CFD WORKSHOP

Novi Sad, 29th March 2018

CALIBRATION OF ATP DAMPER'S MATHEMATICAL MODEL BY CFD SIMULATION

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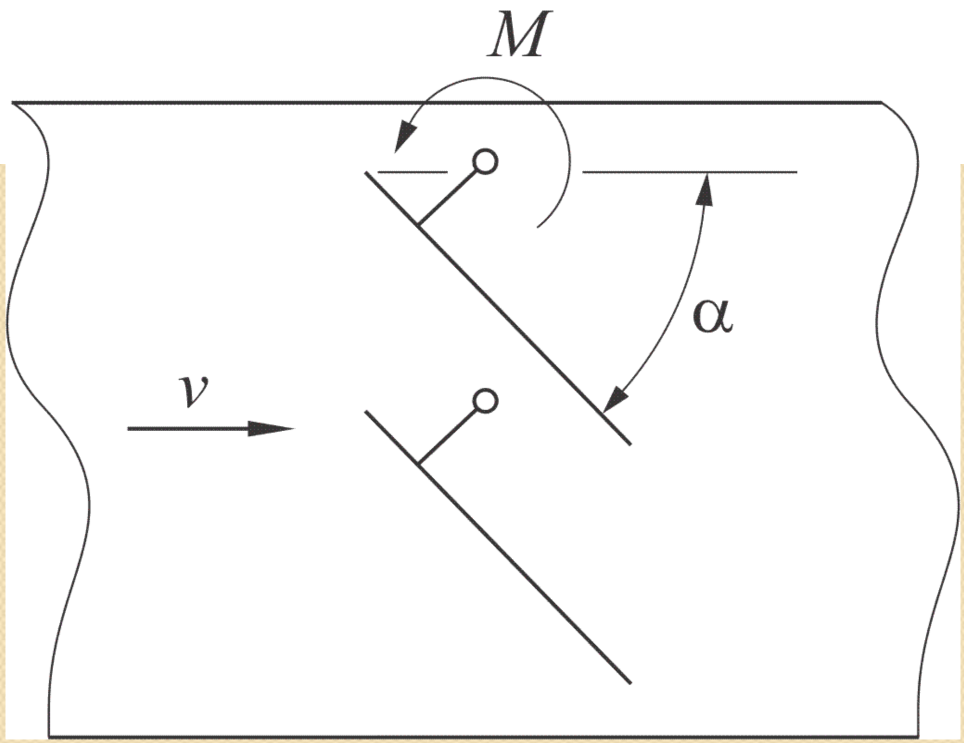
ATP Damper

ATP (Air Torque Position) damper measures air velocity v indirectly by measuring the position of the blades α and the moment M of air acting on the blade:

$$v = f(M, \alpha)$$



Operating parameters of ATP dampers

The Subject of Research

Federspiel came to correlation between the air velocity directly in front of the damper, *v*, the angle of attack of the blade, *a,* and the moment of the air stream acting on the blade, *M*:

$$v|v| = G^2(\alpha)\frac{2M}{\rho A_u D_h}$$

where:

ρ – air density [kg/m³],

D_h – hydraulic diameter [m];

A_u – cross-section area upstream of damper [m²];

The correlation function in previous equation is as follows:

$$G(\alpha) = \left(\frac{D_h}{\frac{y}{C_{Q,a}^2} + \frac{x}{C_{Q,l}^2 \cdot tg\alpha}} \right)^{\frac{1}{2}}$$

where:

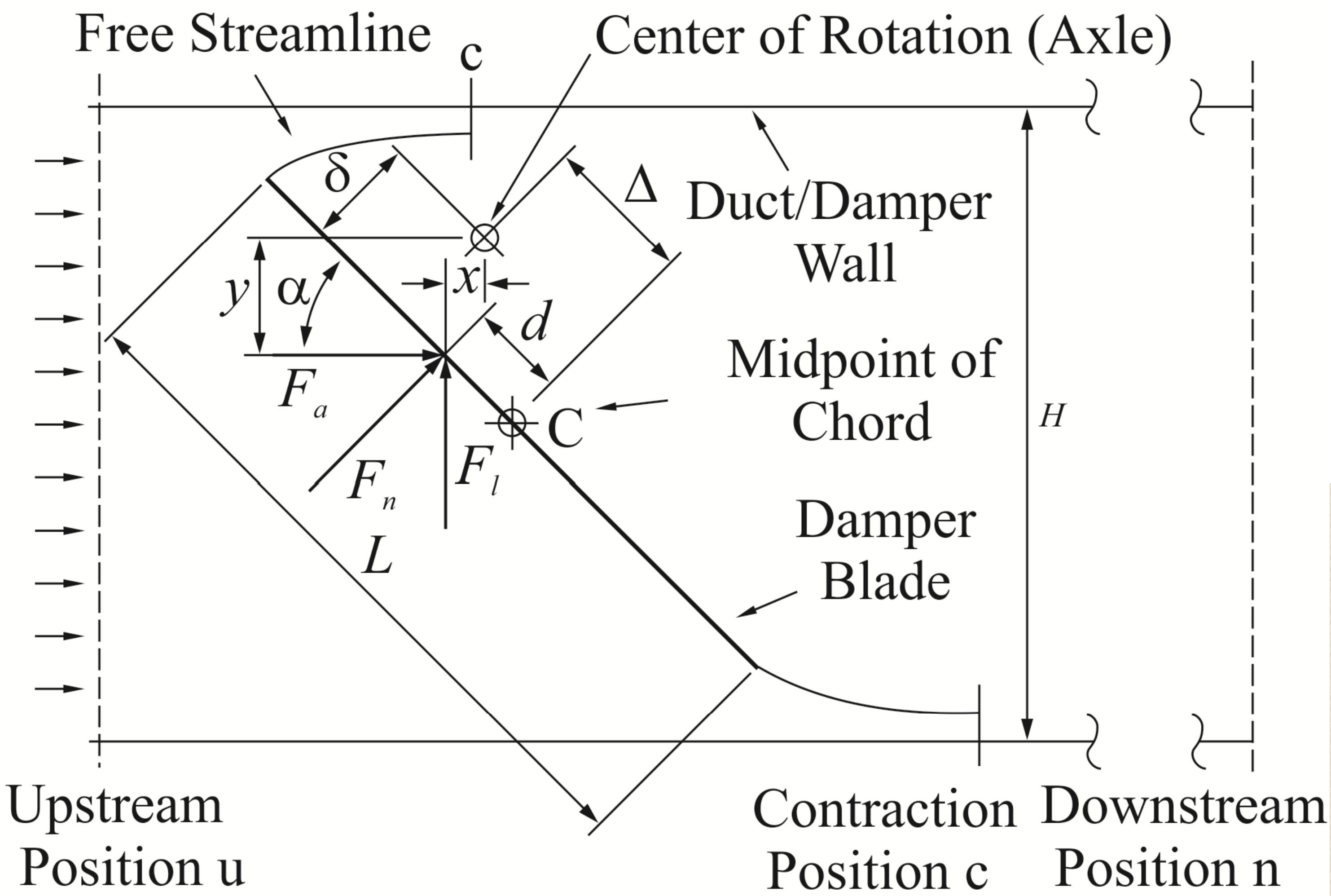
x - is the longitudinal distance from the axle to the center of pressure [m];

y - is the lateral distance from the axle to the center of pressure [m];

$C_{Q,a}$ - is the longitudinal flow coefficient [-] and

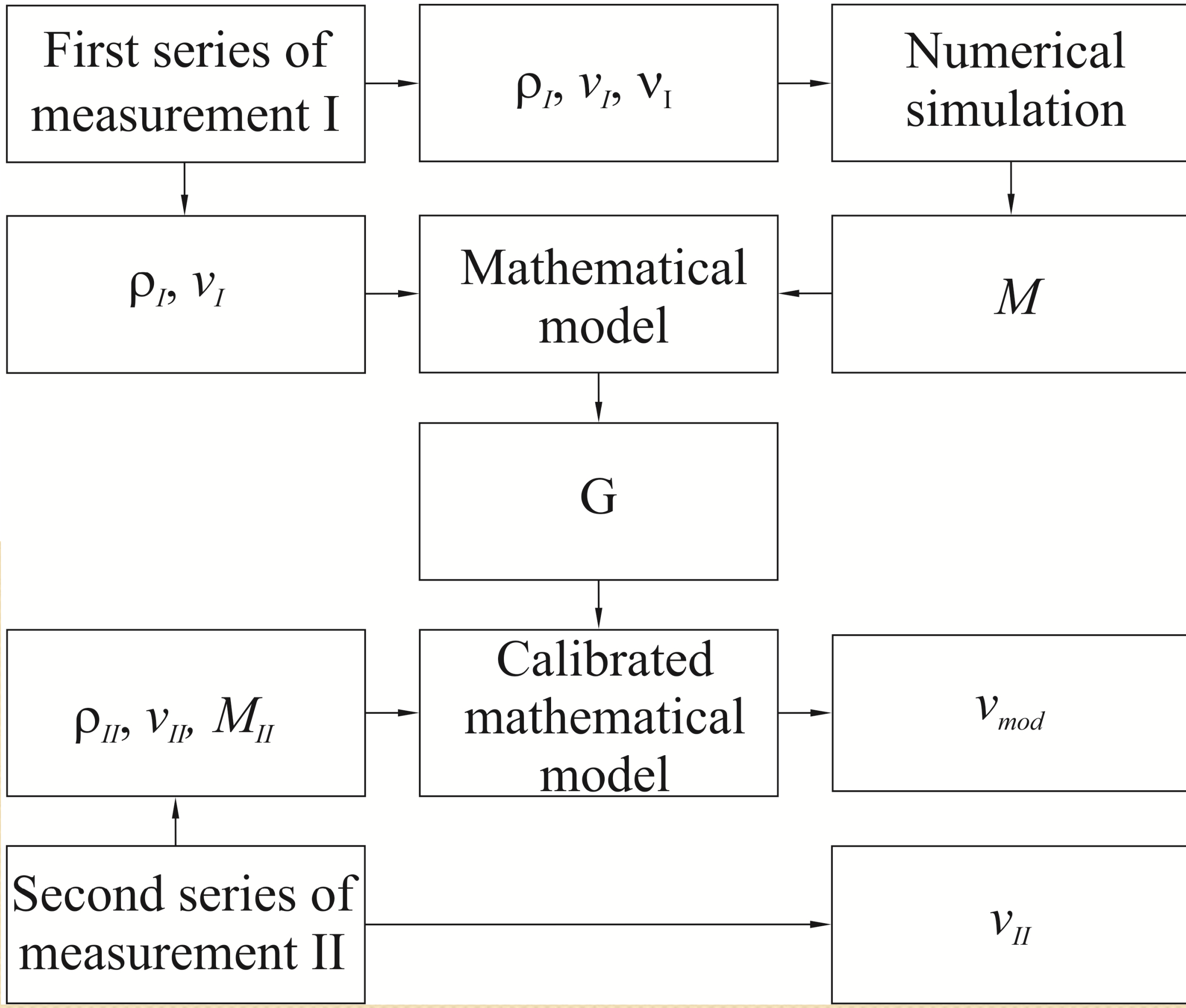
$C_{Q,l}$ - is the lateral flow coefficient [-].

The Subject of Research



Schematic representation of ATP damper with single blade

The Aim of Research

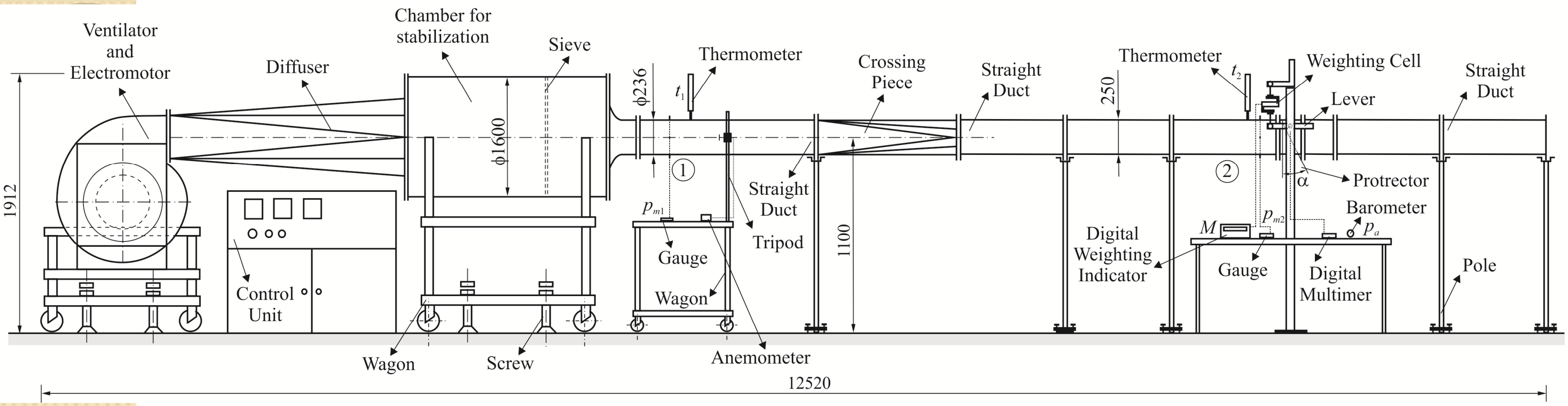


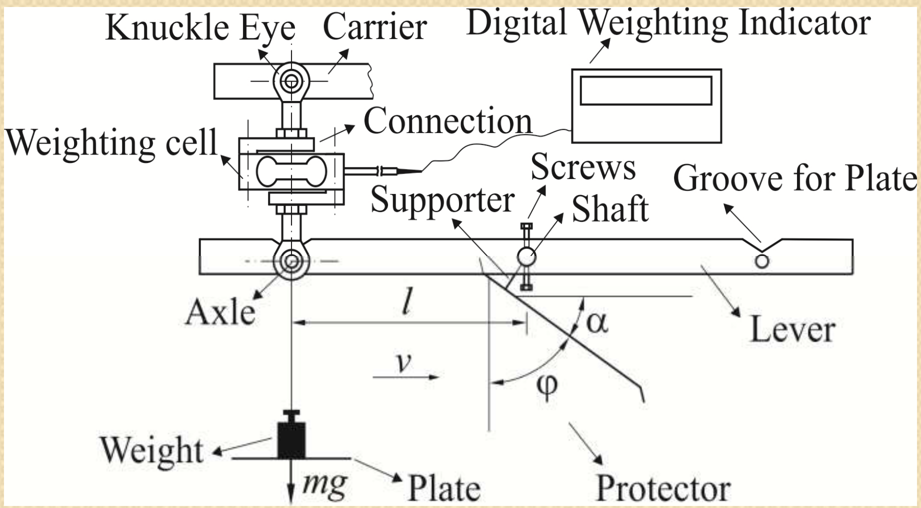
Algorithm of mathematical model calibration with the results of the numerical simulation and its experimental verification for one value of the blade angle of attack α

Experimental setup

View of ATP damper test rig

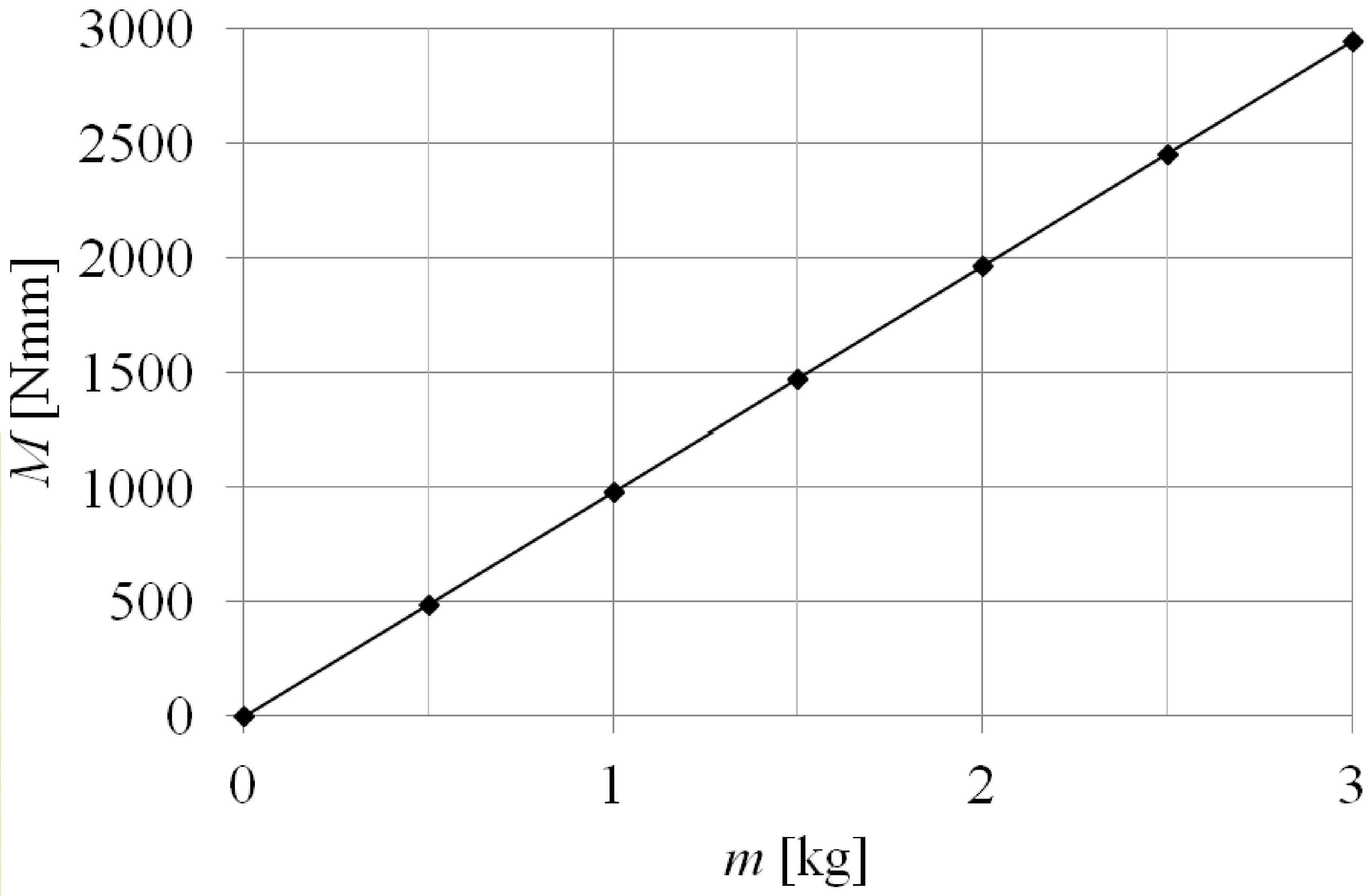
Experimental setup





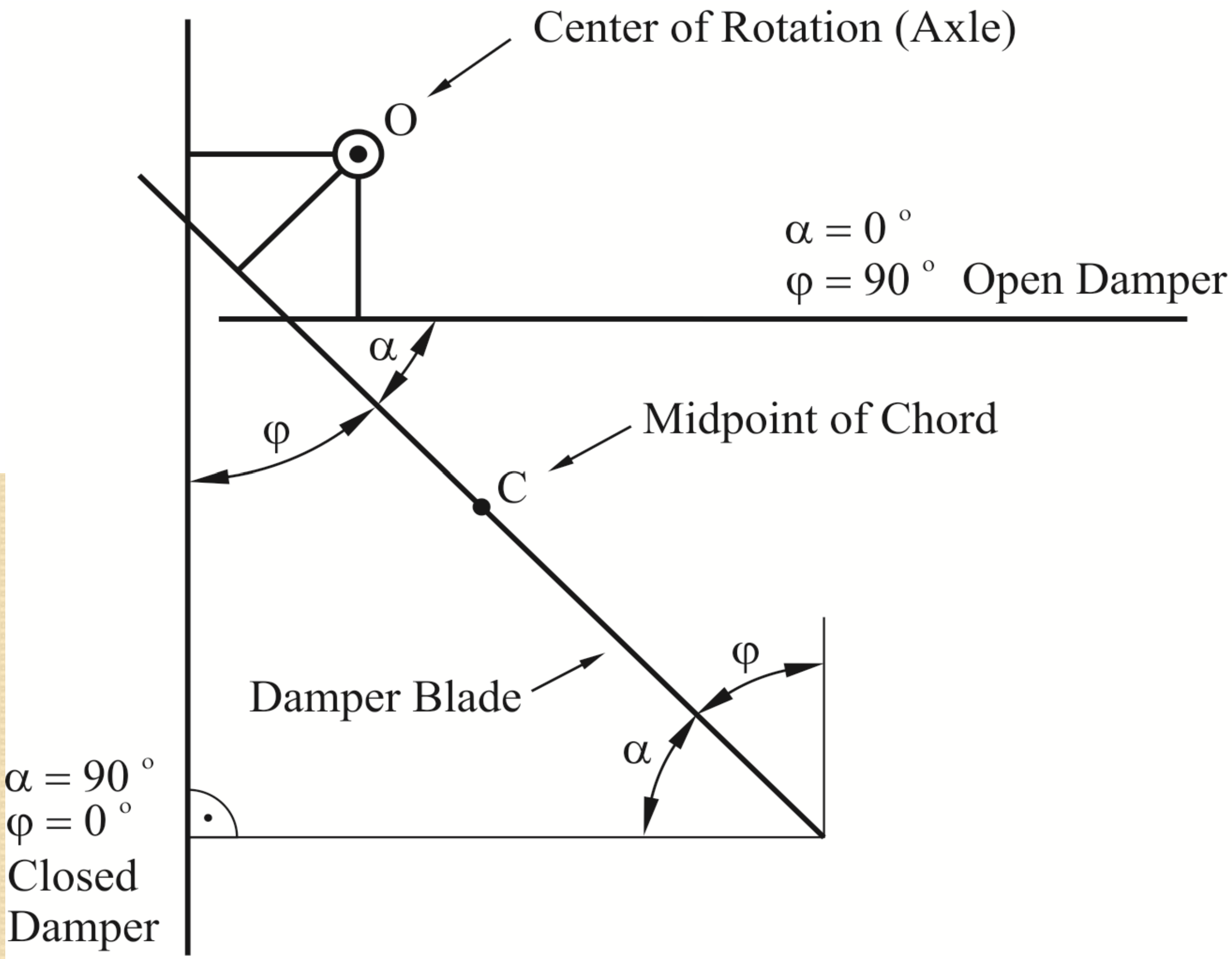
Schematic diagram of the ATP damper test rig

Experimental setup



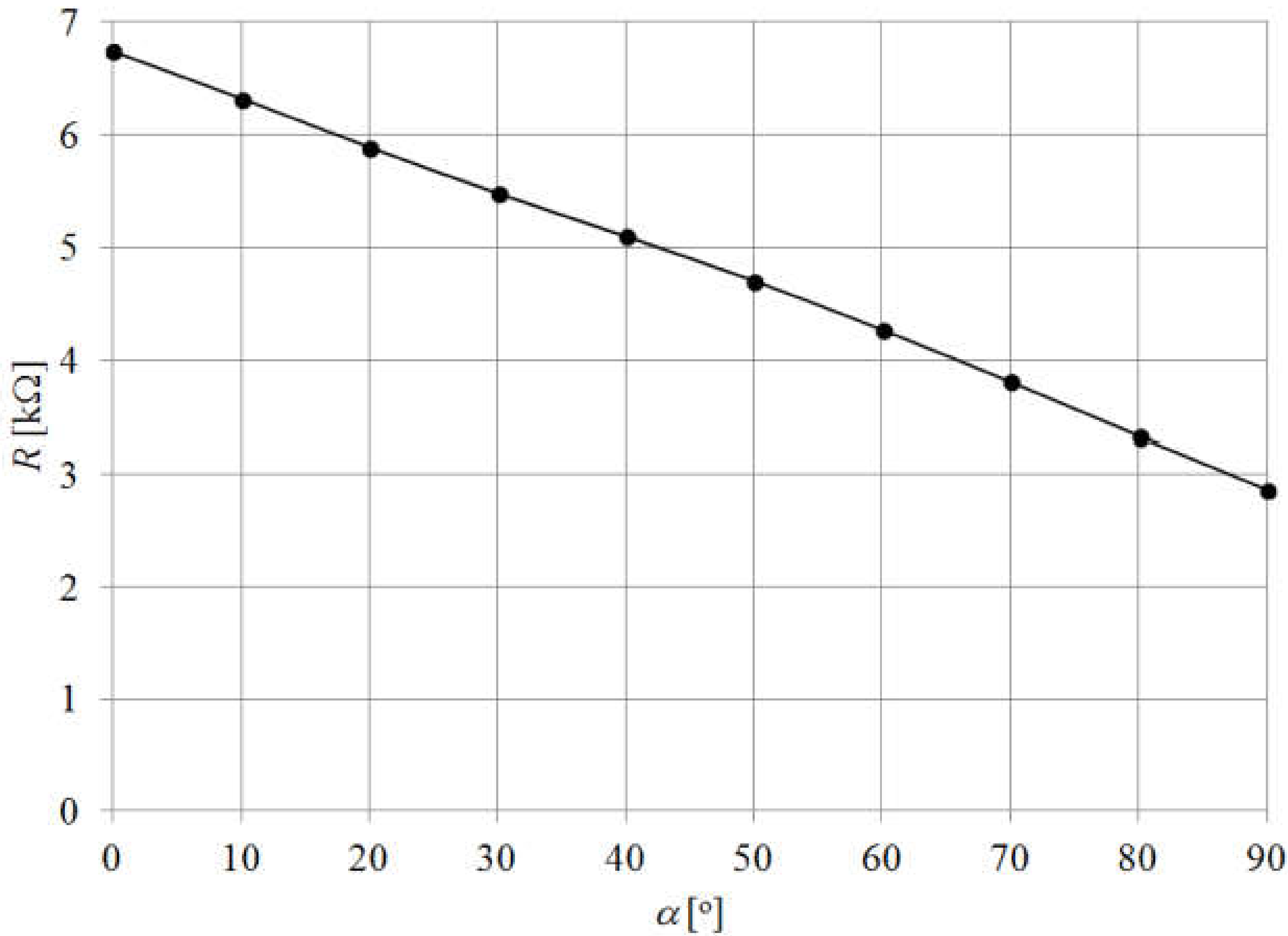
Calibration curve of the moment meter for lever arm length *l*=100 mm

Experimental setup



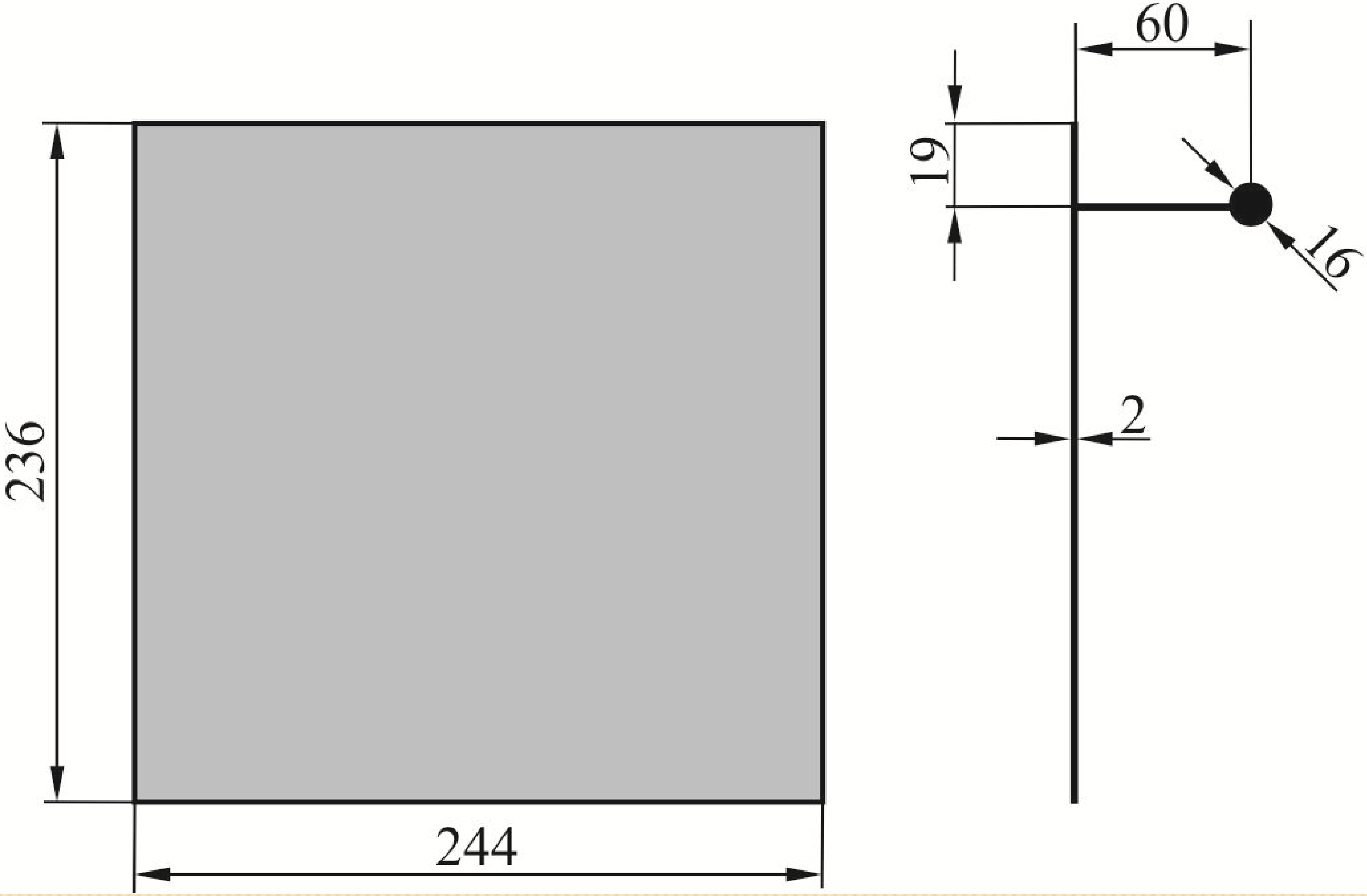
The ATP damper blade angle of attack with the axis of rotation displaced from the axis of the blades

Experimental setup



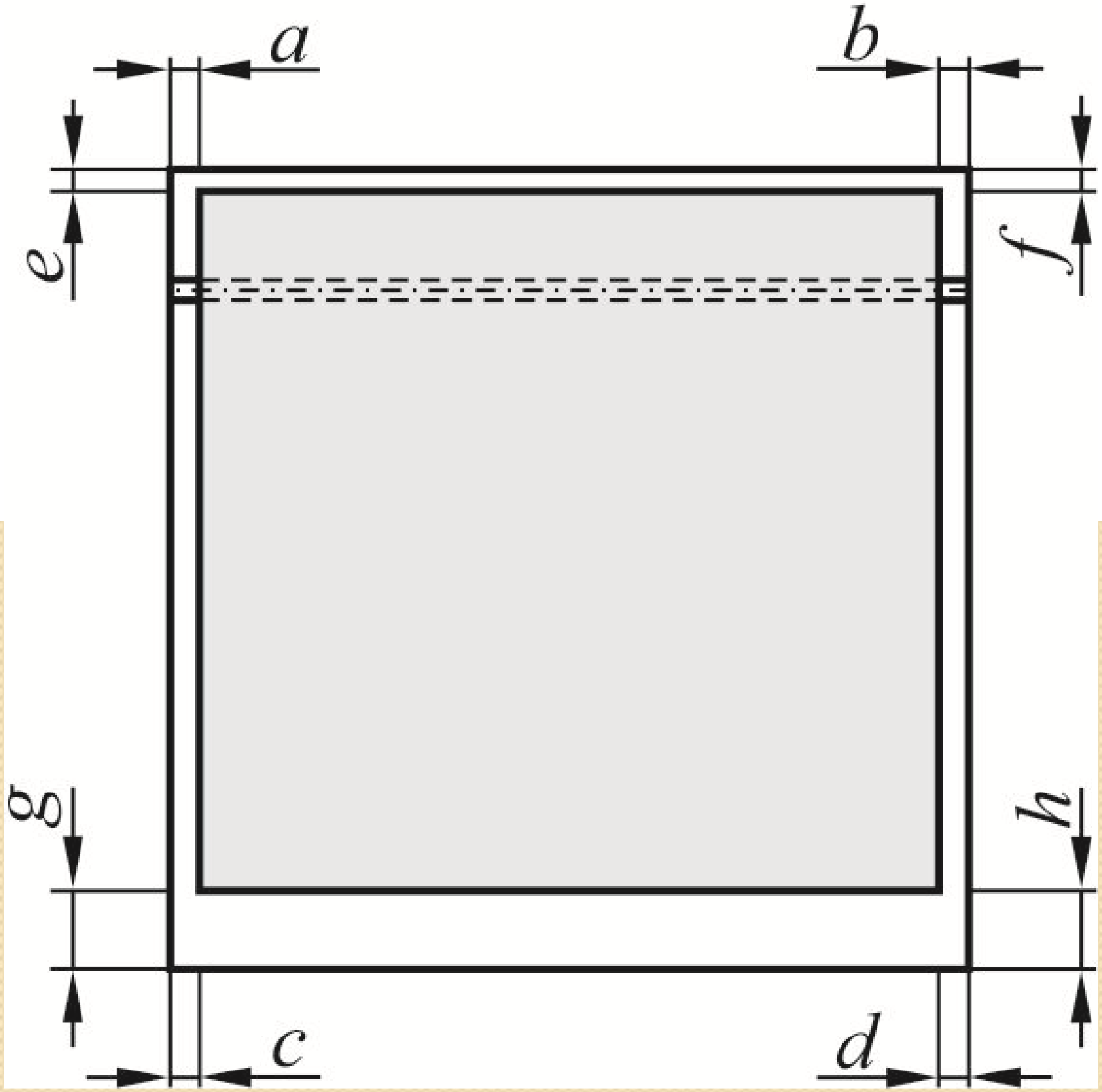
Typical calibration curve of the rotary potentiometer

Laboratory ATP Damper



Dimensions of ATP damper blades

Laboratory ATP Damper



Dimensions of clearance between blade and ATP damper wall

Laboratory ATP Damper

The clearance sizes between blade and damper housing in horizontal direction

α [º]	*a* [mm]	*b* [mm]	*c* [mm]	*d* [mm]
0	2.88	3.62	1.63	2.37
10	2.89	3.61	1.48	2.52
20	2.92	3.58	1.35	2.66
30	2.95	3.55	2.73	4.27
40	3.11	3.64	2.63	4.37
50	3.15	3.60	2.55	4.45
60	3.19	3.56	2.50	4.50
70	3.23	3.52	2.22	4.27
80	3.28	3.47	2.23	4.28
90	3.32	3.43	2.38	4.37

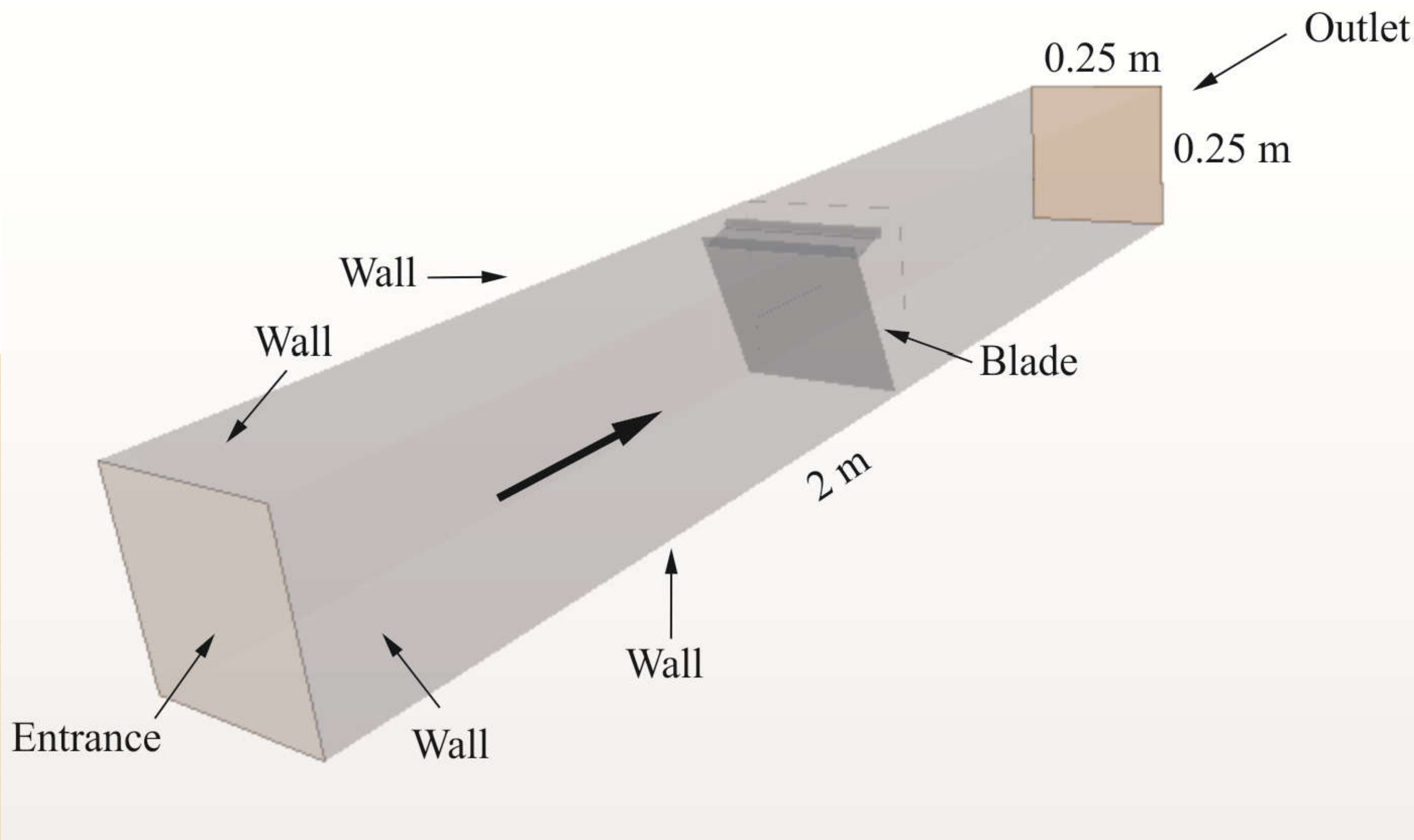
Laboratory ATP Damper

The clearance sizes between blade and damper housing in vertical direction

α [º]	e [mm]	f [mm]	g [mm]	h [mm]
0	82	83	168.24	167.26
10	77.79	78.76	131.48	130.51
20	71.83	72.81	97.7	96.72
30	64.34	65.31	67.91	66.94
40	55.65	56.63	43.03	42.05
50	45.79	46.77	23.8	22.82
60	35.18	36.13	10.81	9.84
70	24.15	25.12	4.71	3.74
80	12.67	13.65	5.19	4.22
90	2.14	3.11	12.61	11.64

Application of CFD

For the purposes of numerical simulation the commercial software was used.



Boundaries of the mesh model

Application of CFD

Space discretization is done with unstructured polyhedral mesh.

The mesh parameters for the blade of attack od 70^o

Mesh parameter	Value
Number of cells	439180
Average cell size	0.007 m
Number of prism layers	2
Prism layer stretching	1.5
Prism layer thickness	0.0007 m
Cell size close to the walls	0.00175 m
Wall distance	3.4

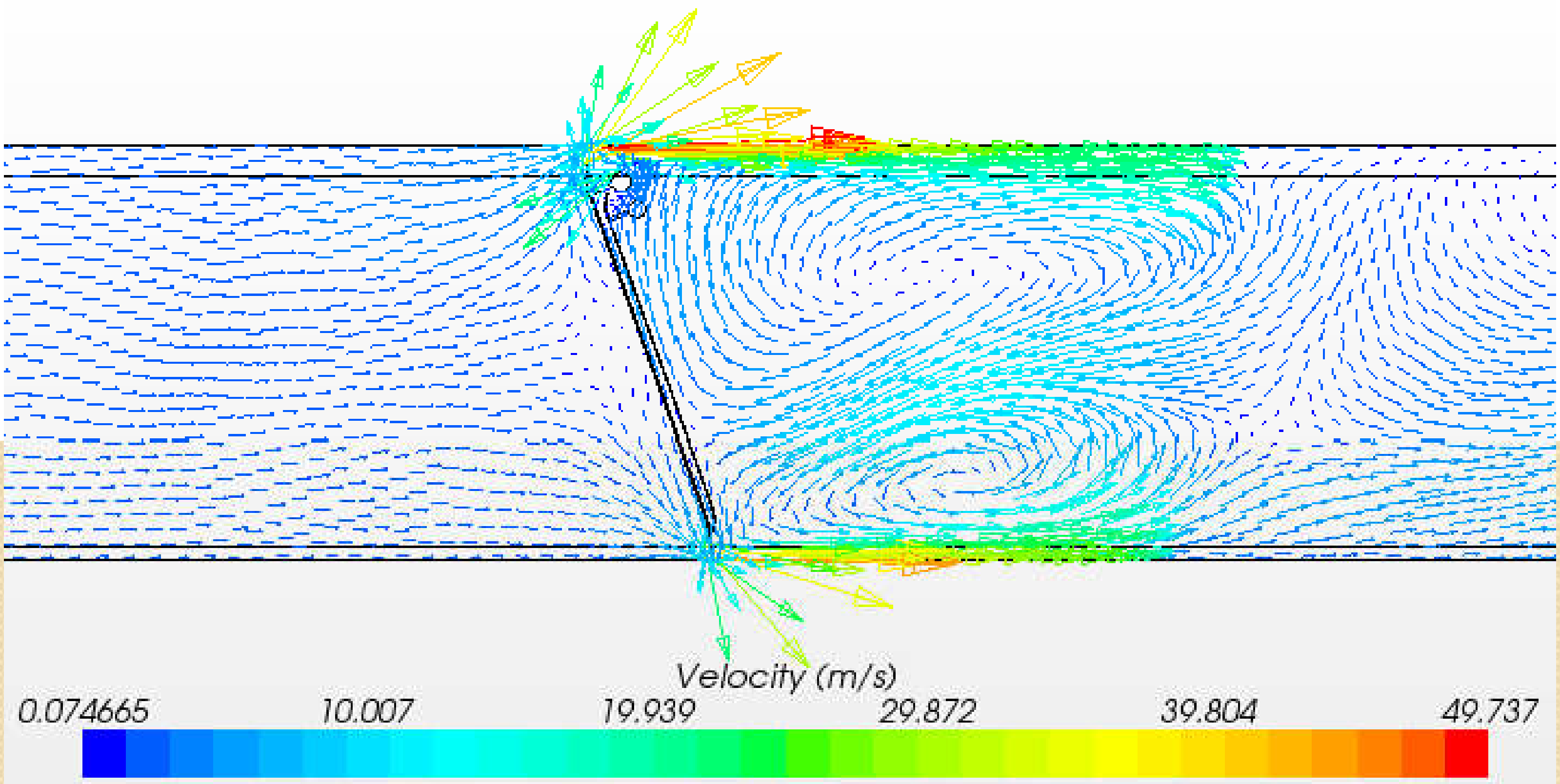
Application of CFD

Discretization of the partial differential equations was done using the finite volume method while the turbulence model was the k - ε model.

Enabled Physics Models

Enabled Physics Models
Constant Density
Three Dimensional
Steady
Gas
Segregated Flow
Gradients
Turbulent
K-Epsilon Turbulence
Reynolds Averaged Navier-Stokes
Realizable K-Epsilon Two Layer
Two Layer All + Wall Treatment

Application of CFD



The velocity vectors field on a plane inside domen for the air mass flow rate of 0.21 kg/s and for the blade angle of attack of 70 ^{o}

Application of CFD

The moment of force on a surface about an axis is defined:

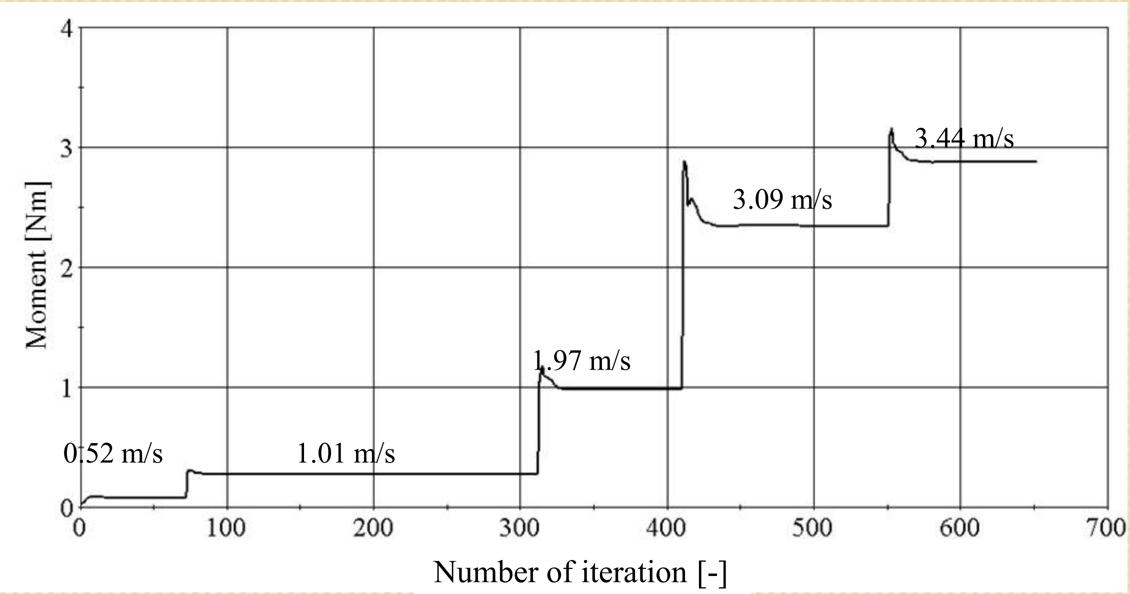
$$M = \sum_f \left[r_f x \left(F_{fp} + F_{f\tau} \right) \right] \cdot a$$

where:

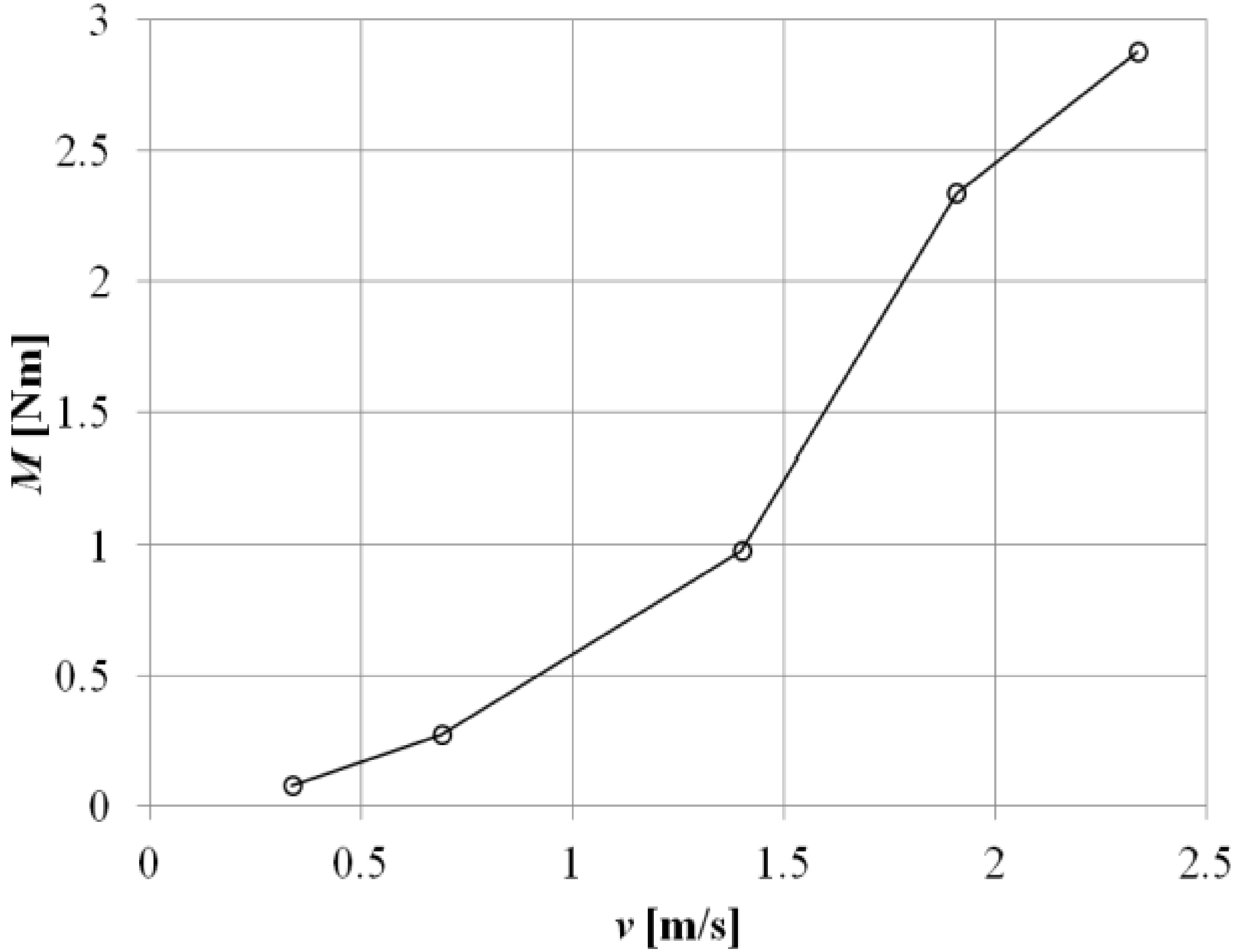
F_{fp} and F_{ft} are the pressure and shear force vectors;
a is a vector defining the axis through point ;
x_0 about which the moment is calculated and
r_f is the position of the face relative to x_0.

This quantity was computed using the inbuilt functions in the flow solver.

Predicted torque for several inlet velocities, for blade angle of attack α=70°



Results



Predicted torque for several inlet velocities, for blade angle of attack α=70°

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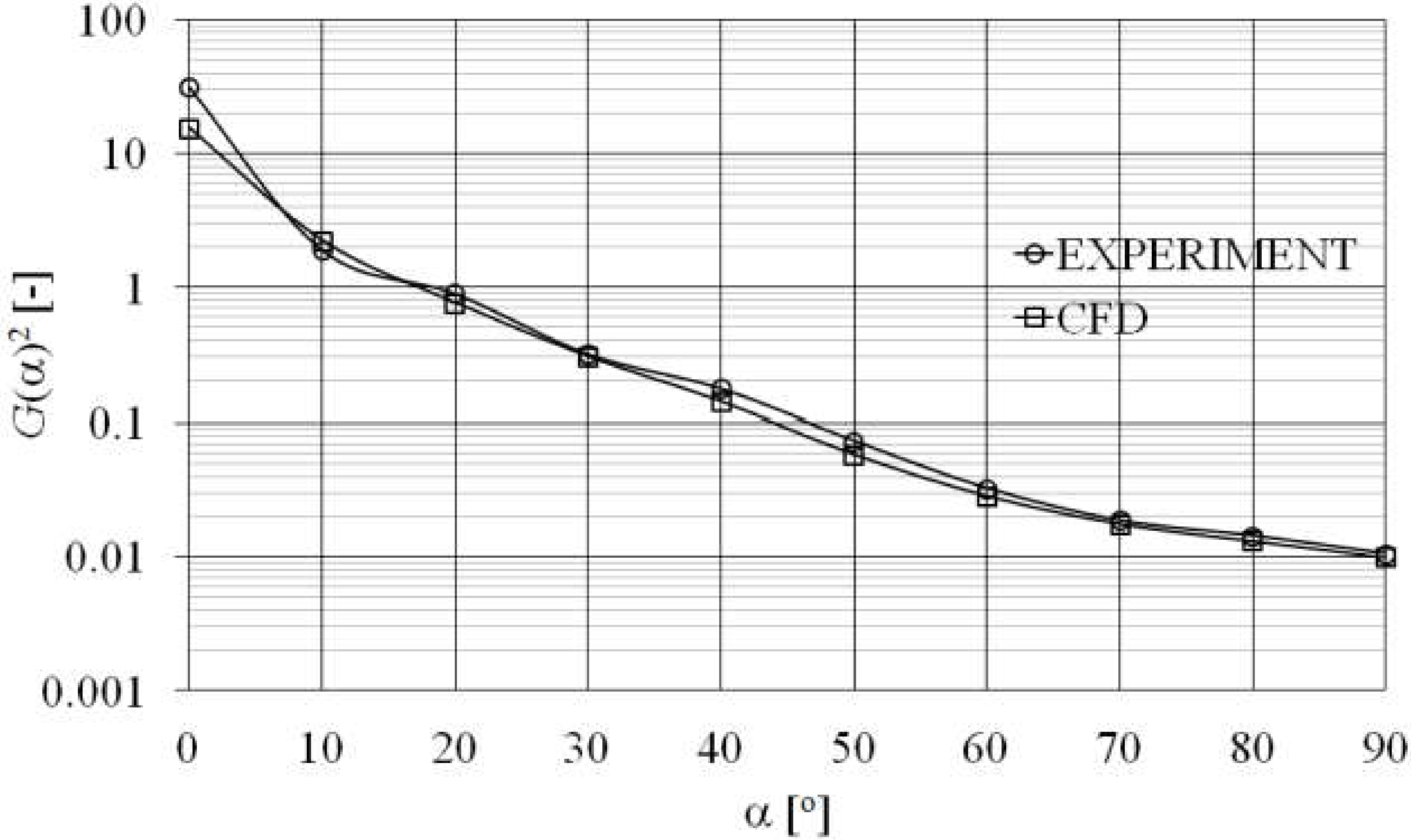
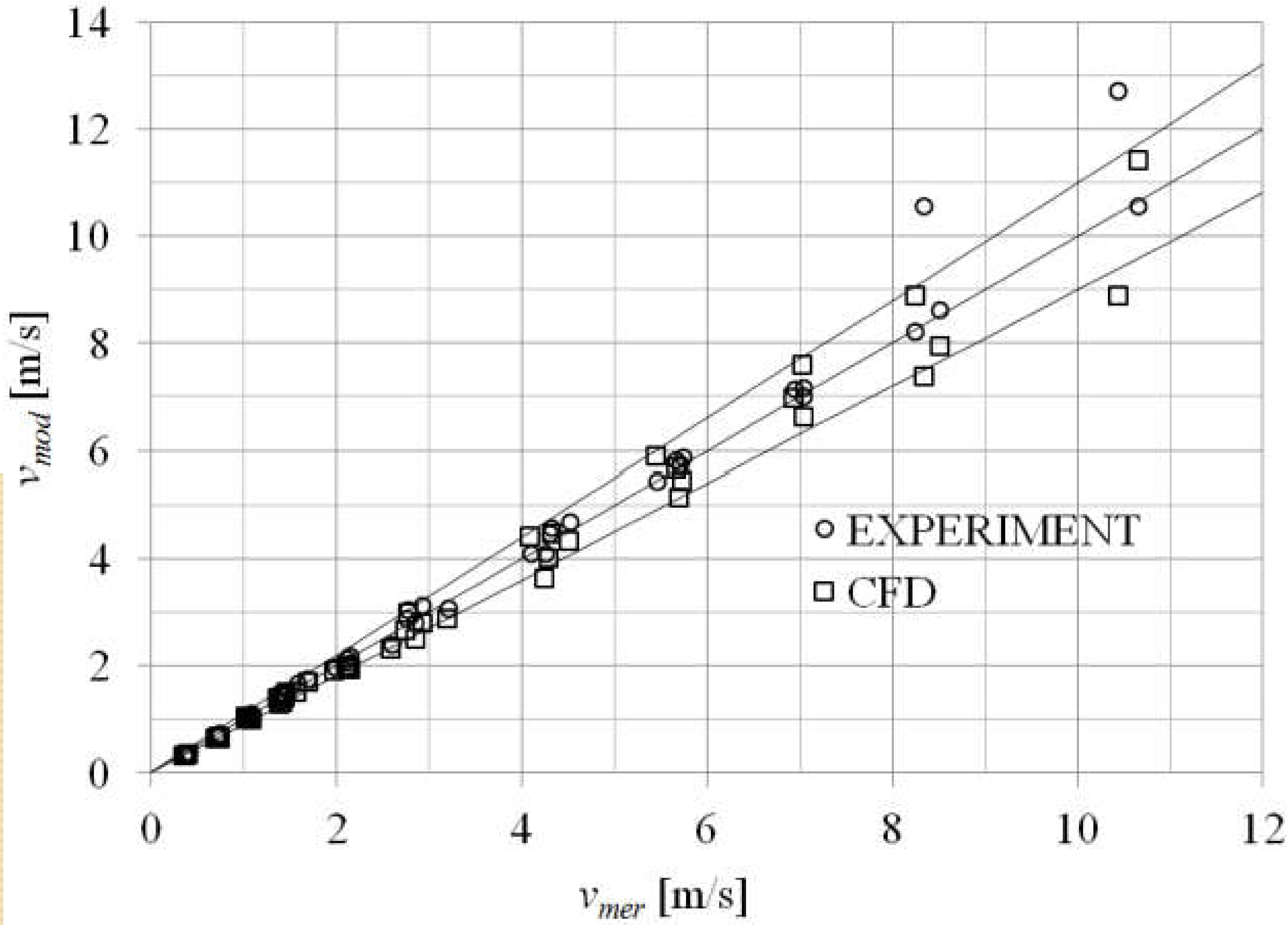


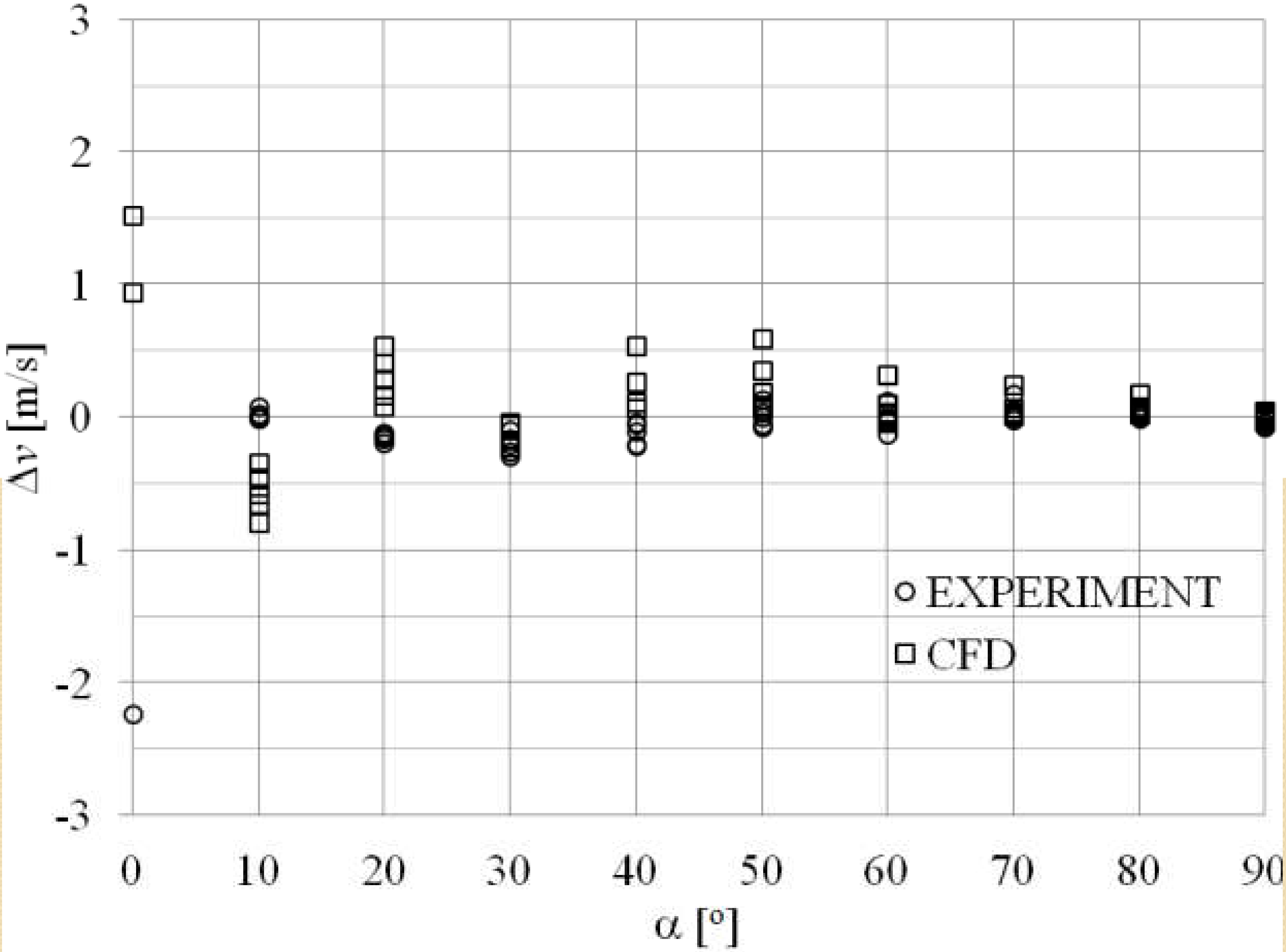
The square of correlation functions of the ATP damper obtained experimentally and with CFD results

Results



Results of experimental verification of mathematical model calibrated with experimental method and CFD results

Results



Results of the verification of the mathematical model calibrated with experimental data and with CFD results

Conclusions

- Numerical calibration of ATP damper mathematical model lead to at least as good results as experimental calibration of the model.
- The difference between the measured and modeled velocity normalized with the measured velocity for both methods of calibration is in the range of ± 10%.
- The difference between the measured and model velocity exceedes the above mentioned limits only when the damper is fully open.
- The share of experiments both in the calibration of mathematical models and the design phase of ATP dampers can be reduced significantly.
- To achieve such a good accuracy in the numerical model, the geometry of the device must be accurately reproduced in the computations.
- The size of the cleareances was found to be an important parameter in the computations.
- Finally, it should be noted that the results of the verification of the mathematical model are in favour of the universality of the existing mathematical models.