

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents final conclusions and subsequently makes several recommendations regarding future ESDM work.

Conclusions

As mentioned previously, the primary objective of this thesis was to experimentally evaluate the ability of ESDM to reconstruct velocity response fields with large in-plane components parallel to a surface in the presence of small out-of-plane components transverse to the surface. This objective was satisfied. The experimental results indicate that ESDM accurately reconstructs such velocity fields. Specifically, large in-plane and small out-of-plane velocity components obtained from ESDM agreed with accelerometer results at most of the same spatial locations on the front surface of one of the test structure columns. From Table 11, percent differences between horizontal in-plane (x -direction) magnitudes only varied about 1% to 13% throughout all accelerometer locations; likewise, absolute differences between horizontal in-plane relative phases throughout the same locations varied only approximately 1° to 6° . Furthermore, percent differences between out-of-plane (z -direction) magnitudes only varied about 2% to 15% throughout the first four accelerometer locations and corresponding relative phases varied only approximately 3° to 5° throughout all locations. Overall, such results clearly indicate that ESDM accurately reconstructs velocity fields with large in-plane and small out-of-plane components.

Other, secondary, thesis objectives were also satisfied. Among such objectives was the development and implementation of a new LDV scanner calibration procedure. The new calibration procedure is simpler and more accurate than past methods. Improved accuracy is extremely important since ESDM directly relies upon information obtained from scanner calibration.

Another secondary thesis objective was the development and fabrication of a test structure suitable for this evaluation and future ESDM evaluations. The resulting test structure has dynamic characteristics that permit motion control. Such motion control was required for this work and is essential for any further ESDM research. Moreover, development of the test structure was documented so that similar test structures with better dynamic characteristics that permit more precise motion control may be fabricated later.

Recommendations

The following recommendations will enhance future ESDM research. These recommendations are associated with six main areas: LDV scanner calibration, test structure dynamic characteristics, test structure fabrication, tri-axial accelerometer attachment methods, LDV registration error and ESDM result uncertainty, ESDM software and future ESDM evaluations.

The new LDV scanner calibration procedure employed for this work relied upon an acoustic digitizer. The digitizer created coordinate systems and measured coordinate system locations. Unfortunately, the particular digitizer used has limited accuracy. Therefore, before future scanner calibration work is undertaken, three possibilities should

be explored. First, a more accurate acoustic digitizer with a larger useful volume should be considered. The current digitizer is accurate within a 8.0x8.0x16 ft (2.4x2.4x4.9 m) volume [72]. A digitizer with a larger volume would allow positioning of the LDV farther from a target surface thereby minimizing error associated with 1) the scanner mirror surface offsets and 2) uncertainty regarding the actual location of the laser beam virtual origin [73]. Second, a larger plate affixed underneath the LDV with greater pin separation would ensure more accurate measurement of the laser beam virtual origin in the digitizer coordinate system. However care should be taken: 1) a stiff plate that resists bending should be used and 2) the plate should be designed such that it does not obstruct any LDV cooling vents. Third, more precise methods and devices for coordinate system creation and location measurement should be investigated. However, better accuracy obtained from such methods and devices may result in less simplicity and practicality, two very important characteristics associated with the digitizer.

The test structure fabricated for this work was designed such that it possessed certain dynamic characteristics that enabled motion control. Unfortunately, the test structure also exhibited properties which prevent extremely precise motion control. More specifically, 1) the test structure exhibits out-of-plane motion which does not demonstrate a smooth, decreasing velocity gradient down the test structure and 2) the current test structure does not exhibit pure in-plane and out-of-plane motion. Such properties did not affect this work since only the capability of ESDM to accurately reconstruct surface velocity fields with large in-plane and small out-of-plane components was evaluated. Large in-plane velocity components were easily controlled and maintained. Furthermore,

no attempt was made to determine the minimum in-plane velocity that ESDM can reconstruct. Such an evaluation would require precise control of test structure in-plane motion. Unfortunately, such control of the current test structure is difficult. The presence of out-of-plane motion which does not exhibit a smooth, decreasing velocity gradient down the test structure is not easily explained. Therefore, the current test structure should be fully analyzed to determine its exact dynamic characteristics. The absence of pure in-plane and out-of-plane motion probably has two causes: asymmetry induced during fabrication and asymmetry associated with the test stand attachment scheme. Thus, fabrication of similar test structures must be tightly controlled and better tolerances must be maintained. Additionally, a different method for constraining the test structure, besides bolts, should be explored. Alternatively, a different test structure that eliminates boundary condition problems yet possesses similar dynamic characteristics may be developed.

ESDM velocity results were compared with velocity results ultimately obtained from tri-axial accelerometers affixed to the front surface of one test structure column at multiple locations. Three accelerometers oriented along three, orthogonal directions were threaded into a small, steel mounting block and the mounting block was affixed to the column front surface with accelerometer wax. Accelerometer data was obtained at each front surface location by manually moving and repositioning the accelerometers. Unfortunately, with wax, exact repositioning of the accelerometers was impossible at each front surface location. Therefore, in the future, the mounting block should be

affixed to the test structure with studs. The use of studs will help minimize any data variability caused by inexact accelerometer repositioning.

ESDM results depend on and are greatly influenced by LDV registration. Hence, any errors associated with LDV registration significantly affect ESDM results. Heretofore, only limited research into registration error has been conducted. The work that has been completed primarily concerns analytical estimates of registration error and resulting registration uncertainty [74]; no experimental evaluation of registration error and uncertainty has been conducted nor has any evaluation of how such error and uncertainty affects ESDM results. Furthermore, no evaluation, either analytical or experimental, of how error and uncertainty propagate through ESDM has been conducted. An analysis of these errors and uncertainties would provide a way to determine the overall accuracy of ESDM results. Because of the lack of such information, future ESDM research should address these issues.

ESDM employs several computer programs. Unfortunately, some of the original programs are poorly designed and, thus, extremely complicated. Consequently, past program modifications have proved difficult. Unless these programs are redesigned, any modifications will continue to be difficult and consume much time. Therefore, the programs should be redesigned with considerations and allowances made for easy modification and improvement.

This research assessed the capability of ESDM to reconstruct surface velocity fields with large in-plane components in the presence of small out-of-plane components. The experimental results demonstrate that ESDM accurately reconstructs such velocity

fields. Moreover, the experimental results indicate that ESDM accurately reconstructs small out-of-plane components in the presence of large in-plane components. Future ESDM research should evaluate the extent to which ESDM can reconstruct surface velocity fields with small in-plane components in the presence of large out-of-plane components. Such a situation exists when a plate is excited in an exact or near out-of-plane direction. Ultimately, such research coupled with this work will permit the development of a resolution envelope that specifies velocity field types and relative velocity component magnitudes for which ESDM results are accurate.