PRESSURE DISTRIBUTION CALCULATIONS BASED ON A FINITE ELEMENT MODEL FOR CROSS COUNTRY SKIS

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Introduction

Traditional laboratory measurements of cross-country (CC) skis often include camber height measurements where a ski is placed upon a flat rigid plate and loaded with various weights. Such measurements are often time consuming and they provide just results from the chosen loads. The goal of this study was (1) to develop a new test bench device which can acquire essential ski characteristic parameters in a fast laboratory test, further (2) to calculate the flexural stiffness and (3) based on these results, create a finite element (FE) model for a CC ski. This model can be used for a number of different simulations, like contact pressure distribution modelling.

Methods

The development of one new test bench resulted in the production of the "Ski Analyzer" device, comprising a rigid, plane steel foundation where the ski is supported vertically. An optical photocell travels along the ski and detects the camber height, with an accuracy of 0.25 µm in the vertical direction. The applied load is computer controlled and monitored by an HBM load cell, and the device is able to measure static and partly dynamic loads.

•The ski profile is measured with and without an applied load in a three point bending setup (Figure 1). The curvature difference between the two shapes and the bending moment distribution is used to calculate the bending stiffness of the ski according to:

$$EI = \frac{M}{k} \qquad k \approx \frac{\partial^2 u}{\partial x^2}$$

•Both the deflected shapes and the curvature are quite heavily smoothed to remove irregularities.

•A FE model of the ski is constructed using beam elements. Each element has its unique properties based on the bending test. The ski is placed on an elastic foundation of 4-noded brick elements (Figure 4). The beam elements are 1 mm long, while the elastic foundation has 10 mm element lengths.

•A vertical load is applied to a single node to simulate the half weight, full weight (or any selected load). The simulation is run with updated geometry (large deformation) and node to surface contact formulation.

•The deflected shape and contact pressure is extracted.

Results

A half-automated test bench was successfully built and tested (Figure 1), and camber profile data from unloaded and loaded data skis was recorded (Figure 2).

The calculated bending stiffness depends strongly on the quality of the curvature measurements and the selected model. An example bending stiffness profile is seen in Figure 3.

Pressure profiles and FE simulations were achieved (Figure 5 and 6) showing a distribution reasonably similar to the measurements with force sensitive pressure mats, like Tekscan^{TM}.

Discussion and Further Work

Double derivation is very sensitive to inaccuracies in the measured deflections. The measurements are in need of significant smoothing to achieve usable curvature levels for the bending stiffness calculation.

The bending stiffness formula is based on linear beam theory with small displacements. The deflection of the ski is probably outside the limits of this theory, and finite deformation theory should be adopted.

The neutral bending axis and the contact axis is the same in the model. The measurements should ideally take in to account the geometrical thickness (vertical offset) of the ski to differentiate bending axis and contact surface.

Figure 1: Developed ski test bench. Loaded ski during three point bending test.

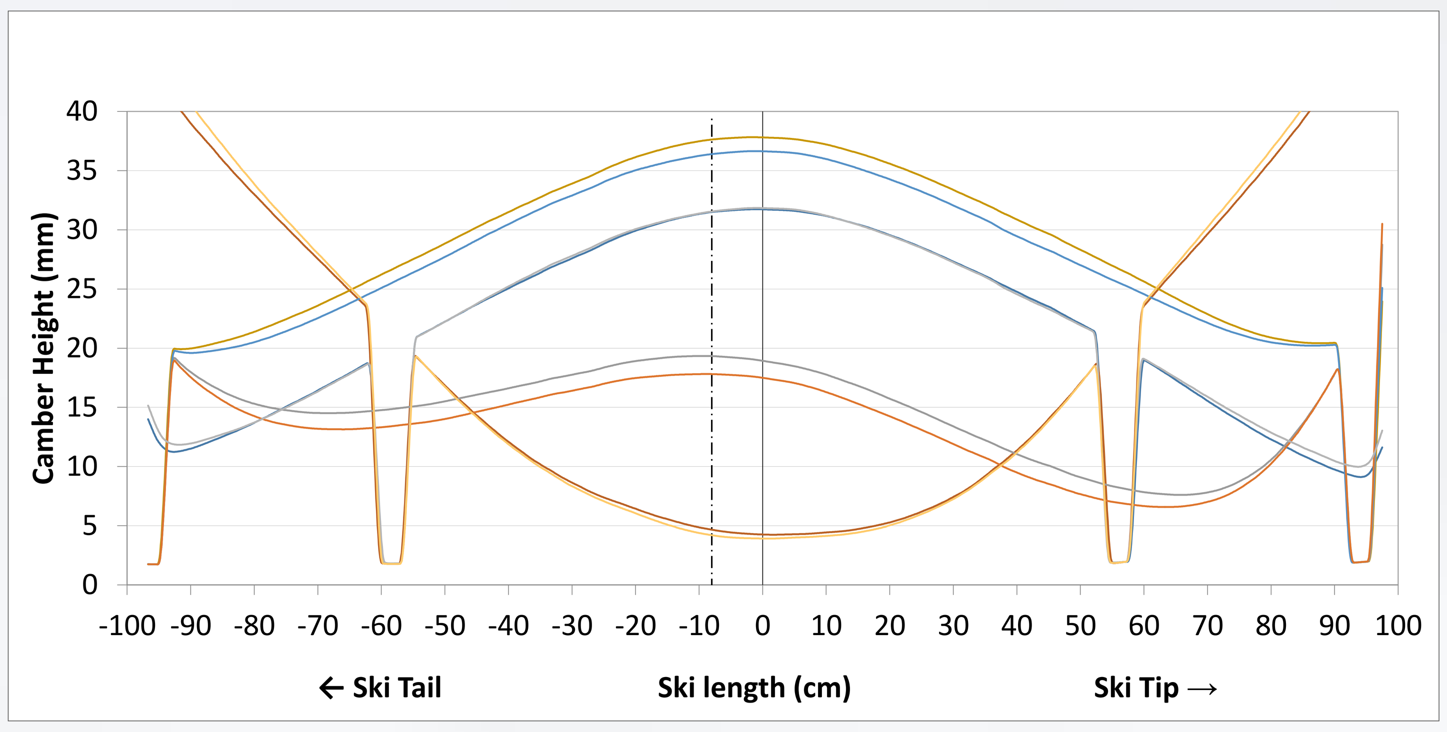

Figure 2: Camber profiles for two unloaded and loaded skis placed on foundations with various spacing.

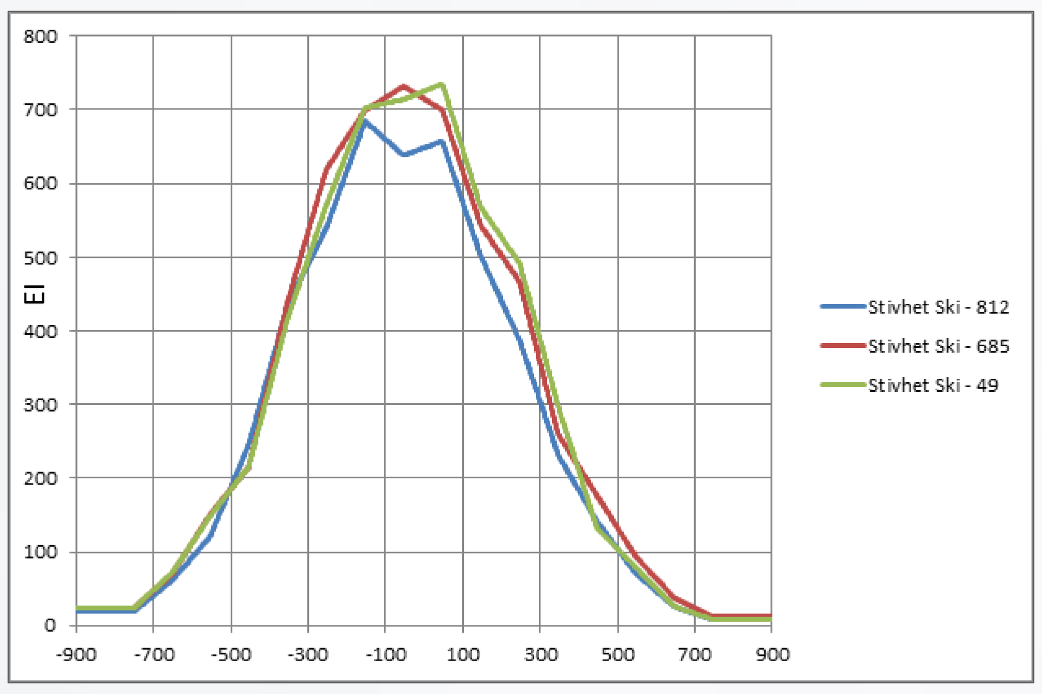

Figure 3: Calculated bending stiffness (EI) based on the applied bending moment and the differential curvature.

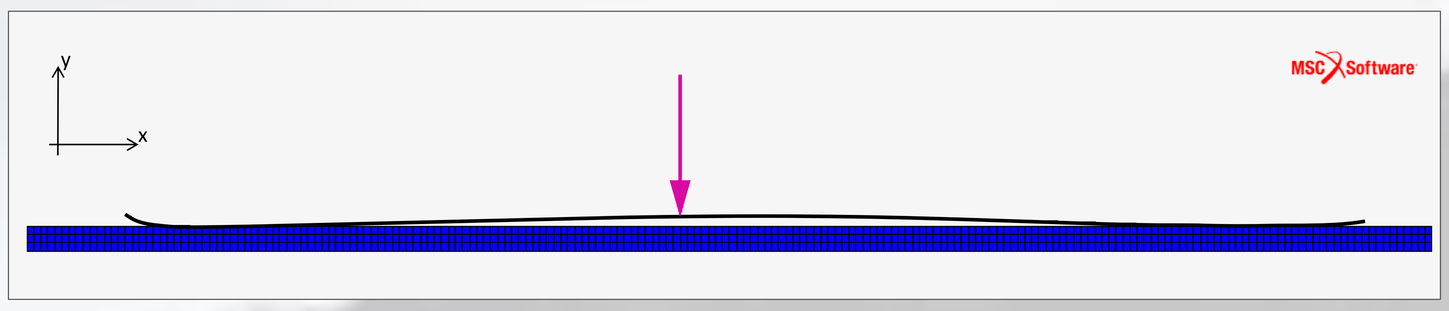

Figure 4: FE beam model of XC ski on elastic foundation.

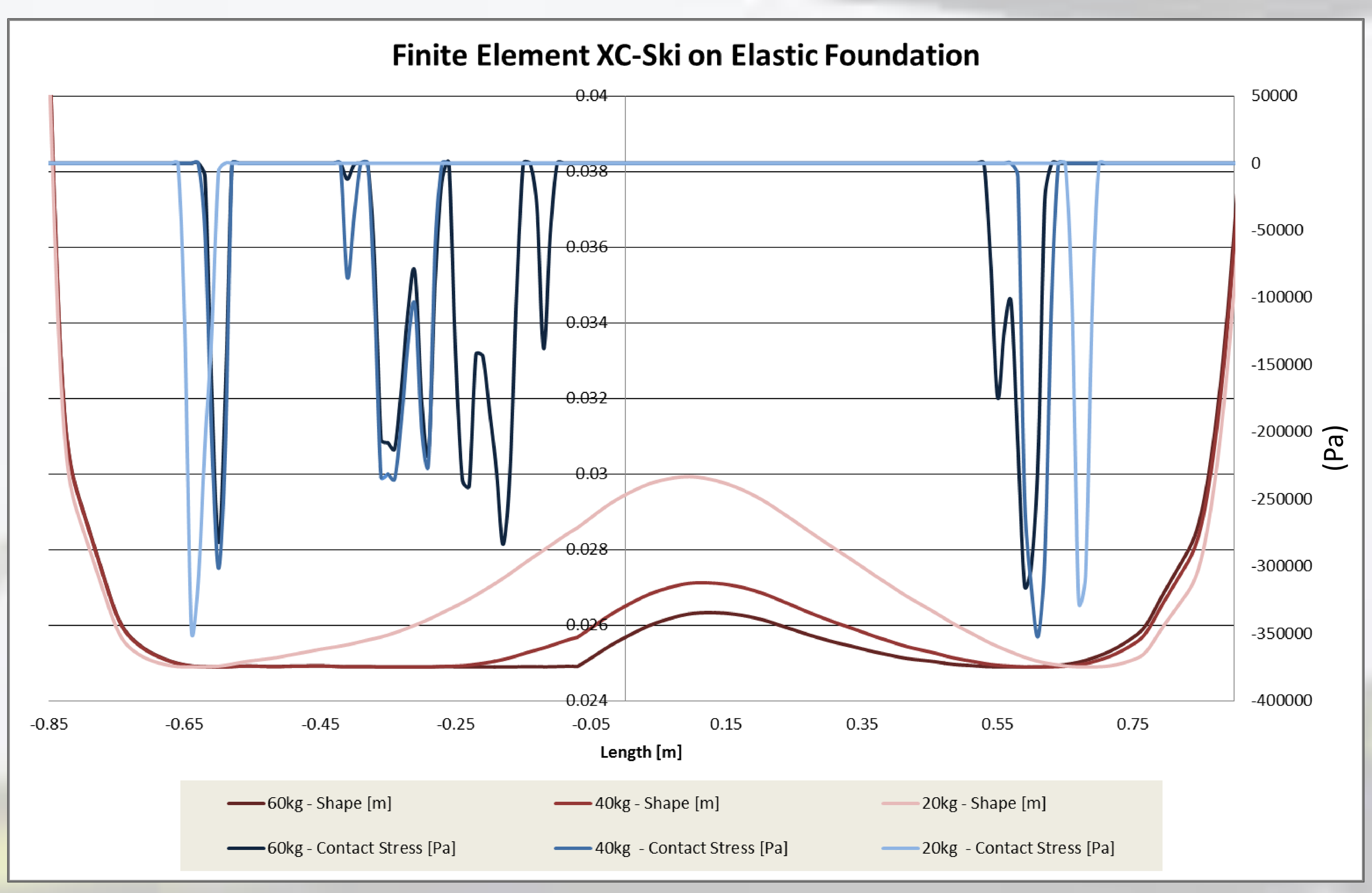

Figure 5: Deflected shape and contact pressure for 200 N, 400 N and 600 N; load application at -7 cm.

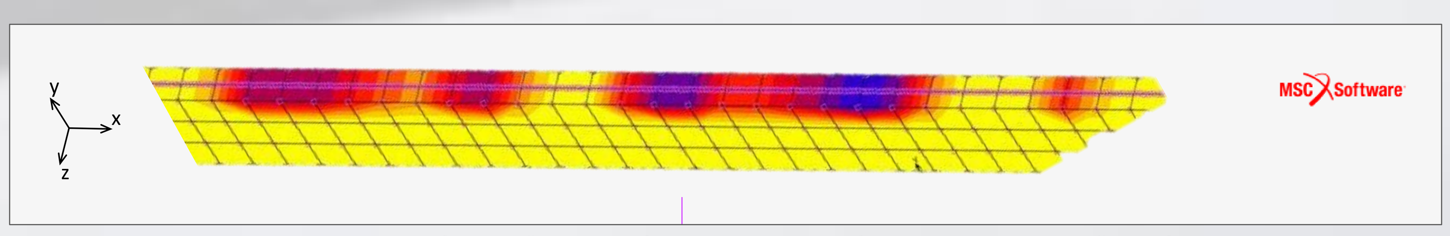

Figure 6: Example for the visualization of the contact pressure distribution.