Shock Waves in Shallow Water on a Rotating Disk

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Shock waves occur in a supersonic gas flow when it decelerates: e.g., near a bullet or near a point where two supersonic flows intersect. An easy way to study compressible gas flows in a school lab is an analogy between gas dynamics and shallow water flow. Let a liquid jet fall onto a rigid horizontal surface. Near the collision area, there is a thin fast-flowing film. Its velocity is greater than waves speed, so the flow is “supersonic.” The flow decelerates due to viscous friction and drops down onto “subsonic” regime forming a “shock wave.” For liquid films, it is called hydraulic jump. The aim of this work is to study transmission between “supersonic” and “subsonic” flows. We affect deceleration of the former one by rotation of the rigid surface. Centrifugal force changes the momentum balance, and the shock wave goes away and entirely disappears if the rotation is fast enough. We obtained a scaling law for the critical rotation rate by dimension analysis and derived a system of ordinary differential equations governing the flow. An experimental setup was developed: liquid goes from a reservoir through a nozzle and falls vertically to the center of a horizontal disk which is rotated by a motor. We changed liquid properties – viscosity, surface tension, flow rate, and rotation rate. Analyzing a light reflection from the liquid surface, we restore its shape and determine the fact of jump existence, its position and structure. Our experimental results coincide with numerical simulations very well.