On the scaling of steady streamwise boundary layer streaks

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A laminar boundary layer has a relatively low skin-friction drag with respect to a turbulent one, and for increasing \( \text{Re} \) the difference in \( c_f \) rapidly increases, and the difference can easily amount to an order of magnitude in many industrial applications. This explains why there is a tremendous interest in being able to delay transition to turbulence, particularly by means of a passive mechanism, which has the advantage of accomplishing the control without adding any extra energy into the system. Moreover, a passive, control does not have to rely on typically complicated sensitive electronics in sensor-actuator systems.

It has previously been shown that transition can be delayed by means of spanwise base flow modulations using circular roughness elements\(^1\). This type of elements is far from optimal considering the stability of the streamwise streaks, which are generated by the roughness elements. The circular elements have a threshold streak amplitude of 12% beyond which the streaks will by-pass to transition. A high amplitude streaky base flow is desired, since for a fixed spacing between the devices, an increasing amplitude will enhance the stabilizing effect. This led to a new idea, i.e. to test classical vortex generators but miniaturized. These specially designed devices are able to set up strong counter-rotating vortices, which modify the boundary layer into a streaky base flow with an amplitude exceeding 30% of the free-stream velocity\(^2\). This experiment was the first of its kind where such high amplitude streaks have been generated in a flat plate boundary layer in which they are still stable as far downstream as 700 vortex generator blade heights of the miniature vortex generators (MVGs). Furthermore, unpublished results by the present authors show that these devices are really effective in delaying transition to turbulence.

The streaks behind an array of MVGs develops differently in the downstream direction depending on many parameters. In Fig 1 we show new experimental results, based on different experimental configurations of the MVGs, on the scaling of the streak amplitude evolution, both in amplitude (\( A_{\text{int}}^* \)) and streamwise location (\( \xi \)), where \( A_{\text{int}}^* \) is a new integral amplitude measure. An important result which facilitates the design work of future MVG devices.

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![Figure 1](image.png)

Figure 1: (a) Streak amplitude evolution for 11 different MVG configurations. (b) Universal scaling of both amplitude and streamwise location. Solid line in (b) corresponds to \( A = \xi \cdot e^{-\xi} \).