Horizontal Sugar Mills

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From pounding stone to roller mill: the Sugar Story.

Most of us are more familiar with corn mills than with cane mills. The development of each through the centuries — indeed through millennia — provides some interesting comparisons and contrasts.

The evolution of the pestle and mortar on the one hand, and the rotary quern on the other, from their common ancestor the smooth piece of rock and the dished rock depression, took about four millennia. Although slow their development was 'morphologically' continuous. The saddle quern and the swinging rubber stone were stages on the way to the fully rotative quern runner. The quern then changed little if at all during the next two millennia, apart from its size, its dressing, its power source and its gap-adjustment method, right up until the hey-day of stone milling before the advent of roller milling in the 1890's. The replacement of a pair of face runner grindstones by a series of edge-runner rollers was the only really radical change in the whole history of grain reduction. The pestle and mortar, the rubbing stone and the rotary quern are still used in the rural areas of the Developing Countries.

In Eastern Asia the pestle and mortar was developed into the radial tilt-hammer, initially foot powered, and later powered by water in the very simple but ingenious oscillating water-lever (or 'one spoke water wheel'). Later still, the vertical water-wheel was used for driving tilt-hammers and vertical stamps — the latter being no more than a robust version of the pestle and mortar. Interestingly these two devices were used not for grain reduction but for grain (rice) polishing; the effect of percussion on rice grains in a mortar is not to break them but to displace them laterally so that continuous friction between grains removes by abrasion the hard coloured outer skin and thus 'polishes' the rice.

In contrast to this, the progress of sugarcane crushing from use of the pestle and mortar (in the eighth century) to the modern horizontal roller mill (in the eighteenth century) was not only more rapid but much more discontinuous and marked by a greater variety of techniques on the way. In India the reciprocating hand-operated pestle became an animal-powered rubbing mill by securing the upper end of an inclined pestle to a vertical post mounted on a long pole so arranged as to turn radially around the base of a conical mortar. A draught animal was attached to the outer end of this traction arm. The rubbing pestle could be regarded as an ancestor of the fully rotative edge-runner turning around a fixed 'bed' (with, as an intermediate stage — morphologically speaking — the 'bi-axial' rotative inclined pestle found in snuff mills, which turns not only around the vertical axis of the mortar but also around its own axis). The rubbing pestle mill certainly was, and the true edge-runner mill probably was, used for sugarcane crushing in Asia and, powered by a horizontal waterwheel, in the Mediterranean area .

Rotating rolls mounted horizontally were used in India in the early twelfth century for separating cotton bolls from cotton-plant stalks. A stouter version of the same device was used for crushing sugarcane in India in the sixteenth century. Two hundred years later, sugar mills began to use a cluster of three horizontal rolls but the development of the latter from the former was punctuated by a period during which vertical rather than horizontal rolls were

preferred. This change in roll-alignment reflected in part the practical problem of how to drive two equal sized rolls at the same speed so as to crush the cane without causing it to disintegrate too much by tearing. Constant speed drive for two rolls would seem not to be a problem at all, but account needs to be taken of the power source.

The earliest horizontal sugar mills were man-powered — as was the two-roll Indian cotton gin — and consisted in essence of two directly driven horizontal windlasses mounted one immediately above the other in the same frame (see figure 1). Each roll had its own operator and constant speed of the rolls was not a problem since the presence of one or more pieces of sugarcane between the rolls would make it very difficult if not impossible to turn the rolls manually at all unless their two speeds were the same. Waterpower, using a vertical waterwheel, appears to have been applied to driving the two roll horizontal sugar mill in Hispaniola (modern Haiti/Dominican Republic) in the early sixteenth century.

However, when animal power was applied to cane-crushing in about the middle of the sixteenth century in India, there was a need for right angle gearing to convert the horizontal motion of the animal into the vertical rotation of the rolls. Inward-facing trundle gears were fitted (one at one end of one roll and one at the opposite end of the other roll), and a long-toothed downward facing trundle gear was mounted above the centre of the roll assembly so as to engage with the teeth of both the two roll-end trundle wheels. This large horizontal gear was turned by a buffalo tethered to the end of a traction arm attached to the upper end of a short vertical shaft (see figure 2).

Such an arrangement must have put a considerable strain on the vertical teeth when driving the lower roll. A more sophisticated arrangement, presumably a later one, found in Egypt used shorter teeth on the horizontal drive wheel together with a larger diameter trundle wheel on the lower of the two rolls. This posed the problem that the lower roll would now turn less than one revolution for each revolution of the upper roll and if the two rolls were of the same diameter they would produce a tearing action where they met. For only crushing and not tearing to occur, the linear distance travelled by a given point on the lower roll during one revolution of the upper roll must equal the circumference of the latter. To meet this condition, the circumference — and hence the diameter — of the lower roll must be greater than that of the upper roll in proportion to the ratio of the diameters of the two roll-driving gears (see figure 3).

In China, this problem of equal linear velocity on the periphery of the two rolls in animal powered sugar mills was solved in the late sixteenth century much more simply by turning the two rolls into a vertical position and then gearing one directly off the other (see figure 4). (Chinese face runner rice mills had used longer toothed looser fitting lateral gearing to drive one runner directly off another since the fourteenth century. This arrangement had the further advantage of improving juice separation from the cane by gravity. It was found that in the horizontal mills part of the expressed juice was re-absorbed by the cane residue (bagasse) on the output side of the crushing rolls. A partly countervailing disadvantage was the inconvenience of feeding cane into a vertical rather than a horizontal pair of rolls (and the impossibility of loading the rolls evenly in this way).

The Chinese two roll vertical sugar mill spread through South Asia and to India in the late sixteenth century. Initially the rolls were made of wood and sometimes of stone. Discarded rolls of both materials can still be found without difficulty in the Philippines. Probably through Spanish influence, the two roll vertical sugar mill spread to Mexico and Peru.

A third roll was added to the two-roll vertical mill in South America in the early seventeenth century. Mechanically speaking this was very simple since the third roll could be

easily directly geared to the other side of the (now) central driven roll (see figure 5). This was a very significant improvement for the cane could now more easily be subjected to two successive crushings, firstly in one direction and then in the other. At first this was all done by slaves feeding the raw cane through one pair of rolls and then catching the once-crushed material and feeding it back in the opposite direction through the other pair of rolls. In the late eighteenth century a specially shaped turning plate was introduced to make the two successive crushings both automatic and safer for the remaining operators.

This three roll vertical mill was well suited for use with wind power, and from about 1700 onwards many very stout hurricane resistant stone towers were built in the Caribbean islands, with the upright shaft driving directly the central roll of such vertical mills (see figure 6). The early windmills used iron sleeves mounted on wooden cores for the rolls but later mills used cast iron rolls. Waterpower was also used for driving three roll all iron vertical sugar mills using right angle gearing (see figure 7).

In the mid eighteenth century, Smeaton turned the three roll geared sugar mill back into a horizontal position but with the rolls forming a triangular cluster so that the cane could be fed by gravity from an inclined tray across the entire width of the rolls which, because of their configuration, would automatically subject the cane to two successive crushings and then reject the bagasse by gravity to a waste heap. Smeaton's design was for a Jamaican water mill, and clearly a vertical water wheel was very appropriate for driving horizontal rolls (see figure 8).

Horizontal three roll sugar mills could equally well be driven by wind power, but the right angle gearing that would have suited a watermill was too bulky to fit, together with the crushing rolls, inside a windmill tower that had originally been built for a three roll vertical mill. Consequently, windmill towers that were converted from vertical to horizontal mills usually had to have the actual crushing unit situated outside the tower (see figure 9). A more compact arrangement of the bevel gearing at the foot of the upright shaft was developed later which enabled the crushing unit to be positioned inside the windmill tower (see figure 10).

Wind powered sugar mills had no brakewheel and instead had a small spurwheel or bevel gear at the tail of the windshaft. The wallower was much larger than in a 'European' windmill in order to provide the power needed by the crushing rolls. (Correspondingly, in water powered sugar mills the 'pit wheel' was very small compared with the wallower.) The only way of stopping such a mill was to turn it out of the wind, or jam an extra large bundle of cane between the rolls, or both! Outside the crushing season, the sails were taken down and only the stocks remained.

Between 1979 and 1989 I was able to visit 18 sugar mill sites in eight of the Caribbean Islands (Antigua, Barbados, Guadeloupe, Jamaica, Marie-Galante, St Croix, St Vincent and Tobago. *(The schematic diagrams were illustrated by slides of actual mill sites in some of these islands).*

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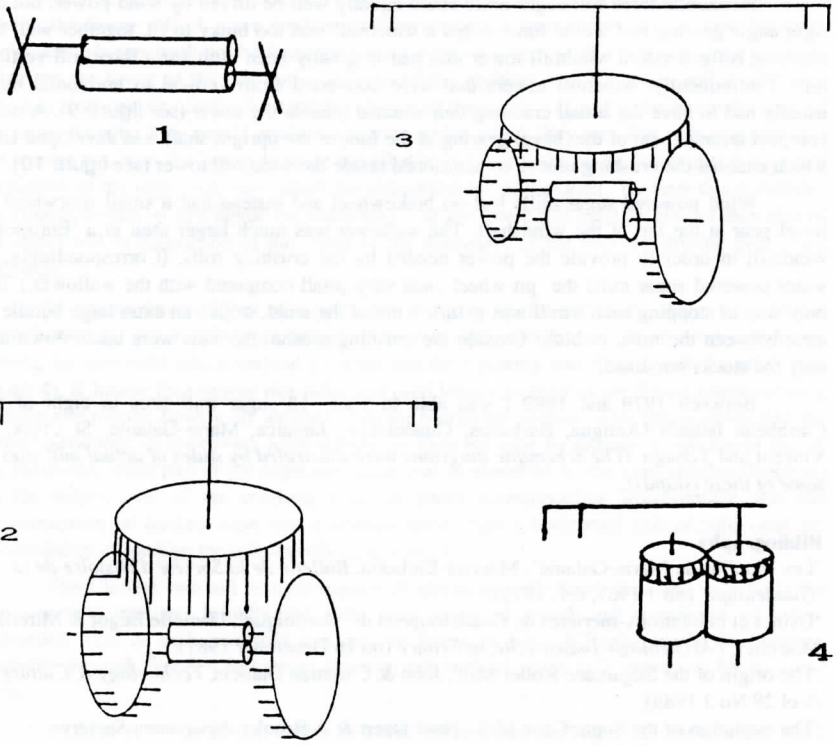
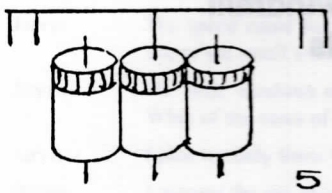
Development of the Sugar Mill





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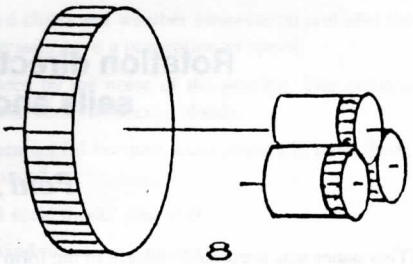

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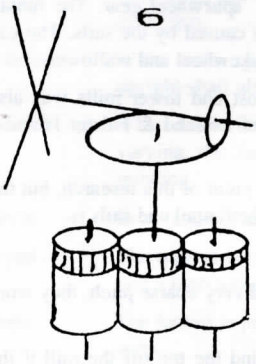

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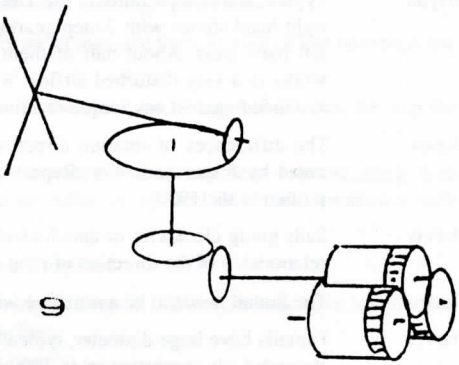

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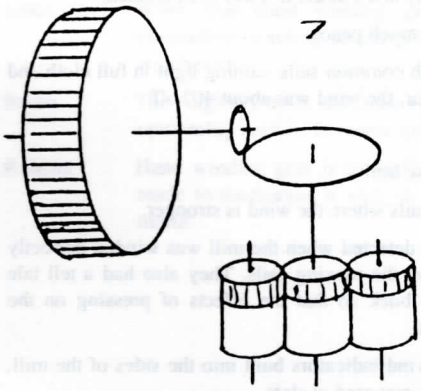

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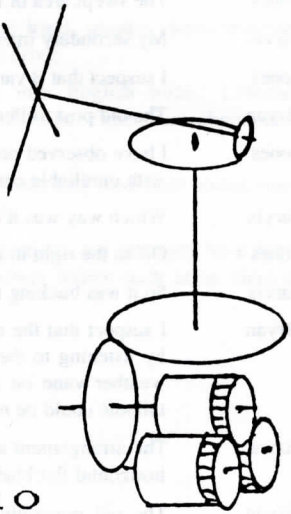

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