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An Experimental Investigation into the Effect of Interface Friction on Bagasse Compaction between Grooved Steel Platens

Thesis submitted by

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BE (Mech.), Universidad Nacional de Trujillo, Perú

in May 2005

for the degree of Master of Engineering Science
in the School of Engineering (Mechanical Engineering)
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04 May, 2005

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Abstract

Modern factory crushing units process prepared sugar cane through sets of counter-rotating grooved rolls. A typical unit in Australia would process in excess of 600 tonnes of material per hour. Throughput and extraction performance is strongly dependent on material behaviour, the geometry and surface condition at the roll bagasse interface. Factories use welding procedures to arc roughen the tips of grooves in an effort to increase friction. Although industry procedures appear ad hoc it is clear that some level of roughness is crucial to performance. A similar statement can be made in respect to roll grooving given the wide variation in adopted practice. This project involved an experimental investigation into the effects of interface friction on bagasse compaction between grooved steel platens. An apparatus was developed for use in the SOE MTS testing facility. A factorial design experiment involving 105 tests randomised in blocks was conducted to discover the interaction between friction (the dependent variable) and groove angle, compaction, and roughness (independent variables). The results indicate that roughness, groove angle and compaction significantly affect friction coefficient. While roughness and groove angle contribute to increase friction coefficient, compaction causes a marked decrease. Observations on samples of bagasse exhibiting pure shear suggest that the frictional forces generated at the interface cannot be sustained by the shear strength of bagasse. Comparisons between friction coefficient and shear coefficient showed that the friction coefficient values approach the shear coefficient values under particular geometric and loading conditions. An empirical model was developed to explore variables. The effect of groove angle, degree of roughness (location and size of roughened asperity) and sample compaction on friction has been ascertained.

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Symbols

A	Cross-sectional area
A_a	Apparent area
A_t	true area
C	Variable compaction
C_c	Compression ratio
C_f	Filling ratio
D	Roller diameter
D_m	Mean Diameter
E	Elastic modules
F	Force
F_c	Compressive force, yield function in cap region
F_n	Normal force
FR	filling ratio
F_s	Yield function in Drucker-Prager shear region
F_t	Tangential force, yield function in transition region
G	Variable groove angle
G_b	Bagasse shear modules
H	Height of bagasse penetration
K	Bulk modulus
K_o	Plasticity constant
L	Length
M	Mass
N	Reacting normal force
N_s	Number of responses
N_x,N_y	Reacting normal force components
R	Variable roughness, experimental parameter
R_a	Average roughness
R_q	Root mean square
R_x,R_y	Reacting forces components

T	Time
V_f	Volume of fibre
V_j	Volume of juice
V_o	Initial no gas volume of cane
W	Gravitational force
c	Cohesion coefficient
c_w	Cohesion coefficient on the wall
d	material cohesion
$d_{\tau'}$	Shear stress differential
d_{γ}	Shear strain differential
$d_{\sigma'}$	Normal stress differential
d_{ε_v}	Volumetric strain differential
$d\tau'$	Differential of shear strain
$d\sigma'$	Differential of normal stress
$\dot{e}$	Shear strain of liquid film
f	Fibre fraction
f_a	Friction force due to adhesion
f_f	Frictional force
g	Acceleration due to gravity
h	Height of asperity
h_d	Hardness
h_m	Height of bagasse blanket
i	initial condition
k	Number of levels
m_f	Final mass of prepared cane or bagasse
m_i	Initial mass of prepared cane or bagasse
p	Hydrostatic pressure
q	Von Mises equivalent stress
s_t	Tangential speed
υ	Peripheral speed
w	Work opening
α	Angle of nip, cap transition parameter

α_a Asperity angle

α_i Initial contact angle

$\hat{a}$ Treatment number

β Neutral plane angle, internal friction coefficient

λ Specific density

γ Compaction

γ_{bss} Bagasse shear strain

γ_{zx} Engineer's strain

$\dot{\gamma}_f$ Liquid film shear strain

δ Displacement differential

ε_e Elastic strain

ε_p Plastic strain

ε_v Volumetric strain

$\varepsilon_{xz}, \varepsilon_{zx}$ Pure shear strain

ζ Asperity tip radius

η Angle of an inclined wall

θ Groove angle

θ_s Shear plane angle

μ Friction coefficient

μ_{pp} Porous pressure

μ_s Static friction

μ_w Friction coefficient on the wall

v Specific volume

π Dimensional product

ρ_c Density of cane

ρ_f Density of fibre

ρ_j Density of juice

ρ_o No gas density of prepared cane

σ Total normal stress

σ' Normal effective stress

σ_Y Yield stress

$\sigma_x, \sigma_y, \sigma_z$ Normal stress components

$\sigma_1, \sigma_2, \sigma_3$ Normal stress components

σ_{sd} Standard deviation of asperities heights

τ, τ' Shear stress

τ_1, τ_2, τ_3 Shear stress components

τ_w Shear stress on the wall

τ_{xy}, τ_{yx} Internal shear stress

ϕ Angle of friction

ϕ_w Angle of wall

ϕ' Effective angle of internal friction

ψ Plasticity index.