A NEW CONCEPT OF FLOW CONDITIONER UNDER TEST

B. Mickan*, G. Pereira*, J. Wu, D. Dopheide***

*** Physikalisch-Technische Bundesanstalt, Department of Fluid Mechanics**
D-38116 Braunschweig, Bundesallee 100
Tel.:++49 531 592 1331, Fax: ++49 531 592 1305
e-mail: bodo.mickan@ptb.de

**** Industrial Technology Research Institute, Flow Measurement Laboratory**
30 Ta Hsueh Road
Hsinchu, Taiwn 300, R.O.C.

---

1 INTRODUCTION

It is a well-known and recognised fact that the behaviour of flow rate and volume measuring devices can strongly be affected very by the flow conditions prevailing in their inlet pipe section. Disturbed velocity profiles caused by pipe configurations such as bends, headers, pressure regulators and convergent or divergent pipe sections in front of a flow meter can lead to deviations of the meter reading by up to several percents. Consequently, flow conditioners are often used to avoid such additional sources of error.

This paper reports about measurements with a static mixer[*] and its effect on a disturbed pipe flow. The static mixer is normally used in the chemical industry for mixing two or more different components of gas or liquid in a very short time (or pipe length rsp). This property is caused by an efficient exchange of mass across the pipe. Exchange of mass means also exchange of momentum, what is one of the main reasons for a fast development of flow. From this we assumed that the static mixer would be also a good flow conditioner and we want to demonstrate this here with a comparison with perforated plates.

After a short description of the test facility the test configuration and the flow conditioners under test are shown. The results of flow profile measurements are divided into three parts:

- the situation without flow conditioner,
- results from different perforated plates and the explanation of the main points of efficiency using a perforated plate,
- results from static mixer and conclusions from that.

2 TEST FACILITY

To carry out flow profile measurements an automated two-component LDV test facility for air measurements under atmospheric conditions was used [1] (Fig. 1). This diagnostic test rig takes advantage of the construction of efficient miniaturised LDV and the use of critical nozzles for the establishment of gas flow rate measurement of highest accuracy and reproducibility. The test rig according to Fig. 1 allows to measure in-situ flow profiles across the cross section in a DN 200 pipe at arbitrary inlet conditions. LDV1 and LDV2 can be traversed perpendicular to the pipe axis x and can be rotated 360 degrees around the pipe axis. It has thus become possible to obtain detailed knowledge of the flow characteristics inside the pipe configurations of interest.

---

[*] Static Mixer Type Sulzer SMV, produced by Sulzer Chemtech AG, Switzerland

The heart of the facility is the LDV measuring unit. The connection to the piping to be investigated is realised by a special pipe segment (Fig. 1). Eight windows allow four different profiles rotated by 45 ° to be scanned. Inside the pipe, each window is made of a glass film to prevent changes in the diameter and to provide for a smooth inner contour of the pipe. The windows outside of the pipe consist of plane glass plates to block pressure differences.

Two separated LDV for the two-dimensional measurement of the flow profiles are installed on a rotating mechanism and positioned face to face on both sides of the pipe, see Fig. 1. Each miniature diode LDV [2] [3] is mounted on a precise linear traversing bench and can be operated by a remote control. A linear scan through the pipe diameter is easily done when the moving tables are driven synchronously.

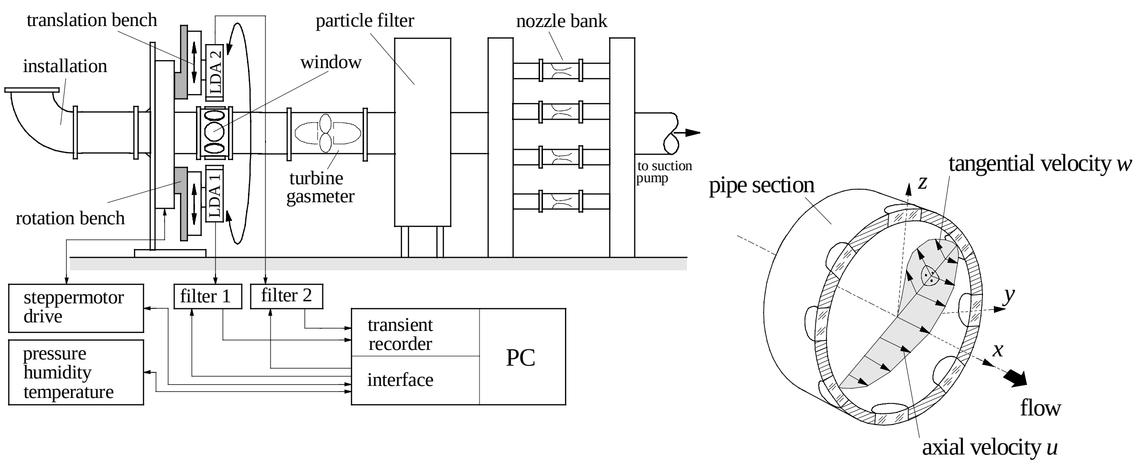


Fig. 1: *test facility for investigation of installation effects*

In Fig. 2 two three-dimensional diagrams of measured axial velocity profiles are shown to give an impression of the quality of measurements.

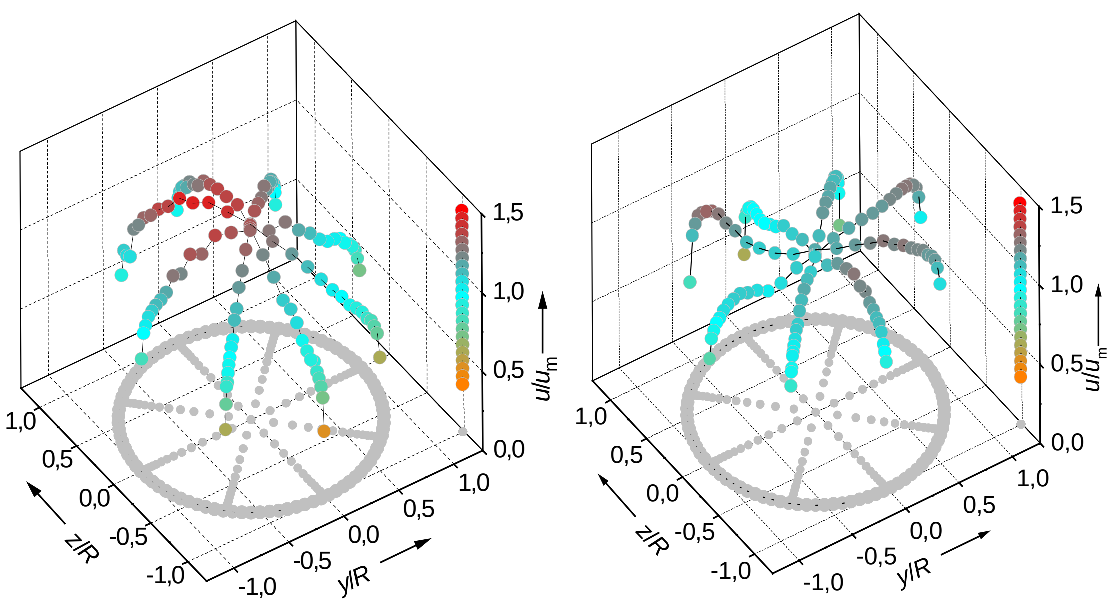


Fig. 2: Measured axial velocity profiles downstream to flow conditioners in Conf. 1 (see Fig. 4)
a) conventional perforated plate (2,5 D distance) and
b) new approach by static mixer (3,5 D distance)

3 FLOW CONDITIONERS UNDER TEST AND TEST CONDITIONS

In this paper not only results of static mixer will be shown. There are also measurements and conclusions for perforated plates which were published last year [4] to give some feeling to evaluate the results of the mixer. In Table 1 a summary of all conditioners are given.

Table 1 - Flow Conditioners Under Test

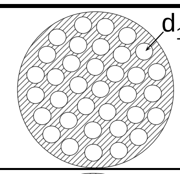
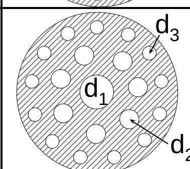
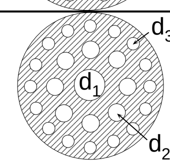
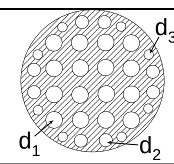
Conditioner	Area covered [%]	Pressure Loss Coefficient K_p †	Thickness or legnth (in pipe diameters D)	diameters (in pipe diameters D) and number of wholes	sketch
Mitsubishi	41	2,3	0,135 D	d_1 : 35x0,13D	
Laws	48	2,8	0,19 D	d_1 : 1x0,2D; d_2 : 7x0,175D; d_3 : 13x0,15D (wholes with phased edge)	
short Nova	53	3,9	0,155 D	d_1 : 1x0,19D; d_2 : 8x0,165D; d_3 : 16x0,12D	
long Nova	53	3,9	0,2 D		
modified Zanker	55	4,5	0,125 D	d_1 : 16x0,14D; d_2 : 8x0,11D; d_3 : 8x0,08D	
static mixer	--	$2 \cdot L_{mix}/D$ ‡	L_{mix} = 1 and 2 D	--	see Fig. 3

***Fig. 3**: Static Mixer Type Sulzer SMV, produced by Sulzer Chemtech AG, Switzerland*

† $K_p = \frac{2\Delta p}{\rho u_m^2}$; $u_m = \frac{4Q}{\pi D^2}$;

‡ The static mixer is available in different lengths. We investigated two of them.

The configurations used for testing flow conditioners are shown in Fig. 4. Because in Germany the application of turbine meters is very important in measurement of large gas flow rates, our investigations were concentrated on perturbations given by OIML R-32 [5]. This recommendation defines perturbation tests of turbine meters to evaluate the meter behaviour. Consequently our aim is to figure out the efficiency of flow conditioners in such situations.

In OIML R-32 two different configurations are used and we choose the High-Level-Perturbation for flow conditioner testing because of the high axial deformation and strong swirl.

In Germany short straight pipe length in front of turbine meters are often required because it is a question of space and expenditure. Going out from this we were interested in applications of flow conditioners immediately downstream to the perturbations. We started with test configurations Conf. 1 and Conf. 2 in Fig. 4. In Conf. 1 all perforated plates could not improve the axial profile in short pipe length, that's why we increased the distance between perturbation and conditioner to 2 D (Conf. 2).

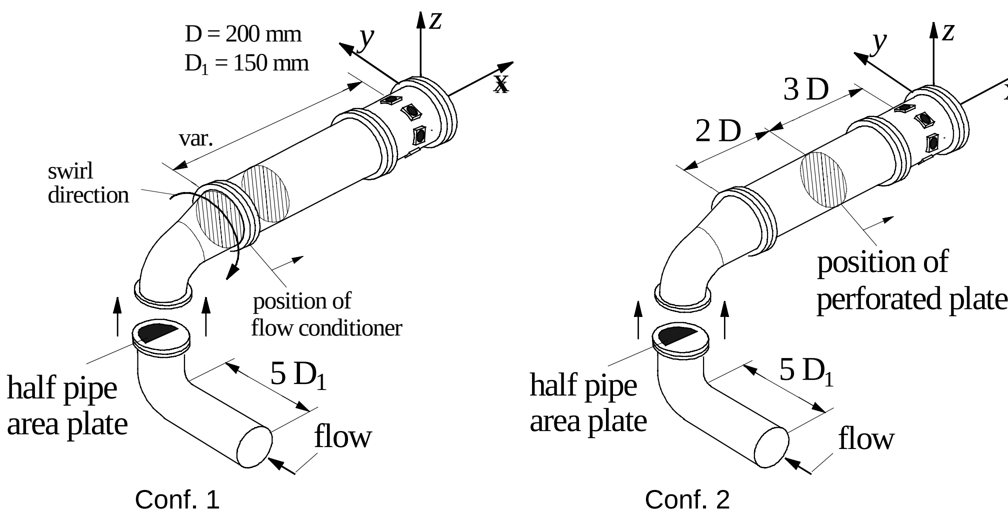


Fig. 4: *Test configurations for investigation of flow conditioner behaviour.*
Conf. 1: High-Level-Perturbation according OIML R32 [5], flow conditioner at exit of diffusor
Conf. 2: similar to Conf. 1, but flow conditioner with 2 D distance to diffusor.

The flow profiles downstream to the OIML high-level-perturbation are shown in Fig. 5. The axial profile is characterised by a significant asymmetry at a distance of 2,5D to the perturbation. This asymmetry decreases with length and the location of the maximum rotates around the axis (due to swirl). At 10D the axial profile is flat, so that the centre velocity is much lower then in the case of a fully developed flow.

The swirl downstream to such a configuration is very strong and dissipates very slowly. Even at 10 D the strength of swirl is nearly the same as at 2,5D. The longer the distance to perturbation the more the fluid rotates as a solid body (except the region near to the wall).

It has to be emphasised that there exist a flow separation at the exit of the perturbation. This is easily recovered if we look to the perturbation. A separation has to occur due to the plate between the two bends which blocks one half of the diameter. The diffusor after the second bend is also a reason for flow separation, so an existing separation will still remain. But the separation is removed 2,5D downstream to the perturbation as one can obtain in Fig. 5.

4 RESULTS FOR PERFORATED PLATES

The results for perforated plates are given here in this paper to give some reference for comparing the results of the static mixer. The efficiency of perforated plates were explained more detailed in [4] last year. In this paper we want to refer to the measurements downstream to Conf. 1 and Conf. 2 in Fig. 4. The profiles for these cases are given in Fig. 6 (Conf. 1) and Fig. 7 (Conf. 2). Some of the main results documented in [4] should be repeated here.

In Conf. 1, where the plates are positioned into the separation region of the flow, the axial profile is worse then without conditioner. The shape of the axial profile is equivalent for all plates. There are differences in the absolute value of the maximum (what is correlated with the blocked area of the plate, the higher the blockage the lower the maximum), but the location of the maximum is always very similar. At longer distances (9 to 10D) the maximum is decreased and therefore the asymmetry too. The profiles do not yet fit into the limits of $\pm$5% deviation to the fully developed flow given by ISO 5167 [6].

In Conf. 2 (see Fig. 7 for results) the situation is more suitable. At shorter distance to the plates (2D, what is 4D to perturbation) we have a little bit better situation then without conditioner. The shape is similar to the case described above, but the values of the maximum is much lower. At the longer distances (about 9D to conditioner or 11D to perturbation) the axial velocities are near to the $\pm$5% limit, but do not fit always into that.

As it could be demonstrated in [1], profiles as such in Fig. 6b and 7b would be normally sufficient for turbine meters constructed by state of the art. Hence, the $\pm$5% limit given by ISO 5167 [6] is also a suitable criterion for turbine meters to exclude error shifts due to axial profile deformations.

5 RESULTS FOR STATIC MIXER

5.1 Axial Profiles

In Fig. 8 the effect of the mixer on a fully developed flow in a long straight pipe is given, Fig. 8a (left) for length of mixer L_{mix} = 1 D and Fig. 8b (right) for L_{mix} = 2D. It can be obtained, that the mixer produces some inhomogeneous flow especially at shorter distances to the mixer. The profile at 3,5D distance has also some asymmetry. In the case of L_{mix} = 1D the asymmetry is not completely removed and the 5%-tolerance band is left to be injured within 10D. The mixer with L_{mix} = 2D starts with a smaller asymmetry and within 10D the flow is nearly back to the fully developed case.

Fig. 9 shows the profile development downstream to the mixer (with L_{mix} = 2D) mounted in Conf. 1 (see Fig. 4). This was the worst case for perforated plates (see Fig. 6). Downstream to the mixer the situation is much more suitable. At 6D the profile would be sufficient to turbine meters and at 10D the axial profile will fit again in the 5%-tolerance.

There was a big difference in the applications of perforated plates in Conf. 1 and Conf. 2 (Fig 4). Fig. 10 shows the results in these two situations for the mixer with L_{mix} = 1D and L_{mix} = 2D. All profiles is Fig. 10 were measured at the same distance to the perturbation. For both lengths of mixers only a slight difference can be obtained. The shape of profile for L_{mix} = 1D as well as for L_{mix} = 2D is nearly the same as in Fig. 8 (effect on fully developed flow). This demonstrates that the mixer is a good isolator, although not optimised yet.

5.2 Tangential Profiles

The ability and the basics for removing swirl due to perforated plates were shown in a very good way by Laws [7] [8]. The swirl is removed if the plate has a sufficient thickness compared with the diameter of perforation. The static mixer is a completely different construction and their effect should be demonstrated here.

Fig. 11 shows results for L_{mix} = 2D in a fully developed flow (Fig. 11a) and for the OIML perturbation (Fig 11b). Here one can obtain that at distances more than 6D the remaining tangential velocities are independent to the upstream profile. The remaining tangential components do not fulfil the criteria of ISO 5167 [6] standard but it is more important that the mixer is a good isolator. There should be enough possibilities to optimise the mixer with this respect.

6 CONCLUSIONS

The measurements of axial and tangential velocity profiles in cases with fully developed and high disturbed flows demonstrate that the mixer is a good isolator of upstream profiles. With a length of L_{mix} = 2D the axial profile is back into the 5% criteria of ISO standard 5167 within 10D pipe length. The remaining tangential velocities are also independent to the upstream swirl.

7 REFERENCES

[1] MICKAN, B., WENDT, G., KRAMER, R., and DOPHEIDE, D. Systematic investigation of pipe flow and installation effects using laser Doppler anemometry - Part II: The effect of disturbed flow profiles on turbine gas meters - a describing empirical model.
In: Flow Measurement and Instrumentation Vol.7, No.3/4, 1996, Special Issue: Optical Methods in Flow Measurement, ISSN 0955-5986, p. 151-160

[2] DOPHEIDE, D., FABER, M., and TAUX, G. Velocity measurements using a semiconductor laser-Doppler-anemometer. In: Waidlich, W. (Edit.): Conference LASER´87, München 23.-26. Oktober 1987; Conference Proceedings: LASER; Optoelectronics in Engineering, Berlin: Spinger-Verlag 1987, S. 242-245

[3] DOPHEIDE, D., FABER, M., REIM, G., and TAUX, G. New optoelectronic velocity and flowrate measuring methods using semiconductor lasers and photodiodes. In: VDI-Berichte Nr. 768 (1989), S. 341-351. Conference Proceedings: FlOMEKO´89, Düsseldorf

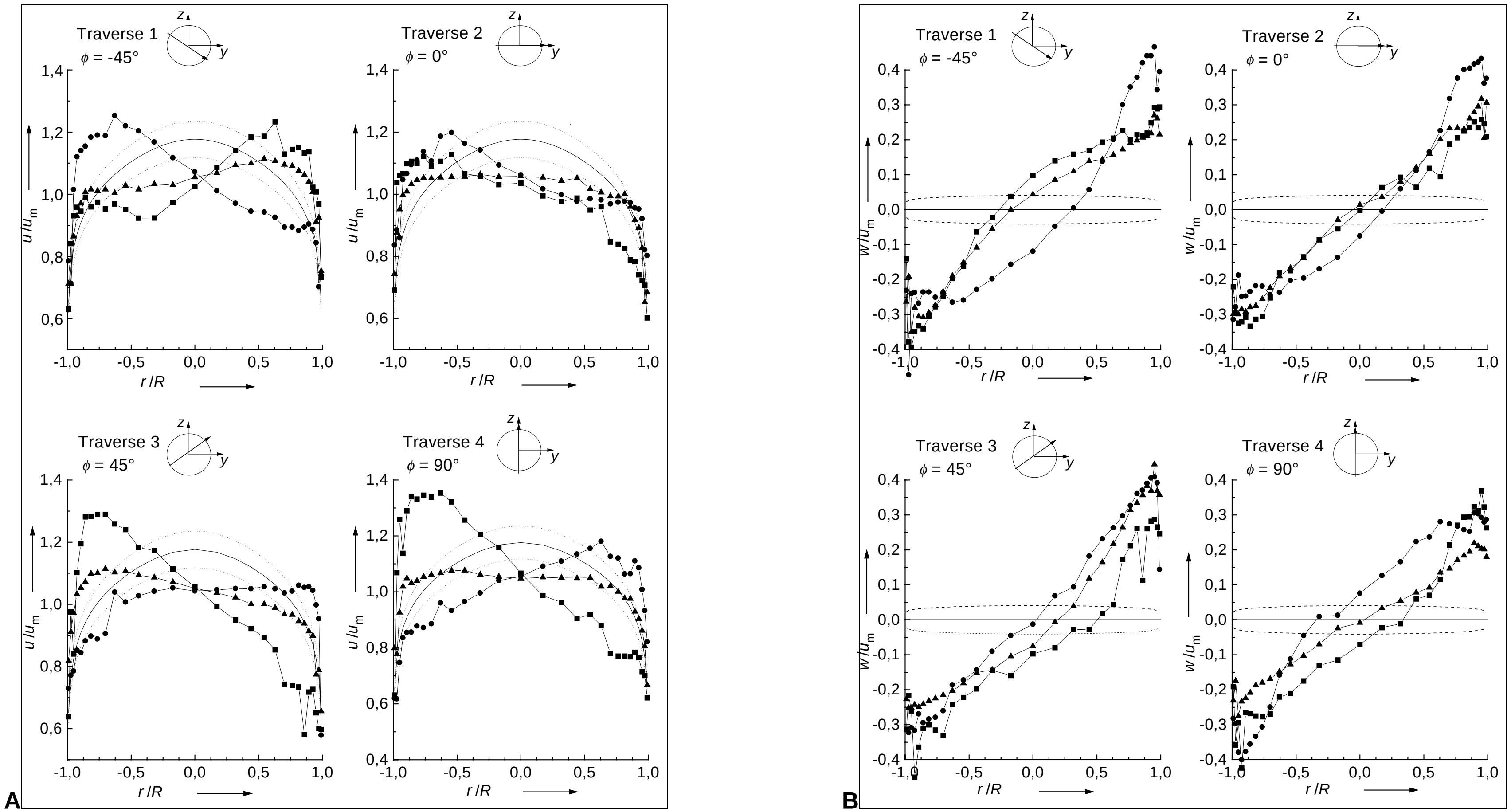
[4] MICKAN, B., KRAMER, R., WENDT, G., and DOPHEIDE, D. Quantified comparison of the efficiency of new flow conditioners. In: Proceedings of the 10th International Conference on Flow Measurement FLOMEKO 2000, 04-08 June 2000, Salvador, Brazil, 10 pages

[5] International Recommendation OIML R-32: Rotary piston gasmeters and turbine gas meters. Edition 1989 (E) International Recommendation OIML R-32: Rotary piston gas meters and turbine gas meters. Edition 1989 (E)

[6] International Standard ISO 5167-1: Measurement of fluid flow by means of orifice plates, nozzles and veturi tubes inserted in circular cross-section conduits running full. ISO, 1991

[7] LAWS E. M. Flow Conditioning - a new Development.
In: J. Flow. Meas. Instrum. 4 (1990), pp. 165 - 170

[8] LAWS, E. M. Quazanne, A.: Effect of plate depth on the performance of a Zanker flow straightener. In: J. Flow Meas. Instrum. 3 (1992), pp. 257-269



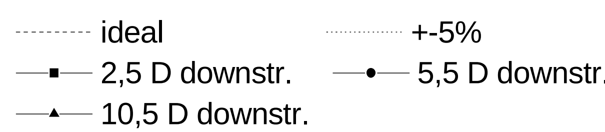
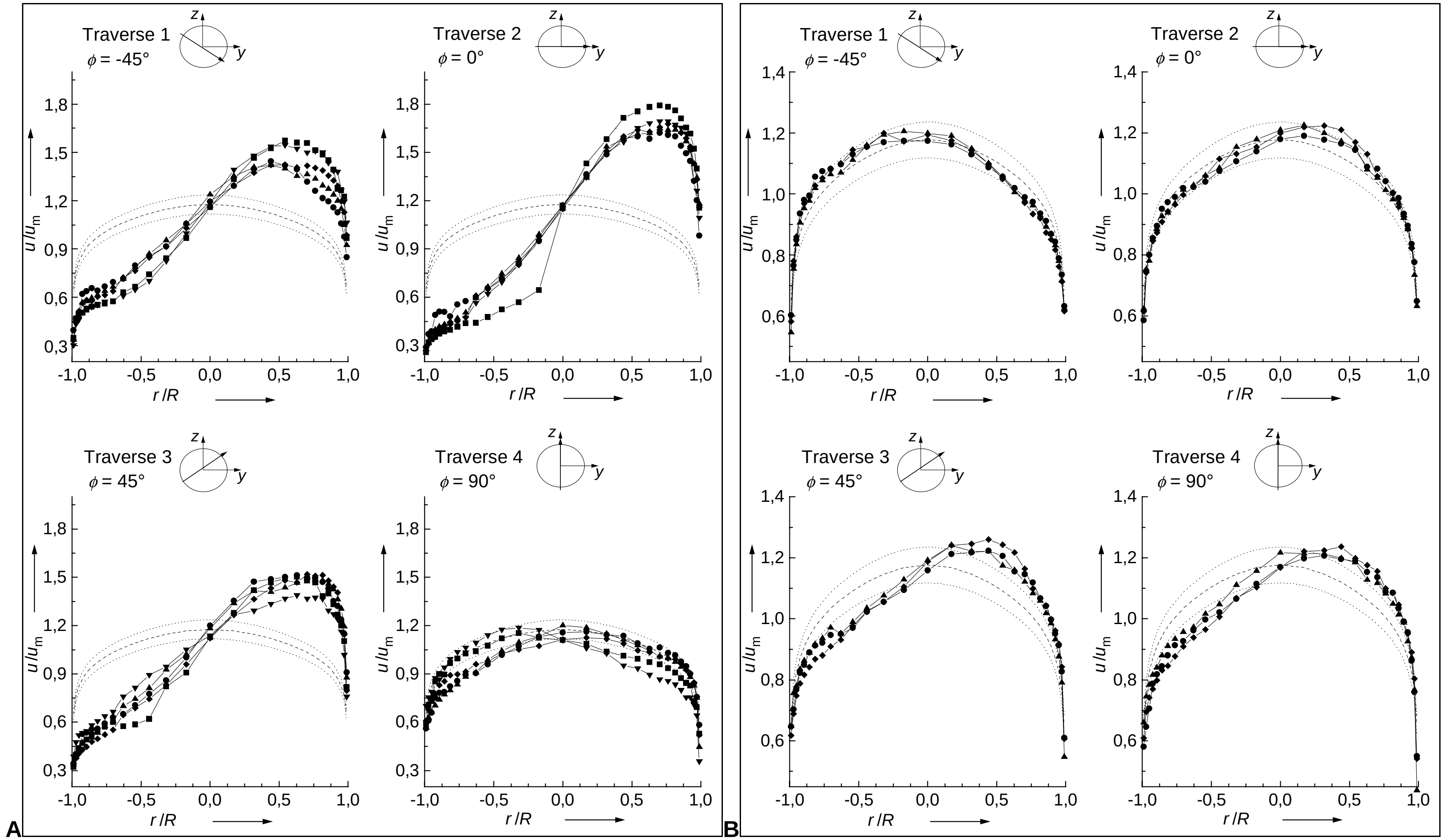


Fig. 5: *Flow profiles downstream to perturbation OIML-High-Level (see Fig. 4 without flow conditioners)*
A*: axial velocities u/u_m*
B*: tangential velocities w/u_m*



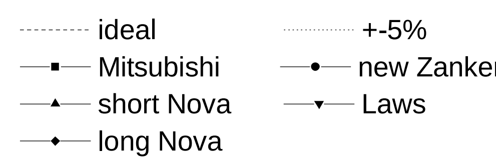


Fig. 6: *Flow profiles downstream to **Conf. 1** with perforated plates (see Fig. 4)*
***A**: short distance to perturbation (about 2 D)*
***B**: long distance (about 9 D)*

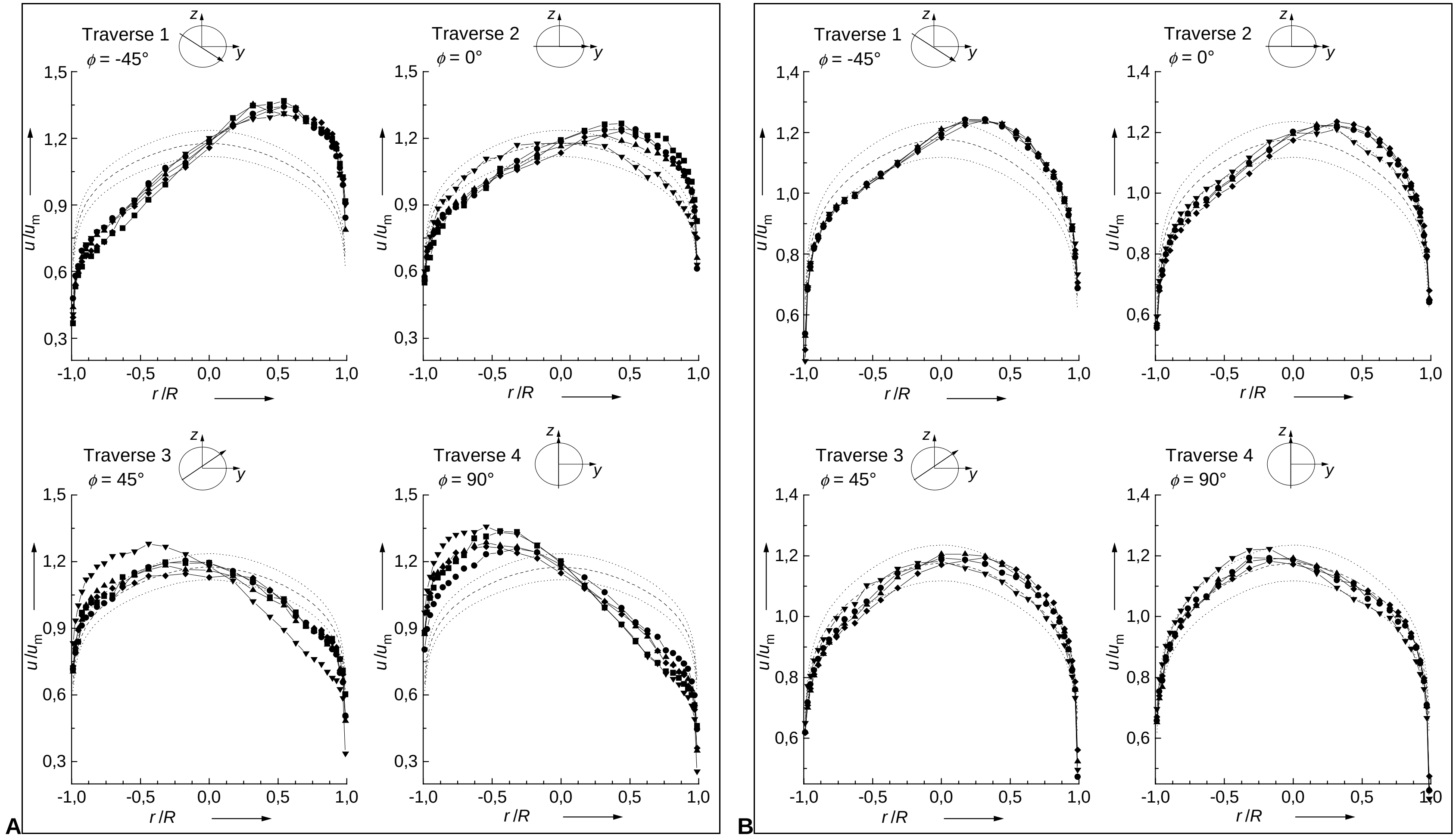


Fig. 7: *Flow profiles downstream to **Conf. 2** with perforated plates (see Fig. 4)*
***A**: short distance to perturbation (about 4 D; 2 D to conditioner rsp.)*
***B**: long distance (about 11 D; 9 D to conditioner rsp.)*

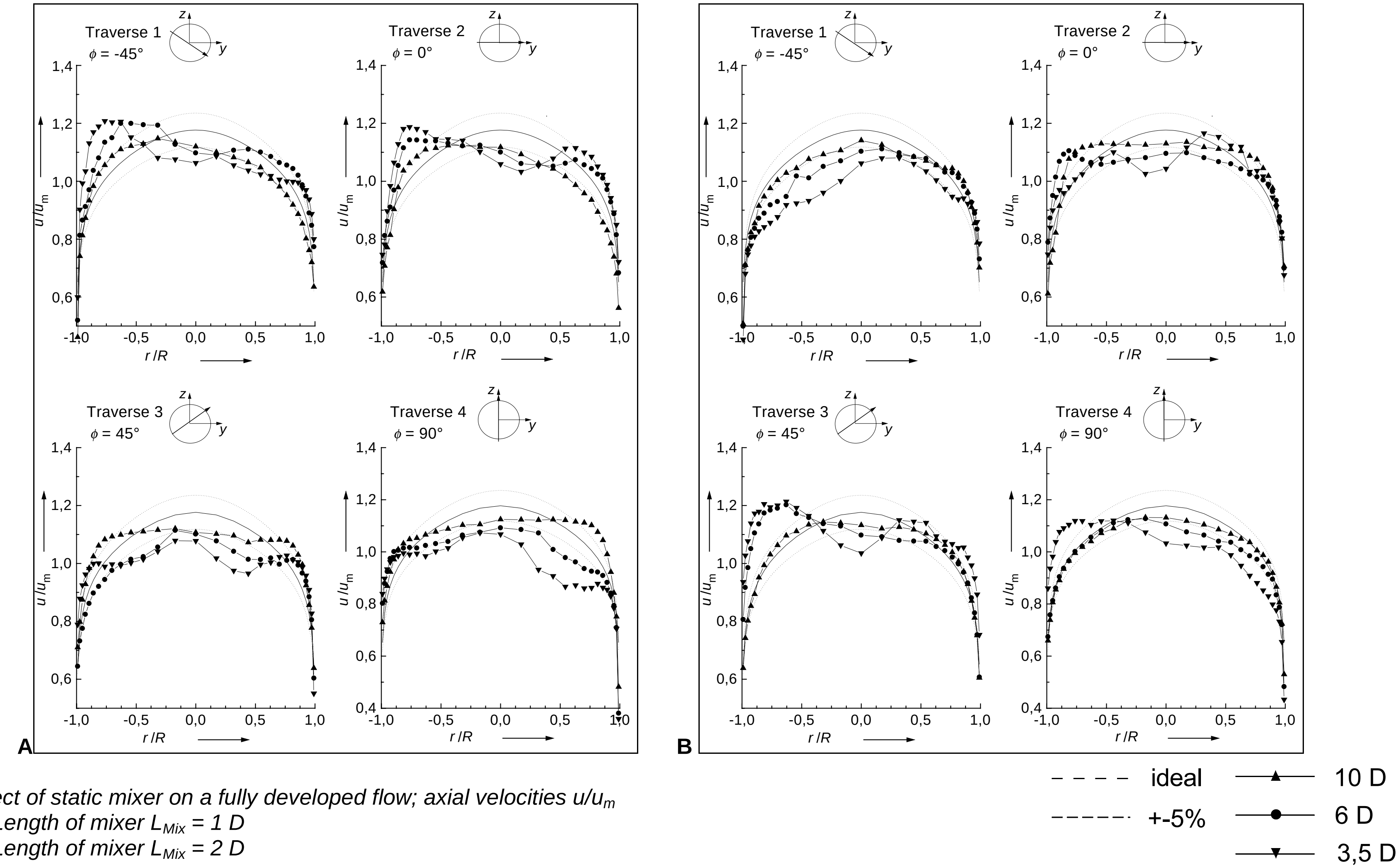


Fig. 8: *Effect of static mixer on a fully developed flow; axial velocities* u/u_m
***A**: Length of mixer* $L_{Mix} = 1\ D$
***B**: Length of mixer* $L_{Mix} = 2\ D$

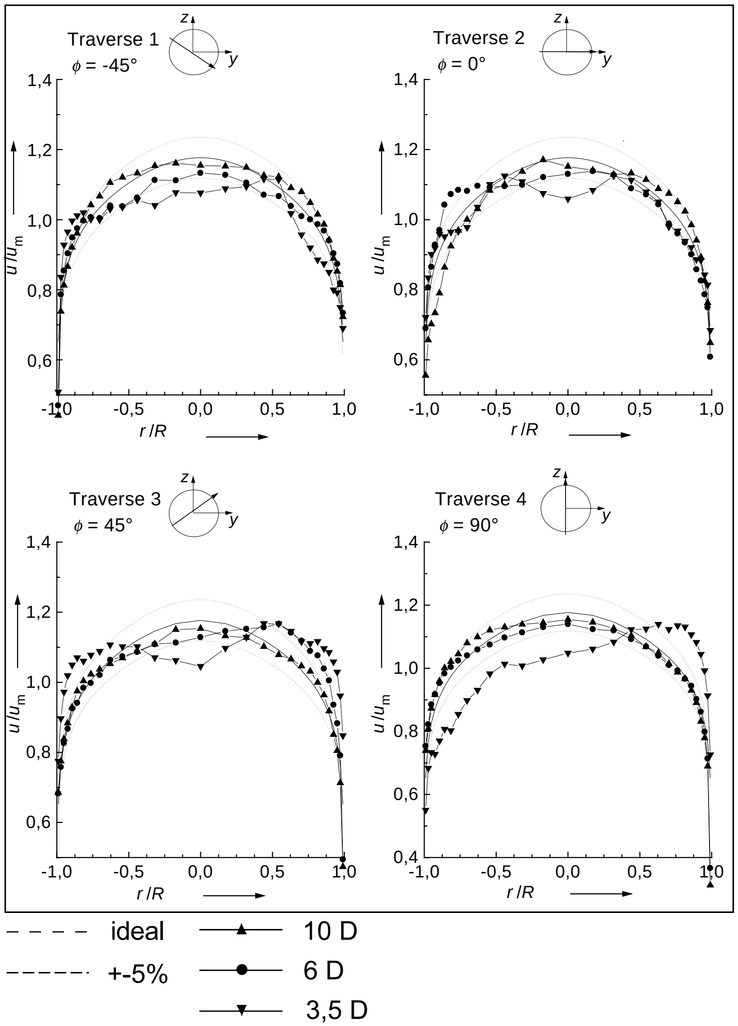


Fig. 9: *Axial velocities u/u_m downstream to static mixer (L_{Mix} = 2 D) in Conf. 1 (see Fig. 4) at difference distances*

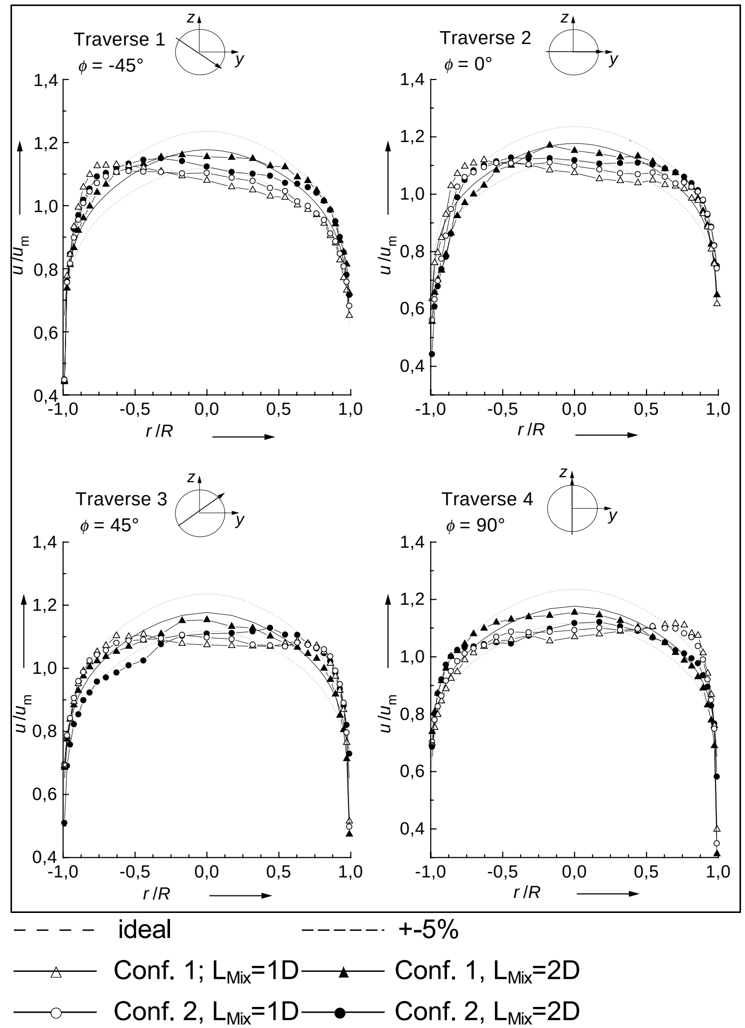


Fig 10: *Axial velocities u/u_m downstream to static mixer in Conf. 1 and Conf. 2 (see Fig. 4) 10 D downstream to perturbation*

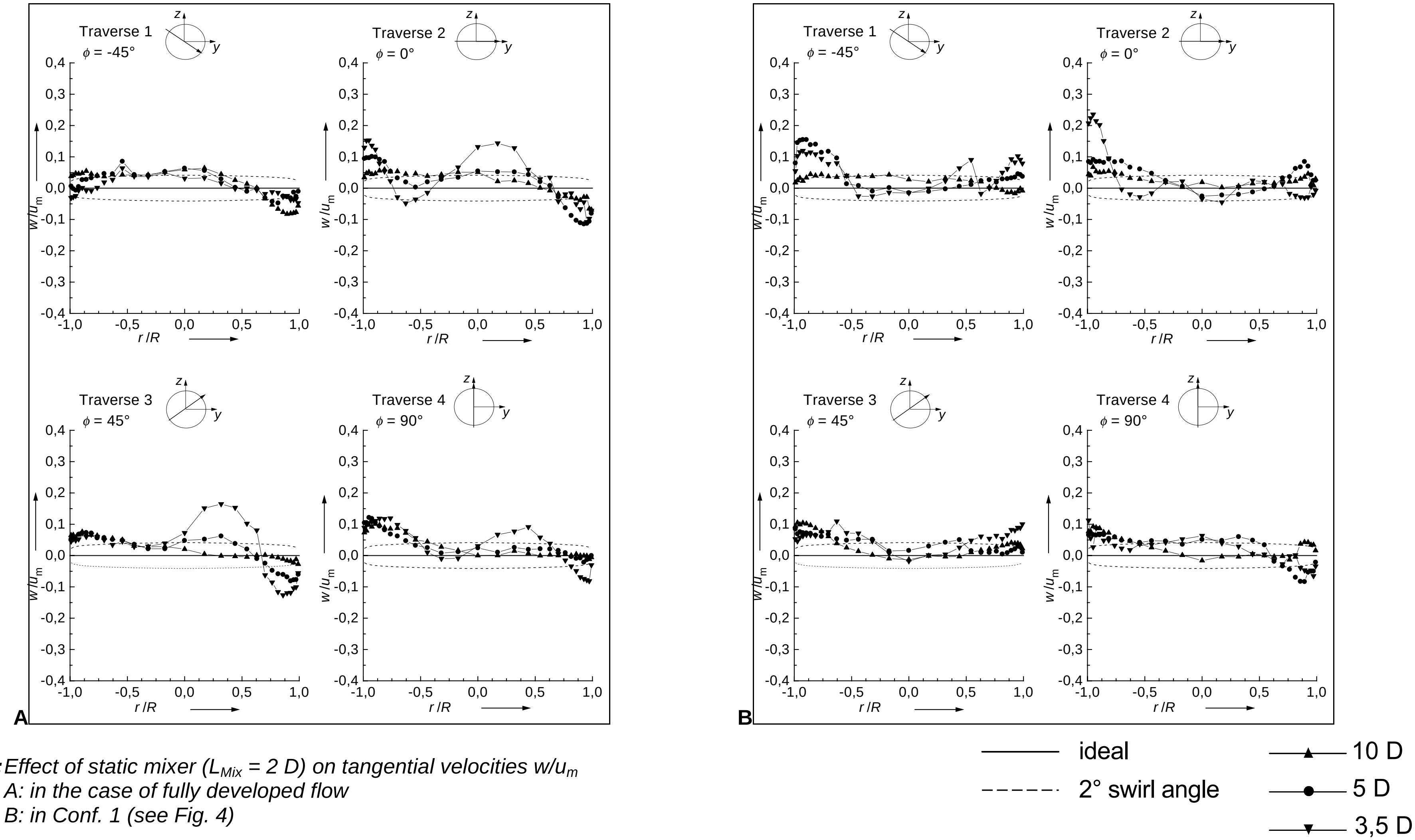


Fig. 11: *Effect of static mixer (L_{Mix} = 2 D) on tangential velocities w/u_m*
A: in the case of fully developed flow
B: in Conf. 1 (see Fig. 4)