A Study of Air Flow Effects on the Cushioning Characteristics of Multi Layered Pre-Compressed Fibreboard

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Student Declaration

"I, Mervyn W Minett, declare that the PHD thesis entitled A Study of Air Flow Effects on the Cushioning Characteristics of Multi Layered Pre-Compressed Fibreboard is no more than 100,000 words in length, exclusive of tables, figures, appendices, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work".

Signature Date 8 - 12 - 2005

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Abstract

Multi-layered corrugated fibreboard, has in recent years been gaining attention as a replacement for polymeric materials for protective packaging for environmental reasons. The properties of pre-compressed multi-layered corrugated fibreboard make it a sustainable replacement for poly-foam and polystyrene. Pre-compressed multi-layered fibreboard cushions have most of the structural resistance and damping removed, and the properties of air-flow through the flutes becomes a more predominant, they behave more like a soft spring.

Artificially restricting the exiting airflow or prudently choosing the direction of flutes in the case of rectangular cushions, allows for the differing design situations that may be required. A mathematical model is developed, to describe the pre-compressing process. Mathematical models and software are developed, based on the airflow characteristics, that allow for the prediction of peak acceleration for differing end conditions or sizes providing the friction component can be estimated using iterative methods.

The models were verified by a static compression test for the pre-compression and by dropping a mass, or platen and recording the resistive acceleration, or dynamic behaviour, over a time range.

There exists an acceleration component prior to platen contact, which is also modelled and should be considered in the interpretation of test results. The study has presented three models to allow for the prediction of the behaviour of multi-layered corrugated fibreboard for the use as protective cushions. The main thrust has been the behaviour of the airflow during and prior to impact whilst testing. The models developed will assist in the design of protective packaging and produce predictive tools for the use in the packaging industry.

List of Abbreviations

Static and Pre-Compression

k = cushion stiffness (k/m)
δ = deflection (m)
F = instantaneous force (N)
F_m = mean force (N)
F_a = alternating force (N)
SF = slope factor
N = the number of cushion layers
y = displacement record (m)
ε = strain - ratio of deflection to unloaded thickness
ε_0 = maximum strain
b = multiplier in equation (3.2)

Air-Flow Models

a = platen total acceleration (m/sec^2)
F = forcing function (N)
IF = impact factor
h = platen-cushion air space (m)
$\dot{h}$ = platen velocity (m/sec)
$\ddot{h}$ = platen acceleration (m/sec^2)
k = cushion static stiffness (N/m)
m = platen mass (kg)
D = cushion width (m)
L = the flute length (m)
h_t = cushion height at time t (m)
A_t = exit area of cushion cross section at time t (m^2)
F_f = frictional resisting force (N)
P_0 = average air pressure (kPa)
P_x = air pressure at point x (k)Pa
ρ = air density (kg/m^3)

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