Controlling turbulent pipe flow

Researchers from the Institute of Science and Technology Austria (IST) have discovered a mechanism to control turbulence in pipe flows. In industrial applications this mechanism can reduce frictional drag by up to 80% and the heat transfer coefficient by up to 95%.

Background

In nature as well as industrial applications two fundamentally different flow states can be observed: laminar and turbulent flow. In contrast to laminar flow, where the fluid moves in smooth layers, turbulence is characterized by huge and rapid fluctuations and strong swirling motion. Thus turbulence is responsible for a drastic increase in frictional drag, heat transfer and fluid mixing. It is the major cause of energy losses in fluid transport. In pipes laminar flow is typically realized only when flow speeds are small. IST researchers have developed a novel and efficient technique to modify the streamwise velocity profile using stationary flow management devices (FMDs). These devices allow to relaminarize fully turbulent pipe flow up to a Reynolds number[1] of 10 000 which leads to a drastic reduction of drag, heat transfer and fluid mixing.

The technology

Simple FMDs, which are mounted within the pipe, are used to locally accelerate the flow near the pipe wall which leads to a complete collapse of turbulence as shown in Figure 1.

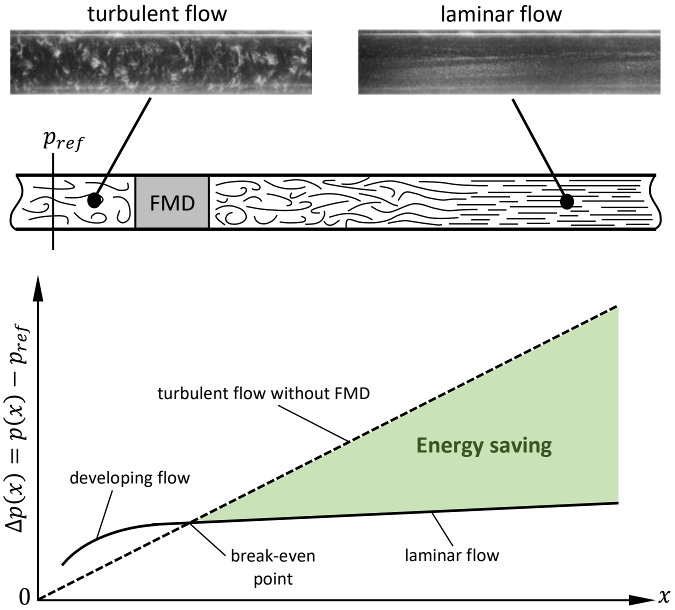

Figure 1: Sketch of the spatial evolution of the flow and pressure drop downstream of a relaminarizing flow management device.

At the break-even point the additional pressure drop caused by the FMD is balanced by the smaller laminar pressure drop. Further downstream a net gain in terms of energy saving is realized provided the flow stays laminar. This is the case as long as perturbations (e.g. bends, valves) are absent. The power consumption of pumps is directly related to the pressure drop in a pipeline system. As a consequence the required pumping power decreases by similar factors if the flow in the pipeline is laminar instead of turbulent.

The application of FMDs in pipeline systems allows

- the reduction of drag by up to 80%,
- a decreased heat transfer coefficient by up to 95% and
- drastically reduced fluid mixing.

Demonstrations of working prototypes can be arranged upon request at our labs at IST Austria.

Intellectual Property

The invention has been protected by PCT patents entitled "Eliminating Turbulence in Wall Bounded Flows" (WO2012069472A1, CN103270321A, 11794422.3 and US20130284272A1), "Eliminating Turbulence in Wall-Bounded Flows by Distorting the Flow Velocity Distribution in a Direction Perpendicular to the Wall" (WO2014140373) and "Re-laminarization of turbulent flow in a duct" (EP15176645.8).

Further information

Explanatory video of the flow control mechanism:
https://www.dropbox.com/s/2qvnjlj0xizmz70/v055-final.mp4?dl=0

Patent application of the technology:
https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2012069472
https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2014140373

[1] For pipe flow the Reynolds number is defined as $Re = U \cdot D/\nu$, in which U is the mean streamwise velocity, D the pipe diameter and ν the kinematic viscosity.

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