RUDDER DEFLECTION STUDIES ON SARAS USING MESH-FREE SOLVER

C. K. Niranjanan[1], Keshav Malagi[1], A. Shikhar Jaiswal[1], K. Madhu Babu[1],
V. Ramesh and S. M. Deshpande[2]
[1] Computational & Theoretical Fluid Dynamics Division, CSIR-National Aerospace Laboratories, Bangalore - 560017, India, e-mail: ckniranjanan@ctfd.cmmacs.ernet.in
[2]Engineering Mechanics Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, Bangalore-560064, India, e-mail: smd@jncasr.ac.in

Abstract

Study of effect of control surface deflection on various aerodynamic co-efficient and control derivatives is an integral part of any aircraft program. Using a FVM code to perform these studies will involve a large number of grids being generated manually, consuming a lot of time, computing resource and human intervention. Obviously, such an approach lacks automation. To address these difficulties, mesh-free solver-based technique has been evolved to efficiently perform control surface deflection studies with full automation. The technique involves usage of a pre-processor and a transformation code to handle space discretization (generation of Point-cloud in case of mesh-free solvers) for various control surface deflections. Once the point-clouds are generated in an automated manner, the PARANAM solver (Parallel NAL MCIR Mesh-free solver) runs on these point-cloud to provide quick and accurate results. This technique has been used effectively to study the effect of rudder deflections on aerodynamic characteristics of SARAS aircraft and the method has been validated with flight test data. The results of this studies along with a brief description of the technique is shown in this paper.

Keywords: Mesh-free solver, Control Surface Deflection Studies, MCIR, LSKUM, 6-DOF

Introduction:

Moving body problems are difficult to simulate using regular Finite Volume Methods (FVM) on unstructured grids/mesh. This is due to the fact that we have to regenerate mesh for every small change in position of the moving body. Automating mesh generation is not easy and getting a quality mesh is also not guaranteed. Overset grid technique is one method to handle moving body problems. But it has its own disadvantages, like it introduces non-physical interpolation errors in the solution. Store separation studies, rocket booster separation studies etc are few examples of moving body problems. At CSIR-NAL, a store separation suite has been developed by integrating PARANAM solver (Parallel NAL MCIR Mesh-free solver) with a Dynamic Cloud Pre-processor and a 6-DOF solver [3]. PARANAM is a mesh-free Euler solver based on Least Squares Kinetic Upwind Method (LSKUM) and Modified-CIR (MCIR) split fluxes [1,2]. The Store separation suite also has the capability to simulate multi-store release scenarios [4]. The Store Separation Suite uses the dynamic cloud pre-processor, which can transform and combine multiple point cloud into single large cloud, to handle the moving objects in flow domain (where point-cloud is a collection of points distributed in the flow domain and their neighbourhood information and Mesh-free solvers use a point-cloud instead of a mesh/grid to solve the flow problem). Control surface deflection studies are a class of moving body problems where a lot of simulations and studies have to be carried out for various settings of control surface deflections. In mesh-based solvers, any change in control surface deflections will require to rotate the control surface to new setting and regenerate the mesh. This process needs manual intervention, and also it is laborious and time consuming. Since the dynamic cloud pre-processor developed for Store Separation Suite already had the capability to handle geometric changes in an automated way, it was slightly modified and extended to be used for control surface deflection studies. The Integration of the dynamic cloud pre-processor (which was slightly modified for control surface deflection studies) and PARANAM solver aided in carrying out studies on effect of rudder deflection on aerodynamic characteristics of SARAS in a quick and efficient manner with very little manual intervention.

The Dynamic Cloud Pre-Processor:

The method developed using PARANAM solver, to study effect of control surface deflection, requires a point cloud around each of the control surface and a point-cloud around aircraft with all the control surfaces removed. The Dynamic cloud pre-processor in the suite rotates, overlaps and merges individual components' cloud with the aircraft cloud resulting in a single point-cloud around aircraft with deflected control surface, on which PARANAM solver is run. The merging involves blanking/deletion of points followed by connectivity regeneration of affected points. Blanking is needed as some of the overlapped point clouds lead to points lying outside the flow domain. Blanking is carried out by the pre-processor by using ray passing technique efficiently. This affects the connectivity of several points close to/on boundary. Connectivity for such points is regenerated by the pre-processor by considering the new neighbourhood. The pre-processor also takes care to avoid nonaerodynamic neighbours in the connectivity. Figure-1 shows a point-cloud around aircraft and rudder being overlapped and merged into a single large cloud.

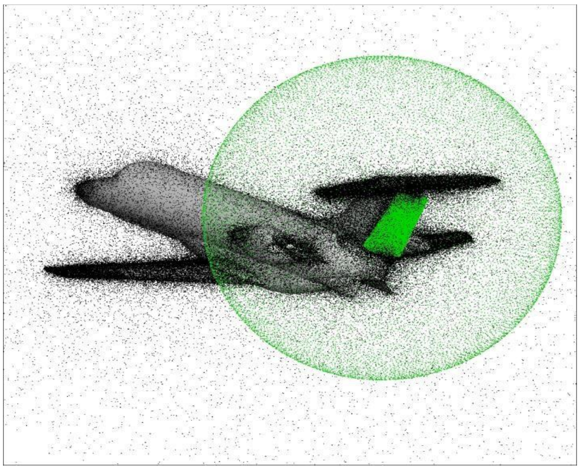
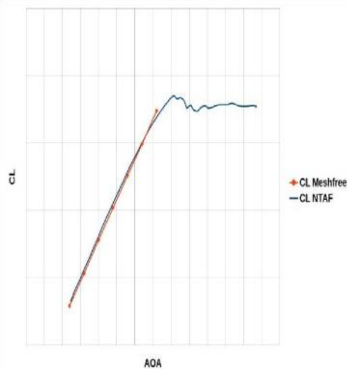


FIGURE 1: MERGING OF RUDDER CLOUD WITH AIRCRAFT CLOUD FOR CONTROL SURFACE DEFLECTION STUDIES

RUDDER DEFLECTION STUDIES ON SARAS USING PARANAM SOLVER

Validation of PARANAM for SARAS configuration:

Before commencing studies on any new configuration, the solver settings, adequacy of point-cloud size etc needs to be validated. Hence validation was carried out by simulating flow over SARAS PT-3 aircraft at M=0.45, Re=3 million, using PARANAM solver. Experimental results were taken from tests were conducted at NTAF tunnel, CSIR-NAL. Figure- 2 and 3 shows the comparison of results from PARANAM solver and experiments. From these figures it is observed that the simulation results are in good agreement with experiments, giving confidence to continue with the rudder deflection studies.



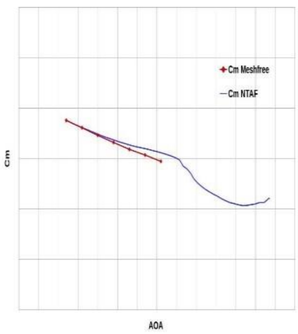
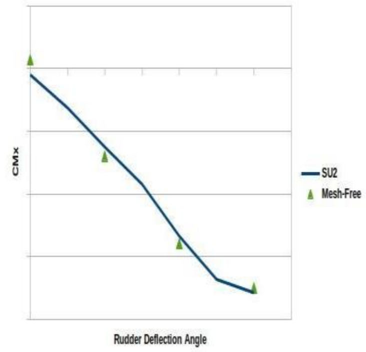


FIGURE 2: C_L VS ANGLE OF ATTACK FOR SARAS
FIGURE 3: C_M VS ANGLE OF ATTACK FOR SARAS

Rudder Deflection Studies:

Effect of rudder deflection for SARAS has been studied using PARANAM solver in an automated way by just providing individual point-clouds around aircraft and rudder separately along with the deflection angles as input. Solutions at different rudder deflections were automatically computed using the above-mentioned method without any human intervention. The simulations were run at M=0.24 and AoA=7deg for various rudder deflection angles. The obtained results were compared with flight test results (wherever available) and SU2 RANS simulations (SU2 RANS simulation results were provided by Dr. T. N. Venkatesh, CTFD, CSIR-NAL and his team). Figure 4,5 and 6 shows the variation of rolling moment co-efficient, yawing moment co-efficient and side force co-efficient respectively with change in rudder deflection angle. Results from SU2 simulations are also plotted in these figures and they compare well. Figure 7 shows the comparison of hinge moments calculated from PARANAM solver solution with SU2 results and experiments. Good agreement between hinge moment predicted by PARANAM and hinge moment measured from flight test can be observed. This acts as a validation of the method.



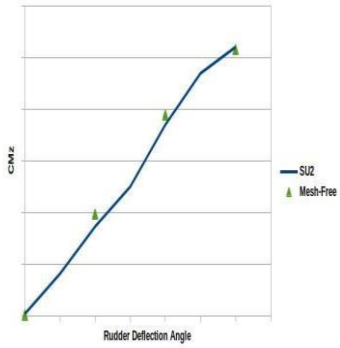
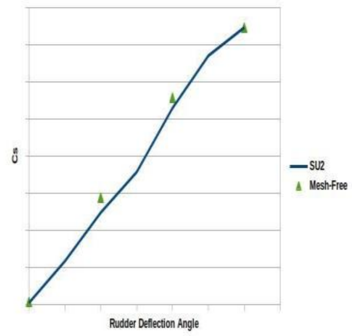


FIGURE 4: CHANGE OF ROLLING MOMENT CO-EFFICIENT WITH RUDDER DEFLECTION
FIGURE 5: CHANGE OF YAWING MOMENT CO-EFFICIENT WITH RUDDER DEFLECTION



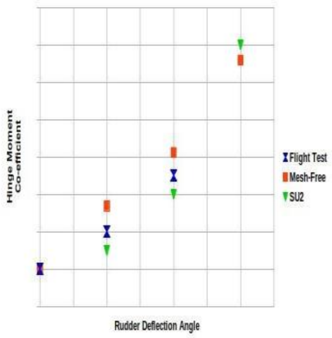


FIGURE 6: CHANGE OF SIDE FORCE CO-EFFICIENT WITH RUDDER DEFLECTION
FIGURE 7: CHANGE OF HINGE MOMENT CO-EFFICIENT WITH RUDDER DEFLECTION

Conclusion:

A new automated method to perform control surface deflection studies has been evolved using PARANAM solver (mesh-free solver). The method has been validated against experiment and has been used on SARAS to study the effect of rudder deflection on aerodynamic characteristics of SARAS. The results obtained demonstrate the capability of mesh-free solvers (in particular, PARANAM solver) to efficiently handle problems where geometry changes due to change in orientation of various components.

References:

[1] Deshpande S M and Ramesh V, 2007, “Unsteady flow computations for flow past multiple moving boundaries using LSKUM”, Computers and Fluids, vol 36. ELSEVIER

[2] Ramesh V, 2002, “Least Squares Grid Free Kinetic Upwind method”, PhD thesis, Indian Institute of Science, Bangalore.

[3] Niranjanan C K, Keshav Malagi S, Shikhar Jaiswal A, Madhu Babu K, Ramesh V and Deshpande S M, 2016, “A Store Separation Suite Using PARANAM Cfd Solver”, 18th Annual CFD Symposium, AeSI.

[4] Niranjanan C K, Keshav Malagi S, Shikhar Jaiswal A, Madhu Babu K, Ramesh V and Deshpande S M, 2017, “A Multi-Store Release Simulation Using PARANAM Mesh Free Solver Based Store Separation Suite”, 19th Annual CFD Symposium, AeSI.