Tangent Curve Mathematical Model for Illustration of Deformation Curve of Rapeseeds

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Abstract: Detailed knowledge of mechanical behaviour of oilseeds such as rapeseeds under compression loading is ideal for development of more cost-effective technology for production of oil. The tangent curve mathematical model based on MathCAD software was used to describe the deformation characteristic curves of rapeseeds of moisture content 11.07 (% w. b.) at different pressing force and speed. Compressive force ranged between 100 and 200 kN whiles the speed varied from 10, 30 to 60 mm·min^{-1}. Pressing vessel diameter 100 mm was used to measure the bulk rapeseeds at pressing height 80 mm where the dependency between force and deformation characteristics curves was described in relation to speed and pressing heights between 30 mm and 80 mm at constant compressive force 100 kN. Based on the statistical analysis of the experimental data, the tangent curve model suitably described the force-deformation characteristic curves of bulk rapeseeds. The fitted model was dependent on force and deformation coefficients of mechanical behaviour of the tangent curve mathematical model.

Tangent curve function

Experimentally, the relationship between force and deformation of bulk oilseed such as rapeseeds can be described by function (Eq.1).

$$F(x) = A \cdot \left[\tan(B \cdot x)\right]^n \tag{1}$$

Where A is the force coefficient of the mechanical behaviour (N), B is the deformation coefficient of the mechanical behaviour (mm^{-1}) and n is the exponent of fitted function (-). In terms of the relationship between force and deformation characteristic curves in relation to different vessel diameter and pressing seed height, the tangent curve model (Eq. 1) requires modification based on the experimental boundary conditions that: when the compressive force increases to infinity the deformation reaches the maximum limit, zero compressive force means zero deformation and the integral of Eq. 1 represents the energy [1, 2, 3, 4]. Theoretically, when the force is approaching infinity (Eq. 1) then the limit deformation, δ (mm) (Eq. 2) which is dependent on the pressing seed height H (mm), can be expressed by deformation coefficient of mechanical behaviour [5, 6, 7].

$$\delta = \lim_{F(x)\to\infty} x = \frac{\pi}{2 \cdot B} \tag{2}$$

The relationship between compression coefficient, G (N) and deformation coefficient of mechanical behaviour, B (mm^{-1}) can be expressed as shown in Eq. 3 [2, 6, 7].

$$G = B \cdot H \tag{3}$$

Where H is the bulk seed height (mm) which affects the deformation coefficient of mechanical behaviour, B (mm^{-1}) [3, 4, 6, 7]. From the experimental results the tangent curve equation (Eq.1) can be mathematically modified (Eq. 4) based on the assumption that the porosity of bulk rapeseeds as well as the compressive stress inside the pressing vessel diameter containing the bulk rapeseeds remain constant. Therefore, the tangent curve model as described in (Eq. 4) indicates that the linear experimental data, that is, the dependency between the force and deformation curve can be fitted based on a single vessel diameter and pressing seed height. Equation (Eq. 4) is generated using the Levenberg-Marquardt algorithm [8] which provides numerical solutions to the problem of minimizing deviations in non-linear functions in relation to function parameters.

$$F(x, D, H) = C \cdot D^2 \cdot \left[\mathrm{ta} \left(G \cdot \frac{x}{H} \right) \right]^1 \tag{4}$$

Where C is the stress coefficient of mechanical behaviour ($N \cdot mm^{-2}$), D is the vessel diameter (mm), G is the compression coefficient (-) and H is the bulk seed height (mm). Using Eq. 4, the dependency between force and deformation characteristic curves in relation to vessel diameter and bulk seed height can be described theoretically.

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