# Development of Chip Destructring Unit-- Prospects & Problems

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In search of better pulping technology, mechanical destructuring of wood chips in cylinder press, prior to cooking has emerged with great potential for higher yield, more homogenous pulp with better strength properties and improved economics, Efficient pulping of denser hardwoods which have hitherto remained problematic seems viable now.

The benefits of chip destructuring are highlighted and problems faced with development of efficient destructuring unit are outlined. Possible routes of further developmental work for successful implementation of chip destructuring technology are discussed for which active coordination among research organization, machinery manufacturers and pulp and paper manufacturing units is essential.

In the coming decades shortage of fibrous raw material poses the most baffling problem in the growth of pulp and paper industry throughout the world in general. The picture in India is still grave. Indeed, inadequate supply of raw material is one of the many reasons why the industry is working at 70% of the capacity today[2]. If paper and board output grows, as expected, by perhaps 7% per year we would need additional production of about one million tonnes by 1990. In contrary to the increasing demand the indigenous supply potential of fibrous raw material from forestry is rather diminishing. In 1947 a third of India was under forest and now the figure is 20-22% only[2]. In order to augment the impending raw material crisis, industry wiil have to look for pulps with higher yield from existing raw mateials and also efficient utilization of available dense and mature mixed hardwoods from the forest produce which have hitherto remained troublesome, in addition to corporate plantation of fast grown wood species.

In search of higher yield pulps and better pulping economics, research is on going in different directions throughout the world of which mechanical destructuring of chip looks promising. In this paper an attempt has been made to briefly focus the beneficial effects of mechanical destructuring of chip and summarise the developmental problems of a suitable destructuring unit.

## BACKGROUND

During cooking the fundamental reaction is the elimination of lignin by depolymerization and solubilization in the reaction medium constituted by various chemicals. The reaction of the chemicals with lignin needs elevated temperature and only starts at about 100°C. However to reduce the delignification time the temperature is increased to 170°C in actual practice. For better homogeniety of the cooking the wood is converted to chip of convenient size. Looking into its mechanism the cooking may be considered to be composed of the following steps :

(a) Transportation of chemical reagents to the site of reaction by penetration of the liquor into the chips and by diffusion of the reagents.

(b) the adsorption at the site of the reaction.

(c) reaction of the reagents with the constituents of wood i e. hemicellulose, lignin, cellulose, resin, tanin etc.

(d) desorption of the reaction products, and

(e) transportation of the reaction products by diffusion.

The reaction kinetics of delignification are essentially controlled by the transportation reactions

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(steps 'a' & 'b') and step 'c'. The transportation of chemical reagents are done exclusively by diffusion process which is essentially the same in all the three directions of the chip. Therefore the dimension, of the chip, its thickness in particular is the most important parameter in controlling the reaction kinetics and determining the chemical concentration gradient and therefore the heterogeniety of delignification as measured by the amount of rejects. The chip size should be such that the cooking liquor can easily penetrate and the chemical concentration within the chip is uniform throughout. If the chip size is such bigger that the chemical can not penetrate & distribute itself uniformly throughout the chip, having less at the centre of the chip, then shives (rejects) will be generated on cooking. Therefore the lower the chip size better the pulping and pulp quality. However there is an optimum lower limit beyond which size the length of the fibers will be short enough that the strength properties of the pulp are badly affected. Therefore for preservation of strength properties of resultant pulp the size of the chips has to be restricted to an optimum limit. The size of the industrial chips varies depending upon chipping equipment but are approximately 30mm × 20mm × 3mm on average. Thus having set the limit of chip size, the uniformity of chemical penetration in the chip will depend upon the absorbency of the chip. Absorbency in turn is dependent upon the basic density of the wood. Soft woods having lower basic density with more open inner structure than hardwoods, have higher absorbency. While reasonable chemical saturation is obtained with industrial chips of softwoods leading to acceptable pulping characteristics, hardwoods, of moderate basic density are comparatively less efficient and dense hardwoods having basic density in the range of 550 to 670 kg/m$^3$ are troublesome. Due to their compact inner structure the liquid penetration into the denser hardwood chip is very less and requires higher chemical doses and longer cooking cycle for production of acceptable quality pulp. It is therefore apparent that still better delignification could be achieved if the chemical penetration rate into the chip could be improved by some means without affecting the resultant pulp strength properties, which led to the development of mechanical destructuring of chips in cylinder press prior to cooking.

## CHIP DESTRUCTURING

It has been observed that mechanical destructuring of wood chips by passing moistened chips through a pair of steel cylinders having nip clearance less than average chip thickness, prior to chimical treatment, improves yield and pulp quality (better homogenitey and higher strength properties. The mechanical force exerted by the steel cylinders causes fractures in the morphological structure of the wood and increases macroporosity of the chips, without much fiber degradation under optimum conditions. The accessible surface area of the fibers are thus increased by many folds. This open structure of the chips enables it to instantly absorp many times more liquid as compared to original chips. The thermal transfer co-efficient in such destructured chip bed also increases by about 20 times as compared to a bed of original chips. Further it is believed that the mechanical force applied causes microfracture[8] in lignin or some other changes which are beneficial to delignification. With such chip characteristics the following improvements are possible :

(a) a drastic reduction of the time to reach the cooking temperature.

(b) use of milder cooking conditions for getting unbleached pulp of similar kappa number.

(c) vapour phase pulping with less liquor/wood ratio resulting in energy economics.

(d) a more homogeneous pulp with less rejects.

## PROTOTYPE UNITS – CONSTRUCTION, OPERATION & RESULTS :

Higgins and Puri[3] used one equipment which consisted essentially three elements :

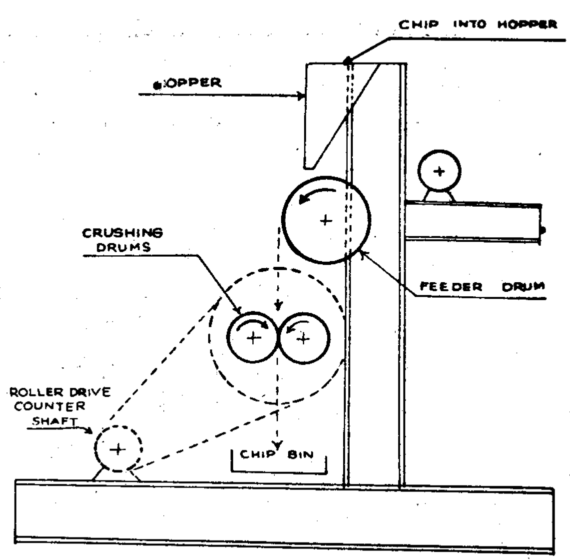
(a) a vibratory hopper
(b) a moving feed belt, and
(c) a pair of parallel cylinder rollers.

The chips were discharged on the belt which fed them into the nip of the rolls. The rolls were 23cm in diameter rotating at 24 rev/min in opposite directions. The separation between the rolls were adjustable. The chips were moistened to about 50% moisture content by soaking in hot water, before passing through the rollers. The nip was maintained at 0.36 mm. Other process parameters are unfortunately not reported in their paper. However Higgins & Puri have reported one interesting observation that if the grain of the chip were initially at an angle to the axis, the chips would orient therselves automatically in the direction with grain parallel to the axis of the rolls.

Oldman[4] used pair of crome finished foils mounted on heavy bearings. Above these two rolls Oldman used another bigger roll parallel to the axis of the two main rolls as "feeder drum" for feeding the chips to the nip of the crushing rolls. A hopper feeds chips to the feeder drum. Necessary provisions were made for setting and maintaining the nip which could be varied from 0 to 5mm or more and also to release the rolls when they become heavily overloaded. Motors were fitted with overload protection.

FIGURE - 1

DESTRUCTURING UNIT OF JOHN A OLDMAN




OVER-ALL DIMENSIONS

| | | |
|---|---|---|
| LENGTH | : | 3650 mm |
| HEIGHT | : | 2900 mm |
| WIDTH | : | 2400 mm |

Sketch of the equipment is shown in figure—1. The equipment 'specification are :—

(a) Roller drive motor : 11 kw, 1450 rpm, 19.8 A, 450 v, 50 Hz.

(b) Effective roll length : 780 mm

(c) Roll drive : Outside 270 mm and 301 mm. Wall thickness 23 mm and 38 mm respectively.

(d) Roller diameter : Inter connected by a pair of super gears with the same pitch circle diameter.

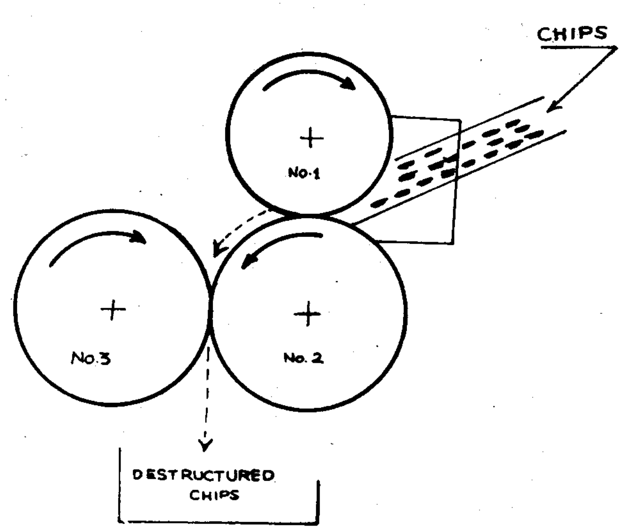
(e) Power train : Vee belt, worn gear box and chain reduction to one roller shaft.

Oldman has reported chip feeding problem. There was lapping of two or more chips at the nip of the rollers. He observed that chip greater in thickness approx 8 mm either as single or lapping chips often did not enter the roller. The lapping chips obstructed the feeding of succeeding chips causing lower output rate. In order to overcome the overlapping of chips, Oldman modified the roller surface by cutting small grooves of 4mm wide by 1 mm deep, parallel to the roller axis. 10mm apart. At 3mm nip the flow was rarely interrupted with grooved rolls. Oldman concluded that a nip separation of 3 mm was best suitable for optimum pulping and pulp properties. 1.5 mm has been concluded to be the lower limit beyond which adverse fibre damage was suspected to occur. Chip orientation was observed to be random, contrary to the findings by Higgins and Puri. It was observed by Oldman that optimum pulping and pulp properties were obtained with fully oriented chips.

Choudens, Lombardo, Michalowicz and Robert[5] did exhaustive study of chip destructuring and have established an emperical correlation between chip dimension and nip clearance for optimum pulping and pulp properties. The machine utilised by these investigators is somewhat different from the others. The schematic diagram of the machine in Figure–2. The

FIGURE - 2

ROLL ARRANGEMENT IN DESTRUCTURING UNIT OF C de CHOUDENS



cylinder press is composed of three cylinders 509 mm long. The top cylinder, 400 mm in diameter, is mounted onto a manually operated articulated arm. The other two cylinders, 600 mm in diameter, are on the same horizontal plane. The rotational speeds of the cylinders can be varied from 9 to 43 rpm. The capacity of the machine is 40 to 50 tonnes/day per linear meter width with hardwood chips and 80 to 100 t/day per linear meter width with softwood chips (O.D.W.).

In this process the chips are treated in hot water to bring the moisture content to 50%. The chip thickness used were 4mm ± O.5 mm for pine and 3.5mm ± O.4mm for Oak. The chips are subjected successively to two mechanical actions, first a light action between the top cylinder and the first cylinder. The second action, which is between the two lower cylinders, causes the actual destructuring of the chips. The rotational speeds were 18 rpm for the top cylinder and 12 rpm for the other two. The nip between the first two cylinders was maintained at 4.2mm where as the nip between cylinders 2 and 3 was varied from 2 5mm to O.4mm. The energy consumption was about 15 to 20 kWh/t (o.d. chip) depending upon the wood species and the degree of destructuring desired.

Microscopic analysis of the destructured chips revealed that at a nip close to e/2 ('e' is chip thickness in mm) there was no apparent degradation of the fibers. Fractures appeared between the fibers without modifying the cellular walls. From a cylinder nip of e/3, the fibers begin to break down, particularly for the lower nips (e/5 & e/10). Less fiber degradation was observed by passing the chips through two nips instead of one. In case of kraft pulping a yield increase of the order of 2-3% based on o.d. wood, higher pulp strength properties and screen reject less than 0.5% was achieved by De Choudens. Further, for a cooking temperature of 180°C the total cooking time could be reduced to 30 minutes for producing suitable pulp with destructured chips as compared to 120 minutes for original chips to reach the same effect.

## FURTHER DEVELOPMENTAL WORK

The process variables which might have positive effect in chip destructuring are many and only a few have been studied, Further research work is therefore needed for investigating effects of other process variables eg. preheating, post extraction chip moisture and crushing in presence of chemicals. Similarly the effects of design parameters such as cylinder diameter, cylinder surface condition and number of cylinders (i.e. nips) need to be established. There are two operational problems with chip destructuring unit. First, bridging effect by oversize and overlapping chips which diminishes output rate. Secondly, chip orientation. The benefits of chip destructuaing diminishes with chips destructured at random orientation[4]. Tne claim by Higgins[3] that chips orient themselves automatically does not sound convincing and has been reported otherwise by Oldman[4] Therefore development of suitable device for smooth chip feeding and chip orientation is vital for efficient operation of the destructuring unit.

As observed by De Choudens[5] differential cylinder diameters (no.1 cylinder being of lower diameter than adjacent No 2 cylinder) might improve smoother chip feeding because of larger pinching angle. Modified roll surface has been found by Oldman to be helpful in smooth feeding of chips (less bridging effect by overlapping of chips). Therefore general roughning of cylinder surface may improve feed reliability and optimum surface modification might be a practical solution to chip orientation.

Further developmental work on chip destructuring unit are in progress in other countries and at least one industrial device is in operation in France. However, little information is available on this industrial unit. In India no work is reported to have been done in this field. CPPRI has taken up a project on mechanical destructuring of wood chips. The objective is to study the effects of mechanical destructuring of wood chips in chemical and chemimechanical pulping of dense hardwoods having basic density in the range of 550 to 670 kg/m$^3$. It is proposed that CPPRI will devise a prototype chip destructuring unit to study various process and design parameters for optimum pulping and pulp properties.

## CONCLUSIONS

From the experimental results of De Choudens, Higgins and Oldman it is evident that better pulping results (higher yield better homogeniety and improved strengh properties of pulp) and better pulping economics can be achieved by mechanical destructuring of chips prior to cooking. It is also expected that due to enhanced mass and heat transfer rates in the bed of destructured chips, denser hardwoods which have hitherto remained troublesome, can now be efficiently utilised for pulping. However, further work is necessary for evaluation and optimization of other process and design parameters of chips destructuring unit. It appears that development of suitable devices for smooth chip feeding and optimum chip orientation are vital for successful commercial exploitation of the chip destructuring technology.

CPPRI has taken up a research project on chip destructuring to study various process and design parameters. In view of the huge quantum of research work needed, the financial inputs required for fabrication of the various modifications of the destructuring unit is expected to be quite high. Active participation of paper machinery and pulp & paper manufacturers could make the task easier. It is hoped that industry will find chip destructuring worthy whose scccessful implementation would mean long term benefit to the industry and would encourage propagation of the project through active participation in it.

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