The analyze of used particles in PIV technique and their generation systems in order to field current seeding

Mohamadreza soufivand[1], Shadi Ghafouri[2], Mohamad Hojaji[3,*] and saeed tolani[4]

[1] Young Researchers and Elite Club, Najafabad Branch, Islamic Azad University, Najafabad, Iran

[2] Department of Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran

[3] Department of Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran

[4] Department of Engineering, Najafabad Branch, Islamic Azad University, Najafabad, Iran

Abstract

In PIV technique, it is indispensable to have a visible field current in order to achieve quantitative data. For this use, the fluid should be invested by some particles. The selection of material and the size of such particles depends on, flow regime, the kind and the phase of the fluid, power and the kind of laser and the pixel of the camera. In PIV, particles should be distributed with homogeneous size and they should have a very high generation rate. It is noteworthy to mention that, the design of investment instrument depends on the kind of the experiment. The objective of this paper is to analyse and introduce seed investment particles in PIV technique. In Addition, considering the wide application of smoke and oil particles, their generation systems will be analysed. From the results of this study, it should be remarked that, oil has higher shine in comparison with water, when they are expositing to the sun. As the viscosity of the oil decreases, the out coming particle volume increases. It should be considered that, the use of industrial oils should be limited-especially in tunnels having no access to exterior space- because they are poisonous and will cause respiratory problems in man. The increase of outcome volume particles ensues from the increase in flow rate. The augmentation of inlet pressure of nozzles causes an augmentation in velocity. As a result, the momentum will enhance. Keeping it in mind, the velocity should be controlled to eliminate the possibility of turbulence and shear stress caused by momentum. At low velocities, it is better to use smoke instead of oil due to its control capability and having required shine. It should be considered, it is harder to produce smoke particles in comparison to generate oil particles thanks to required heat. Some other significant point is that, the outlet smoke is hot and has a higher temperature than exterior space which can cause shearing stress in fluid flow. In low velocities, such phenomenon will cause the increase of turbulence because of low momentum.

Keywords: PIV; investment particles; visible field current; smoke generation systems; bubble generation systems.

1. Introduction

Empirical methods are the most prevalent and persuaded method to evaluate the fluid flow phenomena. The empirical study of fluid flow divided into two methods: measurement and fluid detection. The importance of fluid detection is absolutely crystal clear. The major goal of this method is to detect the different phenomena in field current of fluid such as flow separation, vortex formation, types of boundary layer (laminar or turbulent), flow trail area et cetera. This method will help the researchers to make new hypothesizes or have such a more accurate experiments, in as much as they have the ability to observe the fluid flow phenomena happening in the locality or out of the model domain. Additionally, getting into the visible air flow, can help the researchers have a clearer perception to find flow phenomena and can simplifies the mathematical models. Regarding the mentioned benefits of this method, the effective role of this method in promotion of researches in different fields is deniable. In other words, fluid detecting is an effective method to recognition and realization of fluid phenomena, although, it has not the highest accuracy and just can present and overall view of fluid. Different methods are utilized to achieve this goal. The plans made by Leonardo DA Vinci could be the onset of this method [1]. Prandtl and Reynolds as the pioneers of empirical aerodynamic science worked in this field a lot. On the other hand, the most pioneer in fluid detection is Ernest Mach. For the first time, in 1893, he did the fluid detection in a wind tunnel. He performed his first detection in a wind tunnel with sectional area of 18x25 m^2 and in velocity of 10 m/s. He utilized the cigarette smoke and silky materials to observe the fluid flow. Thanks to low concentration of smoke, he had could not get clear photos. Mach is one of the foremost experts in the field of Schlieren, interference techniques, fast photography and many different methods.

From an engineer level of view, Mach's methods are really simple. He was believed that visual sense of the head is the origin of any scientific proofs. It can be supposed that the fluid detecting experiences were the basis of Mach's phenomenology view. Mach said: ‘’ modern sciences need a structure based on facts, not ideas and theories which these facts will be proven by observations’’ [2].

Nowadays, advanced methods are employed to make the air flow visible. Considering the type of fluid and the condition of flow, such as compressibility or incompressibility of fluid, the velocity and the fluid regime, there are different methods for fluid flow detection. In low velocity wind tunnels, fluid detection methods divided into two categories: 1. Detection on model surface 2. Detection in around of model.

In the first category, the condition of air flow in the model surface, like laminar, transient and turbulent boundary layer and air flow separation in the boundary layer, is visible. In this method, Taft, oil and clay are used to make the flow visible.

In the second method, air current field around the model and some flow phenomena like air flow separation and flow tail area, the vortex results from the model et cetera will be visible. Different kinds of Taft and smokes are useful to make the fluid visible.

It is worthwhile to mention that, the detection of fluid flow just presents qualitative information about fluid current field. It implies that, accurate measuring of the current field is needed to have quantitative date [3]. In 1980s, a new method named PIV or ‘’Particle Image Velocimetry ’’ was patented, which is capable of measuring the velocity field in every moment [4- 6]. PIV is a fully field and non-destructive method to determine the instantaneous velocity field of a moving fluid in 3D or 2D. The mainstay of this method is photographing of current field and processing of the photo [7]. By applying this method, the instantaneous velocity could be achieved without any confusion in flow [8]. The study of low velocity to ultrasonic fluids, is one the most applications of this method [9- 11].

2. PIV Technique

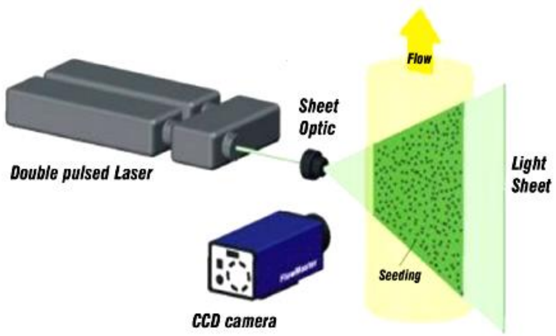
As a design plan of average displacement of a group of floating particles in a fluid, 2D PIV is defined in a short period of time. Such plan is achieved by the connection of two successive pictures of existing particles in a bright plate in fluid flow. In most of measuring methods, the values will be achieved as point to point values. As a conclusion, to have vector charts of entire plate, it is essential to repeat the experiments for several times and finally the diagrams have low accuracy. The most significant advantage of PIV technique is its ability to achieve the velocity vector information from a plate in flow, with high accuracy, especially for unsteady flow, which is very hard to plot their current field [12, 13]. There is no confusion in flow as much as, there is no external object or sensor in the flow. Besides the fact that this technique provides a method to extract the quantitative data, it makes the flow visible which is another advantage of this method. It should be considered that this method can be used for every fluid provided that high quality photos in fluid flow took. As a result, fluid flow seeding with particles having special properties is very important.

A laser is employed to make the fluid, bright, in PIV technique. In this method, the particles shining in front of the light will be mixed with fluid and the particles will move with the fluid flow. By taking two successive pictures from moving particles and considering the time interval between two photos, instantaneous velocity for every point of fluid will be available (Fig. 1). There are two basic conditions in this method:

1. The current field is constant between two pictures
2. The velocity distribution within the cells is uniform

It should be considered that in a real flow, none of two conditions will be satisfied. [14]

Fig1: PIV test schematic



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3. Grain seed investment in PIV Technique

In order to determine the fluid flow and get photos, special particles should be used. The material and size of these materials is in connection with flow regime, the type and the phase of the fluid, the power and the type of laser and the size of camera pixel.

The particles used in PIV experiments ought to have a good light reflection property and density close to the fluid density unless; a settlement velocity component will be added to the results velocities. Keeping this in perspective, after some minutes, the fluid will be settled or will come to rise. The particles should have the right size. Tiny particles will not appear in photos, and very large particles will not float in a fluid. The selection of optimum diameter for seeding is a compromise between an adequate tracer response of the particles, requiring small diameters, and a high signal to noise ratio (SNR) of the scattered light signal, which is necessary for large diameters. A suitable criterion for integrated space, light scattering ability, is scattering cross section (C_s). (Eq. 1)

$$C_s = \frac{P_s}{I_0} \tag{1}$$

This criterion is defined as the total scattering power to the intensity of radiated laser to the particles (I_0) ratio (Tab.1).

Table 1: Scattering cross section as a function of particle size

Diameter d_p	Scattering cross section C_s	
Molecule		$\cong 10^{-33} m^2$
1 µm	$C_s \cong (d_p/\lambda)^4$	$\cong 10^{-12} m^2$
10 µm	$C_s \cong (d_p/\lambda)^2$	$\cong 10^{-9} m^2$

Source: 15

As an empirical principle, the minimum size of the used particles should be two pixels more than the photo. Considering the application of used particle in PIV technique, they can contain Aluminum particles, glass bullets, granulates (polymeric particles) and oil particles and even oxygen bulbs. It should be noted that the particles will not disperse in water in early times due to their surface tension. Keeping this in perspective, soaking the particles in a detergent liquid (such as dishwashing liquid) at least for one hour, is essential. After it, the particles are ready to mix with fluid [16]. There are different methods for dispersing the particles in different fluids. As an example, 5 percent ethyl alcohol solution is used for TiO_2 and ZrO_2 in fire flame [17]. The properties of some of useful particles in turbulent flow seeding are presented (Tab.2).

Table 2: Particle response to turbulent flow

Particle	ρp (Kg m^{-3})	Gas ($10^5 P$a)	Density Ratio S	Viscosity $v(m^2 s^{-1})$	f_c (kHz)	Sk_c	d_p (µm)
TIO_2	3500	Air (300k)	2950	1.50×10^{-5}	1 10	0.0295	1.44 0.45
AL_2O_3	3970	Flame (1800 k)	20250	3.00×10^{-4}	1 10	0.0113	2.46 0.78
Glass	2600	Air (300 k)	2190	1.50×10^{-5}	1 10	0.0342	1.67 0.53
Olive oil	970	Air (220 k)	617	1.45×10^{-5}	1 10	0.0645	3.09 0.98
Microballoon	100	Air (300 k)	84.5	1.50×10^{-5}	1 10	0.1742	8.50 2.69

Source: 15

Here, f is the turbulence frequency, η is the domain ratio, d_p is the particle diameter and sk_c is stokes number. Granting to the former studies, about 15 particles per integration volume are needed to process the photo. It should be considered that the number of the seeding particles should increase with the augmentation of the flow velocity. Mostly, for high speed flows, the minimum required number of particles per integration volume is 30 [15]. The properties of seeding materials according to the light source and fluid phase are given in (Tab.3) and (Tab.4).

Table 3: Seeding particles in gas flow

Material	d_p (µm)	Laser	Pulse energy	Light Sheet W (mm)	Light Sheet T (mm)	Reference
$TiO_2(m = 2.6, \rho = 3500\ kg\ m^{-3})$	<1	Nd:YAG	10 mJ,20 ns	15	0.3	Reuss et al
TiO_2, ZrO_2	0.7-1	Nd:YAG	110 mJ,12 ns			Paone et al
Al_2O_3 (m =1.76 ,ρ=3970 kgm^{-3}	0.3 3 0.8	Nd:YAG Nd:YAG Ruby	400 mJ ,6 ns 9 mJ 20 ns	150	0.2 ≅1	Muniz et al Anderson et al Krothapalli et al
Polycrystalline	30	Nd:YAG	,6 ns 135 mJ			Grant et al
Glass	30	Ruby	,30 ns 30 mJ			Schmidt and Loffler
Oil smoke	1	Ruby	5J			Stewart et al
Corn oil	1-2	Nd:YAG	100 mJ			Jakobsen et al
Oil	1-2	Nd:YAG	120 mJ		0.4	Westerweel et al
Olive oil (m=1.47, ρ=970 $kg\ m^{-3}$	1.06	Nd:YAG	,16 ns 70 mJ	200	0.5	Hocker and Kompenhans Raffel et al

Source: 18-30

Table 4: Seeding particles in fluid flow

				Light Sheet		
Material	d_p (µm)	Laser	Pulse energy	W (mm)	T (mm)	Reference
TiO_2	3	Nd:YAG				Longmire and Alahyari
Al_2O_3	9.5	Ruby	2J ,30 ns	100	0.8	Liu et al
Conifer pollen (ρ=1000 kg m^{-3}	50-60	Ar ion	1-2 w			Westergaard et al McCluskey et al Gallagher and McEwan
Polymer (ρ=1030 kg m^{-3}	30	Ar ion	0.5-5 w		0.5	Draad and Westerweel McCluskey et al
Phosphorescent polymer	80	Ar ion	5 w		1	Willert and Gharib
Fluorescent	50 20	Nd:YAG Cu vapour	45w		1	Hart Roth et al
Polystyrene (ρ=1050 $kg\ m^{-3}$	500 15	Ruby	25mJ, 20 ns			Khoo et al Zhang et al
Thermoplastic ρ =1020 $kg\ m^{-3}$	6	Nd:YAG		50	2	Hassan et al
Reflective ρ=1020 $kg\ m^{-3}$	60 30	Ar ion Ar ion	18w 12-18 w	200		Grant et al Grant and Wang
Metallic coated	4 14	Ar ion Ar ion	2w		2 1	Magness et al Johari et al
Microspheres ρ=700 $kg\ m^{-3}$	<30	Ar ion				Graham and Soria
$H_2\ bubbles$		Ar ion	1w		0.3	Dieter et al

Source: 31-48

4. Popular visualizer smoke

Using of smoke in order to visualize the flow in a wind tunnel is known as a standard and prevalent empirical method. There is a thigh relation between this method and the development and the history of the wind tunnels. Brown studies in Notre Dame University are known as the most important studies resulted in the development and correction of this technique. Systematically, he developed a generation of tunnels which were suitable with the smoke behavior which are known as smoke tunnels nowadays. For more study in this area, the Muller & Keating and Maltby studies about fluid flow visualization could be fruitful. In this paper, the term smoke is used in a wide range of meaning (such as combustion products, vapor and mist) [1].

Generally, the tracker materials should have the following characteristics:

1. Well suspending
2. Non-toxic

3. Low mixing rate with base fluid

It should be noted that the smoke has none of the mentioned characteristics. Forasmuch as there is not any more efficient technique, smoke is the best choice.

The raw materials needed to produce smoke are: burning tobacco, wood or reed, vaporization of mineral oils, mist production as a consequence of chemical reaction between different materials and compressing the vapor in order to make visible mist. All of the mentioned materials are toxic except the last one. The density of tracker material is much larger than air density, but since the particles are very small, - generally smaller than 1μm- sedimentation and deposition effects are really depressed.

The spread of smoke in the air is much larger than the color spread in water, so that in a reasonable distance, the recycle lines are visible just in a laminar flow. Between different kind of smokes, cigarette smoke is the best tracker particle. It is noteworthy to mention that the white oil vapor is the most common material in order to use in wind tunnel studies. Besides, smoke wire, as an electrical controlled instrument, provides the possibility of smoke lines production very well. It should be considered that smoke direct injection should be done with smoke pipes or by using of rick (a multi tube system). In addition, using the produced TiO_2 dust of $TiCl_4$ sediment droplets on the model surface is an indirect smoke injection method which is known as a controlled chemical production method for tracker materials. The use of smoke in closed circuit tunnels will cause the tunnel to be filled with smoke. Considering the fact that the smoke and particles are toxic, the smokes should discharge to the outdoors. Consequently, there is more trend to use the of vapor and water mist as the trackers. In combination with the cooling factor (such as the air), the vapor produces a visible mist. When the heat transfer takes place between the mist and the ambient air, the mist will be disappear. As a conclusion, the main air flow circulating in the system stays clean. If the system uses the mist and vapor as the tracker, the use of a dryer is needed. Also, the nitrogen can be used as the cooling agent. In this method, vapor and liquid nitrogen will discharge into the air with a mixer nozzle (exiting from a mixer nozzle and entering to the air flow). As it reported from early experiments on wind tunnels, mist is more observable in comparison with TiO_2 dust and cigarette smoke. On the other hand, mist particles are much bigger than the other particles. It should be considered that, injecting the smoke before the nozzle (before contraction) and using of a high contraction ratio will cause the smoke lines to be stable. There is no limitation to increase the air velocity for the smoke lines even in ultrasonic flows. In addition to the use of wind tunnels, observing the flow with the smoke can happen in every type of air flow even in large scales and in outdoor. It is important to emphasize the specific application of smokes to identifying flow separation regimes, vortexes and uniform structures in sheer layers [1]. It is hard to produce and supply the particles in suitable sizes and homogeneously in laser plate, especially in high velocities and high pressure areas. It is essential to know that the seeding particles should be smaller than turbulence scale in order to detect the structures around the flow. Kolmogorov length scale, which related to the size of smallest eddy, is defined as the smallest scale of fluid length. From the perspective of data uniformity, choosing the Stokes number of tiny tracker particles is so important (Tab.2) [1].

5. Particle production techniques

The description and properties of seeding particles are reviewed and reported in many papers. On the other hand, there is a little information about the practical particle supplying in flow. Sometimes, seeding process is very easy or there is no need to seed. In such manner, the particles are entirely visible. Subsequently, natural seeding is acceptable; the particles act as a visualizer for PIV. In other manners, it is essential to add the tracker particles to the current field in order to have a favorable contrast and to control the size of particles. For most of the liquid flows, by suspending the solid particles in the fluid and mixing them, seeding process will pass easily in order to get a homogeneous dispersion. It should be considered that in gas flow, a suitable dispersion is needed to provide a safe condition for examiners and to have a high quality experiment and the possibility of PIV measuring techniques. The most of the particles are uncontrollable in as much as: 1) the trend of quick vaporizing in most of liquid droplets 2) high trend of depositing in solid particles. Keeping this in perspective, dispersing the particles for a long time before the measuring process is hard. As a result, particles should be injected into the flow just in a short time before the measuring process. It is so important to have homogeneous particle dispersion in one direction and one place direction without any disturbance in the path of flow [1].

In this study, some of the important methods of particle producing and dispersing techniques in order to seeding in gas flow is provided. The dry powder could be scattered in the flow bed by air jets. The liquid could be vaporized and condensed in compression generators or be produced by the atomizer directly. In addition, atomizers could be utilized to disperse the suspended solid particles in vaporized liquids. In order to produce tiny droplets, the high steam pressure liquids (such as oil) should be mixed with low steam pressure liquids (such as alcohol) so that vaporized before entering the section test [1].

For seeding of wind tunnel flows in order to flow visualizing and LDV, compression generators, smoke producers and polystyrene single spraying or latex particles injected in water-ethanol should be applied. On the other hand, Laskin nozzle producer and oil are mostly usable for air flow PIV measuring. These particles are non-toxic and they can remain in air in a stasis manner for hours. Another advantage of this particle is their trend to have a constant size under different condition. They are widely used in order to seed the whole volume of closed circuit wind tunnels. Additionally, for seeding a special division in a wind tunnel, a flow tube is used by seeding rick with hundreds of tiny holes [1].

Criteria for used particles in PIV technique:

- Uniform distribution of particle sizes
- High generation rate

The choice of seeding system depends on the phase of seeding particles (liquid or solid). Schematic pictures of some of the systems are presented in (Fig. 2-8). The particle coagulation is the paramount element in the design of such systems.

Fig2: Laskin nozzle schematic

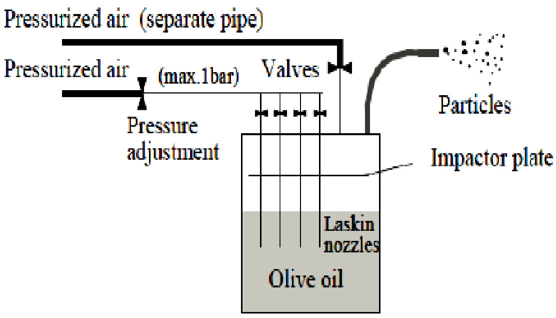

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Fig3: Laskin system nozzles

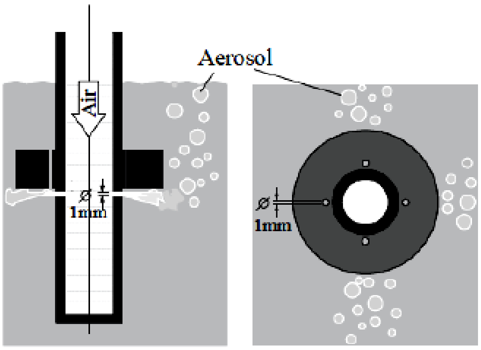

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Fig4: Built Laskin system

Fig5: Nozzles collector, connection method and tank cap of Laskin system

Fig6: (a) The outgoing smoke from smoke producer- (b) Smoke producing system and produced oil particles

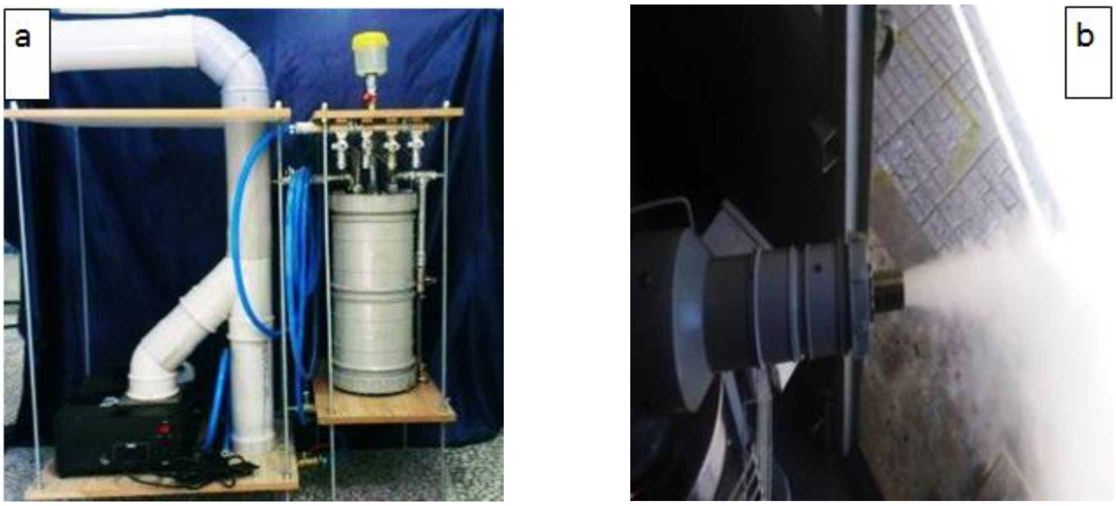


Fig7: The outgoing particles of an oil particle producer system with inlet pressure less than 0.5 bar and single nozzle- the picture is taken with shutter velocity=1/200

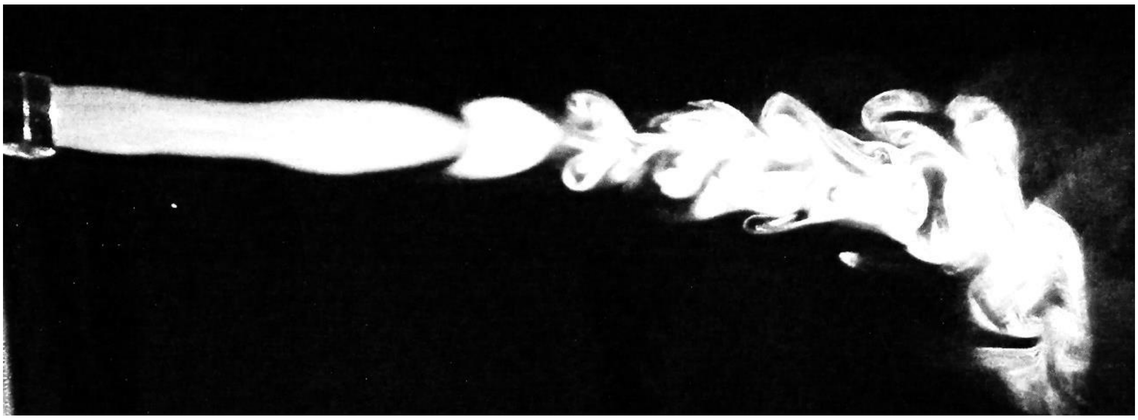
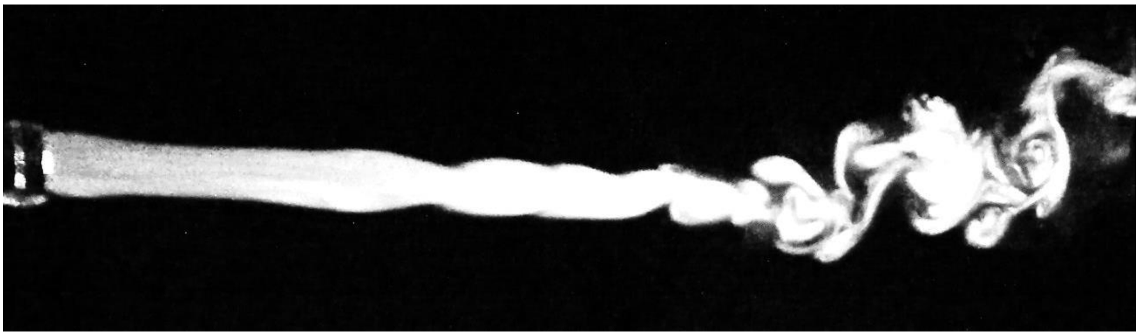


Fig8: The outgoing particles of an oil particle producer system with inlet pressure = 1 bar and single nozzle-the picture is taken with shutter velocity=1/200



6. Particle production methods

- For liquid flow: suitable powder should be combined with the liquid
- For gas flow:
    1. Liquid droplets: atomizing or compressing
    2. Solid particles: atomizing or condensing

Generally, the solid particles are powdery. Practically, liquid droplets excel solid particles because of their more stable production rate. Another advantage of liquid particles is their inclination to preserve their spherical shape which is useful for tracking behavior and scattering property assessments. In addition, in comparison of most of solid materials, the information of the liquid's refractive index is more available. The liquid droplets in inner flow depositing in the windows, could form a non-uniform film causing light distortion by refraction. Temporarily or permanently signal lose could be resulted from such deviation [1].

Liquid droplet producer:

- Laskin atomizer

Commercial atomizers (like TSI)

7. Designed and produced systems

In this study, we designed and built two systems in order to test the PIV technique for fluid flow seeding in a wind tunnel by the utilization of the Laskin nozzle sketch:

1. Smoke producer system
2. Oil particle producer system (Fig. 2-4)

To build the major tank, two gates (diameter = 130 mm) and one beshen as the gates coupler are used. Nozzles are built of four ½ inch tube which the both sides of them are closed and there is a 1 mm hole in tail-ends and the body of the tube. To make the oil height in the tank visible, a 10 mm diameter hose is used. One drain valve embedded on both sides of the tank in order to fill it. To prevent the large particles escaping the tank, a disk is located above the oil surface and under the spout. To control the pressure on the oil surface and the particle expelling, one tube equipped with a valve and one simple tube is considered, respectively. In order to control the number of nozzles according to the required volume and velocity of particles, they are connected to a collector. The system has the ability to change the raw material or to spray the powdery material due to the considered valve on the bottom of the tank. (Fig. 4-6)

Following equations are used in order to calculate the size and the number of nozzle holes;

The required flow rate in order to unify the wind tunnel and particle velocity is estimated by the following equation (achieving by the compressor with hot wire):

$$\dot{m} = \rho u A \tag{2}$$

Where the ρ is the air density, u is the air velocity outgoing from the tube connected to the compressor (measured by hot wire) and A is the area of the tube connected to the compressor.

The velocity will be gained by the Bernoulli equation:

$$p_0 = p_s + \frac{1}{2}\rho v^2 \, ; \, p_s = p_{ambient} + \rho g h \, ; \, p_0 = \rho R T \tag{3}$$

Here, p_s is static pressure which is equal to the summation of ambient pressure and pressure ensues from the oil height on the nozzle holes.

The derived velocity is more than 100 m/s. Consequently, the Bernoulli equation is not valid for incompressible flow.

The following equation is employed in order to deriving the Mach number.

$$\frac{p_0}{p} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma - 1}{\gamma}} \tag{4}$$

Considering the $a = \sqrt{\gamma R T}$ and $M = \frac{v}{a}$, v will be derived. Assuming the diameter of nozzle holes equal to 1 mm, the number of holes can be calculated by flow rate equation. Considered system of this paper, contains four nozzles with three holes in every nozzle.

The volume and the velocity of the outgoing particles if smoke producing system is investigated by using water, wheel oil and edible oils in different pressures and different numbers of nozzles. It is noteworthy to mention that, the use of industrial oils should be limited-especially in tunnels having no access to exterior space- because they are poisonous and will cause respiratory problems in human. According to the results, oil has more shine in comparison of water. As the viscosity of the oil decreases, the out coming particle volume increases. The augmentation of nozzle inlet pressure causes an increase in the velocity and the momentum. To prevent the particles causing chaos and sheer stress due to their momentum, it is essential to control the free flow velocity (Fig. 7-12).

Fig9: The outgoing particles of an oil particle producer system with inlet pressure = 1.5 bar and single nozzle- the picture is taken with shutter velocity=1/200

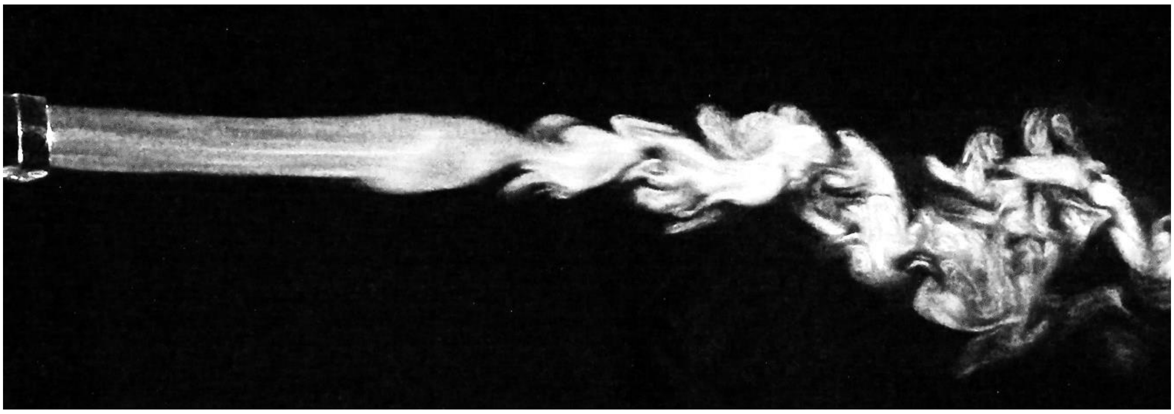


Fig10: The outgoing particles of an oil particle producer system with inlet pressure = 0.5 bar and triple nozzle- the picture is taken with shutter velocity=1/400

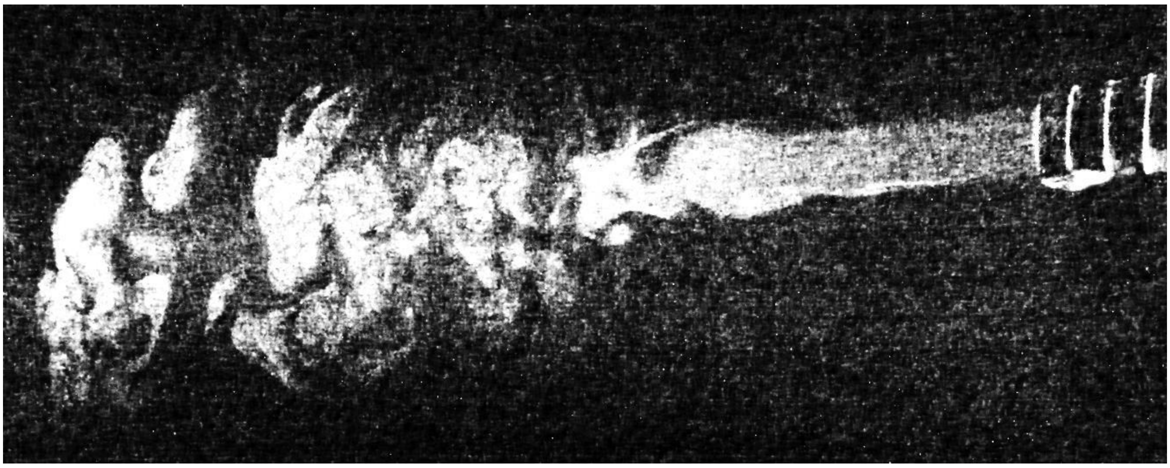


Fig11: The outgoing particles of an oil particle producer system with inlet pressure = 1 bar and triple nozzle- the picture is taken with shutter velocity=1/400

Fig12: The outgoing particles of an oil particle producer system with inlet pressure = 1.5 bar and triple nozzle- the picture is taken with shutter velocity=1/400

At low velocities, it is better to use smoke in as much as, it is more controllable and it has the required shine. It should be considered, it is harder to produce smoke particles in comparison to generate oil particles thanks to required heat. Another important point is that, the outlet smoke is hot and has a higher temperature than exterior space which can cause shearing stress in fluid flow. In low velocities, such phenomenon will cause the increase of turbulence because of low momentum. In this paper, three types of prosperous built smoke producer system are investigated. One of systems is built of an aluminum tank and two 700 W ring elements. To have a more efficient suction, a funnel shape device is embedded into the tank which is connected to the tank cap. Tank cap is connected to e tee from its upper part which can control the outgoing smoke by adjusting the compressor back pressure. Rockwool is used as an insulator (Fig. 13).

Fig13: (a) Smoke producer system with oil burning- (b) System components- (c) Tee pipe of the upper part of the system

It is essential for the oil should be hot enough for burning not for boiling or vaporizing. In another system, a commercial smoke producer is used having the ability to control the smoke velocity by the changes made in their outlet. This property results from the changes in compressor pressure (Fig. 14).

Fig14: Modified commercial smoke producer system

The schematic of some particle producer sketches are provided in (Fig. 15 to 19).

Fig15: A model of Laskin nozzle

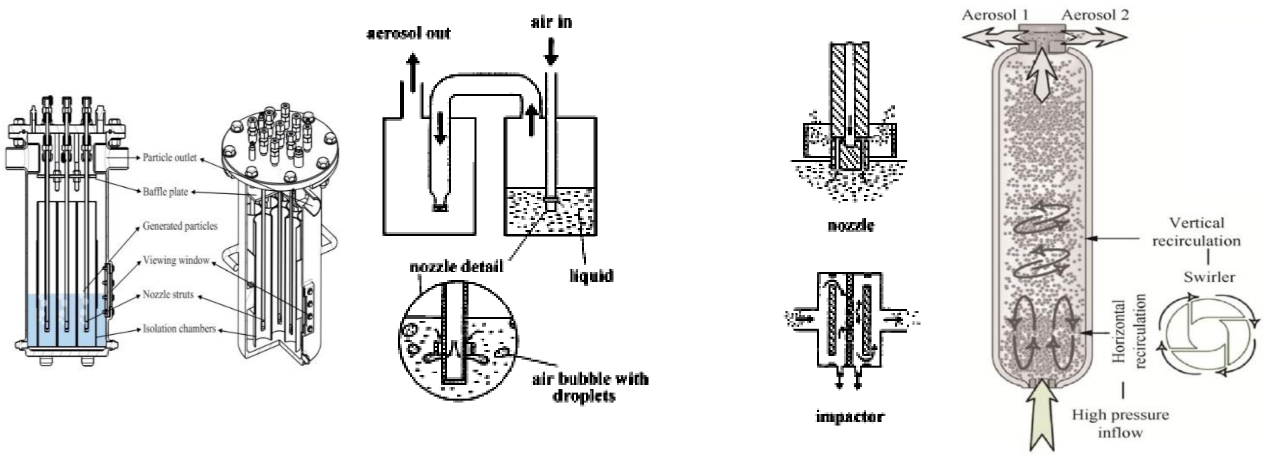


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Fig16: Alternative atomizer schematic

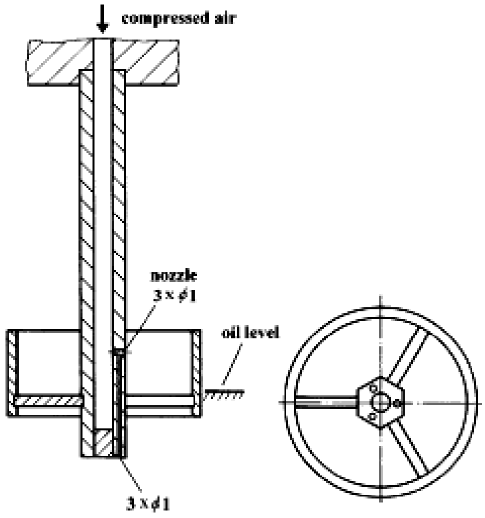

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Fig17: A fluidized bed aerosol generator

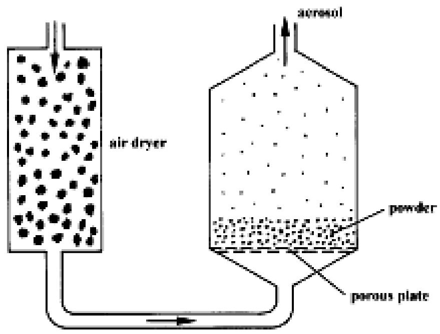

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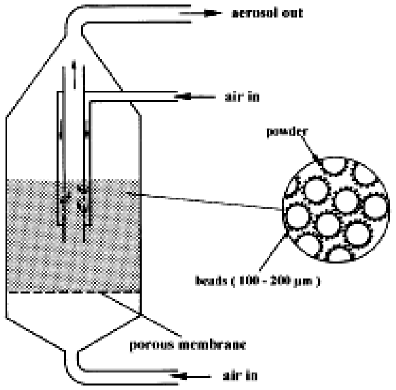
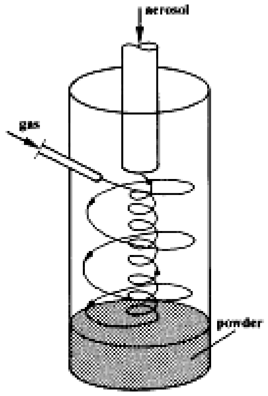
Fig18: A two-phase fluidized bed generator



Source:17

Fig19: A cyclone aerosol generator



Source:17

8. Conclusion

In gas flows, a suitable dispersion is needed to provide a safe condition for examiners and to have a high quality experiment and the possibility of PIV measuring techniques. It is noteworthy to mention that, the design of investment instrument depends on the kind of the experiment. As the viscosity of the oil decreases, the out coming particle volume increases. It should be considered that, the use of industrial oils should be limited-especially in tunnels having no access to exterior space- because they are poisonous and will cause respiratory problems in human. The increase of outcome volume particles ensues from the increase in flow rate. The augmentation of inlet pressure of nozzles causes an augmentation in velocity. As a result, the momentum will enhance. Keeping it in mind, the velocity should be controlled to eliminate the possibility of turbulence and shear stress caused by momentum. At low velocities, it is better to use smoke instead of oil due to its control capability and having required shine. It should be considered, it is harder to produce smoke particles in comparison to generate oil particles thanks to required heat. Another important point is that, the outlet smoke is hot and has a higher temperature than exterior space which can cause shearing stress in fluid flow. In low velocities, such phenomenon will cause the increase of turbulence because of low momentum.

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