FILM COOLING USING TRENCHED HOLES

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Outline

- Introduction

Introduction

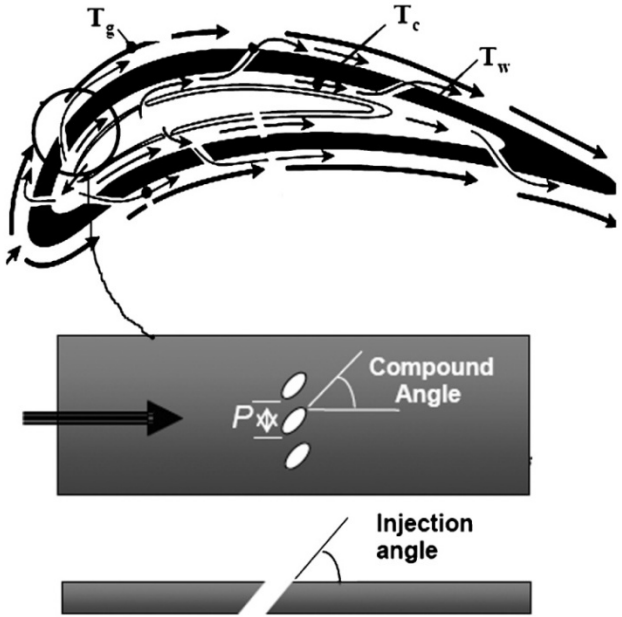
- Gas turbines are used for power generation
- Higher efficiency and power output is desirable
- Increase in gas temperature increases efficiency
- Airfoil encounters thermal stress
- Cooling of blades helps increasing maximum allowable temperature

Motivation and Objective

- Flow pattern is complex

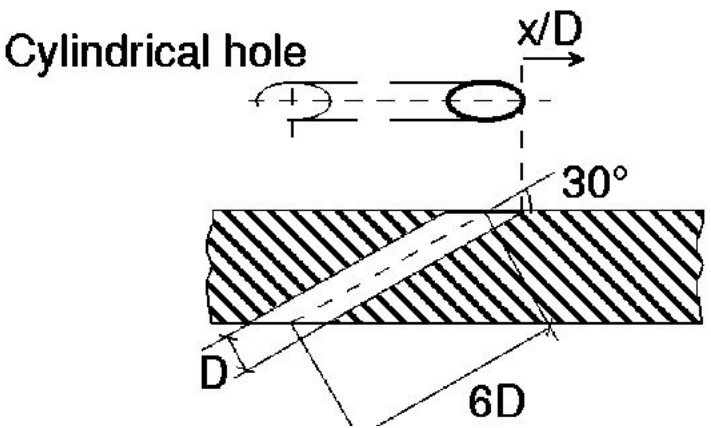
Definitions

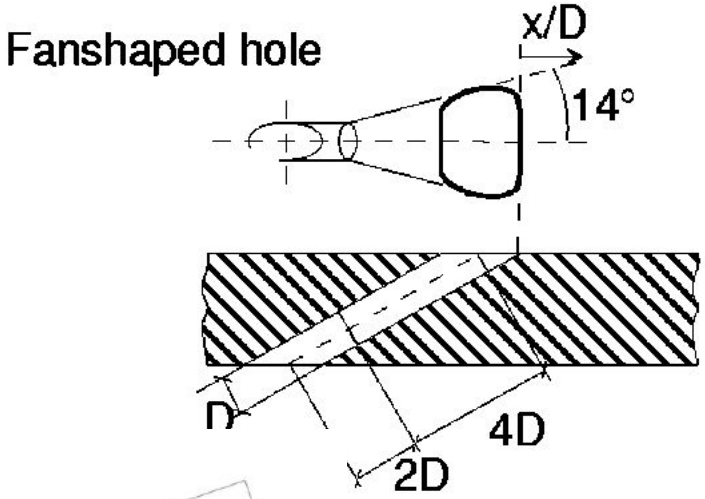
- Heat transfer $q'' = h_f \left(T_{ref} - T_{wall} \right)$
- Adiabatic wall temperature T_{aw}
- Adiabatic effectiveness $\eta = \dfrac{T_\infty - T_{aw}}{T_\infty - T_{c,exit}}$
- Blowing ratio $M = \dfrac{\rho_c U_c}{\rho_\infty U_\infty}$
- Density ratio $D.R. = \dfrac{\rho_c}{\rho_\infty}$

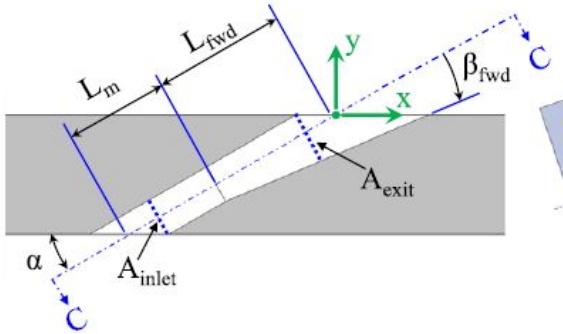


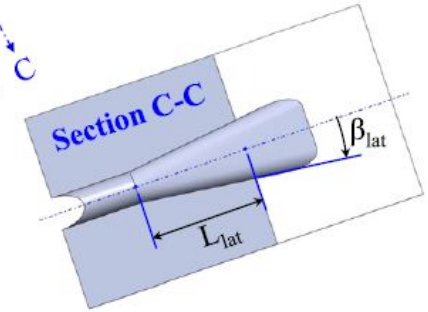
Schematics of film cooling configuration

Hole geometry



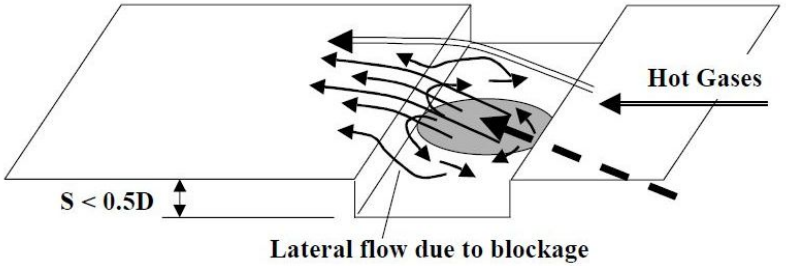




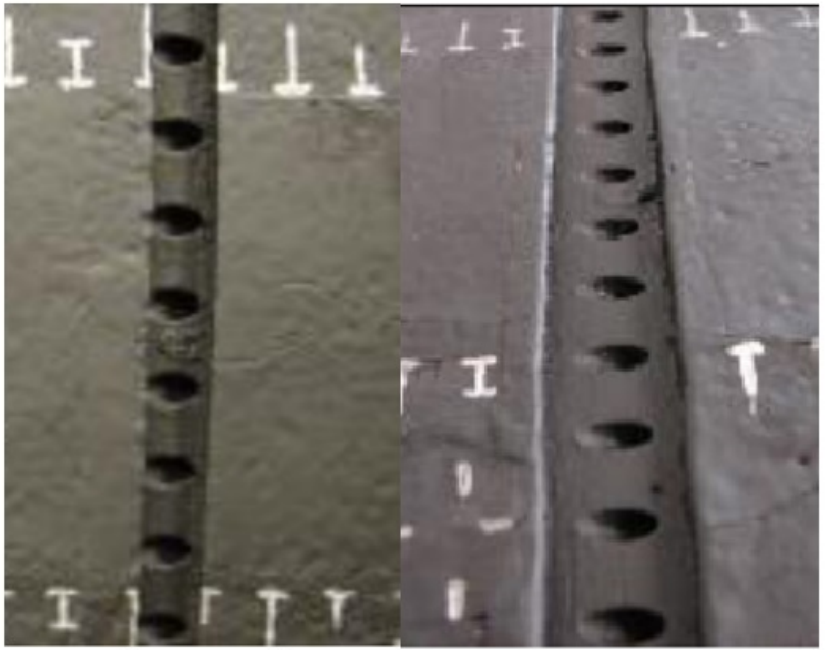


Model from Saumweber [9]

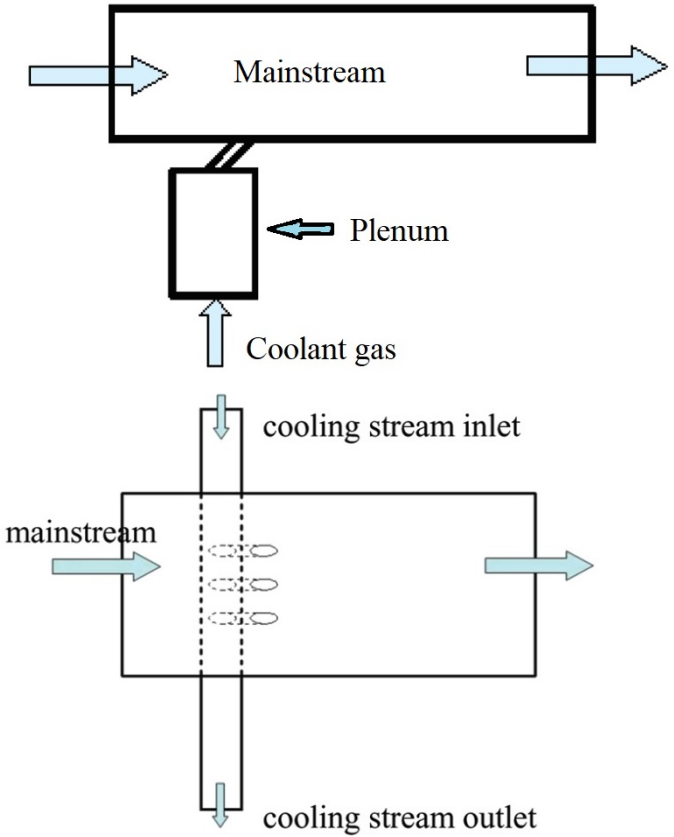
Trenched hole

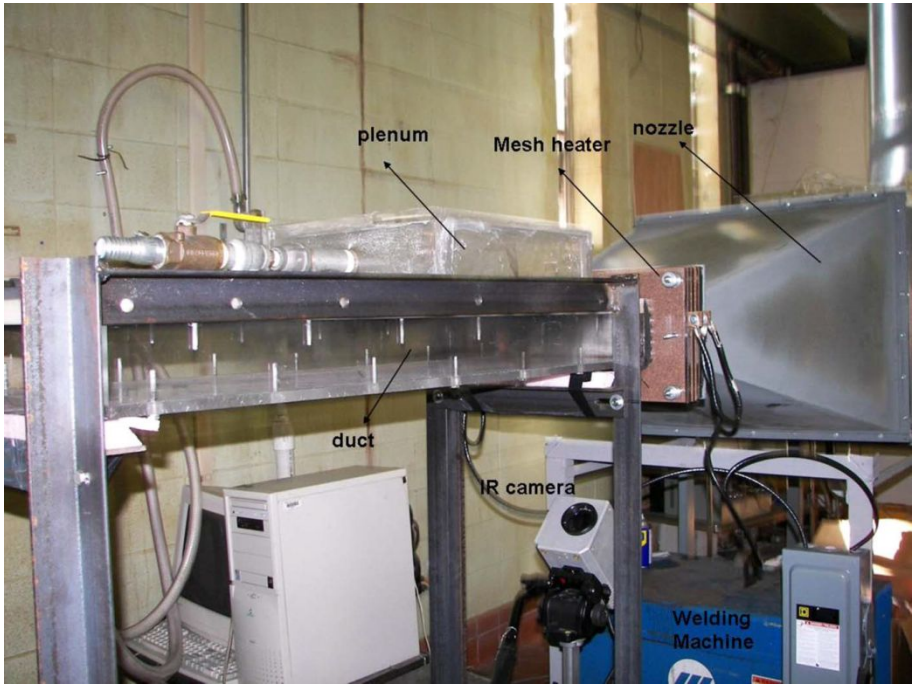


Trenched (shallow) hole introduced by Bunker [13]



Experimental setup

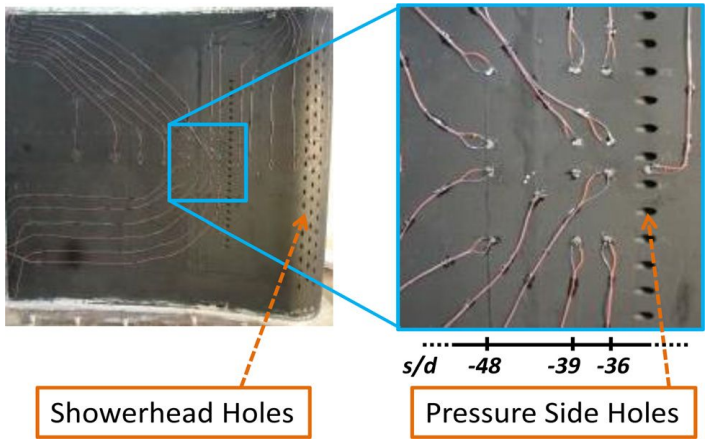




Experiment setup Y. Lu [14]

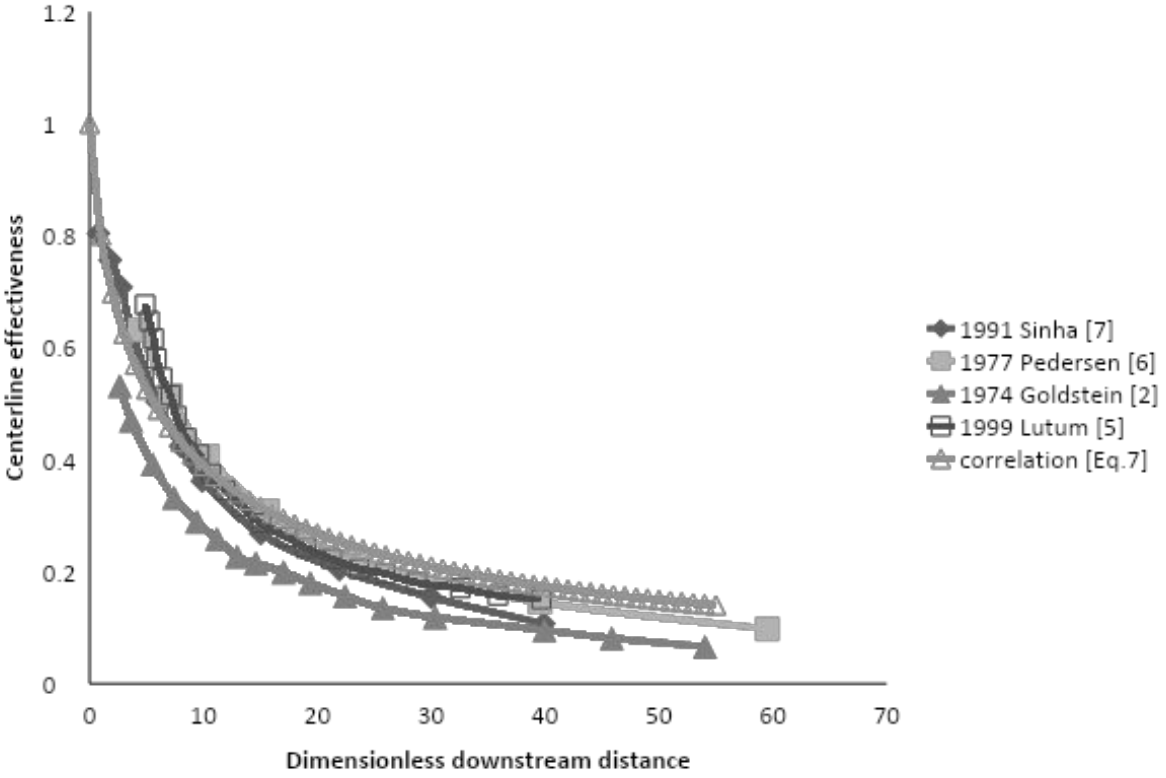
Measurement of Effectiveness

- Array of thermocouples
- Infrared thermographic system
- Heat-mass transfer analogy (Pederson [6])
- Pressure sensitive paint
- PIV and LIF



$$\eta = \frac{c_\infty - c_{aw}}{c_\infty - c_{c.exit}}$$

Effectiveness variation (X/D)

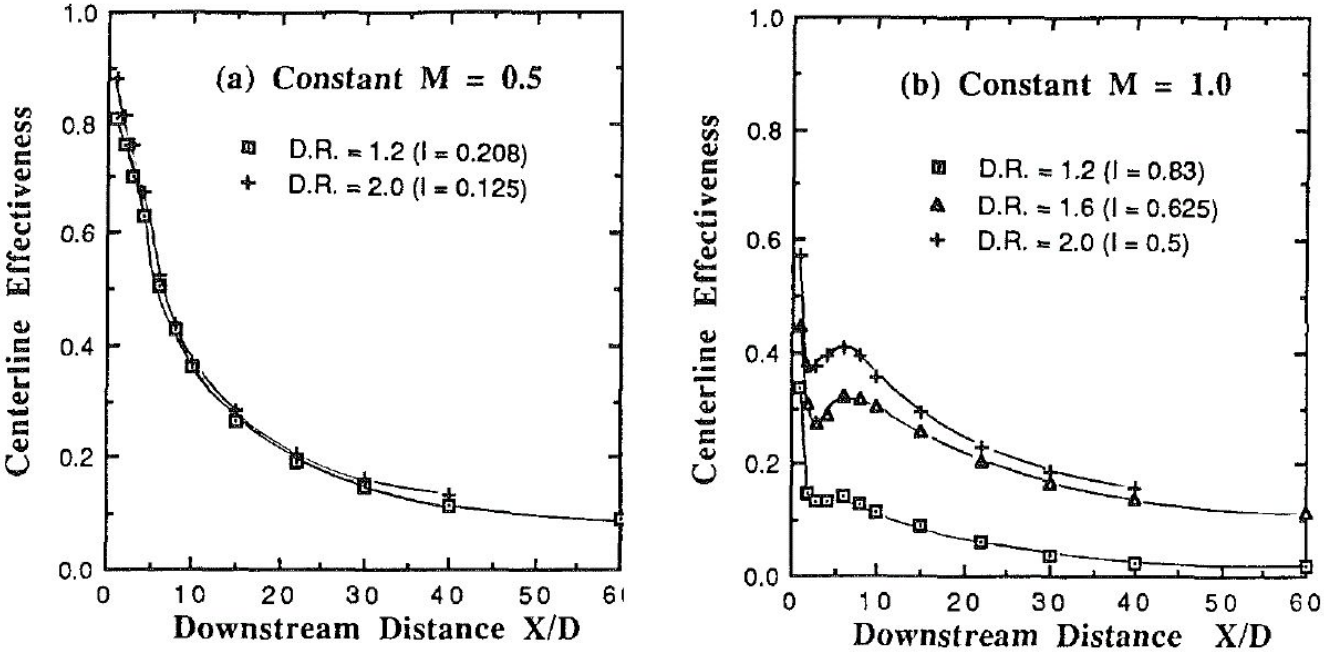


$$\eta = \frac{1}{1 + 0.249\xi^{0.8}} \qquad \text{Eq.7}$$

Valid for M = 0.2 to 1.1

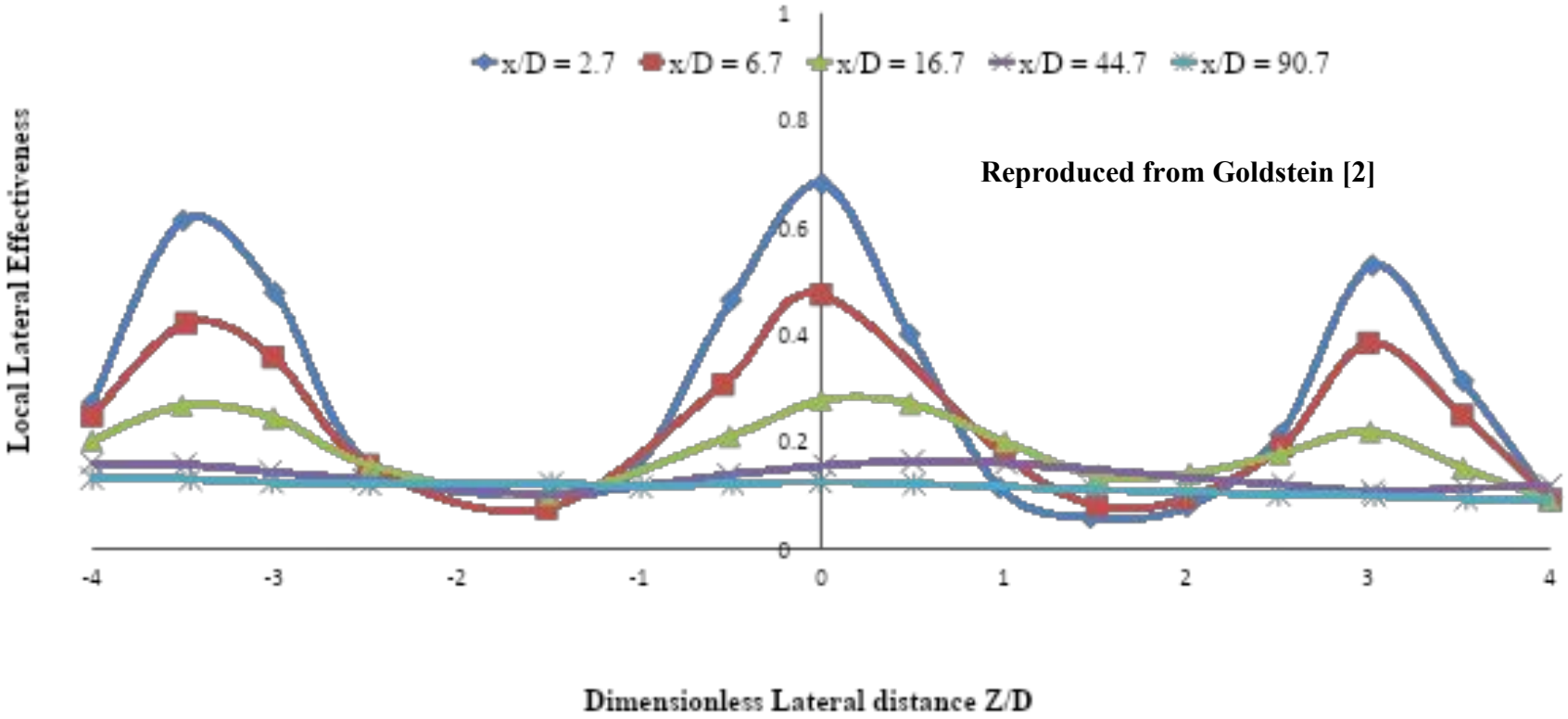
Comparison of centreline effectiveness for cylindrical holes for blowing ratio M = 0.5 and density ratio D.R ~ 1.0 reproduced from the respective papers. (Fig.2)

Effectiveness variation (M and DR)



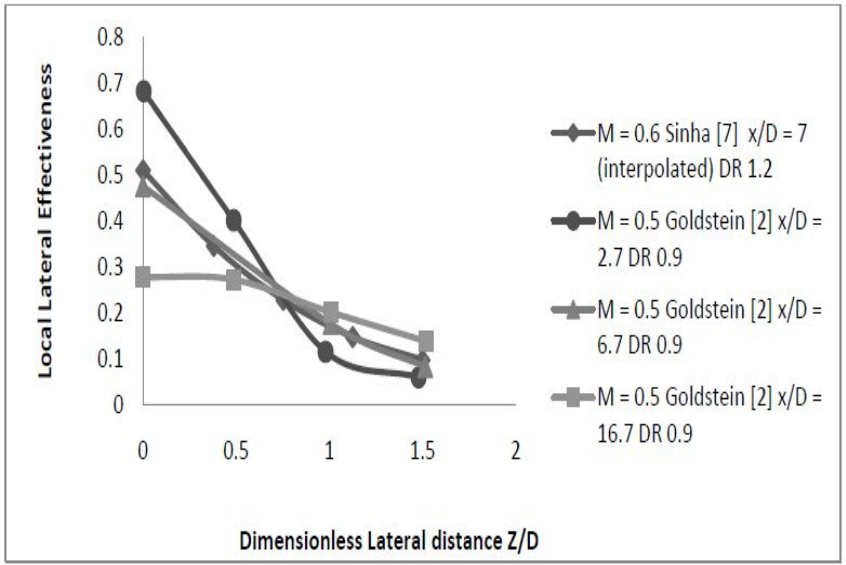
Comparison of centreline effectiveness along the dimensionless downstream distance for varying D.R and M. (Fig.3 Sinha [7])

Lateral effectiveness and X/D

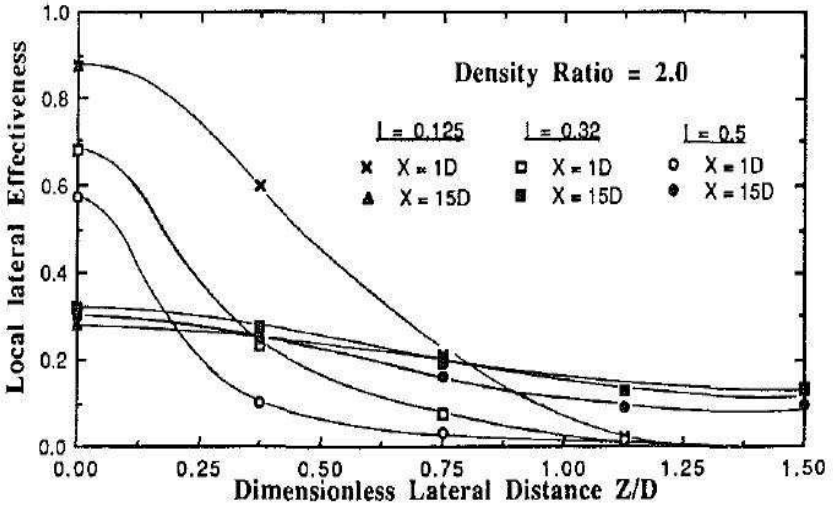


Reproduced from Goldstein [2]

Local Lateral Effectiveness and DR



Sinha[7]



CL Effectiveness of shaped and trenched