DESIGN OF REGRESSIVE FOURIER TECHNIQUES FOR PROCESSING OPTICAL MEASUREMENTS

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Nowadays, optical techniques are applied in a number of measurement fields, ranging from static object profile determination over dynamic object behavior characterization to flow and acoustic measurements. This broad application together with thriving to obtain as much information as possible, brings with it essential conflicts with some general practical issues. Extensive data sets and measuring at a large number of response locations are quite common practice nowadays. Also given the complexity of many test cases, the data is often characterized by a high frequency resolution. These two observations put together basically imply that the stored amount of data, together with the measurement time is rapidly increasing. A constant factor in processing optical measurement techniques is the use of Fourier analysis in general and quite often a fast Fourier transform is applied. Using this technique it has already been proven possible to reduce the amount of data, by simply storing only a selection of spectral lines. The main disadvantage of this Fourier transform is the inability to model the transient effects correctly. This often leads to substantial errors in the end result.

The aim of this thesis is to make a significant contribution towards processing optical measurement techniques and applying it to a number of application fields. In the first part of this work a Fourier technique is introduced, which is able to cope with transient effects, also known as leakage. The technique is based on a Regressive Discrete Fourier Series (RDFS) first developed in by J.R.F. Arruda. However this technique is elaborated to a far more general model, introduced as a Generalized Regressive Discrete Fourier Series technique (GRDFS) and proves applicable to a broad range of optical techniques. Two quite straight forward approaches are derived from the proposed technique which allow a reduction of measurement time for (scanning) Laser Doppler Vibrometer ((S)LDV) measurements. Using the (G)RDFS it is also proven possible to reduce data for operational deflection shapes (ODS) without the effects of leakage. Another optical technique that also uses a Fourier transform is the so-called Fourier Transform Profilometry (FTP). The FTP method uses a 2-dimensional Fourier transform to estimate the phase of a projected grating. This allows an immediate extraction of the structure's geometry from one single image. When measuring complex shapes, the Fourier analysis also proves erroneous due to the assumption that the fringe and height distribution should be periodic within the image window. The GRDFS technique offers a fitting resolution in this case as well.

In the second part of this thesis, a very recently developed technique, which uses an unmodified SLDV to visualize density variations in a perturbed medium, will be looked into. This technique makes it possible to gain insight in an acoustic field or flow field, without any perturbation of the field whatsoever. However this technique remains purely qualitative thus far, and therefore a way to validate the visualized fields is necessary. This has been done for the fluid dynamic case using another full field optical technique: Particle Image Velocimetry (PIV). On top of that simulated results were attained using a computational fluid dynamic package (CFD). Using these techniques it was proven possible to validate not only the frequency content of the flow but also the visual content. Using the LDV it is also possible to visualize acoustic fields. However due to the fact that the technique only measures variations along the laser line of sight, an average is obtained over the measurement volume. Now seeing as acoustic fields - and similarly most flow fields - are three-dimensional obtaining the full visualization of the field is a somewhat cumbersome task. The process consists of acquiring a certain number of 'views' of the field and then combining these measurements in a tomographic algorithm, which in turn reconstructs the full three dimensional field. Measuring these different views requires moving the entire measurement set-up around the field and taking measurements at a certain number of angles. This process is automated and at the same time sped up by placing the acoustic source on a rotating surface and keeping the measurement equipment at a stand still, hence reversing the procedure. Moreover using this approach it is proven possible to localize the exact position of the acoustic source in the measurement volume.