Science Summary

Introduction

The Chalmers DST (dynamic stiffness tester) measures the MD Torsional Siffness of corrugated board by applying a twisting motion to a sample of the board attached to an inertial mass. This exercises the flutes as shown in Figure 1. The natural frequency of this twisting motion is measured and converted into a parameter directly proportional to the torsional stiffness (bpi). This seemingly simple technique has proven to be very reliable, repeatable, sensitive to board manufacturing variables and board crush during subsequent processing.

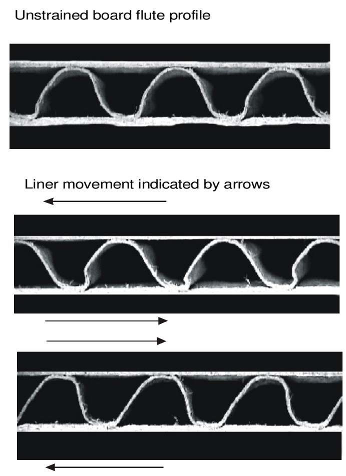

Figure1: Flute movement during MD To5rsional Stiffness testing

Most importantly it has been found that boxes made from board crushed during manufacture fail prematurely when subjected to compression loads in simulated service environments (cyclic humidity). The Chalmers DST is very sensitive to the quality of corrugated board and has proved to be the best predictor of box performance compared to standard board and box tests.

Cyclic Humidity Compression Creep Performance

The Forest Research Institute of New Zealand in conjunction with Visy Board Australia performed a series of loaded box crush tests in a cyclic humidity environment alternating from 50% to 90% RH over a 12 hour period.

Visy manufactured the board, some of which was crushed between rollers to simulate typical conditions in a corrugating plant. Several levels of crush were applied then the box blanks were cut using an XY cutting table.

Visy performed Chalmers DST and standard board tests along with box crush (BCT) before shipment of the flat blanks to NZ. In NZ the tests were repeated and the cyclic humidity tests performed. Figure 2 shows typical results for one of the four sets of samples.

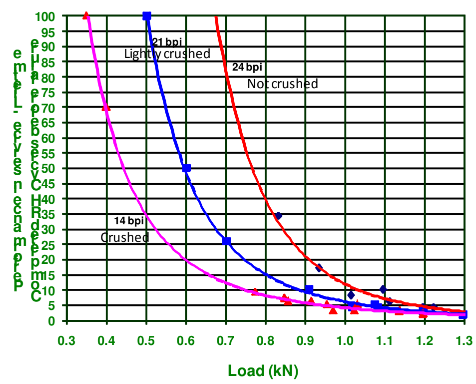

Figure 2: Cyclic humidity performance of 3 sets of boxes crushed to different levels as measured on the Chalmers DST

The uncrushed board with a DST result of 24 bpi shows a much larger load carrying capability under cyclic humidity conditions than a slightly crushed board at 21 bpi and a more severely crushed board at 14 bpi.

If a box had to withstand say 40 cycles during its service an uncrushed box could take a load of 0.8 kN (80kg), the 21 bpi box 0.63 kN and the 14 bpi box only 0.48 kN. The 24 bpi box can take 67% more load than the 14 bpi one, yet all the board materials and corrugating conditions were the same, the only difference being the amount of crush received. A bpi of 14 is a large degree of crush but not uncommon on printed boxes coming from an unregulated (no Chalmers DST) plant. The BCT results on the 3 sets of boxes were 4.7 kN, 4.5 kN and 4.3 kN for the 24, 21 and 14 bpi boxes respectively, all with Standard Deviations of close to 0.5 kN (n=20). So BCT is unlikely to predict real service environment performance, which is understandable because BCT is a 'short time' test with a minimal creep component. Boxes very rarely fail under BCT conditions and need safety factors to estimate real conditions.

Caliper and Edge Crush (ECT) vs Chalmers DST

How does caliper and ECT compare with DST? In a simple experiment 30 samples of good quality board were cut from a large sheet of C flute Kraft liner and SC medium board.
The samples of board were then crushed using a machinist's vice (Figure 3) to different extents from zero crush to about 25% crush, which was about 1mm on the 4mm thick board.

A digital micrometer was used to measure the gap between the jaws of the vice for the actual crush figure. After about 3 hours each sample of crushed board was checked for caliper using a Tappi Standard device and the Chalmers DST used to measure the torsional stiffness. The 25 mm x 145 mm DST sample was then trimmed to 100 mm long and a Standard Fefco ECT test done. Figure 3 shows the vice used for sample crushing, Figure 4 the percent value retained after 3 hours for caliper and DST. Figure 5 shows the Fefco ECT versus percent crush.

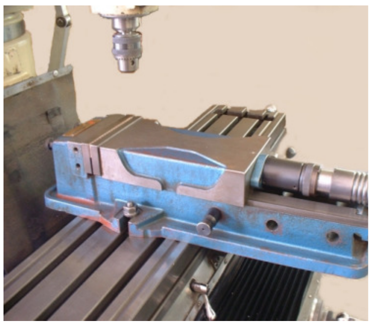

Figure 3: Board sample crush device

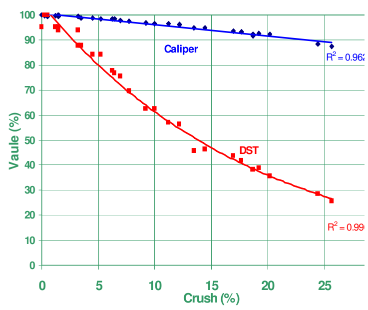

Figure 4: Percent Caliper and DST loss versus percent crush

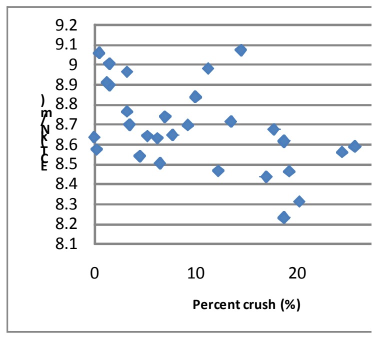

Figure 5: ECT (Fefco) vs percent crush

From Figure 4 you can see that at 25% crush the caliper loss has only been about 10% while the DST has lost 70% of its no crush value. In Figure 5, the ECT shows very little correlation to degree of crush.

Crush in boxes

How much crush occurs in real life? A lot! Figure 6 shows bpi figures for different parts of a print on a wine box. The unprinted part of the box has a bpi of 15.5 while a heavily printed part is down to 3.3. This may not matter on this box because the bottles will take the load but the results are typical of the industry.

A large amount of crush results from the feed rolls into and out of the press. Remember, if you can't measure it, you can't control it. Of course board crush is only part of the problem, you have to make good board on the corrugator to begin with…and that is another story.

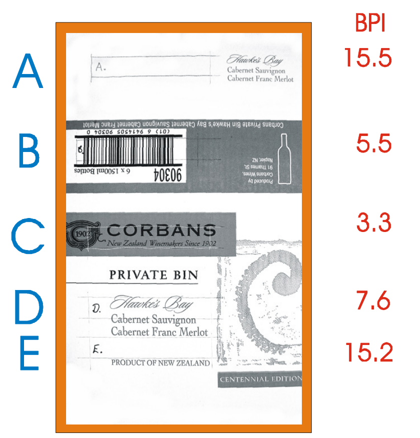

Figure 6: Chalmers DST results on different printed areas of a wine box.

References:
Chalmers I.R: A new method for determining the shear stiffness of corrugated board. *Appita Journal Vol59:5 Sept 2006 P 357-361*
Chalmers I.R:The use of MD shear stiffness by the torsional stiffness technique to predict corrugated board properties and box performance. *Appita Journal Vol 60:5 Sept 2007 P 357-361*