# Wind tunnel experiments on boundary layer transition caused by coarse distributed roughness

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Bons(2010)


Cyrus and Bromley(2009)

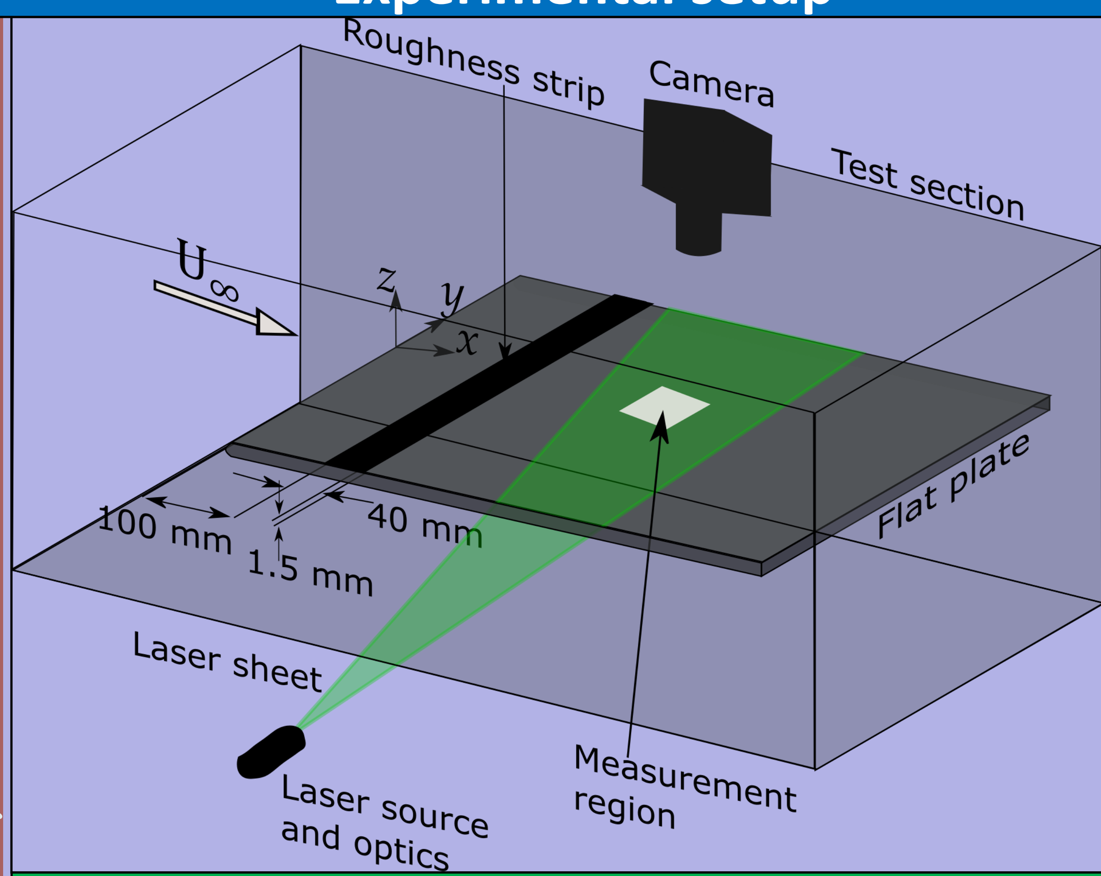

Yun et al(2005)

## Introduction

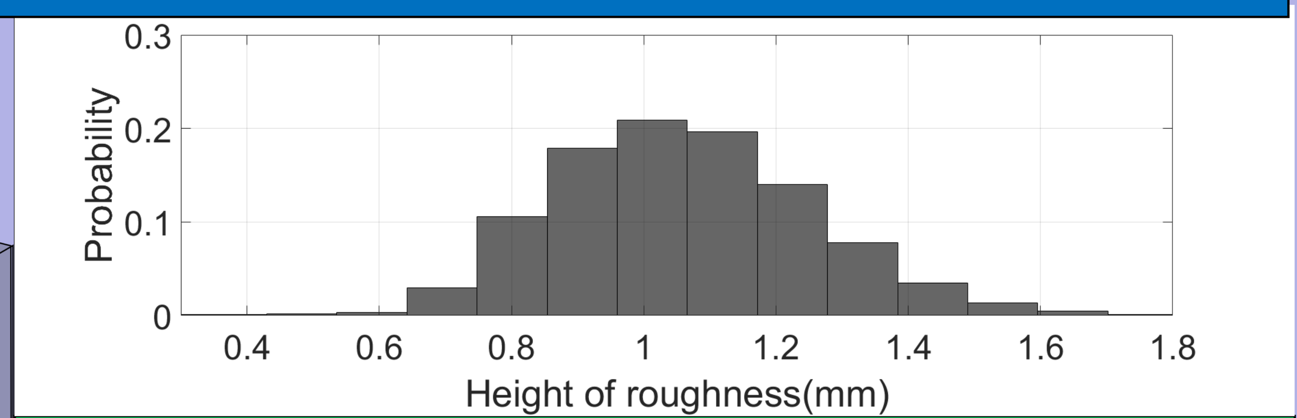
- Distributed roughness in the form of dust, combustion products, fouling etc occur on compressor and gas turbine blades ( near the leading edge)
- The distributed roughness causes early boundary layer transition resulting **in <u>increased skin friction, reduced lift-to-drag ratio and higher heat transfer over the blade</u>**
- **<u>Sandpaper roughness</u>** is used as an equivalent for distributed roughness to demonstrate underperformance (Yun et al. (2005)).
- Better understanding of distributed roughness transition will help in (1) **modelling the effect of distributed roughness** (2) Devising techniques to mitigate effect of roughness(Durbin(2017))

## Experimental setup

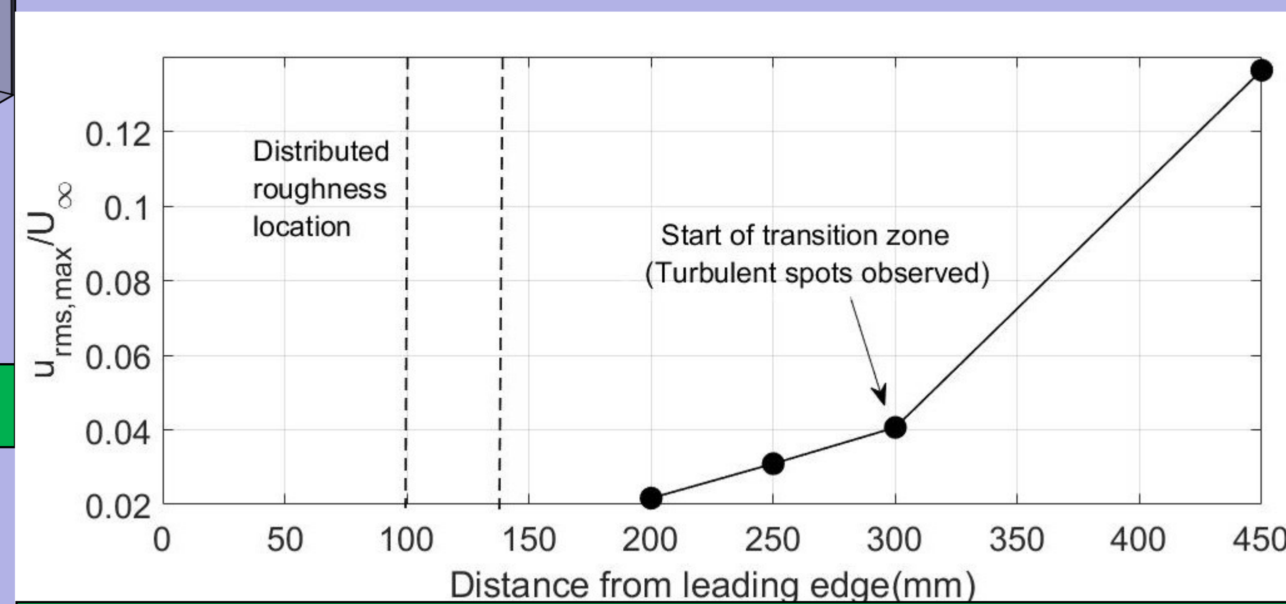
- Experiments conducted in a low-speed open circuit wind tunnel at Dept. of Aerospace Engineering, IISc-Bangalore
- A 24 grit emery sheet is used as distributed roughness. The emery sheet is scanned using FARO EDGE LASER Scanner and it shows grits of different size and concentration
- Flow becomes transitional at 450mm from the leading edge with sudden increase in $u_{rms,max}$.
- Spanwise PIV measurements just downstream of an isolated, cylindrical roughness presented for comparison.



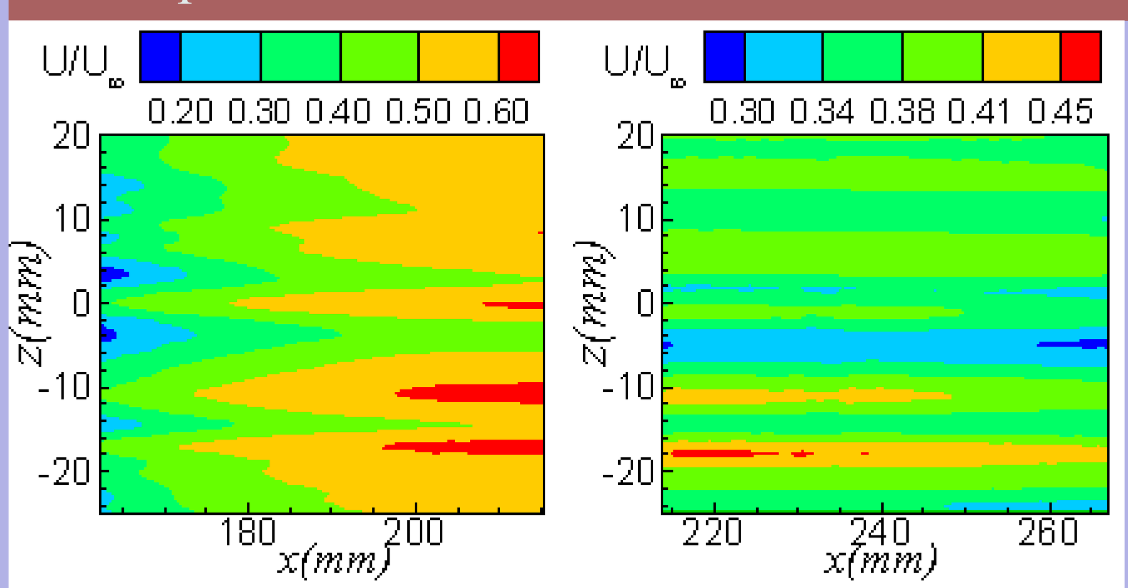
Schematic of experimental setup



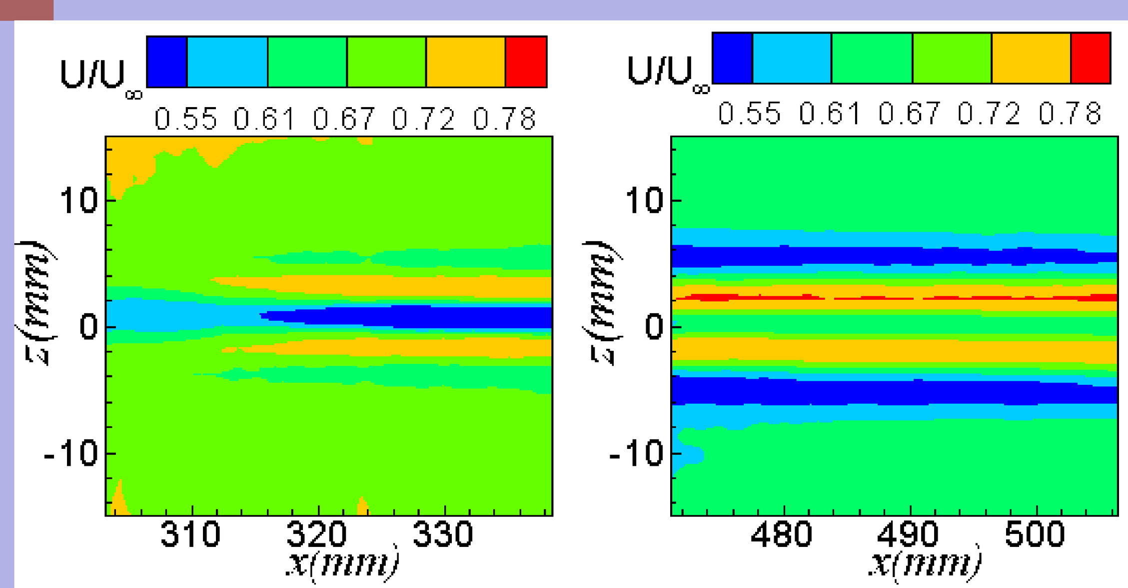
Roughness grit size distribution



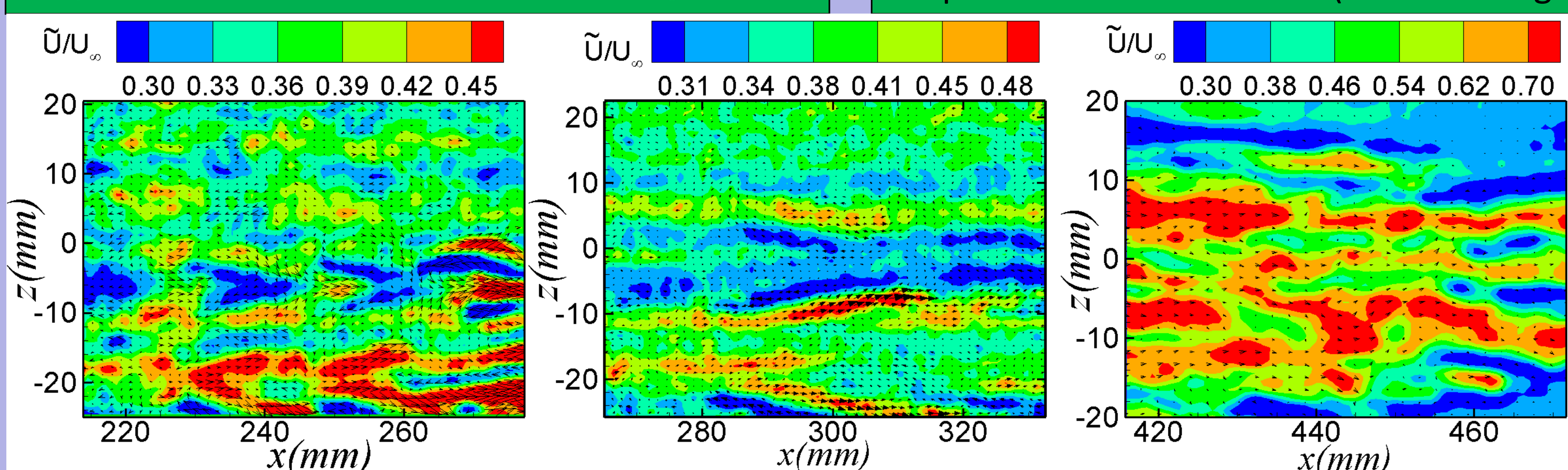
Growth of maximum disturbance energy



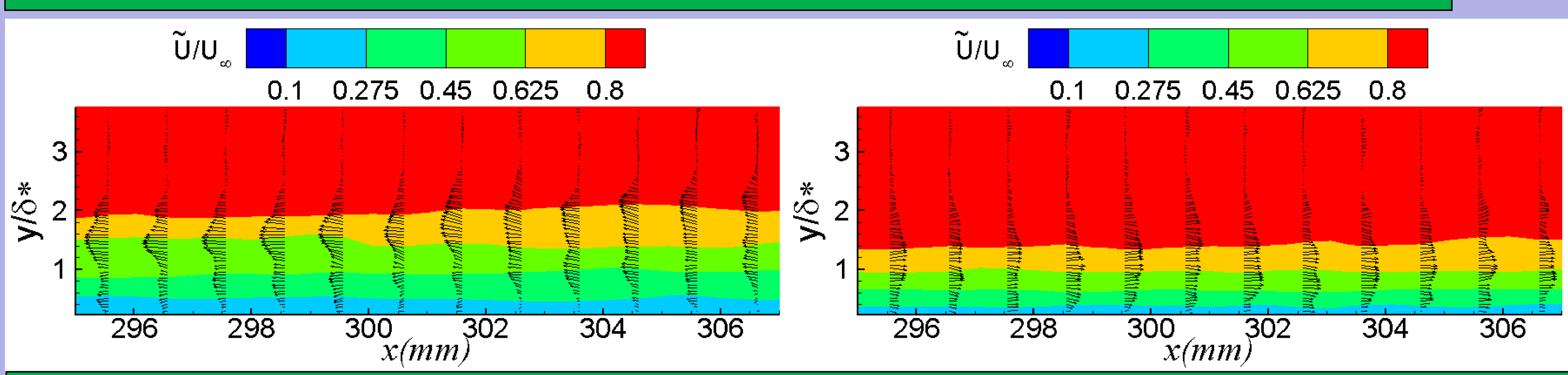
Spanwise measurements (Distributed roughness)



Spanwise measurements (Isolated roughness)



Instantaneous Spanwise PIV measurements



Instantaneous Wall-normal PIV measurements

## Discussion

- Spanwise PIV measurements show **<u>steady high and low speed streaks</u>** of varying strength . The streaks are likely caused by concentrated regions of roughness grits
- The presence of steady streaks in distributed roughness is **<u>similar to isolated roughness</u>**. This is in contrast to FST induced transition, where steady streaks are not observed.
- Instantaneous PIV measurements show **spanwise localized** instability near strong streaks. Thus **<u>single point measurements (like hot-wire measurements) might give misleading results</u>**
- Efforts to model distributed roughness induced transition **<u>should take into account the spanwise distribution of roughness</u>**.
- Wall-normal PIV measurements show unsteady streaks resembling FST induced transition. Unlike FST induced transition, where streaks are a result of shear sheltering, in case of distributed roughness, the unsteady streaks are a result of instability developing on steady streaks.
- These results could **<u>help in modelling distributed roughness induced transition and be of relevance to transition on turbomachinery blades.</u>**

## References


- Bons JP, *J Turbomach(2010);* 132: 021004
- Meher-Homji, C., Bromley, A., & Stalder, J. P. (2009). *Turbo Expo: Power for Land, Sea, and Air*. Vol. 48852.
- Yun, Y. I., Park, I. Y., and Song, S. J. (2005). *J. Turbomach.* 127.1 (2005): 137-143.
- Durbin PA (2017), *Flow, Turbulence and Combustion 99.1 (2017)*: 1-23.