Experimental and Numerical Investigation of the Flow Topology During Airdrop Operations

TAU User Meeting
18 – 19 October 2011, Braunschweig

S. Geisbauer, N. Schade, S. Enk
DLR Institute of Aerodynamics and Flow Technology

H. Schmidt, J. Arnold
DLR Institute of Aeroelasticity
Outline

- Motivation and Objectives
- Approach and Challenges
- Results
- Summary and Outlook
Motivation
Capabilities of modern military transport aircraft

- Formation flight and aerial refuelling
- Operation on unpaved runways
- Low altitude flight
- Cargo and paratrooper deployment
Motivation

- High costs / risk potential of flight tests
- Time-consuming certification process

Increasing demand to develop **accurate** and **well-validated** simulation tools for airdrop operations

**DLR’s objectives**

- Process chain to simulate an airdrop sequence, using CFD and MBS methods
- Experimental setup to conduct W/T airdrop investigations
- Validation data base
Outline

- Motivation and Objectives
- Approach and Challenges
- Results
- Summary and Outlook
Approach and Challenges
(1) Experimental methods

Objective
Provide data for the validation of the numerical airdrop simulation

- Four campaigns (2006 – 2008) carried out in the DNW-NWB low speed wind tunnel facility in Braunschweig, Germany

Experimental setup
- Generic transport aircraft with lowered ramp and ejection mechanism
  - R/C jackscrew drive
  - Aluminium rack
  - Cargo incl. markers
Approach and Challenges

(1) Experimental methods

Objective
Provide data for the validation of the numerical airdrop simulation

- Four campaigns (2006 – 2008) carried out in the DNW-NWB low speed wind tunnel facility in Braunschweig, Germany

Experimental setup
- Generic transport aircraft with lowered ramp and ejection mechanism
- Generic cargo bodies (with/without parachute, rigid/hinged, varying masses)
- Markers to track position/attitude
Approach and Challenges

(2) Numerical methods

Objective
Establish a simulation environment which allows for an accurate computation of an airdrop sequence in the vicinity of the aircraft

- Combine Computational Fluid Dynamics and Multi-Body Simulation methods
  - DLR TAU RANS solver
  - Commercial MBS software SIMPACK

- Assess interference effects during airdrop

- Compute aerodynamic forces and moments
Approach and Challenges

(2) Numerical methods – CFD / DLR TAU code

- uRANS computations with DLR TAU code
  \( \Delta t \approx 3\text{ms}, 1500 \text{ inner iterations} \)

- Backward Euler, central scheme with matrix dissipation, SA turbulence model

- Overset grid technique
  - Semi-automatic hole-cutting process
  - 27.3e6 points, 80 CPUs, 435h

- Preceding studies
  - Turbulence model influence
  - Higher-order methods (RANS vs. DES)
  - Comparison with experiments (RANS vs. PIV)
Approach and Challenges
(2) Numerical methods – MBS / SIMPACK

- Commercial Multi-Body Simulation software SIMPACK

- Dynamic, non-linear analysis of any mechanic or mechatronic system

- SIMPACK models
  - Aircraft (rigid, non-moving)
  - Cargo / parachute (rigid, 6-DOF)

- Quaternion formulation
Approach and Challenges

(3) CFD – MBS coupling

**Flight mechanics**

- Initial position
- Translation and rotation
- Position and attitude
- Forces and moments

**Aerodynamics**

- CFD solver
  - DLR TAU code
- Aerodynamic loads

**MBS solver**

- SIMPACK

Forces and moments
Outline

- Motivation and Objectives
- Approach and Challenges
- Results
- Summary and Outlook
Results
(2) Coupled airdrop simulation (v=18 m/s)
Results

(3) Trajectory evaluation

- Relevant part of the experimental trajectory was computed (0.3s)
- Computed translational behaviour complies very well with the experimental data
Results

(4) Attitude evaluation / Euler angles

- During the first 0.1s good agreement in pitch angle, max. deviation at the end of the simulation approx. 18%
Outline

- Motivation and Objectives
- Approach and Challenges
- Results
- Summary and Outlook
Summary and Outlook

- Experimental airdrop setup
- High-quality wind tunnel airdrop experiments
- Extension of the DLR TAU code functionalities
- Successful coupling for multi-disciplinary application
- Good quantitative results, further investigations necessary

Successor project MiTraPor II (2010 – 2013)

- Additional wind tunnel experiments
  (further validation data)
- Higher complexity of the simulation
  (hinged parachutes, gravity drop incl. aircraft reaction)