M4 Structures Studio Recent Updates and Demonstration

Thomas Nascenzi
Tyler Winter
Tim Cuatt

OpenVSP Workshop 2022
Overview

• M4 Structures Studio Overview
• Some Selected Applications
• Recent Developments/Future Work
• X-57 Maxwell Demonstration
• Goal is to predict structural weight for unconventional vehicle designs
  – Where history is not valid
• Requires ability to predict structural sizing
  – Depends on stress
    • Depends on loads
      – Depends on fuel distribution
      » Depends on ...
• Filling in these “depends on” items is time consuming and difficult with conventional processes, but can be automated
• M4 Structures Studio represents 15 years of tackling this problem
• Integration with OpenVSP really allows acceleration
M4SS-SPL

- Sketch Points
- Automated layouts

M4SS-Sketch

- Structural model definition
- Analysis and load cases

M4SS-FEM

- Component FEM generation

M4SS-Merge

- FEM merging
- FEM trimming

NASTRAN

- Minimize weight subject to load cases

M4SS-Weight

- Comprehensive weight statement
- Component breakdown

M4 Engineering Proprietary
M4SS-SPL
• Sketch Points
• Automated layouts

M4SS-Sketch
• Structural model definition
• Analysis and load cases

M4SS-FEM
• Component FEM generation

M4SS-Merge
• FEM merging
• FEM trimming

NASTRAN
• Minimize weight subject to load cases

M4SS-Weight
• Comprehensive weight statement
• Component breakdown

Horizontal Tail
Vertical Tail
Wing
Fuselage
Tiltrotor Nacelle
NASTRAN Analysis Execution

M4SS-SPL
- Sketch Points
- Automated layouts

M4SS-Sketch
- Structural model definition
- Analysis and load cases

M4SS-FEM
- Component FEM generation

M4SS-Merge
- FEM merging
- FEM trimming

NASTRAN
- Minimize weight subject to load cases

M4SS-Weight
- Comprehensive weight statement
- Component breakdown
M4SS-Weight

M4SS-SPL
- Sketch Points
- Automated layouts

M4SS-Sketch
- Structural model definition
- Analysis and load cases

M4SS-FEM
- Component FEM generation

M4SS-Merge
- FEM merging
- FEM trimming

NASTRAN
- Minimize weight subject to load cases

M4SS-Weight
- Comprehensive weight statement
- Component breakdown

WEIGHT STATEMENT

VEHICLE SUMMARY

COMPONENT SUMMARY

CONM2s ASSOCIATED with RBE2s

PROPERTY SUMMARY
Overview

• M4 Structures Studio Overview
• Some Selected Applications
• Recent Developments/Future Work
• X-57 Maxwell Demonstration
Some Selected Applications

- Rotorcraft
- Tilt Rotor
- Commercial Transports
- Hypersonic
- BWBs

- DEP
- VTOL
- Fixed Wing
- Supersonic Transports
- RLVs
- HALE
- Spacecraft
- UAM
Overview

• M4 Structures Studio Overview
• Some Selected Applications
• Recent Developments/Future Work
• X-57 Maxwell Demonstration
Recent Developments

• NASA’s University Leadership Initiative
  – Rapid Development of Urban Air Mobility Vehicle Concepts through Full-Configuration Multidisciplinary Design, Analysis, and Optimization
  – M4SS is used to build weight surrogate models for UAM vehicles

• Direct-to-phase-II SBIR (AFRL)
  – Physics-Based Structural Analysis Model Development and Integration with CAPS
  – Developing capability to integrate with Engineering Sketch Pad geometry data
  – Developing M4SS API
  – Expanding capabilities to cover additional use-cases

L+C Structural Model for ULI
• These recent developments were supported by:
  – Dr. John Hwang (UCSD) and the NASA University Leadership Initiative under prime contract 80NSSC21M0070, and
  – the AFWERX via AFRL/RQVC under SBIR contract number FA864922P0973
• M4 Structures Studio Overview
• Some Selected Applications
• Recent Developments/Future Work
• X-57 Maxwell Demonstration
Demonstrated at 2021 OpenVSP Workshop

• Imported OpenVSP vehicle
• Laid out sketch points
• Initialized Sketch Model
• Created component cards
  – Material & property cards
  – Structural cards
• Created merge cards
  – Specifies how the components are merged together
• Created load case cards
  – Normal modes analysis
Import OpenVSP File

X-57 Maxwell Simplified CRM v.

Downloads: 502
Uploaded by: Brandon Litherland (NASA LaRC)
• Only 4 components modeled
  – Fuselage
  – Wing
  – Horizontal Stabilizer
  – Vertical Stabilizer
• Points only on half of component
  – Perpendicular to through-structure
  – Wing: top side
  – Fuselage: starboard side
  – Etc.
• Symmetric components
  – Only defined for one component
  – (Wing, H-Stab)
Define Sketch Model

1. Sketch Points

2. Through structure
   - Bulkheads
   - Ribs/spars

3. Skin
   - Nonstructural masses
Run M4SS-FEM and Merge

Generate mesh

Run analysis and view results
Continuing the demonstration

- Create M4SS aero cards
  - Define aero panels and control surfaces
- Create M4SS analysis and case cards
  - Define 2.5g static aeroelastic trim solution
  - Define wing sizing optimization using 2.5g maneuver
- Update OpenVSP geometry and regenerate FEM
  - Immediate turnaround after updating geometry
  - Demonstrates maintained connectivity to OpenVSP model
NASTRAN aero model
Connected with splines to structural FEM
Unoptimized sizing (overbuilt wing)

Optimized sizing (sized to 2.5g maneuver stress)
Automated Weight Statement for Sized Vehicles

<table>
<thead>
<tr>
<th>SUBCASE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASELINE</td>
</tr>
<tr>
<td>Struct</td>
</tr>
<tr>
<td>NSM</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Component Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROPTAG</td>
</tr>
<tr>
<td>CleanWing_ALL</td>
</tr>
<tr>
<td>STRUCT_BASELINE</td>
</tr>
<tr>
<td>STRUCT_INITIAL</td>
</tr>
<tr>
<td>STRUCT_OPTIMIZED</td>
</tr>
<tr>
<td>NSM_BASELINE</td>
</tr>
<tr>
<td>NSM_OPTIMIZED</td>
</tr>
</tbody>
</table>
Quick Model Turnaround Once Base Model Set Up

High Aspect Ratio

• Only changed AR in OpenVSP
• Model updates automatically
  • Points mapped to UV

Low Aspect Ratio
Questions/Suggestions/Contact:

Tyler Winter
twinter@m4-engineering.com

Thomas Nascenzi
tnascenzi@m4-engineering.com

Tim Cuatt
tcuatt@m4-engineering.com

M4 Engineering, Inc.
www.m4-engineering.com
Phone: (562) 981-7797

M4SS and IXGEN
Software Licensing Inquiries:
Dan Abir
dabir@m4-engineering.com