CHAPTER – 4

EFFECT OF APPLIED POWER, APPLIED LOAD, COMPRESSION RATIO AND RE-ABSORPTION
ABSTRACT:
For any industry, the parameters of performance, namely efficiency and capacity and also the power or energy consumption also, are most important factors and sugar industry, though tradition based, cannot be an exception to this principle. The Mill section and the individual Cane Crushing Mill, responsible for the governing of the juice extraction operation is the key to success and profitability of the plant in perhaps numerous ways. Each of the subject factors is most important towards these goals. Installed power, being calculated with due margins, allowing for factor of safety and other margins as per thumb rules and experiences, plays a leading role. Other factors playing their complimentary but critical roles.

4.1 APPLIED POWER
In Extraction process by cane milling, this is the most vital factor. The Applied Power, in this case is to be considered as Power that is actually consumed for cane crushing or juice extraction operation by cane Milling. This is essentially, a Part of installed Power.

In the Cane Milling Operation, feed rate or crush rate is most important because this determines the plant capacity and controls the subject parameters. Most unfortunately, in a cane crushing operation, the feed rate of the cane cannot be controlled within reasonable limits, as discussed repeatedly earlier. There are unavoidable wide fluctuations in the feed rate of the cane, though there are many factors responsible for this, it must be noted that these variations, unavoidable as they are, cause resultant fluctuations in the final production and also in efficiency parameters of Milling Operation. Further, on account of this unavoidable nature of the feed rate fluctuations, sufficient margin has to be maintained in the installed power so that the fluctuations on positive side can be taken due care of. Though, in case of Milling operation by conventional mills, fluctuations in negative side do cause loss of efficiency and resultant financial damage.

The fluctuations in the feed rate may have following causes –
The loading of the cane carrier depends upon the method of unloading. For example, in case of bullock carts, as in India the cane cannot be unloaded evenly. In case of unloading by tipplers or inefficient or inexperienced handling by the unloading crane operators, even more uneven loading of the cane carrier happens.

Method of loading of cane Trollies or trucks would also contribute to uneven loading of the carrier.

There is always a possibility of having some gap or interval in the transportation system or some other account, which would also contribute to the uneven loading of the cane carriers.

In spite of having cane levelers and cutters in the system, the variations in the feed may be controlled but – unfortunately cannot be eliminated.

The Applied Power comprises - depends upon - crush rate, Mill Roller Speed, The Mill configuration (number, size and arrangement of rollers), Mill feeding method, Mill settings and hydraulic load on top roller etc. and also dictated by –

### 4.1.1 POWER CONSUMED IN CRUSHING OPERATION

The operation of Crushing of Cane leading to extraction of juice is a mechanical operation and consumes substantial power for the actual working. Also the requirement of power depends upon selection of Cane Variety, Fibre % cane, type of Cane Crushing Mill, Type of Drive selected for the Mill, and also the selection of related installations like the Pressure feeding system etc.

Power is also lost in the process as –

### 4.1.2 LOSS OF POWER IN THE DRIVING EQUIPMENT

Different kinds of driving systems for the Mills are available and depending upon present capacity, expansion plans, the fibre content in the Cane etc., the driving system is selected. On account of difference in mechanical
arrangement and engineering details, the efficiency of such driving system differs. Accordingly the power lost in such equipment differs.

4.1.3 **LOSS OF POWER IN TRANSMISSION**
The Driving power for the Cane Crushing Mill is provided by the main drive such as Steam Turbine - in olden days, and electric motor, DC or AC as at present. The power provided by such main drives has to be transported upto the Mill Roller Shaft using a requisite power transmission system. Naturally power is consumed in the process and is called “Transmission Loss”.

4.1.4 **LOSS OF POWER IN FRICTION IN TRASH PLATE**
This item has been discussed earlier also and it is to be noted that maximum amount of power say about 20% to 25% is lost in this particular item only, as seen earlier. However the power required for the Mill is considered to include this loss. This has already been discussed in details in 2.3.E.VII.

4.1.5 **POWER LOSS IN CLOSED PRESSURE CHUTE - PROVIDED**
The closed pressure chute provided for the conventional pressure feeder systems assists transporting the Prepared Cane from the Donnelly chute exit to the feed nip of the mill rollers. Since the bagasse mass is under pressure delivered by the pressure feeder rollers and since this bagasse mass has to travel through the restricted space through the closed pressure chute, it has to overcome the frictional resistance generated. Power is lost in this action. This loss of power is included in the item of power consumed by the relevant pressure feeder system.

4.1.6 **POWER LOST DUE TO “RE-ABSORPTION”**
Immense power is consumed and provided for juice extraction operation of the cane crushing mill. When re-absorption occurs, part of the power is lost. This has already been discussed in details earlier in 2.3 E. VII.

4.1.7 **LOSS OF POWER IN FRICTION IN OTHER MILL PARTS**
There are other parts in the mechanical design arrangement of the Mill like bush bearings provided for the Mill rollers, couplings, pinions etc., which consume power and contribute to power loss.
To control loss of power in above items, alternative design and arrangements could be sought.

### 4.2 APPLIED LOAD

It is to be noted that in case of the Mills, the success of juice extraction process by Milling depends “heavily” upon the applied load and can be safely said to be proportional to the load applied – in conformity of the Mill settings - and the trick lies in “breaking the heart” of the fiber cells, of course!

The use of hydraulic load – which has to be decided in consideration of the fiber density - has enabled maintaining a constant pressure, independent of the lift of the top mill roller. In India, the hydraulic system is designed for oil pressure of 280 Kgs / CM², while the operating pressure is about 180 Kgs / CM², and in the range of 160 – 210 Kgs / CM².

It may be noted here that, depending upon the design and engineering of the Mill, the advanced energy efficient mill works on average less oil pressure of about 120 Kgs / CM² only.

#### 4.2.1 TO OVERCOME STATIC REACTIONS

The static reaction / forces from the feed and discharge settings and the trash plate all pass through the top roller of the Mill.
4.2.2 REACTION OF BAGASSE FIBRE

It is essential to consider and understand the nature, characteristics and behavior of the bagasse fibre.

The cane has a structure having woody tissues and matter of pulp contained therein. This particular formation of the woody tissues of the cane determines its reactions under the influence of pressure of the Mill rollers.

If we study the manner in which the cane and the bagasse behave when subjected to certain pressure $P$, it will be seen that, for the same increment of pressure $\delta P$, the cane will be deformed by an amount $\delta h$ greater than $\lambda$ by which the bagasse will be compressed.

This phenomenon is due to the factor of elasticity of the cylinder of the rind and the small partitions of the nodes. Considering the work to be done and the Power applied, it is seen that the power expended in the case of cane is superior to that expended in the case of the bagasse. The work of course is the product of force $P$ and displacement $\delta h$. 

Fig 4.1: Load Diagram for Applied Load.
4.2.3 OPENING OF CELLS OF BAGASSE FIBRES

It is accepted that the power exerted by a crusher or a Mill will depend on the degree of preparation of the cane (PI) that is fed to the Mill Rollers. In this respect, the power expended in the process of the preparation – in Shredder or a Fibrizer – can be recovered or compensated to some extent and saving obtained, on account of converting the canes into a fibrous and compressible material. Also the load on the Mills is reduced to some extent due to the fact that the juice extraction process is made easier due to opening of the cells of the fibre or in other words disintegration caused. This would naturally lead to proportionate increase in the crush rate of the Mills.

4.2.4 PROVIDING NECESSARY TORQUE

In operation of the Mill, friction and feeding action result in various resistances to overcome which requisite torque forces have to be provided.

4.2.5 POWER ABSORBED BY FEED AND DISCHARGE ROLLERS

E. Hugo states that (page 238) distribution of power is about;

<table>
<thead>
<tr>
<th>Roller Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top roller</td>
<td>55%</td>
</tr>
<tr>
<td>Feed roller</td>
<td>10-20%</td>
</tr>
<tr>
<td>Discharge roller</td>
<td>25-35%</td>
</tr>
</tbody>
</table>

The net force from the discharge Mill roller is much greater than that from the feed roller of the Mill. The ratio of these two forces varies widely, and is considered to be varying and is generally around 2. The ratio depends on the Mill design (will be lower for the Mill with pressure feeder systems than the three roller mills), feeding arrangements, position of the Mill in the Tandem, Mill settings and other factors.

4.2.6 TOTAL ABSORBED POWER

Absorbed power by the conventional three roller mill, measured at the prime mover, is usually 10 to 13 Kw/tfh. Allowing for transmission losses in gearing, coupling etc. of about 20-25% this works out to 8 to 11 Kw/tfh at the input of the top mill roller. This would also depend upon the factor of Mill Roller RPM.
In terms of the torque, for the Mill roller speed of 3 rpm the absorbed torque is thus 40 kN.m per tfh to 50 kN.m per tfh.

For Mill roller speed of 5 rpm the torque absorbed is about 25 kN.m per tfh to 30 kN.m per tfh.

### 4.2.7 ABSORBED POWER FOR INDIVIDUAL MILL

It is accepted fact that these forces, as explained above, are too complex in nature for detailed and reasonably accurate analysis. It is considered relevant to consider the main direct (linear) forces (i.e. excluding torques) acting on the top Mill Roller which influence headstock, shaft and bearing designs.

Since the first Mill in a Mill Tandem is considered to offer high Mill extraction, the power consumed by the first Mill is maximum and that of the intermediate mills on the sequentially lower range. The last mill plays equally important role since it is responsible for bagasse moisture and hence consumes proportionately more power. Again all this depends upon factors like crush rate, setting etc.

*In case of a Tandem of conventional Mills, as per E. Hugot, the power per Mill, without the unloading / handling / preparation section is, on an average 13- 15 KW / TFH.*

### 4.3 COMPRESSION RATIO

The Milling or extraction efficiency very much depends upon the factor of the degree of compression generated or obtained in the working of the cane crushing Mill. This can also be described as the reduction in the volume obtained in the bagasse mass to generate extraction. The compression ratio of a cane crushing Mill or to be exact, the compression ratio relating to the passage of the material – bagasse – between two given Mill rollers (the compression ratio may be related to either the feed rollers or the discharge rollers) is the maximum value assumed by this ratio in the course of passage of the bagasse through the opening of the given rollers or given opening (feed opening or discharge opening). The compression ratio is – in reality – of substantial interest only for the first
Mill. There are two openings which are really a matter of theoretical interest which are –

4.3.1 **AXIAL OPENING**
Opening in the axial plane of the two Mill Rollers which can be called “Axial Opening” is one of the important factors.

In any conventional Mill the openings are, Feed opening, Trash Plate setting and Discharge opening.

It is said that the success of the conventional Three Roller Mill is on account of the fact that it provides feed roller pressure, passage on the trash plate and finally the discharge roller pressure and the setting or the openings can be so arranged that the bagasse arriving at the discharge roller is not too wet so as to avoid choking (E. Hugot). There is an optimum ratio between these openings and Hugo further states that setting of this ratio is in reality “an Art” and cannot be aimed merely by a mathematical solution.

![Fig 4.2: Axial opening.](image)

4.4 **RE-ABSORPTION AND WASTAGE OF POWER CONTRIBUTED BY EQUIPMENT DESIGN.**
While it is common practice to employ optimum pressure to avail optimum extraction efficiency, the typical behavior of the bagasse mass creates obstacles in the designs of the Mill Engineers. This is caused by occurrence of the phenomenon of Re-absorption which has been discussed in details earlier.
However, it can be said that the cause of Re-absorption could be attributed to faulty design or inadequate design of the cane crushing Mill. This could be due to –

4.4.1 **INADEQUATE PASSAGE FOR JUICE DRAINAGE OR JUICE ESCAPE**

The Mill grooving has to be carefully designed and provided so that the juice finds easy path to get out of the bagasse mat under pressure.

4.4.2 **PROVISION FOR IMPROVED JUICE DRAINAGE**

Lotus roller could offer substantial juice drainage facility and would be useful in reducing the re-absorption loss. However it may be noted that in case of conventional Mill installations, it is generally not advised to incorporate Lotus Roller for the last Mill, for fear of increased re-absorption due to geometry of the Mill Rollers.

![Fig 4.3: Arrangement Details of Nozzles.](image)

4.4.3 **MESSCHAERT GROOVES**

Provision of Messcheart Grooves offers better juice drainage facility and also lesser chances of clogging of grooves of the Mill rollers with bagasse, This would provide some relief from the damage due to Re-absorption.

4.4.4 **SLOWER MILL ROLLER RPM**

Slower Mill Roller RPM or lesser surface speed would enhance the retention time of bagasse in the Mill Roller Compression zone and would reduce Re-absorption. But would also reduce crushing capacity.
### 4.4.5 PRE-JUICE EXTRACTION
Subject to additional adequate drive power certain pressure feeder system could improve pre juice extraction and could be able to limit the damage due to Re-absorption.

### 4.4.6 GOOD ARCING
Better and continuous maintenance of Mill rollers would reduce the damage. For this purpose good arcing practice with regular touch ups is highly recommended.

However it must be noted that slower Mill Roller RPM would result in reduction in the crushing capacity of the Mill Tandem and may not be a possible solution always. Also there is hardly any conventional pressure feeder system available which could offer satisfactory solution to the problem. If at all some pre juice extraction is attempted, substantially additional Mill drive power has to be harnessed and it may not be possible in the given set up to provide that much of additional power.