**European Drag Reduction and Flow Control Meeting – EDRFCM 2017**
**April 3–6, 2017, Rome, Italy**

# LARGE-EDDY BREAKUP DEVICES - A NEAR 40 YEARS PERSPECTIVE

**P. Henrik Alfredsson & Ramis Örlü**
Linné FLOW Centre, KTH Mechanics, Royal Institute of Technology, S-100 44 Stockholm, Sweden

## INTRODUCTION

In the 1970's a dramatic increase in oil prices made it urgent to find methods decreasing drag on vehicles and especially aircraft. This was concurrent with the discovery of coherent structures in shear-flow turbulence in general and in wall-bounded turbulence in particular. Earlier a remarkable finding that minute amounts of polymer additives to turbulent water flows in pipes could reduce pressure drop with as much as 80%, and this was taken as evidence that it was possible to affect and reduce turbulence. This made NASA in the US interested in different possibilities to achieve drag reduction that would work also in air flows [2].

The idea of Large Eddy BreakUp (LEBU) devices as a method to reduce skin friction in turbulent boundary layers and ultimately drag on bodies moving through fluids can be traced back to this time. It was believed that the near wall region where the turbulence production has it maximum is influenced by the large scales (of the order of the boundary layer thickness) and that the interaction between the outer and inner regions was important for turbulence production and hence skin friction. By interfering with the large scales it was suggested that the interaction could be disrupted (or at least limited) and would result in a lower turbulence production. The devices themselves would have some inherent penalty drag, but with a smart design it was believed that the integrated reduction of skin friction could be larger than the penalty drag.

## REVIEW OF RESEARCH DONE

Two studies by a group of researchers at IIT Chicago, published within 8 months of each other in the early 1980's were triggering the LEBU effort. In the first [4] it was shown that a stack of thin plates spanned across the boundary layer could change the outer turbulent structures substantially, but in that study no net drag reduction could be found. However just 8 months later a second study [5], where two blades placed in a tandem configuration in the outer part of the boundary layer, it was claimed that a 20% drag reduction could be obtained. These experiments were all done on a flat plate in a wind tunnel at rather low Reynolds numbers and drag was measured by indirect methods. These results spurred significant interest and LEBU research started and took place at several dozens institutions around the world. However no attempted the the crucial test, namely direct drag measurements, until this was done in two campaigns at KTH published in 1986 and 1988, [6, 7]. These measurements were made on a flat plate equipped with LEBU devices where the drag measurement were made in a towing rank. The plate was one meter wide and 6, respectively 8 meters long. It was towed at speeds up to 5 m/s and in the second campaign the drag on the LEBU devices, which here were thin airfoils, could be measured separately. These measurements showed that no drag reduction could be obtained at high Reynolds numbers. Similar negative results were later obtained on an axisymmetric body [1, 8].

Recently in 2016 a Large Eddy Simulation (LES) of a similar LEBU set up has been reported from KTH and University of Melbourne [3]. These simulations show excellent agreement with and confirm the findings in the towing tank experiments, i.e. no net drag reduction could be observed.

## CONCLUSIONS

The study of the LEBUs raises at least two crucial questions. First of all: how come that the original experiments carried out at IIT Chicago showed substantial drag reduction? Were the experiments flawed in some way, was the accuracy insufficient or were they affected by wishful thinking by the experimentalists? Secondly; how come that so many groups followed in the steps of these first experiments without questioning the results and taking steps for the crucial experiment, i.e. a direct drag measurement on a moving body.

The questions that can be raised go beyond the area of fluid dynamics and are of a more general nature, namely: What is the responsibility of scientists when new spectacular findings are proposed? Many times such findings lead to the bandwagon effect, namely several groups join the field without asking the crucial questions and funding agencies are eager to follow. However the LEBU case also showed that the scientific system in some sense worked as one would hope. Namely that almost no journal publications appeared on LEBUs except for the direct drag measurements ([6, 7] showing negative results, but were still published) and now lately similar simulation results [3]. If one search the literature in terms of conference proceedings and abstract books one will find that many researchers presented their results at conferences and workshops which of course is justified, but that the work did not make it into archival journals.

## REFERENCES

[1] J.B. Anders. LEBU drag reduction in high Reynolds number boundary layers. AIAA-Paper 89-1011, 1989.

[2] D.M. Bushnell. Recent turbulent drag reduction research at Langley Research Center. NASA-TM-78688, 1978.

[3] C. Chin, R. Örlü, J. Monty, N. Hutchins, A. Ooi, and P. Schlatter. Simulation of a Large-Eddy-Break-up device (LEBU) in a moderate Reynolds number turbulent boundary layer. *Flow Turbulence Combust*, (doi:10.1007/s10494-016-9757-y):1–16, 2016.

[4] T.C. Corke, H.M. Nagib, and Y.G. Guezennec. Modification in drag of turbulent boundary layers resulting from manipulation of large-scale structuresa new view on origin, role and manipulation of large scales in turbulent boundary layers. NASA-CR-3444, 1981.

[5] T.C. Corke, H.M. Nagib, and Y.G. Guezennec. A new view on origin, role and manipulation of large scales in turbulent boundary layers. NASA-CR-165861, 1982.

[6] A. Sahlin, P.H. Alfredsson, and A.V. Johansson. Direct drag measurements for a flat plate with passive boundary layer manipulators. *Phys Fluids*, 29:696–700, 1986.

[7] A. Sahlin, A.V. Johansson, and P.H. Alfredsson. On the possibility of drag reduction by outer layer manipulators in turbulent boundary layers. *Phys Fluids*, 31:2814–2820, 1988.

[8] M.J. Walsch and J.B. Anders. Riblet/LEBU research at NASA Langley. *Appl. Sci. Res.*, (46):255–262, 1989.