AERODYNAMIC FORCES ON ELASTIC BODIES IN SIMPACK: THE MODAL APPROACH

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Major Fields of Application of MBS

Automotive

Wheel / Rail

Aerospace

Mechanics, Mechatronics,...
“Aerodynamics” in Aircraft Ground Dynamics

- Landing impact
- Dynamic behaviour
- Loads
- Handling qualities
- Unconventional configurations
- ...

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Requirements

Conceptual Design
Requirements

Conceptual Design

Preliminary Design
Requirements

- Conceptual Design
- Preliminary Design
- Detail Design
Requirements

- **Scope**
  - (Quasi)-steady airloads
  - Airloads on flexible bodies
  - Pilot control inputs / control surface deflection
  - Aerodynamic damping/excitation effects
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- **Physical approach**
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    - (Quasi)-steady airloads
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  - **Physical approach**

  - **Embedded into CAE environment**
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  - (Quasi)-steady airloads
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- **Physical approach**

- **Efficiency**
  - Standardised / automated generation of input data
  - Rapid modelling
  - Fast computation
  - Easy handling
  - Robustness
Coupling Techniques

Loose coupling
Coupling Techniques

Loose coupling

Close coupling

\[ \nabla^2 \phi = M \ddot{\phi} + D \dot{\phi} + K \phi \]
Elastic Bodies in MBS

All necessary data for representing flexible bodies can be processed prior to the MBS analysis:
Elastic Bodies with “Aerodynamic Pre-Processing”

An approach which enhances this pre-processing tool to include aerodynamic properties as well will fulfill the requirements:
Aerodynamic Preprocessing

Aerodynamic / Aeroelastic Preprocessor AeroFEMBS:

Pre-Processing Part

NASTRAN

VSAERO

enhanced MBS - Preprocessor

AeroFEMBS

SIM PACK

states forces
Workflow

flexible body model ($\Phi$) -> CFD file name -> rigid body aerodynamics -> output file
Workflow

- flexible body model ($\Phi$)
- CFD file name
- select relevant motion
- rigid body aerodynamics
- aerodynamics of rigid body motion
- output file
Workflow

flexible body model ($\Phi$) ->

CFD file name ->
rigid body aerodynamics

select relevant motion ->
aerodynamics of rigid body motion

define controls, define type of deflection, (characteristics) ->
control surface deflection

output file
Application Example

Application example:

- Aerobatic glider Mü 28 of Akaflieg München
Application Example

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Application Example
Application Example
Application Example

Steady Flight
Application Example

AeroFEMBS

VSAERO

SIMPACK

data file

derivatives

Comments: basically simple rigid body aerodynamics
Application Example

SIMPACK Simulation
Application Example
Application Example

Aircraft Trim
(Long. Control)
Application Example

AeroFEMBS

VSAERO

derivatives

data file

SIMPACK

SIMPACK Trim Module

elevator force AoA of std. fl.

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Application Example

AeroFEMBS

der1
der2
der3
cdl

elevator force AoA of std. fl.

data file

derivatives

VSAERO

SIMPACK

Comments: vertical trim force on tail or trim of elevator setting (→ a/c control)

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Application Example

SIMPACK Simulation
Application Example

[Image of an airplane wing and sky background]
Application Example
Application Example

Definition of complex manoeuvres via input functions for control surface deflection
Application Example

VSAERO
- elevator
- aileron
- rudder

standardised rotation of control panels

AeroFEMBS
- incl.: control efficiency factors
- ground effect
- ...

SIMPACK

data file
Application Example

VSAERO
- elevator
- aileron
- rudder

AeroFEMBS
- standardised rotation of control panels
- kinematic velocities (rot. and trans.)
- incl.: control efficiency factors
- ground effect
- ...

SIMPACK

Data file
Application Example

Comments: full free-flight control of the aircraft
Application Example

SIMPACK Simulation
Application Example
Application Example
Application Example

NASTRAN

eigenmodes static modes

VSAERO

selected eigen- and/or static modes

mode 1

mode 2

AeroFEMBS

“Automised” functionality for grid transformation using COPMAT and/or MPCCI routines

data file

SIMPACK

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Application Example

NASTRAN

VSAERO

AeroFEMBS

SIMPACK

Comments: efficient analysis (<5min for the simulation)
Application Example

SIMPACK Simulation
Application Example
Application Example

Manoeuvres with Flow Separation
Application Example

... for these and similar non-linear applications, this method fails ...
Application Example

... for these and similar non-linear applications, this method fails ...

(only?) possible solution: IPC / Co-Simulation
Conclusions

✓ (Quasi-)steady aerodynamic forces on flexible structures can be included in MBS.
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☑ ... and it is compatible to most common CAE tools (esp. in FEA and CFD).
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✓ The approach allows very efficient modelling and computation...
✓ ... and it is compatible with most common CAE tools (esp. in FEA and CFD).
✓ Finally: easy to use / fits for most industrial design processes.
Thank you...