Acoustic impedance (z) – its relevance to shock propagation

- \( z = \rho \times a \) of a medium, where \( \rho \) - density and \( a \) - speed of sound.
- If \( z \) of two media is the same, shock wave would propagate through these media without any reflection.
- Tailored mode of operation is an example of the match of acoustic impedance between regions 2 and 3 of a shock tube.
- As the \( \rho \ll a \) in gases, magnitude of \( a \) is considered for the determination of the status of wave propagation at the interface.
The fraction of wave reflection due to mismatch of acoustic impedance between two media is given by the expression for $R$, where $R$ is the coefficient of reflection at the interface.

Coefficient of transmission, $T = 1 - R$.

Shock wave reflects as the wave of the same nature if the medium ahead of the interface is denser; and as the wave of the opposite nature if the medium ahead is of lower density.

- Non-tailored modes
Non-tailored modes-physics

• When \( a_2 > a_3 \): for a given shock speed, \( M_s \) could have increased in region 8, which could have resulted in a higher pressure in 8. To preserve pressure equality b/w 7 & 8, a shock wave reflects back into region 5. The shock in region 8 is slowed down.

• When \( a_2 < a_3 \): \( M_s \) could have decreased in zone 8 for the same shock velocity. To preserve pressure equality b/w 7 & 8, an expansion wave reflects back into region 5. The shock in region 8 is accelerated.
Problems to identify the possible wave systems generated due to collision of shock wave & contact surface.

Q1. A quick valve of a shock tube, filled with He on the driver side and air on the driven side opens suddenly, generating an incident shock wave of Mach 3. The driver gas was initially at a temperature and pressure of 300 K and 930 kPa, respectively. The driven gas initial conditions were 21 kPa pressure & 300 K temperature. Determine the wave system generated at the end of the tube when the waves interact with the contact surface.

Procedure: 1. For given $M_s$, find $T_2/T_1$ from the gas tables. Once $T_2$ is obtained, find $a_2$.
   2. Next objective is to find $a_3$.
      Find $p_2/p_1$ for given $M_s$; obtain $p_2$. Across contact surface $p_2 = p_3$.
   3. Analyze the driver side: Driver gas encounters an expansion fan. Any expansion (hypersonic/supersonic) is isentropic, as far as no chemical reactions.
      Find $T_3$ from isentropic relation: $p_4/p_3 = (T_4/T_3)^{\frac{\gamma}{\gamma-1}}$; $\gamma = 1.667$ for He.
      Find $a_3$. 
If $a_2 < a_3$

If $a_2 > a_3$