Manufacturing — Engineering

PHOTOGRAPHIC ANALYSIS OF THE ACTION OF A CANE SHREDDER

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ABSTRACT

High speed photographic analysis of the action of a pilot plant shredder has been carried out to obtain a better understanding of the shredding mechanism and the behaviour of both hammer and cane during the shredding process.

At shredding rates equivalent to 300 t/h for a 2.130 mm wide unit, hammer swingback was not observed at any stage either before the grid or across the grid for either 6.4 kg or 15 kg hammers.

The comminution of the cane was observed in two distinct phases:

(i) impact phase prior to the grid bar system;
(ii) grid bar phase in which hammer impact action was again a major factor.

Measured velocities of the cane particles on impact were about 7% of the hammer tip speed above the grid bar and about 30% of the tip speed when moving across the grid.

The high speed photographic techniques were an effective guide to the development of specific shredder configuration which can subsequently be evaluated in practice.

INTRODUCTION

The performance of a milling train depends significantly on the preparation of the cane presented to it. Good preparation depends on efficient shredding. To obtain a better understanding of the shredding mechanism and the behaviour of both hammers and cane during the shredding process a series of high speed photographic tests were carried out using a pilot plant shredder, 460 mm wide, and capable of swept diameters from 1.320 mm to 1.780 mm.

DESCRIPTION OF TESTS

The tests were carried out with the co-operation of the Photographic Department of the University of Queensland who provided and operated a 16 mm Hycam high speed motion camera. Film speed was approximately 5 000 frame/sec. Each run consumed 120 metres of film and represented approximately 1.5 seconds of shredding. At the normal projection rate of 16 frame/sec this represents an effective "slowdown" for viewing by a factor of approximately 300.

Photographs were taken through perspex viewing windows cut in the side of the pilot plant shredder. The window locations are shown in Fig. 1. The camera setup is shown in Fig. 2. In all, 15 films were taken. Particular aspects which were looked at with the high speed film techniques were:

a) Light and heavy hammers, 6.4 kg and 15 kg (the details of the hammers are shown in Fig. 3. Two different rotors were used. For the 15 kg hammers there were 5 hammers across the 460 mm width in
Figure 1. Window location for photographable core.

Figure 2. Scope of Hydram showing viewings windows and lifters.
each row. Swept diameter was 1.450 mm. For the 6.4 kg hammers there were 10 hammers in each row. Swept diameter was 1.320 mm. In both cases 8 rows of hammers were used spaced at 45° around the circumference;

b) Deep pocketed grid and shallow pocketed grid;
c) Grid clearance settings of zero and 10 mm;
d) Protrusion of grid from front plate;
e) Feeding with knifed cane, chopped cane, direct, and prepared cane that had already been through the shredder once.

All tests were at 960 rpm. The rate during tests was nominally 65 t/h (equivalent to 300 t/h in a 2130 mm wide machine).

Analysis of the results was carried out using the Film Motion Analyser facilities at the University of Queensland Photographic Department to measure the relative velocity of hammers and cane particles and the angle of swingback of the hammers. Radial lines were marked on the shredder casing and on the hammers through their centres of gravity to enable the swingback to be measured.

RESULTS

Photographs were taken in 2 locations: above the grid and approximately halfway along the 90° wrap grid section.

Above the grid — location 1

a) Heavy hammers

For the 15 kg hammers with chopped cane, it was quite evident that a considerable amount of work had already been done by the time the cane reached this section. The action of shredding here was basically one
of the hammers exploding the cane particles on impact. Most of the particles which had been smashed from sticks on entry were thrown to the periphery and moved down the front plate. The speed of particles moving down the front plate was on the average 75% of the tip speed of the hammers.

It is interesting to consider the thickness of a blanket of cane if it were moving at the tip speed of the hammer. At 300 t/h for a 2 130 mm wide shredder with swept diameter of 1 450 mm, the thickness would be only 1,5 mm. On the front plate of the shredder the thickness of the blanket moving down to the grid entry was seen in the photographs to be approximately 25 mm thick. The blanket was sliced off by the hammers as it reached the grid section.

It is also interesting to consider the freefall velocity of material into the shredder. For the fall of 2 metres the velocity at shredder entry would be 6,2 m/s. Tip speed of the 1 450 mm machine is 72,5 m/s, i.e. freefall velocity is approximately 8,5% of tip velocity. Average speeds down the front plate therefore are marginally slower than freefall velocity.

By changing the protrusion of the grid relative to the front plate from 10 mm to 25 mm, the only difference that could be observed was that larger particles tended to move down the wall because they could more readily escape the arc of swing of the hammer. No different action on the grid protrusion was observed.

When the material was knifed before presentation to the shredder the blanket on the front plate seemed to be more stable. It appeared to have been formed further up than with the chopped cane. Again the average speed of the material down the front plate was of the order of 7% of tip speed. There was less pronounced evidence of “explosions” as cane met hammers than with the chopped cane feed.

For the recycle condition when previously shredded cane was fed to the machine a very pronounced blanket was formed on the front plate. There was no evidence of any material within the swept diameter of the hammers. The material almost “flowed” down the plate until it met the grid. The hammers could do no work on the cane until the blanket met the grid. Mean speed of the material down the front plate was 12% of tip speed indicating a slightly more “fluid” flow than with chopped or knifed cane.

b) Light hammers

For the 6,4 kg hammers and chopped cane being fed to the machine the thickness of blanket formed on the front plate was significantly thicker than with the heavy hammers. The movement down the front plate of the blanket was slower, averaging 3% of tip speed. When recycled material was fed to the shredder a wedge formed on top of the grid. The hammers as they came around “plucked” material from the tip of the wedge and carried it through to the grid bar section at a speed of approximately 17% of tip speed. The wedge formed in this test appeared quite stable. It is difficult to explain why this wedge should have been formed with this type of hammer and not the other.
On grid — location 2

a) Heavy hammers

For the shallow grid with grid bar protrusions of 25 mm from a backing plate and spacing between grid bars of 150 mm, and zero setting (i.e. hammers running nominally tip to tip with the grid) a wave motion developed, material being forced down to the backing plate and returning up into the path of the hammer. This wave action was less pronounced when the grid setting was increased to 10 mm. When the deep grid was used however (150 mm deep, 200 mm spacing) the wave action was most pronounced. In all cases the velocity of particles relative to tip speed was approximately 30%.

When the shredder was being fed with recycled material using the shallow grid bar arrangement the waveform was still developed, the material however had an average speed relative to the tip speed of 45%, a thinner blanket, and the motion of the wave developed appeared more “fluid”.

b) Light hammers

For the deeper grid the 6.4 kg hammers developed a waveform pattern, although this was not as pronounced as the one developed with the 15 kg hammers. The negative rake of the front edge tended to plow through the material, helping to destroy the wave motion. On recycled material the light hammers produced a condition very much like fluid flow.

DISCUSSION

a) Hammer design

It was most significant that for both the 6.4 kg and 15 kg hammers no swingback of the hammers was observed at any stage either before the grid bar or as the hammer moved over the grid bar. There can therefore be no justification in increasing the weight of the hammer above 15 kg. Indeed justification can be seen for reducing the weight of the 15 kg hammer to reduce stresses (provided of course coverage of the width of the shredder at the tip is not reduced). The pointed front edge of the 6.4 kg hammer appears to have a detrimental effect and should not be used.

b) The mechanism of shredding

The shredding process can be considered as consisting of two distinct phases:

i) Impact phase

This occurs before the gridbar system. Observation of the photographs suggests that with the feed of chopped cane the explosions that occur when billets meet the hammers reduce the material by the time it reaches the grid bar section to a condition similar to that obtained with knifed cane feed by the time the grid bar is reached. A considerable amount of work is done on the cane in this phase. With a feed of knifed cane (and this effect is even more pronounced with recycled shredded cane) the hammers, or windage caused by the hammers, force the incoming material to the front plate where it falls at approximately free fall velocity until it reaches the gridbar section.
FIGURE 4. Grid bar profile developed from photographic analysis.

FIGURE 5. High speed photographs of shredder hammer—window location 1.
ii) **Grid bar phase**

The mechanism of shredding in the grid section is not one of holding the cane in a pocket and ripping material from it; rather it is one of impact. The work that can be done on impact is strongly dependent on the relative velocity of particles on impact. Improvements in shredding in the gridbar section can then be achieved by either of two methods:

a) Increasing length of gridbar section to obtain more impacts per revolution.

b) Increasing the efficiency of each impact by developing a grid bar profile to obtain maximum relative velocity of cane and hammer. One such arrangement is shown in Fig. 4.

**CONCLUSIONS**

The evaluation of shredder performance can only be done by extensive tests on different configurations using a range of cane varieties and measuring preparation against power relationships.

High speed photographic techniques, however, enable a greater appreciation of the actual shredding mechanism to be obtained. This visual examination of the action proves an effective guide to the development of specific shredder configuration which can subsequently be evaluated in practice.

**ANALISIS FOTOGRAFICO DE UNA DESFIBRADORA DE CAÑA**

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**RESUMEN**

Se ha efectuado un análisis fotográfico de alta velocidad de una planta piloto desfibradora para conocer mejor el mecanismo de desfibraación y el comportamiento tanto de los martillos como de la caña durante el proceso de desfibraación.

A ratas de desfibramiento equivalentes a 300 ton/hora para una unidad de 2 130 mm. de ancho la oscilación de los martillos no había sido observada en ninguna etapa ni antes de la rejilla ni a través de la rejilla con martillos de 6,4' — 15 Kgr.

La desintegración de la caña fue observada en dos fases distintas:

(i) Durante la fase de impacto antes del sistema de rejilla de barras.
(ii) Durante su paso por la rejilla de barras en el cual la acción de los martillos es el factor predominante.

Las velocidades que adquieren las partículas de caña debidas al impacto fueron de alrededor del 7% de la velocidad de las puntas del martillo, cuando se encuentra encima de la rejilla de barras y alrededor del 30% de la velocidad de las puntas cuando se mueven a través de la rejilla.

La técnica fotográfica de alta velocidad fue una guía efectiva para el desarrollo de la configuración específica de las desfibradoras las cuales pueden ser evaluadas posteriormente en la práctica.