VKI Lecture Series – Post-Processing of Numerical and Experimental Data
Rhode St Genèse, Belgium - 11-15 February 2008

CLASSIFICATION OF LASER VELOCIMETRY TECHNIQUES

A. BOUTIER

Office National d'Etudes et de Recherches Aérospatiales
BP 72, 92322 - Châtillon Cedex, France
Phone: 33 1 46 73 40 06 – e-mail: alain.boutier@onera.fr

SUMMARY

Laser velocimetry is an optical technique which locally measures instantaneous flow velocities. We shall introduce the various ways to determine this velocity parameter, which have led to various concepts for optical schemes. The vocabulary associated with the different set-ups will be given; advantages and problems related to this measurement technique will be listed.

1. GENERALITIES

Velocity determination in fluid mechanics is fundamental in order to have a better knowledge of the flow behavior. Maps of the velocity flow field help for determining the flow structure, its turbulence properties, therefore allowing validating codes.

Laser velocimetry is an optical technique which uses fine particles as flow tracers in order to determine the local velocities and their fluctuations; many optical schemes have been developed since the first paper published by Yeh and Cummins in 1964 [1].

We shall distinguish the various techniques which are all related to laser velocimetry but with different names; even if the purpose is always the velocity determination, the information delivered must be well clarified.

Setting up any laser velocimeter involves the following subjects to be treated:

* what is the purpose of the velocity measurements in a well defined flow ? This generally allows determining the optical scheme of the apparatus.

* as measurements are generally local, the mechanics supporting and moving the optics must be studied in relation with the facility context.

* as all measurements rely upon the presence of scattering particles inside the flow, the flow seeding and the particle characterization are two main problems which must be looked at carefully.

* signal processing of the data is one of the most important features of any apparatus; depending upon the efficiency of the processor, measurement quality may extremely vary: sensitivity to different particle sizes, time necessary for obtaining convenient statistics, etc.

* a computer on line with the whole laser velocimeter is fundamental, because of its multiple functions: data acquisition from the processors; displacement management of the measuring point; data reduction (taking into account initial conditions of the flow) in order to display results along understandable curves, maps or organized data banks.

In the following lectures, optical devices will be described in details because their choice is very crucial: at first the general arrangement defines the way the velocity is measured, thus the further possible data interpretation; secondly the quality of the optical set-up must be carefully checked in order to provide optimized signals that the electronic processors will never improve!

The other main topics which will be covered are:

* processing and post-processing of the signals
* flow seeding and particle size measurement
* measurement accuracy

Laser velocimetry has become a really operational measuring tool; this is proved by the periodic international conferences which are held dealing with advances and applications of laser velocimetry; the proceedings of the main ones are listed in references [2] to [26]. For national French conferences, the references [27] to [36] are also available.

2. VELOCITY DEFINITION AND VOCABULARY

At first let us do a few semantics. Two words are currently used to name the velocity measurement in fluid mechanics: laser velocimetry and laser anemometry. The first one issued from the Latin "velox" really means speed measurement of quick things; the second one issued from the Greek "anemos" really means wind measurement. Therefore as fluid dynamics includes aerodynamics as well as hydrodynamics and combustion (at least!) the expression laser velocimetry appears more general. We shall further explain other abbreviations (such as LDV or LDA) where D means Doppler, this word being used for historical (and obviously physical!) reasons linked at the first developments of the technique.

The velocity is by definition the first derivative of the trajectory of a mobile object; it is obviously a vector which is determined by three components. It is why we shall have always to deal with velocity components to be measured. The usual terminology is the following:

1D : apparatus giving access to only one velocity component
2D : apparatus giving access simultaneously to two velocity components (velocity vector projection on a plane): interesting feature in 2D flows
3D : apparatus giving access simultaneously to the three velocity components, i.e. the instantaneous velocity vector which enables to further determine by appropriate calculations and statistics all the turbulence properties of the flow.