Particle Tracing in a Micromixer

1)Important Info's: -

➔*Micromixers can either be static or dynamic depending on the required mixing time and length scale.*

➔ *For static mixers, the Reynolds number has to be suitably high to induce turbulence-enhanced mixing. Often micromixers operate in the laminar flow regime due to their small characteristic size.*

➔ *The diffusivity of a solute in the flowing fluid may also be extremely small, on the order of* 10^{-10} m^2/s. *One way to alleviate this problem is to add mixing elements to induce vorticity into the flow.*

➔ *Dynamic mixer uses rotating blades to enhance the mixing process, allowing for smaller-scale devices. The one big disadvantage of a dynamic mixer is that moving parts are required.*

2)Model info's: -

➔*Particles enter the mixer through 3 Inlet features and exit through the Outlet feature. The particles enter the modeling domain through the inlets in a continuous stream.*

➔*New set of particles is released every **50 milliseconds** for a total duration of one second. After this, no more particles are released but the model is solved for an additional second.*

➔*For each release inlet and each release time, 50 particles are released with an initial velocity equal to the fluid velocity, so a total of **3 × 21 × 50 = 3150** particles are released.*

➔*The blades are rotating at a constant angular velocity of **1 revolution per second** in the **anti-clockwise direction***

3)Physics and Equations: -

➔*The particles obey Newton's second law: where*

$$\frac{d(mpV)}{dt} = F_t$$

- *m_p (SI unit: kg) is the particle mass,*
- *v (SI unit: m/s) is the particle velocity, and*
- *F_t (SI unit: N) is the total force on the particle.*

➔*In this example, the total force is dominated by the Drag Force F_D, for which Stokes's law is where: -*

$$F_D = 3\pi\mu d_p(u-v)$$

- *u (SI unit: m/s) is the fluid velocity,*
- *μ (SI unit: Pa s) is the fluid dynamic viscosity, and*
- *d_p (SI unit: m) is the particle diameter.*

➔*In addition to the drag force, the optional virtual mass force F_{vm} and pressure gradient force F_p on the particle can also be considered. These forces are defined as*

$$\boldsymbol{Fvm = \frac{1}{2} mf \frac{d(u-v)}{dt}}$$

where m_f (SI unit: kg) is the mass of the fluid displaced by the particle volume, and ρ (SI unit: kg/m^3) is the density of the fluid.

$$\boldsymbol{mf = \frac{1}{6}\pi dp3\rho}$$

➔ *The virtual mass and pressure gradient forces can usually be neglected when the density of the particle phase is much greater than the density of the fluid phase, as is true for solid particles in a gas.*

➔ *The particles make their way normally inward from the inlets and, like the fluid velocity, begin to assume a parabolic profile.*

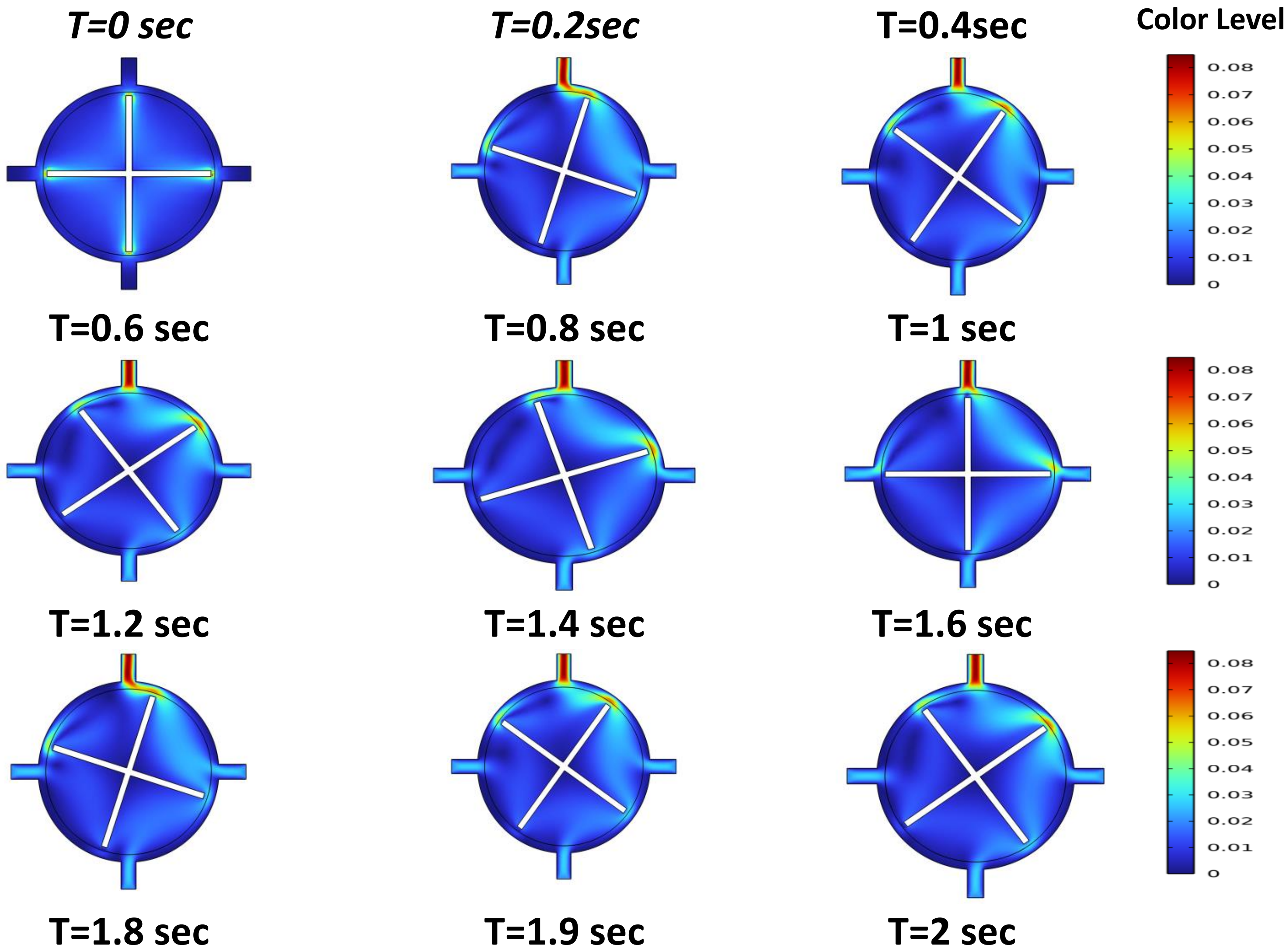
➔ *The particles entering from the left (the blue particles) are then swept downward due to the presence of the rotating blades. However, a few of these particles released at later times actually go clockwise, depending on the exact position of the blades when they first enter the mixer.*

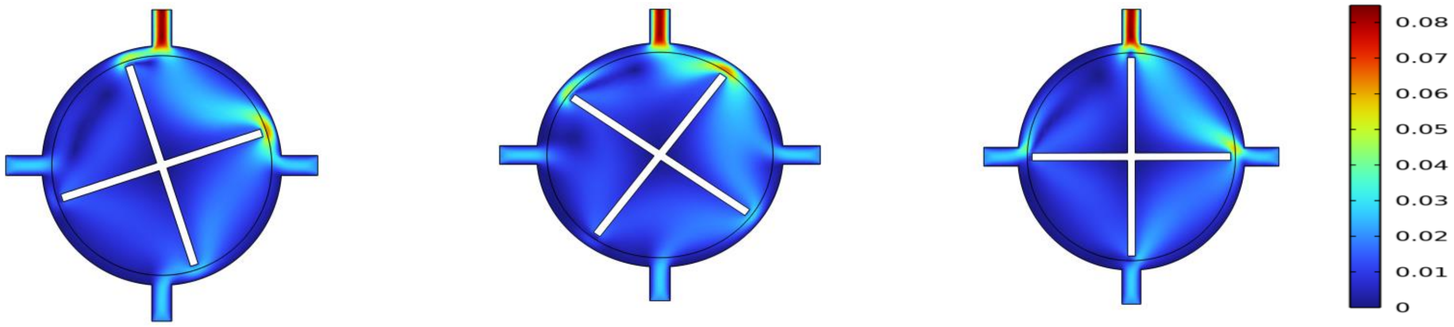
➔ *The particles entering from the right (red) are swept upward, but some of the particles go past the outlet because of the momentum they gained from the surrounding fluid. At about 0.6 seconds, particles from the bottom inlet (green) begin to reach the outlet as well.*

➔ *Mixing of the three particle streams continues even after new particles stop entering the domain at 1 s. This is because liquid continues to flow in from all of the inlets after the particle stream is terminated, and because the mixing blades continue to rotate.*

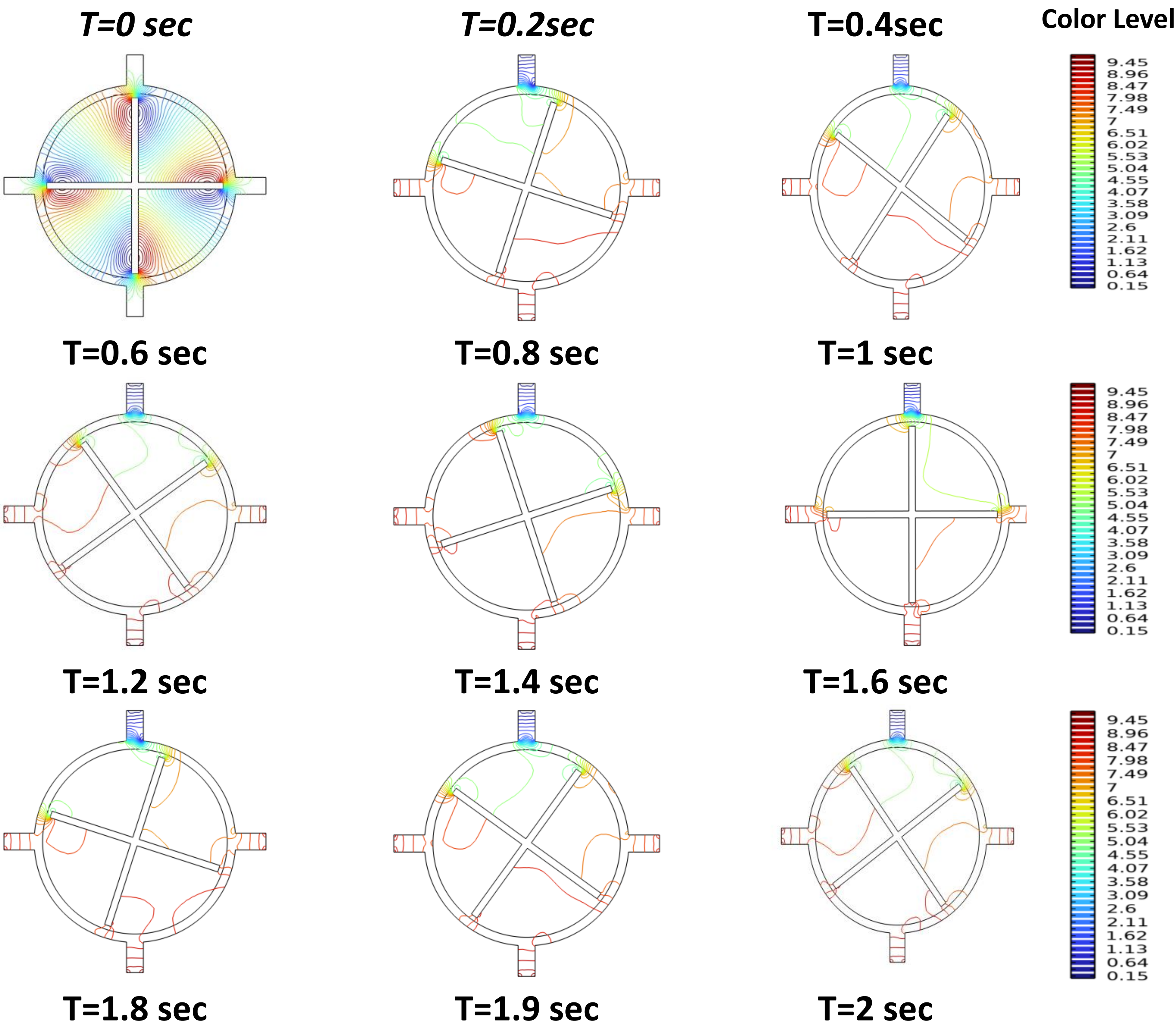
<u>2)Results:-</u>

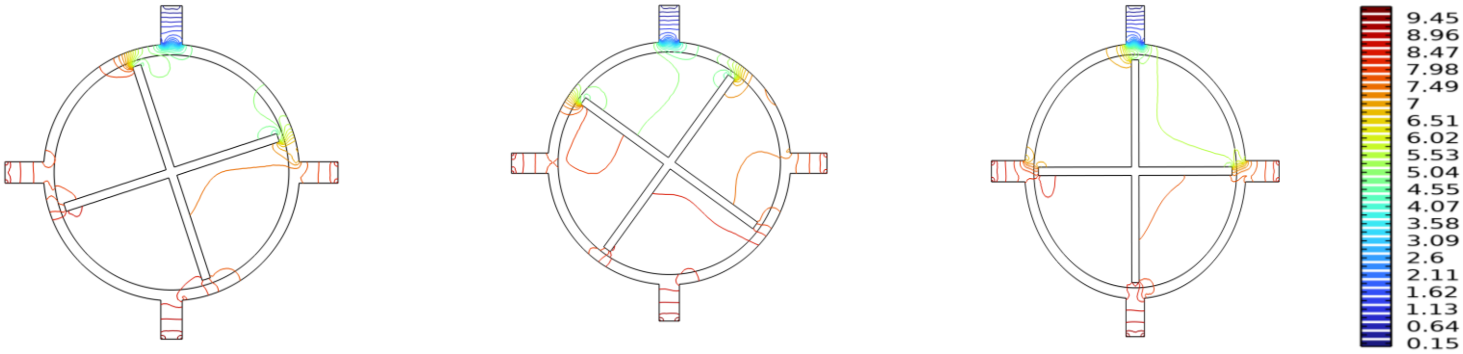
➔*Velocity Field Plot: -*





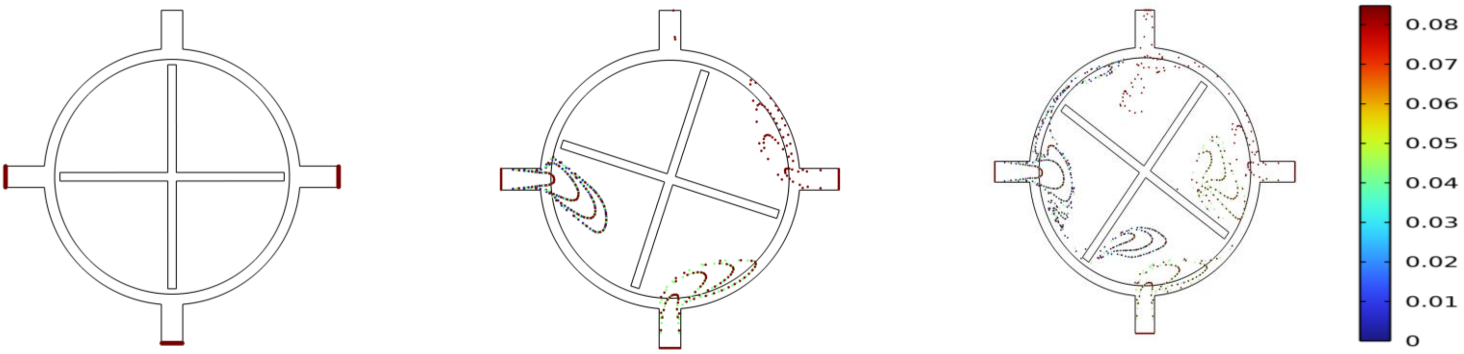
➔**Pressure (Contour)plot: -**



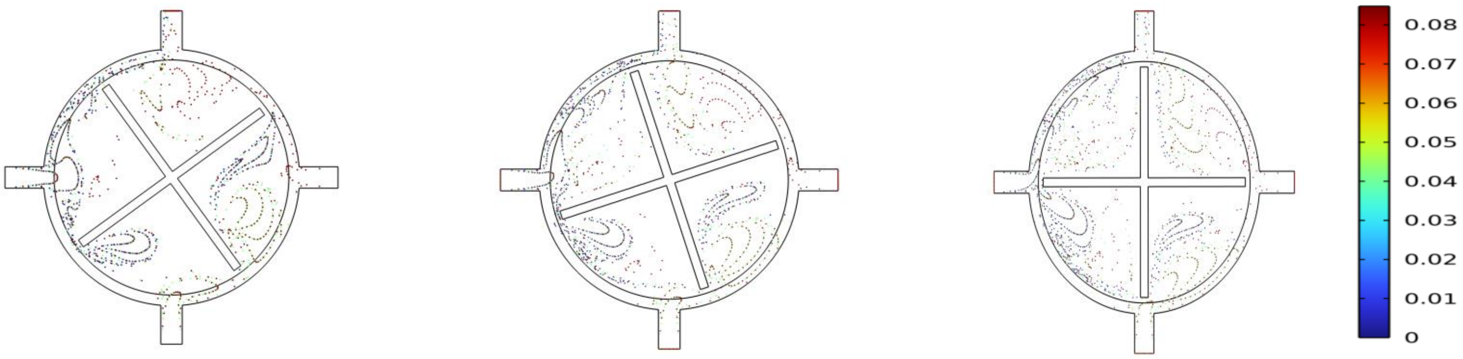


➔Particle Trajectories plot: -

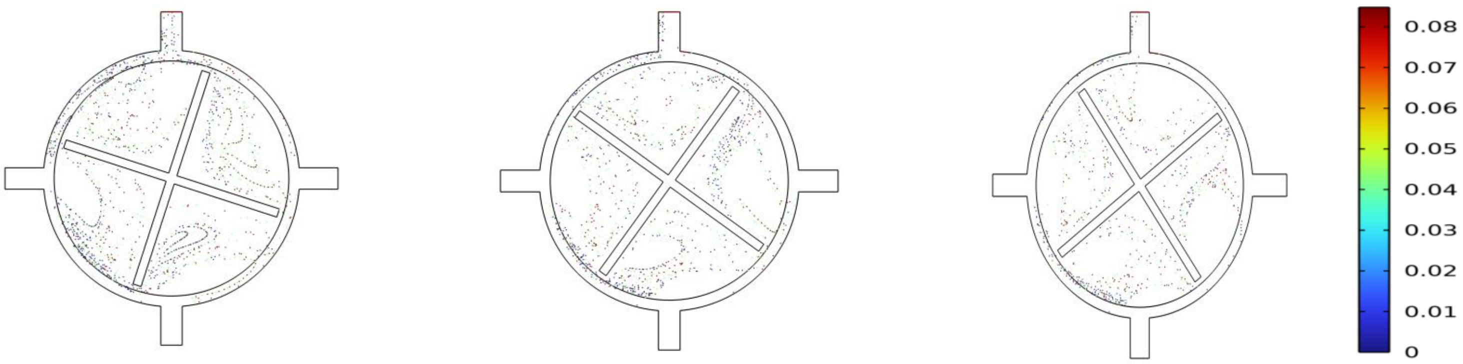
T=0 sec	*T=0.2sec*	T=0.4sec	Color Level



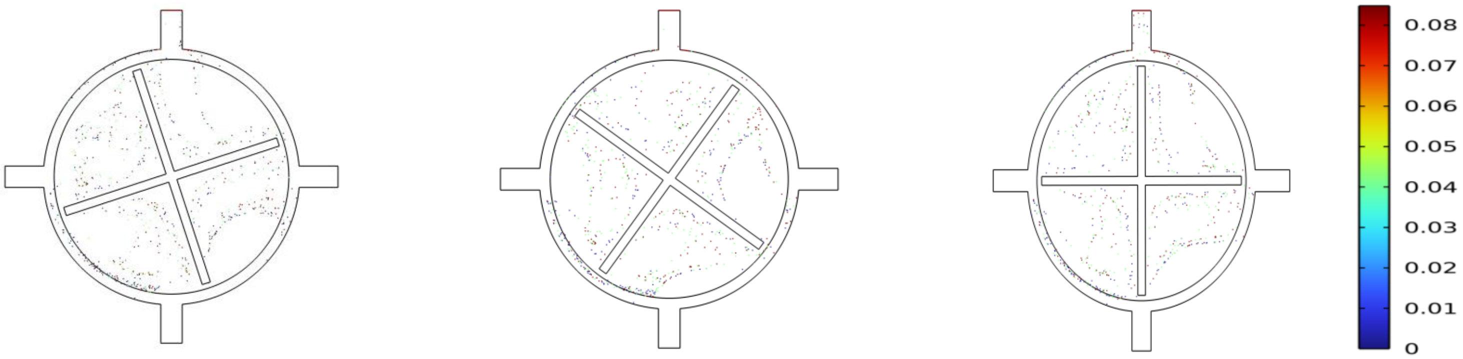
T=0.6 sec **T=0.8 sec** **T=1 sec**



T=1.2 sec **T=1.4 sec** **T=1.6 sec**



T=1.8 sec **T=1.9 sec** **T=2 sec**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