RESEARCHES CONCERNING THE IMPACT OF A HIGH SPEED JET ON A VARIABLE ANGLE

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Abstract: In the present paper the depths and the forces per unit width that the rigid surface exerts against the jet are calculated. The FLUENT simulations are presented too.

Keyword: High speed jet, variable angle, streamlines

1. INTRODUCTION

The high-speed two-dimensional jet shown in the sketch strikes a rigid horizontal surface and divides in two. The velocity V_1, the jet dimension, B_1 and the angle θ are known. We will calculate the depths B_2 and B_3 and the force per unit width that the rigid surface exerts against the jet. Both gravity and tangential boundary stresses will be neglected, figure 1.

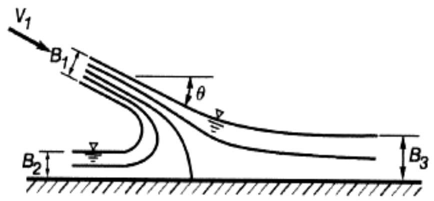

Figure 1. The work's scheme

Since velocities are assumed to be large, application of the two free streamlines shows that the velocity magnitude equals V_1 at every point on both free streamlines. Thus, the uniform velocities at cross section 2 and 3 both have magnitudes of V_1, and an application of the continuity equation to a unit width control volume gives

$$-V_1B_1 + V_1B_2 + V_1B_3 = 0 \quad (1)$$

Division by V_1 gives the following equation width unknown values of B_2 and B_3:

$$B_2 + B_3 = B_1 \quad (2)$$

Since gravity has been neglected, we can dot both sides of equation

$$-\frac{1}{\rho}\nabla p + g + \nu\nabla^2 V = \frac{DV}{Dt}$$

(where ν are kinematics viscosity; $V=V(x, y, z, t)$; x, y and z, are coordinates of the particles are all functions of t) width e_n is normal to the straight, parallel streamlines. Because the directional derivate

$$V = \nabla\Phi$$

(where Φ are the gradient of a velocity potential function) allows this result to be written as

$$\frac{dp}{dn} = 0 \tag{3}$$

Since this shows that p is not changing in a direction normal to the streamlines, and since $p = 0$ on each of the two free streamlines, we see that $p = 0$ across each of the three cross section 1, 2 and 3. Thus, the only force acting on the control volume of fluid is a normal pressure force exerted by the rigid horizontal surface, as shown in the following free body diagram, figure 2:

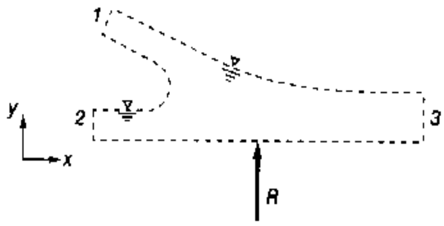

Figure 2. Free body diagram

2. AN APPLICATION OF THE MOMENTUM EQUATION

$$Rj = \rho(V_1 \cos\theta i - V_1 \cos\theta j)(-V_1 B_1) + \rho(-V_1 i)(V_1 B_2) + \rho(-V_1 i)(V_1 B_3) \tag{4}$$

Dotting both sides of this vector equation with i and then j gives the following two scalar equations:

$$0 = \rho V_1^2 B_1 \cos\theta - \rho V_1^2 B_2 + \rho V_1^2 B_3 \tag{5}$$

$$R = \rho V_1^2 B_1 \sin\theta \tag{6}$$

The second equation gives the required force per unit width, and the first equation can be solved simultaneously with $B_2 + B_3 = B_1$ to obtain

$$\begin{aligned} B_2 &= (1-\cos\theta)B_1/2 \\ B_3 &= (1+\cos\theta)B_1/2 \end{aligned} \tag{7}$$

For a partial check on these results, we see that $B_2 = B_3 = B_1/2$ when θ = π/2 (which must be true from considerations of symmetry) and that $B_2 = 0$ and $B_3 = B_1$ when θ = 0.

3. FLUENT SIMULATIONS

The simulations are made for an air fluid 10 m^3/s flow rate and for the variable angle for the plan surface.

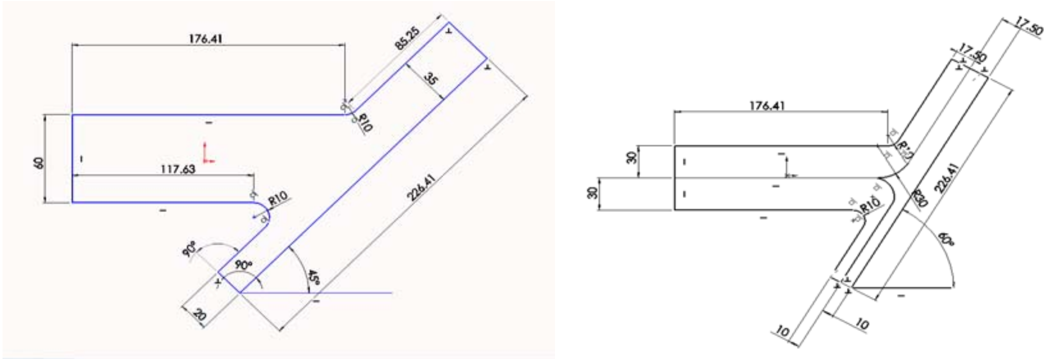

Figure 3. Work's schemes

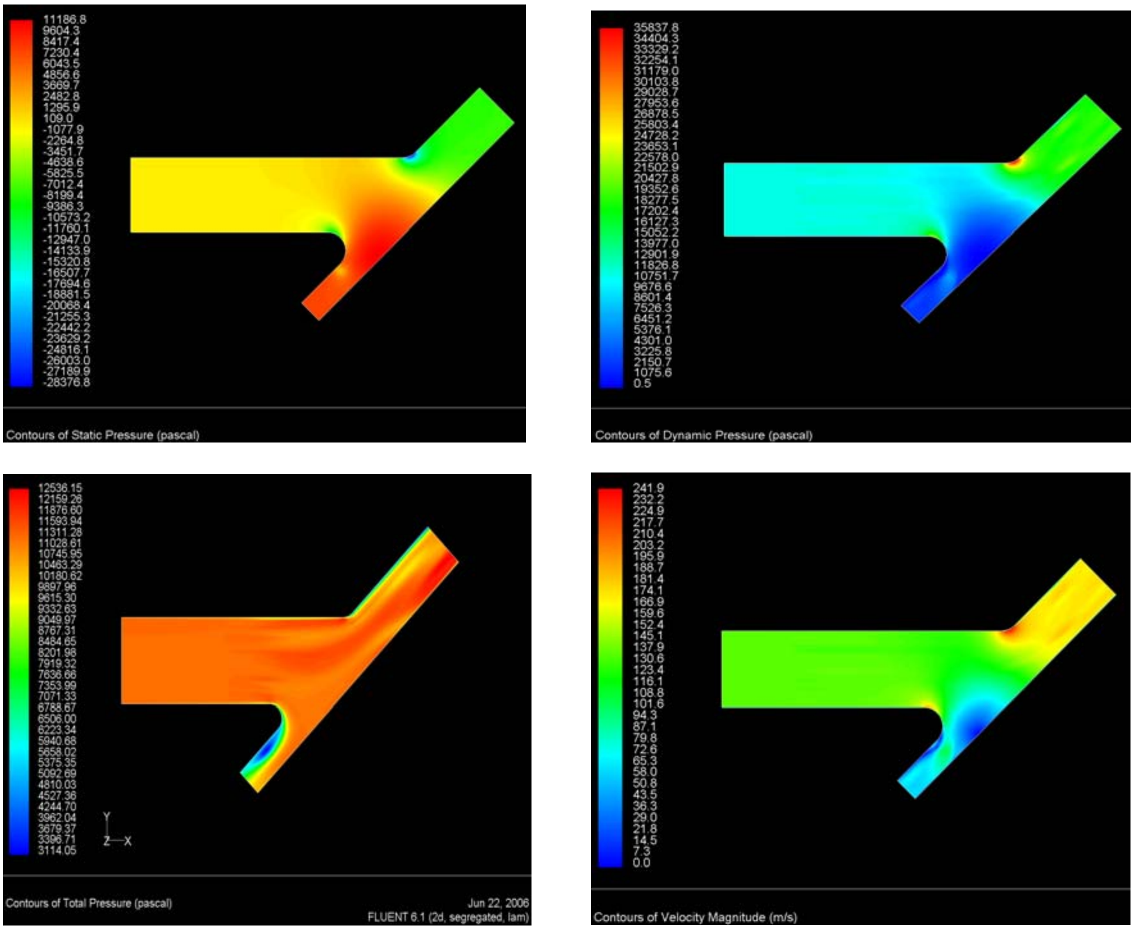

Figure 4. The FLUID simulations for a 45^{o} angle

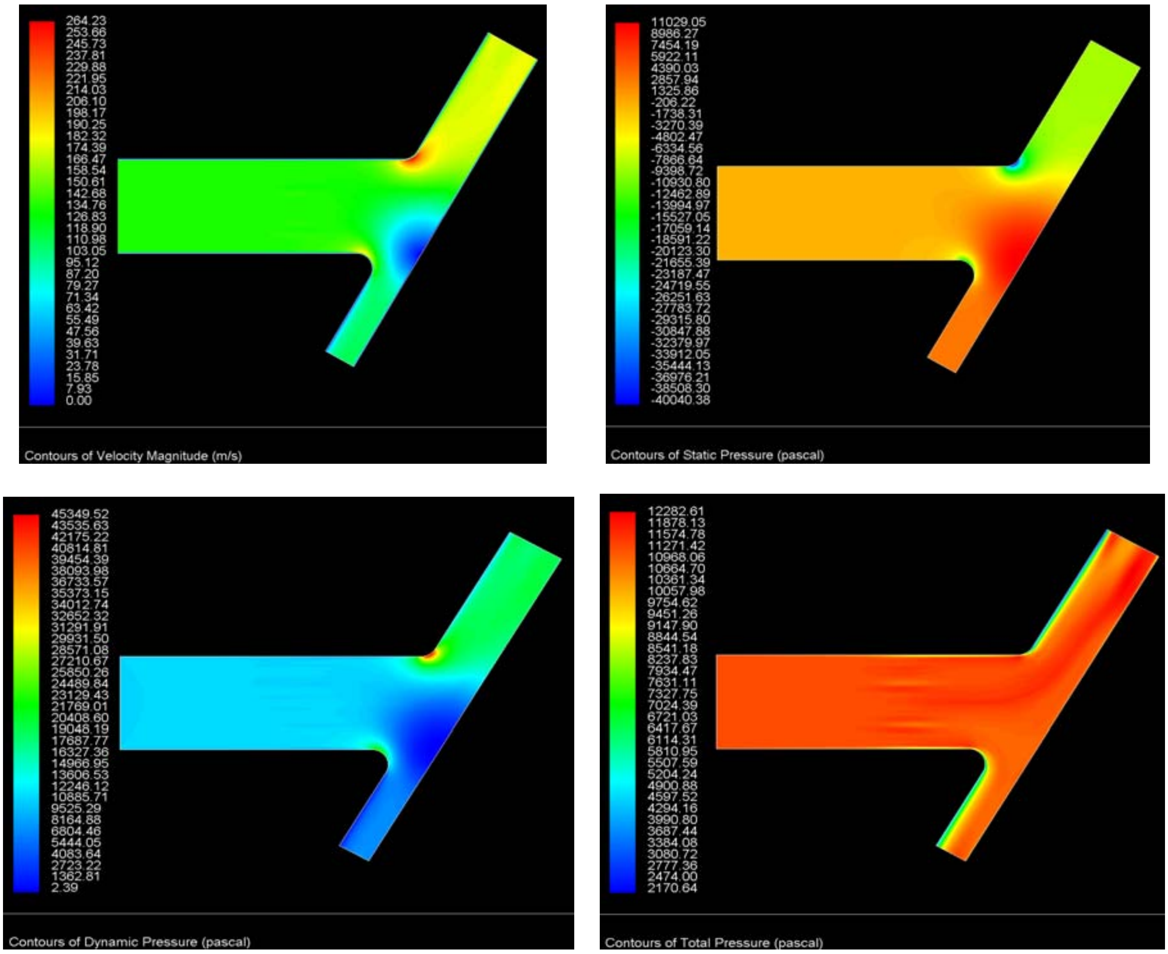

Figure 5. The FLUID simulations for a 60^{o} angle

4. CONCLUSION

Studding figure 4 and 5 it is shown that:

1. the different variations for the pressure distributions (statically, dynamically and total) under the plane surface contact with the high speed flow;
2. the different variations for the particle velocities in the field of the moving fluids;

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