EXPERIMENTAL RESEARCH OF MIXING NOZZLE FOR EJECTORS

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Abstract

In this article, two positions of a lobe-shaped nozzle intended for the ejector mixing process are compared. The objective of the experiments was the identification of the cross-shaped nozzle flow pattern. The measurements of nozzle velocity profiles were conducted at a pressure of 2 kPa. Separate nozzle velocity profiles were measured from the nozzle mouth up to the distance of 90 mm and 180 mm, in 15 mm or 30 mm intervals respectively. In this way, 10 velocity profiles were measured per each nozzle position and consequently used for the final diagram. An important principle for the recommendation of a nozzle for the mixing process was the characteristics of cross-shaped nozzle velocity profiles measured at different positions, using the modern contactless measurement method - Laser Doppler Anemometry (LDA). Based on the measured data, the cross-shaped nozzle velocity profiles were described in detail. Defects of the cross-shaped nozzle were identified by the experiments and thus its unsuitability for the ejector mixing process.

Introduction

Despite an extensive boom of software modeling techniques the experimental approach to the research handling the area of fluid mechanics is still an irreplaceable source of information. Even the best mathematical-physical model deals with simplified or idealized conditions. For that reason, it is necessary to adjust the model and verify it by comparing the results with a proven method.

In recent years, fluid mechanics has exploited more and more measuring methods that are based on optoelectronic principles, using light. These methods include, for example, LDA (Laser Doppler Anemometry), PDA (Phase Doppler Anemometry), PIV (Particle Image Velocimetry) etc. Laser anemometry seems to be an extremely exact tool for measuring real objects. Its benefit is that it is contactless. It measures a medium speed using microscopic particles that are diffused in the medium. The measurement is linear within the whole range. The results do not depend on the surrounding conditions, such as pressure, temperature, humidity etc.

Previously, the laboratories of the TUL have already dealt with experimental research of mixing nozzles for ejectors. The first measurement faced a big problem. A Pitot tube was used to affect significantly the ejector functionality. In addition, this affect was not constant, but depended on the tube insertion into the mixing chamber. The result recalculation was necessary. The next experimental method of the flow pattern examination was the method of hot wire (CTA method). However, the CTA method did not allow for the measuring of the flow pattern without any object influence – the CTA probe of the anemometer. The interruption of the flow by the probe led to a measurement error.

1 Laser Doppler Anemometry

The LDA method is the most commonly used modern contactless measurement technique for the research of liquid flow. It is best suited for studies of stationary flow. Due to a small measuring probe it allows an extraordinary spatial resolution. We have chosen this method for the aforementioned benefits.

1.1 The LDA method principle

LDA is a contact less measuring method that exploits the Doppler's effect. LDA measures a difference in frequency of laser light diffused on a particle that is carried by the examined liquid.

To measure the frequency change (Doppler's shift) the heterodyne detection is used, as shown in *Fig. 1* Two laser beams intersect at an angle of Φ, their intersection creates an optical probe. On a particle, passing through the optical probe, two light waves fall with a frequency of f, in the directions of unit vectors ei1 and ei2. [1]

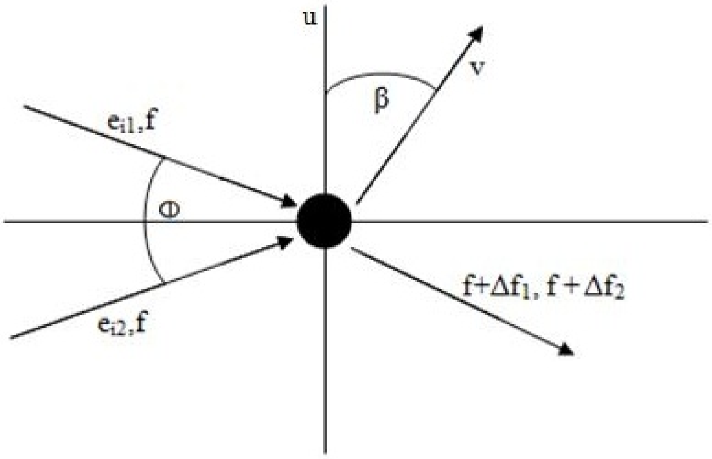

Fig. 1 Heterodyne detection scheme

A detector detects the light, diffused by a particle. This detector registers the differential frequency, so called Doppler's frequency f_D. The Doppler's frequency is proportional to the velocity component u. The velocity component u lies in the plane of the intersected laser beams and it is perpendicular to the central line of the angle Φ, closed by the two beams. The velocity component of the flow is possible to evaluate from the Doppler's frequency:

$$u = \frac{\lambda}{2\sin(\theta/2)} f_D, \quad (1)$$

where θ is anangle of the two intersected laser beams, u is a component of a particle velocity $\boldsymbol{v}$ projected into a direction (e_{i2}-e_{i1}),λ is a wavelength of laser light.

1.1.1 Laser Doppler anemometer

A basic arrangement of a laser Doppler anemometer in the differential mode is shown in *Fig. 2*. The laser beam is led from a laser towards a divider, which divides the beam into two identical beams that are parallel with the central line of the system. Thetransmitting/receivinglens focalize these beams into a focus point. Within the focus point an optical probe consisting of the intersection of the two beams is created. A particle passing through this probe diffuses light. This light is led through optics to a detector. Two waves diffused by the particle are examined by the photo-detector using heterodyne detection. The photo-detector is positioned in a so-called backscatter. This arrangement has considerable benefits, for example, only one adjustment of the optical transmitting and detecting part is needed. The disadvantage of this method is the low intensity of the diffused light; therefore it is necessary to use a sufficiently powerful laser. The main task of the photo-detector is to transfer an optical Doppler's signal to an electric signal and its consecutive amplification. The output signal of the photomultiplier is a current that contains information of the measured velocity. The aim of the evaluating processor of the LDA is to measure the frequency of the Doppler's peak.

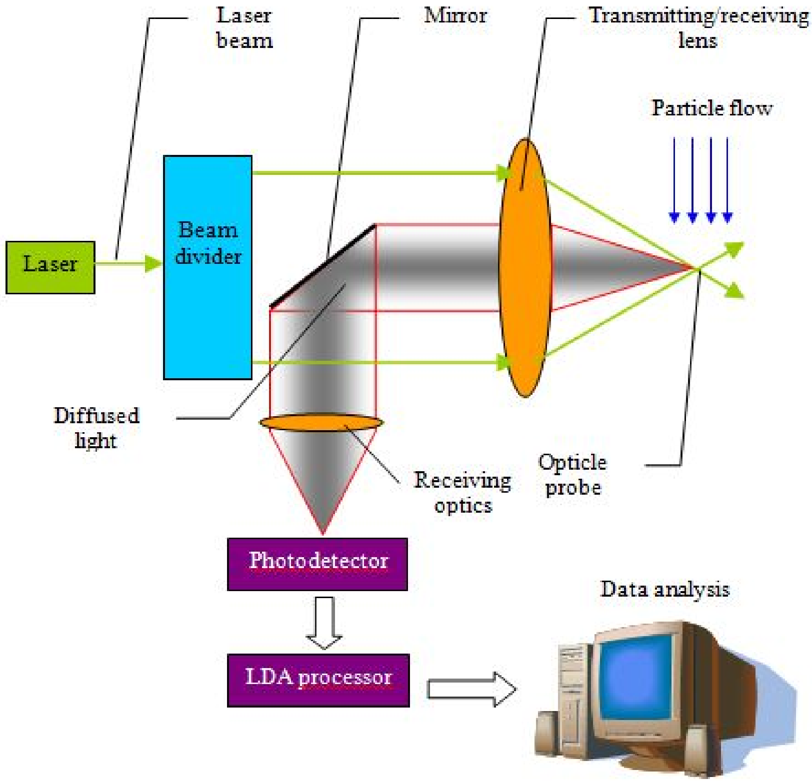

Fig. 2 Scheme of laser Doppler anemometer

1.1.2 Analysis of measured data

The output of the measurement at the position of the optical probe is a set of Doppler's signals. These are furthermore converted to speed according to formula (1); the speed values are then evaluated by statistical analysis. In the LDA, these statistics normally provide for example average speed, standard deviation and turbulence intensity.

$$\bar{u} = \frac{1}{N}\sum_{i=1}^{N} u_i, \quad \sigma^2 = \frac{1}{N-1}\sum_{i=1}^{N}(u_i - \bar{u})^2, \quad Tu = \frac{\sigma}{\bar{u}} * 100\,, \qquad (2)$$

where $\bar{u}$ is average speed, σ is variance and T_u is turbulence intensity.

1.1.3 Limits and imperfection of the LDA method

Most possibly, exact current measurement, evenness of the measured medium saturation with tracer particles and their properties belong among the basic conditions for correct functionality of the LDA.

The limiting condition of the LDA applicability is the deviation of current direction from the measured velocity component. The band error, “fridge bias”, is possible to eliminate successfully if using a Brag’s cell. The velocity error, “velocity bias”, is possible to eliminate if introducing a weighting function inversely proportional to velocity [1].

2 Experiment

The experiment was carried out with a cross nozzle (*Fig. 3*).

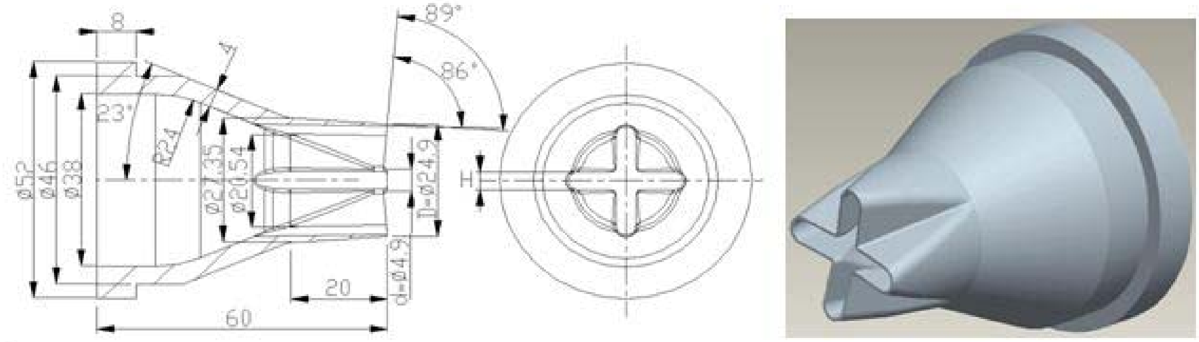

Fig. 3 Cross nozzle [2]

2.1 Conditions of measurement

The measurement of the velocity profiles on the nozzle was performed at a pressure of 2 kPa. At this pressure of the flowing air, we can expect a maximum velocity of about 60m/s from the nozzle. In consideration of this speed such transmitting/receiving objectives were selected, so that the maximum Doppler’s frequency would not exceed the maximum frequency of approximately 150MHz, which was possible to measure with the used counter (Dantec company) . An objective with a focal distance of 250mm was selected whichfulfilled the defined condition.

2.2 Measurement

A laser Doppler’s anemometer in operation is shown in *Fig. 4*. The detail displays the nozzle and objective, focusing the laser beamson the focal point. The created focal point creates the optical probe.

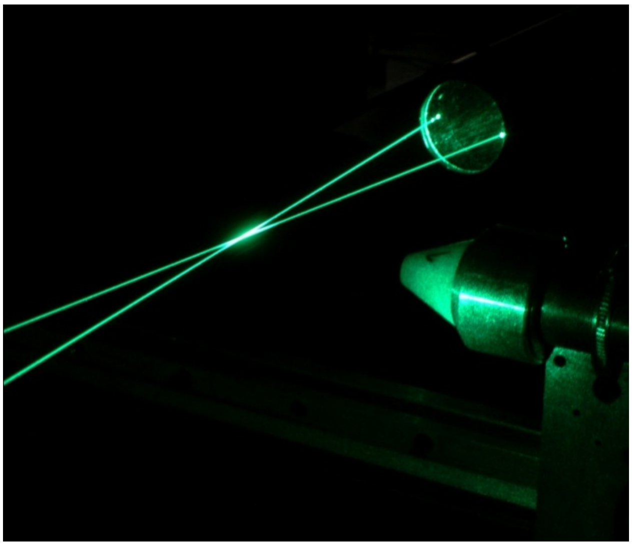

Fig. 4 Optical probe with the nozzle

3 Results of the measurement

Individual velocity profiles of the nozzle were measured using laser Doppler's anemometry from the nozzle aperture up to 90mm/15mm, and from 90 mm up to 180mm/30mm. This means that for one nozzle position, ten velocity profiles were gained, based on these profiles the final chart was drafted.

3.1 Cross nozzle

The cross nozzle was measured using the LDA method in the basic position (*Fig. 5*) and then rotated by 45° (*Fig. 6*).

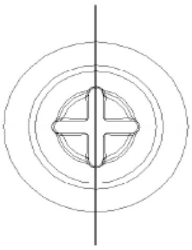

Fig. 5 The cross nozzle with an indicated position of the measured velocity profile

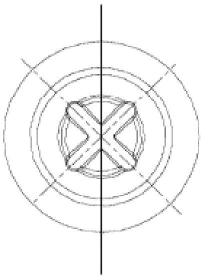

Fig. 6 The cross nozzle with an indicated position of the measured velocity profile after rotating by 45°

Individual positions of the nozzle showed different characteristics of the flow pattern. The measurement results are documented in the charts in *Fig. 7* and *Fig. 8*.

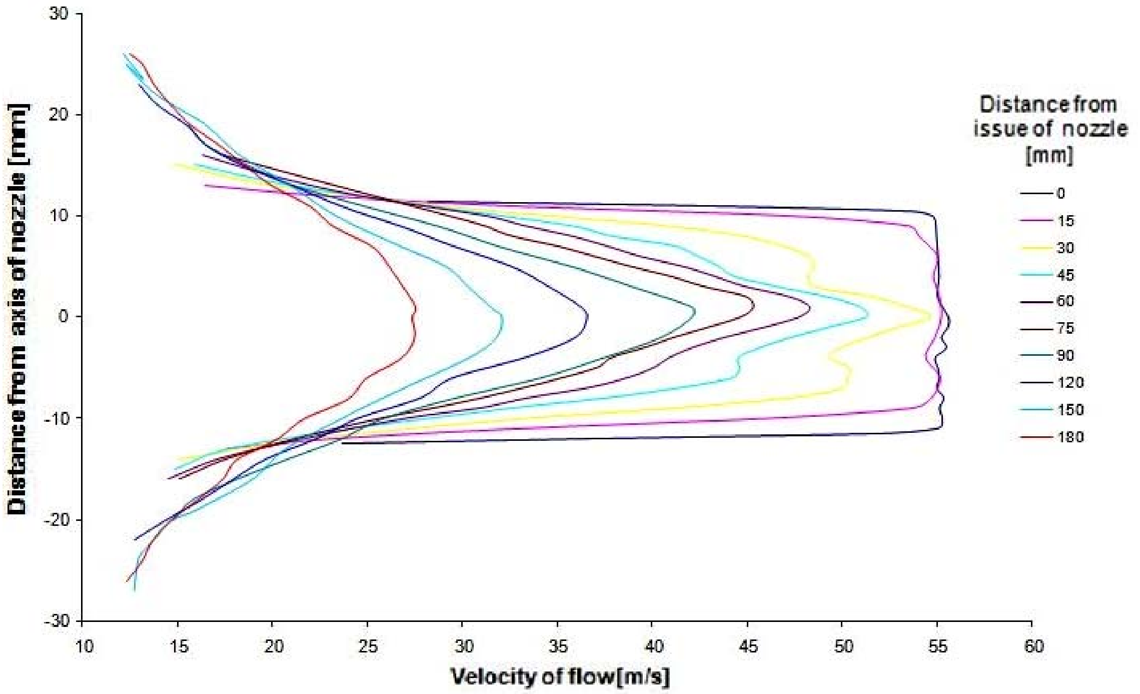

Fig. 7 *Velocity profiles of the cross nozzle in their basic position.*

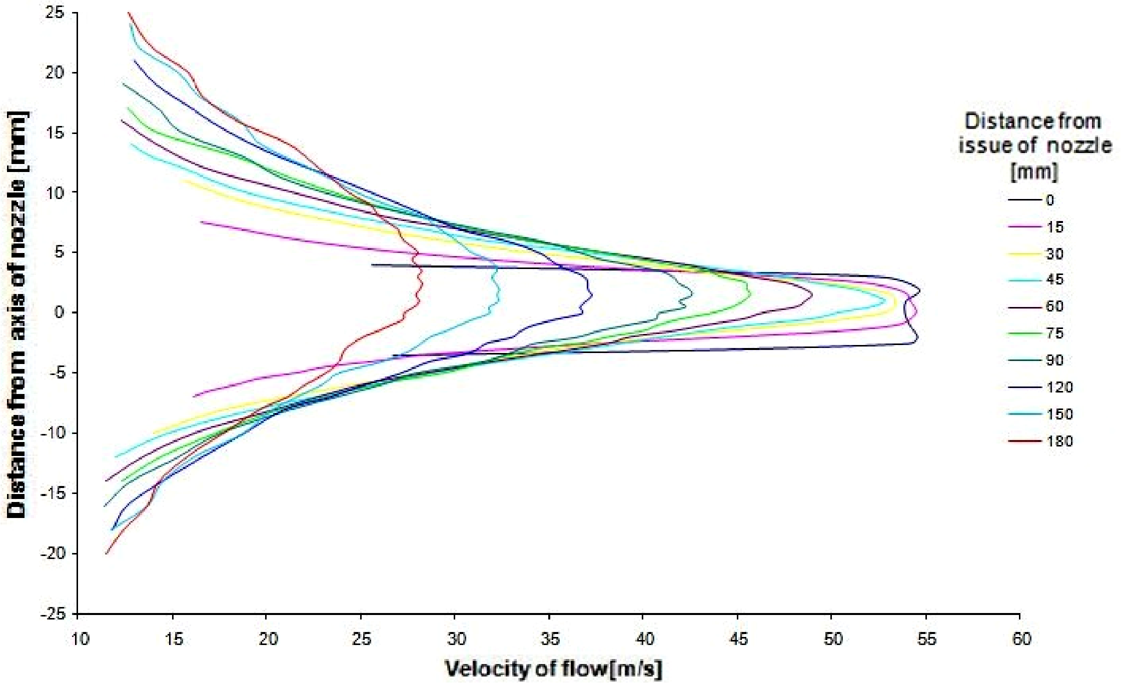

Fig. 8 *Velocity profiles of the cross nozzle rotated 45°.*

Conclusion

The experimental results of the cross nozzle in its basic position are shown in the chart in *Fig. 7*. Deformation of the velocity pattern of one side was noted. This deformation was probably caused by a defect in manufacturing, or by wear. The nozzle deformation caused that the symmetry of the flow was disturbed and the velocity dropped from the point of its maximum. With increasing distance from the nozzle's aperture the velocity was slowly decreasing, the flow pattern decayed, and therefore there was less and less deformation to the velocity profile of the nozzle. The deformation had the biggest impact on the velocity pattern up to the distance of approximately 2.5 times the diameter of the nozzle.

In the case of the measurement of the cross nozzle rotated by 45°,no deformation influence on the examined airflow was detected. The results of the measurement are shown in *Fig. 8*. No other possible deformation of the flow pattern was noticed. The measured flow was, in this case, different especially in the shape of the core, which was narrower than in the previous case. The air flow velocities were almost identical in both measured cases.

Literature

[1] KOPECKÝ, V.: *Metody Laserové anemometrie v mechanice tekutin*, Tribun EU 2008.

[2] VÍT, T.; DANČOVÁ, V.; DVOŘÁK, V.: *Experimental Fluid Mechanics*, TU v Liberci 2006. ISBN 80-7372-141-4

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EXPERIMENTÁLNÍ VÝZKUM SMĚŠOVACÍ TRYSKY PRO EJEKTORY

V tomto článku jsou porovnávány dvě polohy lalokovité trysky určené pro směšovací proces ejektoru. Předmětem pokusů bylo experimentální zjištění charakteristik proudových polí křížové trysky. Měření rychlostních profilů trysky probíhalo při tlaku 2 kPa. Jednotlivé rychlostní profily trysky byly měřeny od ústí trysky do 90mm po 15mm a od 90mm do 180mm po 30mm. Pro jednu polohu trysky bylo tedy změřeno 10 rychlostních profilů, které pak vytvořily výsledný graf. Důležitým hlediskem k doporučení trysky pro směšování byly charakteristiky rychlostních profilů křížové trysky měřené v různých polohách, které byly naměřené moderní bezkontaktní měřící metodou - laserová Dopplerovská anemometrie. Na základě naměřených dat jsou podrobně popsány rychlostní profily křížové trysky. Experimentováním byly zjištěny defekty na křížové trysce a tedy i její nevhodnost pro směšovací proces ejektoru.

EXPERIMENTALUNTERSUCHUNG ÜBER DIE MISCHDÜSE FÜR EJEKTOREN

In diesem Artikel werden zwei Lagen der für den Mischprozess eines Ejektors bestimmten Zackendüse verglichen. Versuchsgegenstand war die experimentelle Bestimmung von Charakteristiken der Stromfelder der Kreuzdüse. Das Messen der Geschwindigkeitsprofile der Düse wurde unter einem Druck von 2 kPa durchgeführt. Die einzelnen Geschwindigkeitsprofile der Düse wurden von der Düsenöffnung bis zu 90 mm je nach 15 mm und von 90 mm bis zu 180 mm je nach 30 mm gemessen. Für eine Düsenlage wurden 10 Geschwindigkeitsprofile gemessen, die dann das Enddiagramm bilden. Wichtiger Gesichtspunkt für die Empfehlung einer Düse für Mischung waren die Charakteristiken der Geschwindigkeitsprofile der Kreuzdüse, die in verschiedenen Lagen unter Anwendung der modernen kontaktlosen Messmethode, Laser-Doppler-Anemometrie, gemessen wurden. Aufgrund der gemessenen Angaben werden die Geschwindigkeitsprofile der Kreuzdüse ausführlich beschrieben. Durch Versuche wurden Defekte an der Kreuzdüse festgestellt, demzufolge ist deren Anwendung für den Mischprozess des Ejektors nicht geeignet.

EKSPERYMENTALNE BADANIE DYSZY MIESZAJĄCEJ DLA EJEKTORÓW

W niniejszym artykule porównywane są dwa położenia dyszy krzywkowej przeznaczonej do procesu mieszania w ejektorze. Przedmiotem przeprowadzonych prób było eksperymentalne ustalenie cech pól strumieni dyszy krzyżowej. Pomiary profili prędkości wykonywano przy ciśnieniu 2 kPa. Poszczególne profile prędkości dyszy mierzono od wylotu dyszy do 90mm co 15mm oraz od 90mm do 180mm co 30mm. Dla jednego położenia dyszy dokonano zatem pomiarów 10 profili prędkości, które następnie naniesiono na wykres wyników. Istotną kwestią w zakresie zalecenia dyszy do mieszania były cechy profili prędkości dyszy krzyżowej mierzone w różnych położeniach, których pomiary zostały wykonane przy zastosowaniu nowoczesnej bezkontaktowej metody pomiarowej - laserowej Anemometrii Dopplerowskiej. Na podstawie danych pomiarowych szczegółowo opisano profile prędkości dyszy krzyżowej. W wyniku przeprowadzonych eksperymentów stwierdzono usterki na dyszy krzyżowej, czyli nie jest ona odpowiednia dla procesu mieszania ejektora.