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Stage Separation Performance Analysis Project

Monthly Progress Report

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OBJECTIVES

Stage separation process is an important phenomenon in multi-stage launch vehicle operation. The transient flowfield coupled with the multi-body systems is a challenging problem in design analysis. The thermodynamics environment with burning propellants during the upper-stage engine start in the separation processes adds to the complexity of the entire system. Understanding the underlying flow physics and vehicle dynamics during stage separation is required in designing a multi-stage launch vehicle with good flight performance. A computational fluid dynamics model with the capability to coupling transient multi-body dynamics systems will be a useful tool for simulating the effects of transient flowfield, plume/jet heating and vehicle dynamics. A computational model using generalize mesh system will be used as the basis of this development. The multi-body dynamics system will be solved, by integrating a system of six-degree-of-freedom equations of motion with high accuracy. Multi-body mesh system and their interactions will be modeled using parallel computing algorithms. Adaptive mesh refinement method will also be employed to enhance solution accuracy in the transient process. The following tasks are proposed to accomplish the technical objectives.

TASKS PERFORMED IN THIS REPORTING PERIOD

In this reporting period, strategies and algorithms for constructing the conservative boundary conditions across the Chimera grid boundaries are formulated. The methodology employed in the present model is suitable for generalized coordinates mesh systems that are used in the UNIC-UNS code.

There are mainly two approaches in constructing conservative Chimera grid boundary conditions. In the first approach, the interfaces between the background (big) mesh and the component (small) mesh systems are created using hanging-nodes method to link data across the interfaces (see Figure 1). All grid cells outside of the flow domain or the background cells within the domain of the component mesh are blanked out. This involves searching and reconstructing the interface for every time step when there is relative motion between the background mesh and the component mesh. In the second method, the larger blanked out region of the background mesh is created. Then, space between the component mesh boundary and the active background cells are filled with a new mesh (called filled mesh) using automatic mesh generator within the code (see Figure 2). Flow variables are then interpolated onto the filled mesh. The relative motion effects are accounted for using moving grid method for the filled mesh cells. The blanking the filling procedure is only required when the mesh quality of the filled mesh becomes unacceptable based on some mesh quality criteria (e.g. skewness, aspect ratio, cell volume, etc.). The second method is better for conservation since no hanging nodes and interface construction are required. For dynamic cases, the second method can also be more efficient since the blanking and filling procedure is not required for every time step.

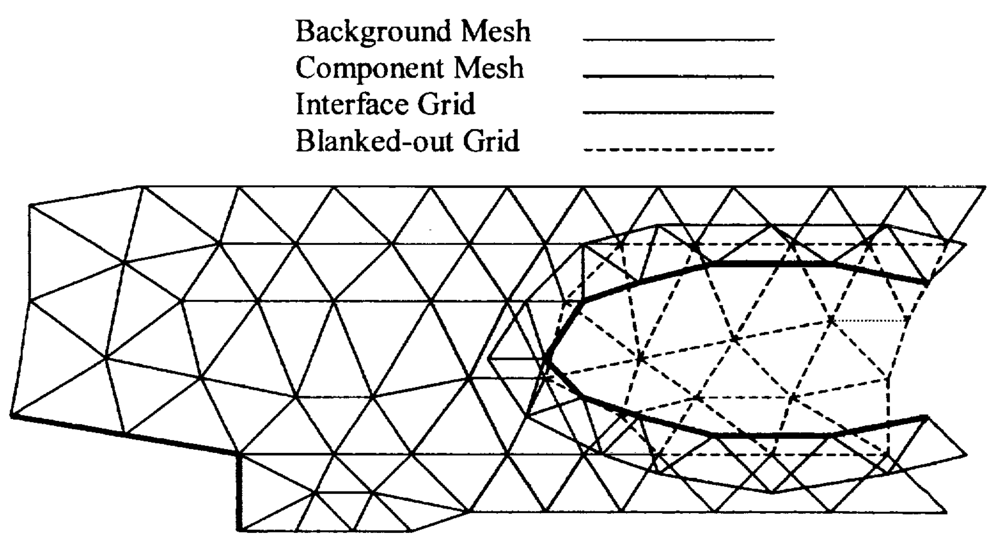

Figure 1. Chimera grid method using reconstructed interface and hanging nodes.

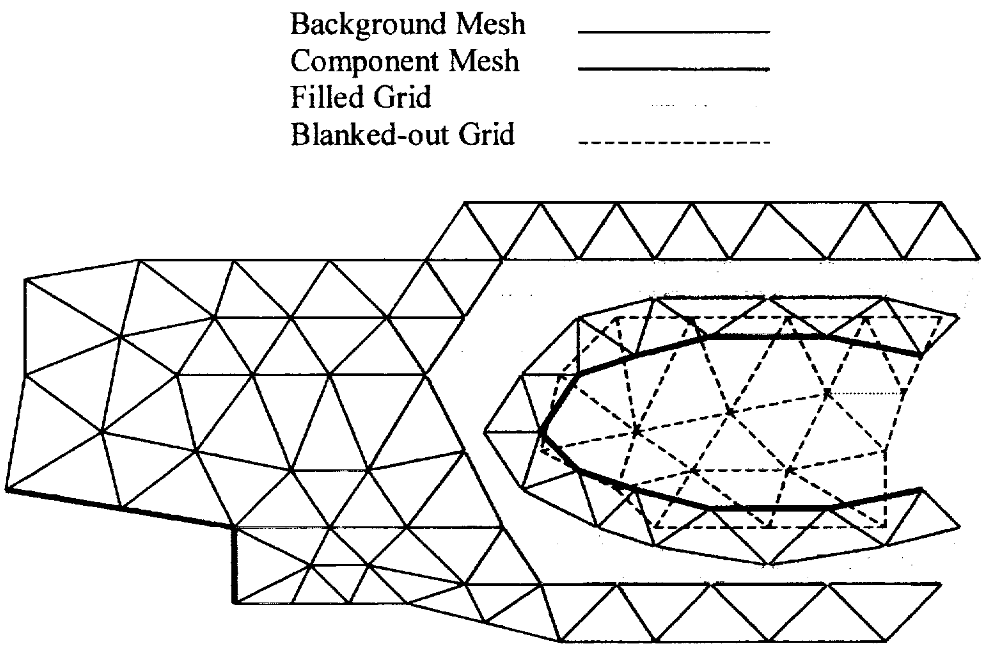

Figure 2. Chimera grid method based on the cell blanking and filling procedure.

Therefore, the second method described above will be implemented and tested based on the UNIC-UNS code. Static Chimera grid models will be investigated using available experimental test cases.

TASKS TO BE PERFORMED IN THE NEXT PERIOD

1. Implement the cell blanking and filling procedure in the UNIC-UNS code.
2. Perform static Chimera grid cell blanking and filling model for testing the effectiveness of the method.

CONTRACT PERFORMANCE AND FUNDING

12% of the proposed technical effort has been accomplished with 12% of the funding billed. No technical problem of the current model development has been encountered.

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Stage separation process is an important phenomenon in multi-stage launch vehicle operation. The transient flowfield coupled with the multi-body systems is a challenging problem in design analysis. The thermodynamics environment with burning propellants during the upper-stage engine start in the separation processes adds to the complexity of the entire system. Understanding the underlying flow physics and vehicle dynamics during stage separation is required in designing a multi-stage launch vehicle with good flight performance. A computational fluid dynamics model with the capability to coupling transient multi-body dynamics systems will be a useful tool for simulating the effects of transient flowfield, plume/jet heating and vehicle dynamics. A computational model using generalize mesh system will be used as the basis of this development. The multi-body dynamics system will be solved, by integrating a system of six-degree-of-freedom equations of motion with high accuracy. Multi-body mesh system and their interactions will be modeled using parallel computing algorithms. Adaptive mesh refinement method will also be employed to enhance solution accuracy in the transient process. The following tasks are proposed to accomplish the technical objectives.

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