MODELLING THE SUGAR BEET STORAGE ENVIRONMENT

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BACKGROUND: The sugar beet crop in Europe is stored post-harvest in the field in a system referred to as a clamp. It is a challenging storage environment (Figure 1). Airflow will have large impacts on the rates of temperature and moisture change, which in turn will have large impacts on the rates of sugar loss during storage. The clamp cover properties will have large impacts on the rates at transfer between the clamp and ambient environments.

PURPOSE: Develop a series of models of temperature and moisture in naturally ventilated sugar beet clamps for use in research and in information to growers. The models should include ambient air speed and temperature, clamp size, beet size, and cover properties. The first step is to develop a baseline Computational Fluid Dynamics (CFD model version 1) – presented here. The accuracy of the airflow modelling in the model CFD v1 was initially assessed against the accuracy of the temperature field.

FIGURE 1: A sugar beet clamp in the field. The non-woven polypropylene cover on the clamp has come loose in the wind. This clamp is ca. 9m wide, 3m high, on a North-South bearing, and situated in an open field in southern Sweden.

METHOD (CFD v1):

Computational Fluid Dynamics (CFD)
Program: OpenFOAM

Porous medium approach
Porous zone: clamp
Darcy-Forchheimer coeffs.: 100000 / 370*

Clamp size: 9.00 x 3.00 m
Mesh: 6123 cells (2D)

Temporal model: Transient
Turbulence model: *k*-epsilon
Solver: PISO
Discretisation (U): linear upwind

Equations:
Airflow = *f*(… , permeability)
Temp. air = *f*(… , airflow, convective transfer)
Temp. beet = *f*(… , convective transfer, heat of respiration)

To deal with the challenging system environment, and to align with the available experimental data:

- the domain is symmetric around the y-axis (Figure 2a)
- two versions of the mesh are available, with the inlet and outlet at opposite ends (Figures 2a & b)
- the model proceeds in 15 minute intervals
- the airflow field is solved to a stable field, then passed to the solver for temperature.

Model parameters taken from literature and new experiments. Validation data from experiments during the 2011/12 storage season (ca. 60 days)**.

*Source: L. G. Tabil, J. Kienholz, H. Qi & M. V. Eliason, (2003) "Airflow Resistance of Sugarbeet", Journal of Sugar Beet Research, Vol. 40 Issue 3 Pages 67-86

** Source: Olsson, R. (2013) "Storage of sugar beet – possibilities and limitation for five types of water and frost protection", NBR Report

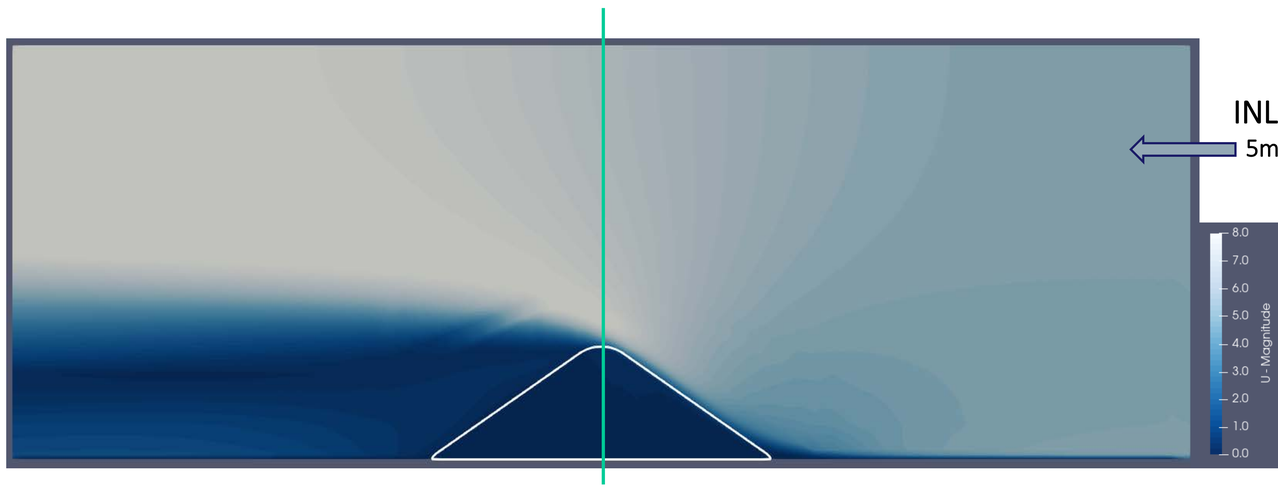

FIGURE 2a: Entire model CFD v1 model domain, with outline of porous clamp region shown. Airflow right to left. Uncovered clamp. Vertical green line is the line of symmetry. Inlet velocity 5 m/s. Scale: 0 – 8 m/s.

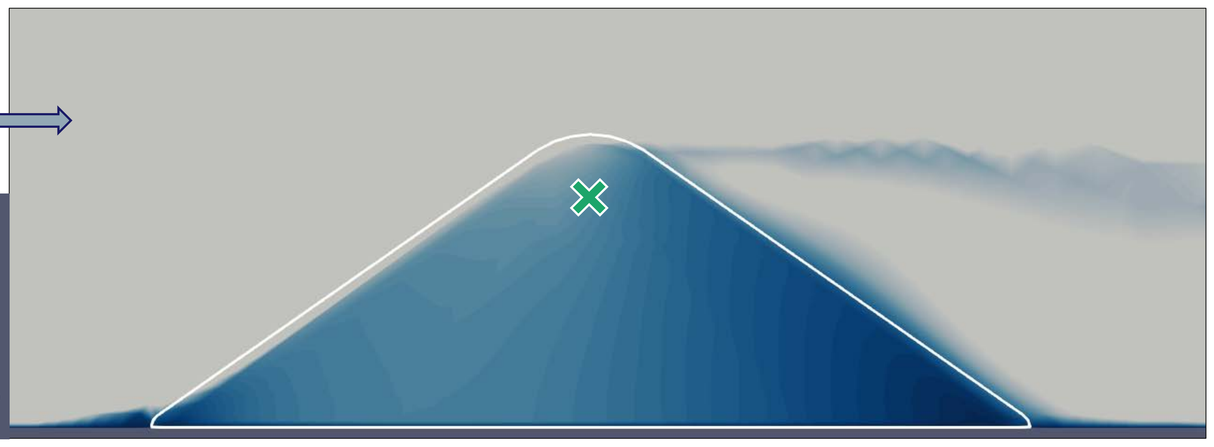

FIGURE 2b: Focus on porous clamp region of model CFD v1. Airflow left to right. Uncovered clamp. Inlet velocity 5 m/s. Scale: 0 – 0.4 m/s. The green cross marks the point ca. 0.5 m down from the peak of the clamp for which results are shown in Figure 3.

RESULTS (CFD v1):

The CFD v1 model appears well behaved: the relationship between rates of change in temperature and the inlet velocity seen in the experimental data is also seen in the model (Figure 3).

No data is available for field validation of the airflow.

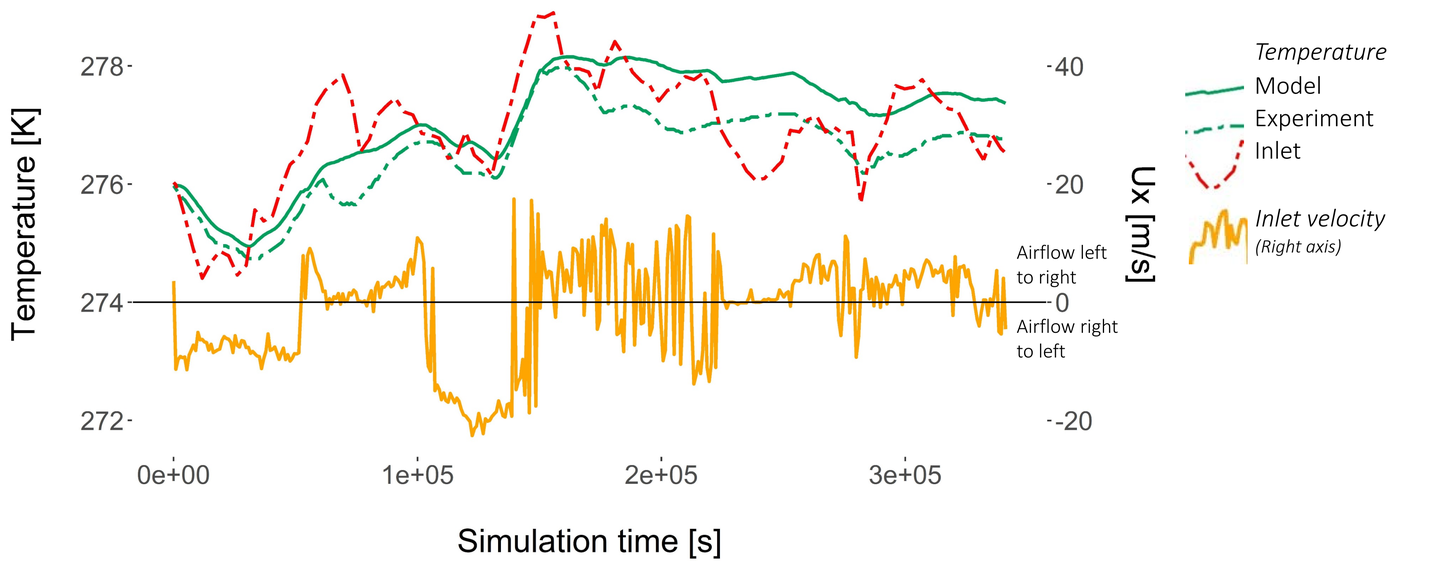

FIGURE 3: Comparison of model temperature to experimental data for model CFD v1. Green lines show temperature data from inside of porous clamp region at 0.5 m down from the peak of the clamp. Red and orange lines are model inlet conditions. Uncovered clamp.

OUTLOOK

CFD Version 2:

The further development of the CFD model has numerous avenues to pursue, including the extension to include:

- Natural convection (the idea that hot air rises)
- Radiation
- Soil thermal properties
- Moisture transfer

Digital-twin:

- Connect to established sensor network to create digital-twins

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