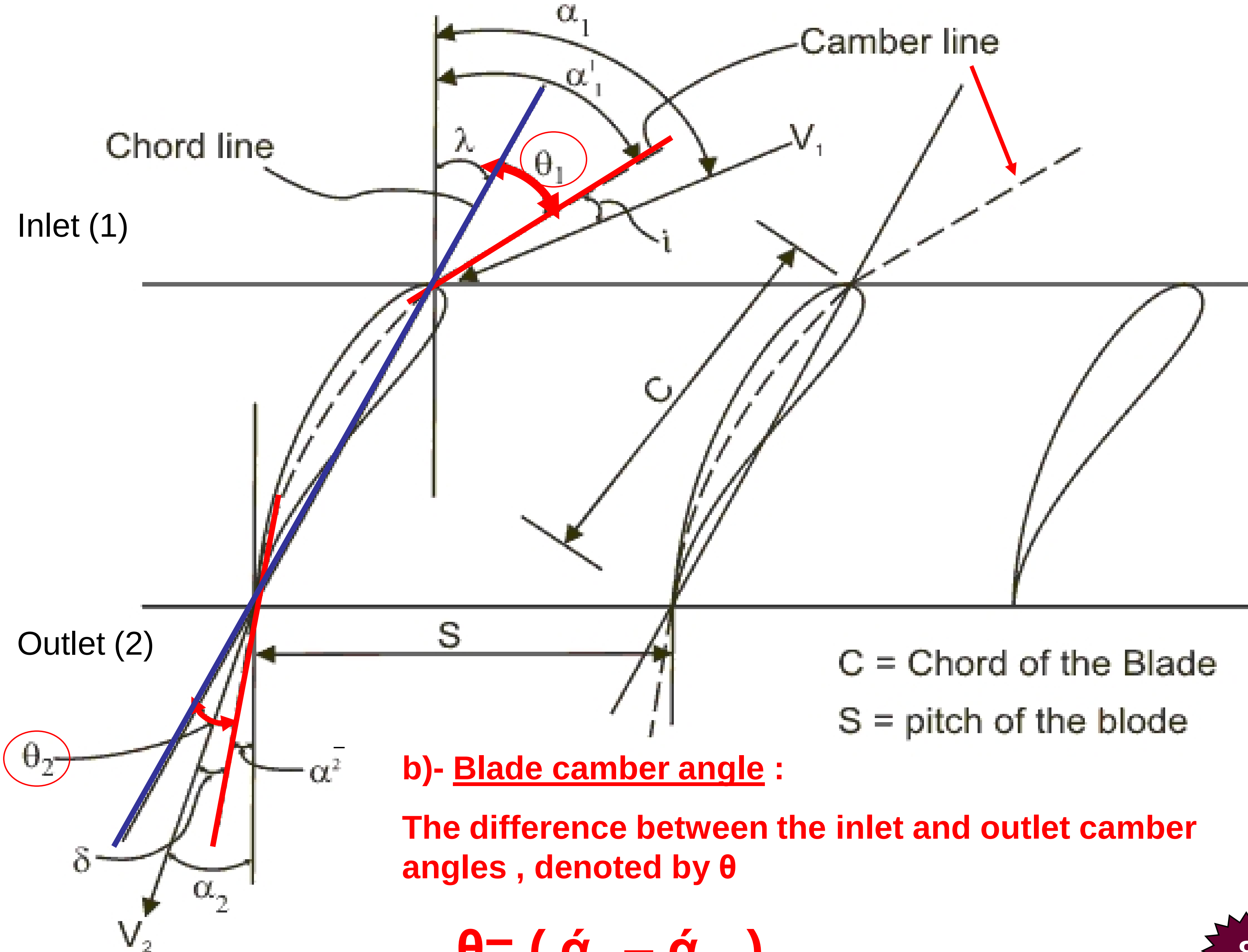




a)- Camber angle :

It is between the camber line and the axial direction . Denoted by ά

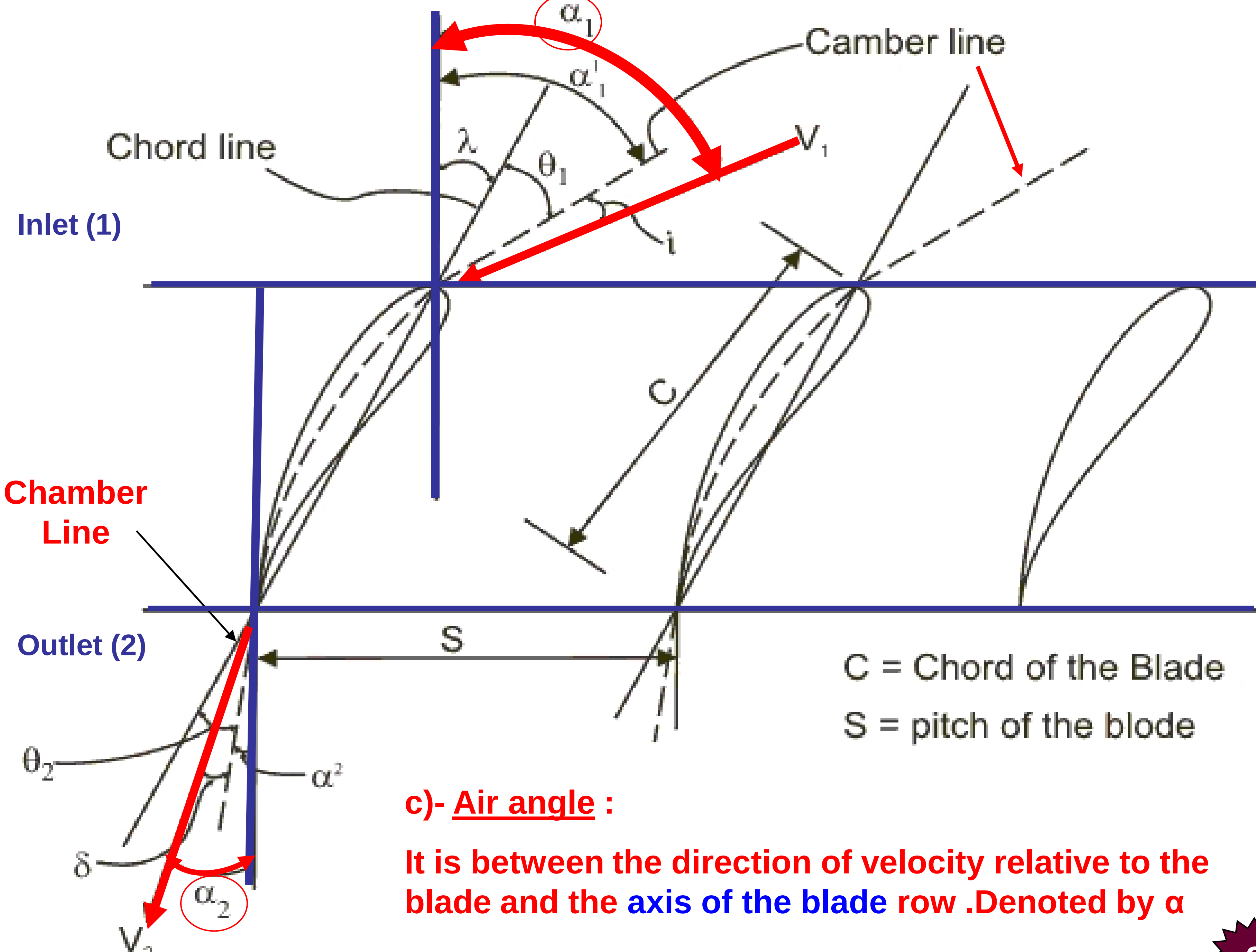
From the figure (ά 2 = α2-δ) , (ά 1 = α1-í)



b)- <u>Blade camber angle</u> :

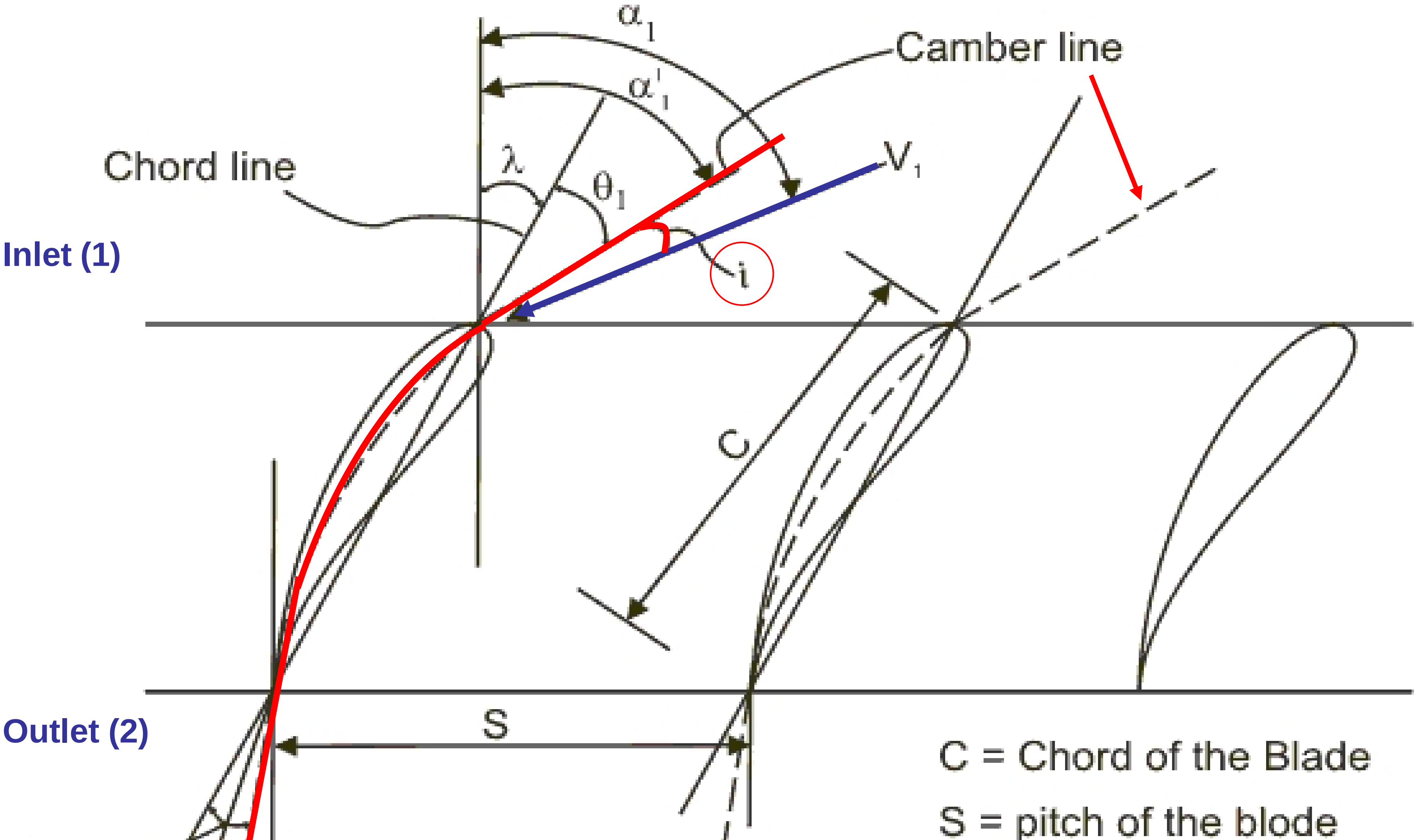
The difference between the inlet and outlet camber angles , denoted by θ

$$\theta = (\acute{\alpha}_1 - \acute{\alpha}_2)$$



c)- <u>Air angle</u> :

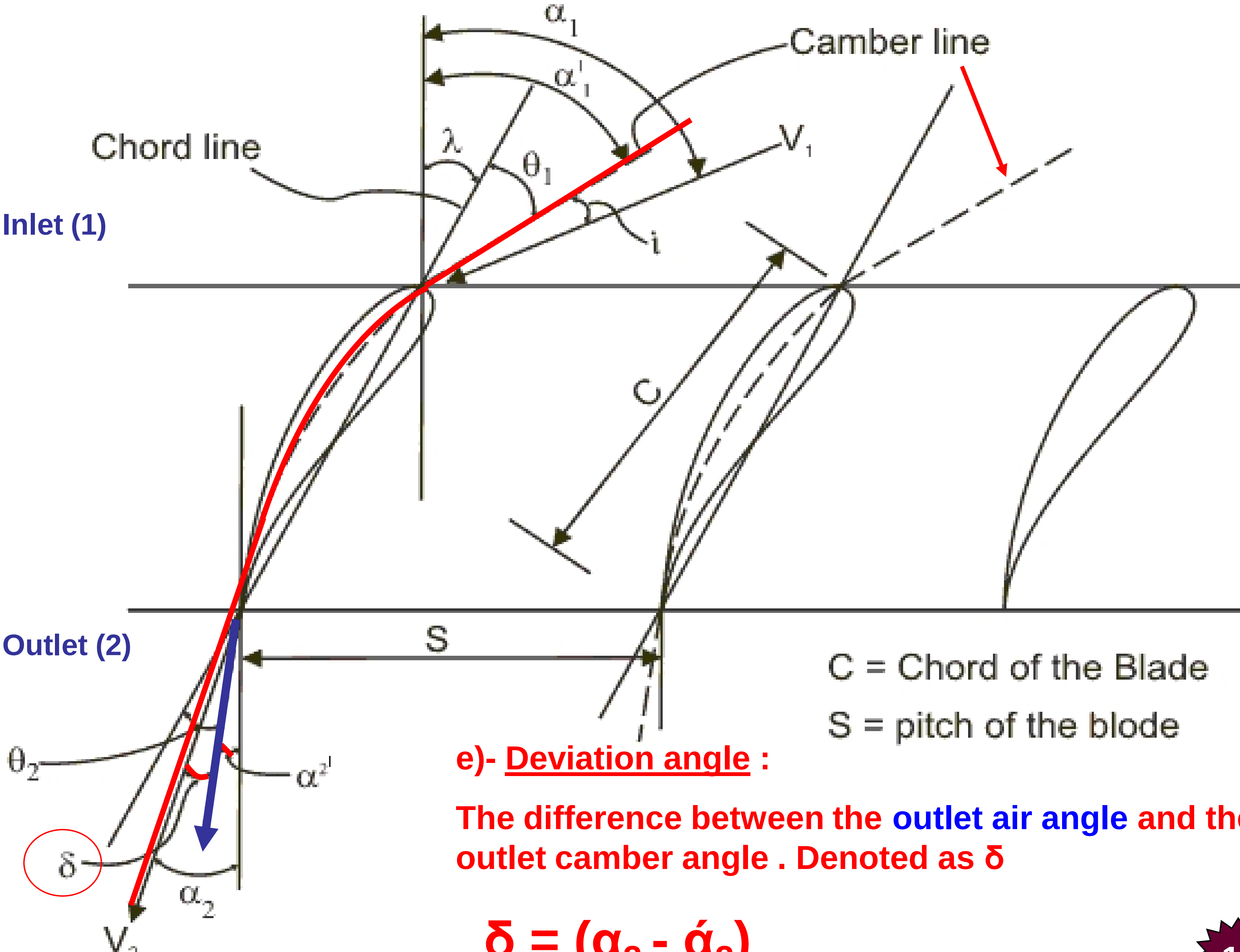
It is between the direction of velocity relative to the blade and the axis of the blade row .Denoted by α



d)- <u>Angle of incidence</u> :

The difference between the inlet air angle and the inlet camber angle .Denoted as i

$$i = (\alpha_1 - \acute{\alpha}_1)$$



e)- <u>Deviation angle</u> :

The difference between the outlet air angle and the outlet camber angle . Denoted as δ

$$\delta = (\alpha_2 - \acute{\alpha}_2)$$

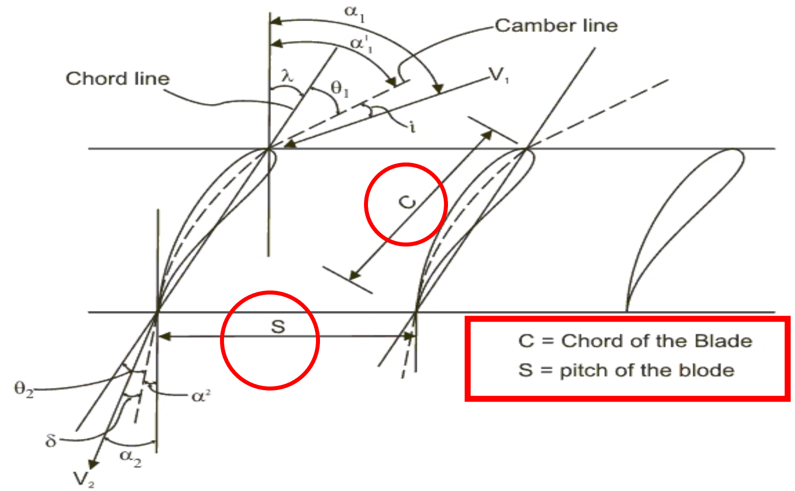
δ is given by the empirical relationship

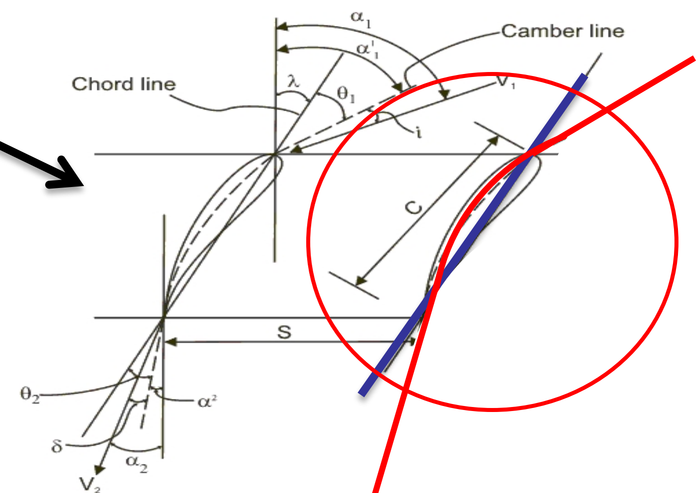
$$\delta = m\,\theta\,(s/c)^{0.5}$$

$$m = 0.23(2a/c)^2 + 0.1(\alpha_2/50)$$

A= is the distance **along the chord** to the **point of maximum camber**.

s/c = Pitch-chord ratio





Note: When assume **zero incidence**

1- this value **$(2a/c)^2$= (1)** for a circular arc camber line

2- That cascade air angle is equal to the compressor relative air angle . That is **$\alpha_1 = \beta_1$** & **$\alpha_2 = \beta_2$**

3- **$\acute{\alpha}_1 = \alpha_1$**

f- Air deflection angle :

The difference between the inlet air angle and the outlet air angle is denoted as ε

$\varepsilon = \alpha_1 + \alpha_2$ for the turbine

$\varepsilon = \theta + i - \delta$ for the compressor

Not:

1- The blade camber angle for the turbine is defined :

$\theta = (\acute{\alpha}_1 + \acute{\alpha}_2)$ as the sum of inlet and out let camber angle

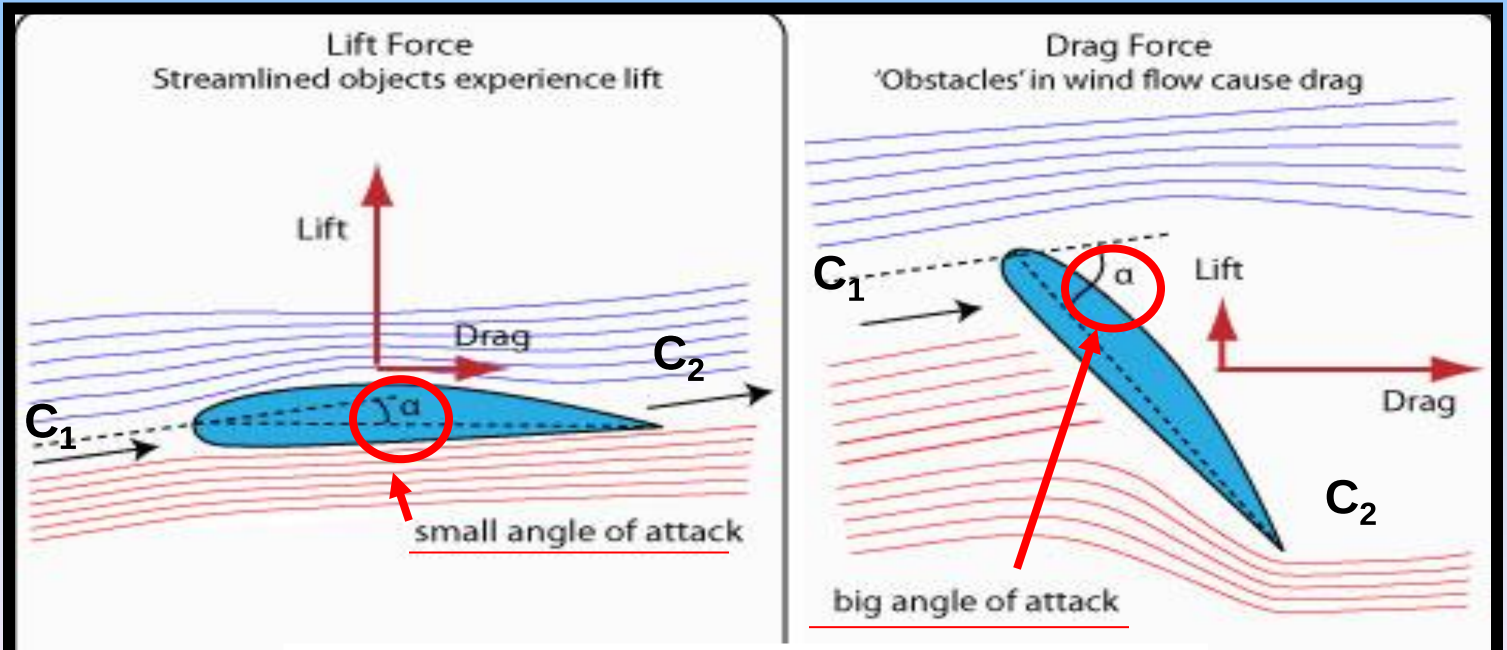
2- **$i = (\alpha_1 - \acute{\alpha}_1)$ is the same in compressor or turbine .**

3- **$\delta = (\acute{\alpha}_2 - \alpha_2)$ for the turbine**

(Drag & Lift)-Force

- The lift is due to an unbalanced force (pressure distribution is denoted as (L)

- The drag is due to the shearing stress at , the surface and the consequent boundary layer. The drag force is made up of a friction drag and is denoted as (D)



the forces of lift and drag on turbine blade

Lift and Drag Coefficients

C_l = Lift coefficients is a measure of the ability of a given section to support a weight when caused to move through a fluid , as in the case of aeroplane wing.

$$C_L = \frac{L}{(0.5\ \rho W^2_m A)}$$

Drag coefficient is a measure of the loss of energy associated with the useful task of producing lift .

$$C_D = \frac{D}{(0.5\ \rho W^2_m A)}$$

Not.

W_m =Mean relative velocity .

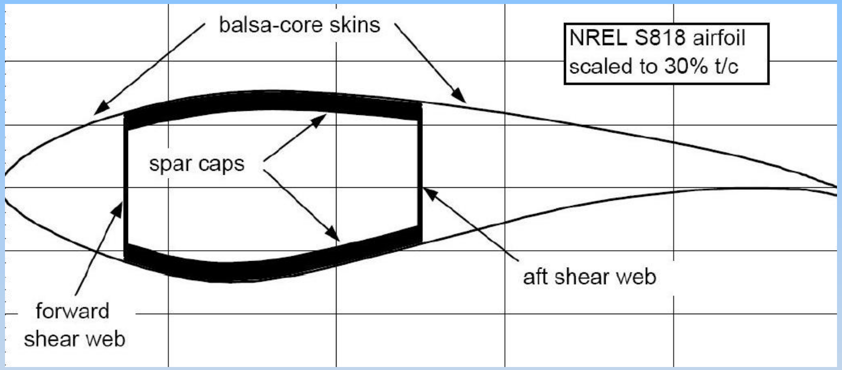
A=Area of the body.

0.5= factor.

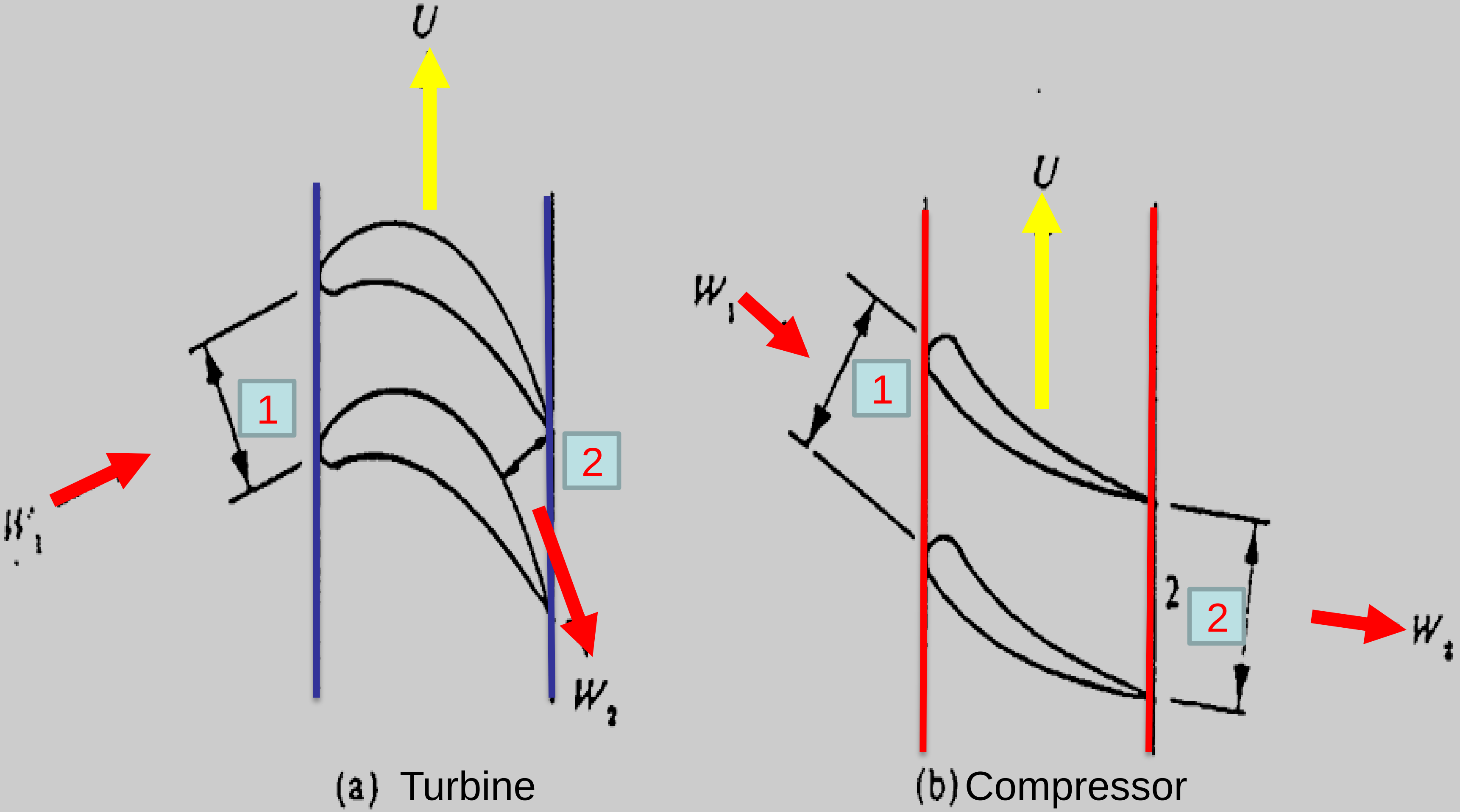
$0.5\ \rho W_m^2$= Dynamic Pressure.

The condition for a blade section should attempt to approach those for laminar flow over a flat plate , as this gives the lowest possible drag coefficient. But it is difficult to a chive this in practice , because :

1. Blades must have the curvature to change the direction of the fluid , introducing a pressure gradient and a tendency for flow separation.



2. Blades must have a finite thickness from consideration of strength.
3. The fluid has a high turbulence level.



Q: Compare between the turbine and compressor blade passage

W1&W2=Velocity Vectors **U= The impeller tangential velocity**