Standing Waves (Fluid and Sound) of Transition

Fluttering handbreadths for students studying shear waves of transition
Extend your right hand out in front of you, with the fingers and thumb extended horizontally (as you would lay the hand on a table), creating one handbreadth.

Imagine holding it just above a simple harmonic (SH) corrugated panel, the rigid long crested SH waves transverse to the handbreadth. The distance from mid wave crest to mid trough is one handbreadth, the lateral margin of the thumb touching the mid wave crest and the lateral margin of the 5th finger touching the mid trough.

Now imagine the hand moving ("flowing") horizontally just above the corrugated surface at a steady rate, with the thumb and 5th finger fluttering up and down as they trace the contours of the SH wavy surface. The handbreadth will be oscillating like a seesaw – its fulcrum in the mid-wrist, moving in a horizontal plane.

If the left hand is held similarly, with the left thumb remaining in contact with the right thumb and with the horizontal hands moving together at the same steady pace, the hands will be oscillating coherently, each hand 180 degrees out of phase.

If you now look at the joined hands, they will be oscillating (fluttering) like a standing wave in a skipping rope, with loops at both ends (where the rope is being activated by the holders' hands) and a loop in the middle. The wavelength of the standing wave would be twice the distance from loop to loop. In the case of the handbreadths, a wavelength would be two handbreadths (two joined seesaws).

The fluttering up and down movement of the thumb and 5th finger would create SH vibrations (coherent sound) perpendicular to the steady horizontal movement (flow). Because standing wave sound is propagated in all directions from the sound source, there will be a horizontal coherent standing wave component directed along the corrugated surface (boundary), with the standing wave sound generator (the seesawing hands) moving as a travelling wave at the speed of the fluttering hands. Thus we have physical standing waves in the two handbreadths – and we have standing wave sound generated by the fluttering up and down seesaw movement.

Fluttering fluid waves of transition If now we consider laminar flow along a boundary as occurring in brick-shaped blocks of fluid with lengths equal to the distance from crest to trough of the SH shear waves that will develop during transition.

Replace the two hands (that are just above a smooth boundary) with two brick-shaped blocks of water flowing at a pre-transition laminar flow rate. The lengths of the virtual bricks bear the same length relationship to the SH boundary oscillations that will appear as transition onsets. The bricks will be rectangular at the instant when transitional waves appear, but will mold to the contours of the developing shear waves, oscillating up and down at the rate of flow, creating the same fluid waves and sound waves as described above with the two handbreadths. Diminishing the fluid block thickness to the thickness of a lamina will show how a laminar sheet flows along in the boundary layer, snaking (fluttering) up and down, creating transverse standing wave sound that is also propagated along the boundary at the rate of flow (a traveling wave).

The SH wavy paths slide along a smooth shiny boundary at a steady rate, but much slower than the fluid lamina which snakes along with SH rhythmicity at the rate of flow of the lamina.

The flowing water is incompressible; therefore adjacent laminae stay in contact, with layered blocks flowing in-phase as the distance from the boundary increases. The liquid forming the laminae can neither converge nor diverge. This shows that the Schubauer and Skramstad concept of divergence and convergence of laminae (which is possible in air) is impossible with liquids. As a corollary, the liquid cannot separate from the boundary, under the crests (without cavitation) – nor can there be compression where the waves' troughs meet the boundary. There must be SH liquid waves on the boundary, under the wave crests. Thus, transition's SH boundary layer flutter (BLF) waves are accompanied by sub-BLF SH waves.

Although the flutter waves are moving at the rate of flow (in each individual lamina), the simple harmonic wavy paths – and the sub-BLF waves on the boundary) are sliding along the boundary at a steady rate that is much less than the speed of flow.

The wavy paths, along which the BLF waves flow, become stationary when the boundary is compliant (sand, snow, dolphin epidermis) and the sub-BLF waves are replaced by stationary compliant boundary waves (CB waves).

When the boundary is compliant and is another fluid, the compliant boundary waves (CB waves) are moved along by viscosity entrainment, moving much slower than the flowing fluid creating the shear waves. This is the nature of waves that form in water in the wind and in air strata in the sky. Because of the standing wave nature of the long crested air waves, they can derive increasing energy and amplitude from the flow, allowing the air waves to indent the surface of the much more dense water. Air flow viscosity forces cause the slow movement of surface water and the entrainment of the surface water, creating long columnar rotational water movement under the water wave crests; these rolling columns under the wave crests arch over and crash on the shore as the lower margins are slowed as they intersect the sandy bottom in shallow shore water, accounting for the term "rollers" in older English literature and lyrics to describe wind-induced waves that break on the seashore.

Thus, there are four types of standing waves generated by fluid shear: 1) BLF flutter waves (which create all others), 2) the SH wavy tracks along which the BLF waves flow, 3) sub-BLO waves along the boundary and 4) compliant boundary waves, which may be stationary (sand, snow, or dolphin epidermis), or steadily moving (in a fluid boundary or in a particle layer on a smooth shiny surface). The dominant BLF flutter waves are the source of the coherent standing wave sound.

Damping BLF waves and coherent sound waves will delay (or prevent) turbulence.