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Quantification of wood wastage in mechanized match manufacturing

Ramesh Chand Dhiman, Deepak Dhiman

***Abstract*— Safety match is one of a very old wood based industries, in India. Wood raw material is one of the major input costs and its wastage during manufacturing process affects working and economical status of the industry. The present study was conducted in the mechanized manufacturing of safety matches in WIMCO's factory, Bareilly, Uttar Pradesh using locally grown poplar matchwood. Results indicate significant variation for wood wastage among various sections and subsections of match manufacturing process. Debarking (23.66%), saw mill in Log yard (6.51%), peeling (44.03%) and splint processing (23.45%), emerged as major sources of wood wastage in the manufacturing process. Among subsections; end cuts, peeling, and centre core contributed towards significantly higher wood wastage than many of the remaining subsections. Developing an effective machine-wood-human inter-phase could help in reducing wastage and making this low value and high volume industry cost-effective and market- competitive.**

***Index Terms*—Wood wastage, Match manufacturing, Manufacturing process, Machines, Splints, Sticks.**

I. Introduction

Safety match is one of a very old wood based industries, in India. The industry has been playing a significant role in domestic and national economy by value addition to wood, employment generation, and revenue collection through different taxes. This product has been considered as one of the essential used commodity by common-man and is still a basic need and life line for numerous families in the low income group residing inside rural areas who are dependant on match boxes to lit their local lamps and houses besides being extensively used by smokers to lit cigarettes and biries (leaf cigarette). Match box is also an integral component of worshiping material, mainly incense sticks, in numerous worship places and houses across the country. Mechanized match manufacturing was started by Western India Match company (WIMCO) in 1923 and has now been controlling around 18% of total market share (27 thousand million boxes of 50 sticks each) in the country. Of recent, its match manufacturing has been integrated with Match and Agarbatti Business (MAB) of ITC. The production capacity of mechanized match manufacturing is 695,000 cases (7200 boxes/case) and the remaining is produced in small and cottage scale units (1). Safety matches, though a low value wood based product, is highly complex manufacturing process involving number of machines and processes which need to synchronize with back-end and front-end operations to make it efficient, cost-competitive and viable operation. A match box contains three components viz., match sticks (number vary with execution), inner (card board tray carrying match sticks) and outer (card board cover to hold inner with sticks) with two opposite chemically coated rough (friction) surfaces to lit the match sticks by striking their heads.

Wood is the main raw material and cost centre for making safety matches. The industry was established with undertakings given by the state governments for sustained supply of matchwood. Both central and state government were supporting the industry with sustained supply of wood raw material from government forests. The central government had issued directives to the states not to divert the wood of match making species to other industries and also to encourage planting of matchwood species in view of the shortage of wood experienced by this industry (2, 3). Growing of matchwood species were also recommended in Chapter 42 (Recommendation No. 20 and 21) of the implementation of National Commission of Agriculture recommendations (4). In its around hundred years of existence, the industry initially used imported softwoods (broadleaved low density woods) mainly *Populus* species (*Populus tremula*, *P. deltoides*, *P. balsamifera*) (1), developed usage of local softwoods like, *Bombax ceiba*, *Ailanthus* species, *Anthocephalus cadama* and a few others inbetween and is now dependent on plantation raised poplar (*P. deltoides*), white mutty (*Ailanthus triphysa*), maharukh or yellow mutty (*Ailanthus excelsa*), kadam (*Anthocephalus cadama*) and a few others which are grown in different parts of the country. Some quantity of wood of *Populus* species is also imported now and then based on cost and wood availability (5). There is some wood, splint and stick wastage at every level of making safety matches and it is extremely important to document the same for creating controls and for improving the efficiency in this industry. The present study was carried out in WIMCO's Bareilly factory, Uttar Pradesh by using poplar matchwood which is grown and procured locally. The junior author planned and organized the study, whereas, the senior author executed the study and supplemented it with basic inputs and information.

II. Material and Methods

Freshly procured logs or those stored in fresh water circulating tanks for conditioning are debarked, cut to appropriate lengths called billets, peeled to veneers of desired thickness, made into layers and chopped into splints. During processing of splints, they are moved to different operations through conveyers or blowers and are subject to karborization (dipping into phosphoric acid solutions), dried in specially designed driers, polished and cleaned, charged on match bars for dipping and head formation, discharged form match bars once fully dried, collected in aluminum trays and supplied to box filling section. In box filling section, match sticks brought in aluminum trays from dipping section are arranged in ROJ machine and dressed, Trays are loaded on the

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Ramesh Chand Dhiman, R&D Centre, Wimco Seedlings, Wimco Ltd., Rudrapur, Udham Singh Nagar, Uttarakhand, India. 9927042364.
Deepak Dhiman, MTech Final Year, Department of Industrial Production, NIT, Kochi, Kerala, India , 07736435508.

machines to fill on an average 50 sticks in each tray by volumetric controlled system. In packing section, match boxes received from box filling section are put in a VAT machine for packing boxes in each pack and then these boxes are filled in trade packs of bigger size (600 boxes in 5F trade box), Tradeable packs are then moved to store-houses for further dispatch to market outlets (Fig.-I).

Wood, splint and stick processing in match factory passes through five main sections, viz., debarking in log yard, peeling and chopping in peeling section; karborization, drying, polishing waxing, head formation in splint processing section; stick filling in box filling section; and box packing in packing section. Wood wastage (including stick and splint wastage) was monitored and compared within and outside each processing section. 1200 poplar logs were processed during each day (shift) which were weighing 981 qtl, 1037qtl, 1034 qtl, 1022 qtl and 1037 qtl in 1st, 2nd, 3rd, 4th and 5th day respectively. Minor variation in weight of logs with same number of logs/shift was due to their varying thickness. The data on wood consumption and its wastage at each level was converted into uniform consumption of 1000 qtls log weight per shift and corresponding values for wood wastage were calculated for each section operation. The weight of the wood was recorded with bark at intake level. On debarking, the corresponding values for wood weight (bark free) were recorded, wood wastage at different levels of safety match manufacturing for each shift was also monitored and recorded. The data for each shift was considered as a separate replicate and therefore there were five replications for analyzing the data. The data was subjected to ANOVA using MINITAB software and the wastage means at each level were compared at 95% critical difference level for drawing inferences. The meanings of different terms used in the paper are given in Box-I and a flow chart of mechanized match manufacturing in Fig-I.

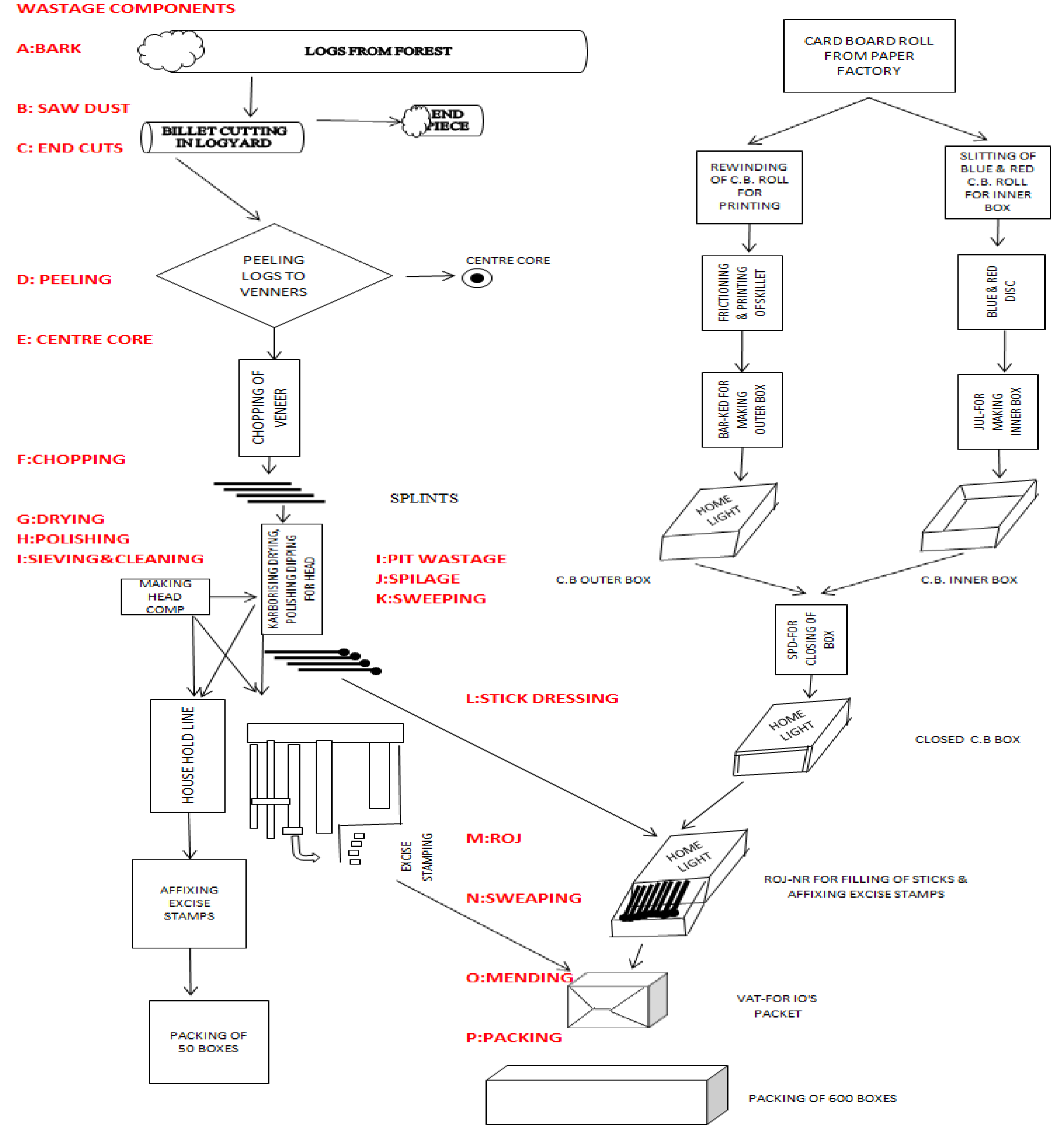
Table-1: Machines/tools and processes used in different sections of mechanized match manufacturing.

Sr. No.	Section	Machines/tools and operations
1	Log yard	Local shawls (iron tool) for debarking, circular band saw for cross cutting logs into billets
2	Peeling	High speed Swedish made peeling lathes
3	Chopping	High speed Swedish made choppers
4	Karborization	Karborazied drum with provisions of spray of chemical solution
	Dryers	Arenco –SF-Dryers
5	Splint polishing	Polishing drum to rub the sticks with wax
6	Splint processing	Arenco splint processing automatch and other machines including head composition in Wall mills
7	Box filling	ROJ Swedish Match machine
8	Packaging and shrink wrapping	Indian made machines

Box-I: Terms referred in the paper and match industry

Log: A section of tree stem/branch of desired dimension (length and thickness).
Bark: Corky layer of dead tissues (non-woody) forming an outer covering on log/tree trunk.
Wood. Inner portion of stem/log that is used for making veneers and splints.
Matchwood: Wood logs used for making match splints, inner and outer of boxes.
Billeting: Cutting logs into useable small sections called billets.
End cuts: Discarded end pieces (unpeel-able) of logs left after billeting.
V**eneer**: A sheet of wood peeled off with fixed sharp knives while fast rotating the wooden logs on lathes.
Centre Core: A thin circular and central portion of billet left unpeeled because of its reduced thickness.
Layer: Number of veneers placed one above another to make a stack for chopping.
Chopping: Chop layers into splints of desired dimension (length, thickness and width).
Match splint: A small wood piece of desired dimension obtained after chopping and further processed to form a match stick.
Match stick: Processed splint discharged from match bars and ready to be used.
Karborization: Process of impregnation of phosphoric acid into splints by dipping/ soaking them in 5% chemical solution (to avoid glowing of sticks after burning).
Drying: Process to reduce moisture content of splints to 7-8% post-karborization for further polishing.
Polishing: Process to smoothen the splints by rubbing their surfaces with wax in a polishing drum.
Paraffining: Impregnation of wax into a portion of splint (by capillary movement) by its dipping into melted paraffin.
Sweeping wastage: Collecting the splint wastage spread on the shop floor.
Pit wastage: Collection of uncharged splints from a pit located under the charging section.
Spillage: Fallen sticks below the ROJ machines (filling machine).
Stick dressing: Arranging the dipped splints in a tray before loading into ROJ box filling machine.
ROJ: Trade name for Arenco box filling machine.
Mending wastage: Unrecovered sticks left after recovery of useable splints.
Match Bar: Iron bar with multiple holes to insert individual sticks in each hole for dipping and head formation.
Head formation: Process of forming head of chemical composition on its one end by its dipping into the head composition solution.
Charging: Process of inserting the wooden splints into the match bar holes for dipping and head formation.
Discharging: Ejecting the dipped splints from match bars after head formation and drying.
Box filling: Filling the match sticks into match boxes by mechanical or volumetric method
Packing: Bundling match boxes in tradable packs.
Shrink wrapping: Process of intermediate packing of a water resistant plastic material on a match pack.
Safety match: A box containing karborized match sticks which stop glowing immediately after burning.

Fig.-I: Flow chart showing manufacturing and wood wastage in match industry



III. RESULTS

Data presented in Table-II for wood wastage at different sections of safety match manufacturing indicate significant differences among most of them. Maximum wood wastage of 216.69 qtl, out of a total 1000 qtl wood used per shift, was recorded at peeling section which was significantly higher than that in all other sections. On percentage basis, wood wastage at this section was 22.62% based on total wood used (bark free) and 20.33% (with bark) on log weight basis. Debarking, saw mill and peeling sections together contribute around three-fourth wood wastage in the match manufacturing process. Higher wastage in these three sections is because of primary processing of wood logs into billets and then from billets to splints. Minimum wood wastage on log consumption basis was recorded at packing section. It was 5.58 qtl per shift out of 1000 qtl total wood consumption basis, 0.58% on log weight basis and 0.52% on wood weight basis. The differences in mean values of wood wastage for all the four studied parameters between debarking and splint processing; and between box filling and packing were statistical at par though minor non-significant differences existed between these combinations. Wood wastage based on per cent of wood consumption, per cent of wood weight and per cent of log weight followed the same trend as was recorded for wastage that was recorded based on original wood consumption.

Table II: Wood wastage in different sections of safety match manufacturing.

Manufacturing process section	Wastage based on			
	Original wood consumption (qtls)	Per cent of wood consumption	Per cent of Wood weight	Per cent of Log weight
Debarking	111.40	23.66	12.51	11.25
Saw mill	31.93	6.51	3.59	3.23
Peeling	216.69	44.00	22.62	20.33
Splint processing	115.22	23.45	12.77	11.48
Box filling	10.82	2.20	1.12	1.01
Packing	5.58	1.14	0.58	0.52
SE diff	5.61	0.83	0.56	0.62
CD0.05	15.21	2.248	1.52	1.68

Sector-wise wastage

Wood wastage recorded subsector-wise in different sectors is given in Table-III to Table-VII below. Within log yard, two subsections viz., end cuts and sawdust had shown non-significant differences for all the four parameters between these two wastage components. End cut recorded non-significantly higher values when compared with that of sawdust as wastage. Within log yard section, 54.87% of wastage was in the form of end cuts and 45.13% in the form of sawdust. The percentage of wood wastage was between 1-2% in relation to total wood used per shift.

Table-III: Wood wastage within log yard section.

Log yard subsection	Wastage based on			
	Original wood consumption (qtls)	Per cent of wood consumption	Per cent of Wood weight	Per cent of Log weight
End cuts	17.90	54.87	2.02	1.79
Sawdust	14.03	45.13	1.59	1.40
SE diff	2.54	4.87	0.29	0.25
CD0.05	NS	NS	NS	NS

In Peeling section, three subsections contributed towards wastage. Centre core recorded maximum values (100.70 qtl/shift) based on original wood consumption and also on percentage basis (46.41%) and these values were statistically at par with that of peeling sub-section but statistically different when compared with that of chopping subsection (45.86%). Chopping section recorded significantly lower wood wastage of 16.70 qtl, and 7-73% based on original wood consumption(weight) and percentage of wood consumption basis respectively, 1.88% based on per cent wood wastage and 1.67% based on per cent log weight basis.

Table-IV: Wood wastage within peeling section.

Peeling subsection	Wastage based on			
	Original wood consumption (qtls)	Per cent of wood consumption	Per cent of Wood weight	Per cent of Log weight
Peeling	99.28	45.86	11.23	9.93
Chopping	16.70	7.73	1.88	1.67
Centre Core	100.70	46.41	11.39	10.07
SE diff	2.17	0.66	0.57	0.52
CD0.05	23.05	2.96	2.54	2.30

In splint processing section, wastage is recorded in the form of splint and stick wastage in five subsections post-peeling and chopping section. Maximum wastage of 58.07 qtl (50.44% within splint processing section) was recorded as pit wastage which is located below splint charging in the match bars. Overall, the pit wastage contributed towards 6.57% for wastage based on wood weight and 5.81% based on log weight. These wastage values were significantly higher than those recorded at all other subsections. Minimum wastage values were recorded for spillage. The trend for wastage in each subsection was similar for all the four traits recorded in this section.

Table-V: Wood wastage within splint processing section.

Splint processing subsection	Wastage based on			
	Original wood consumption (qtls)	Percentage within splint processing section	Per cent of Wood weight	Per cent of Log weight
Drier sweeping	8.53	7.38	0.97	0.85
Polishing	14.57	12.66	1.65	1.46
Sieving and cleaning	25.51	22.11	2.89	2.55
Pit wastage	58.07	50.44	6.57	5.81
Spillage	3.37	2.92	0.38	0.34
Sweeping	5.17	4.49	0.58	0.52
SE diff	0.91	0.73	0.10	0.09
CD0.05	2.47	1.98	0.28	2.46

Data presented in Table-VI for wastage in box filling section indicate significant differences for wastage values based on original wood consumption, per cent value of wood consumed within this subsection, per cent wood wastage on wood weight basis and per cent value on log weight basis between stick dressing and ROJ subsections. Stick dressing subsection recorded significantly higher values than those recorded for ROJ.

Table-VI: Wood wastage within box filling section.

Box filling subsection	Wastage based on			
	Original wood consumption (qtls)	Per cent of wood consumption	Per cent of Wood weight	Per cent of Log weight
Stick dressing	5.81	53.60	0.66	0.58
ROJ	4.97	46.10	0.56	0.49
SE diff	0.64	2.54	0.07	0.06
CD0.05	4.92	19.61	0.55	0.49

Wood wastage in packing section has also shown significant differences in the recorded values. Packing recorded significantly higher values for all the four quantified parameters when compared with that in sweeping and mending subsections. Within packing section, maximum wastage of 81.45% was recorded in packing followed by that in mending and sweeping subsections.

Table-VII: Wood wastage within packing section.

Packing subsection	Wastage based on			
	Original wood consumption (qtls)	Per cent of wood consumption	Per cent of Wood weight	Per cent of Log weight
Sweeping	0.20	3.61	0.023	0.020
Mending	0.83	14.88	0.093	0.083
Packing	4.55	81.52	0.515	0.455
SE diff	0.175	0.63	0.019	0.01
CD0.05	0.78	2.79	0.88	0.07

IV. DISCUSSION

Wood wastage in match industry is dependent on a number of machine, wood and human skill related factors. The back-end and front-end synchronization of machines with human skills and wood/splint/stick quality at different operational level sections is extremely important for holistic studies. However keeping in view the operational aspects, the present study was only focused to quantify the wood wastage at different sections of mechanized match manufacturing by not considering individual contributions of machines, wood handling at each level and human skills deployed at different levels. Number of machines and tools are used from harvesting of trees with saws and axes in forests/farms to their conversion into logs with cross cut saws, transportation to factories in lorries through manual or machine loading and unloading, machine and mechanical handling in log yards, manual or mechanical debarking in log yards, cross cutting logs in saw mills, making veneers in peeling lathes, making splints in chopping machines, transportation of splints and stick through conveyers/blowers, splint drying in dryers, splint polishing in polishing drums, splint charging and processing in charging machines, packing in box filling and packing section (Table-I and Fig.-I).

Wood wastage at the initial stage of its processing before chopping i.e., at debarking, saw mill and peeling section together is major and significant one. Poplar logs contain 10-12% bark (based on clone diversity) on weight basis and this portion is made up of dead and corky (non-woody) tissues with lot of tannins and other deposits and therefore is not suitable for making splints and many other wood based uses. This wastage is therefore beyond control and has to be a part of the cost in this product manufacturing process. Cross cutting logs into billets is made on circular saw mills which uses around 2 mm (equivalent of saw blade teeth) log length that is converted into saw dust. There is also a little scope of managing this wastage, through effective sawing of logs depends on tree species, clone (variety), moisture content and density of wood which are extremely difficult to control at wood procurement level. Three components at saw mill and peeling level viz., end cuts, peeling and centre core, could be managed with little efforts at wood procurement level. Length, thickness, circularity, straightness and taper of logs affect wood wastage and splint quality in match manufacturing (6). There are studies that thick and circular logs produce more veneers and splints and could only be procured for making match manufacturing. The preference of wood quality for this small wood product is so specific that basal tree logs with better wood quality produce better splints than those from top portion of tree stem (6). The average percentage of logs received in Bareily Match Factory has been recorded 42% logs between 45-60 cm mid girth and 58% over 60 cm mid girth (under-bark). The market price of thick log is high than thin logs and the industry tries to economize costs by adjustments made between wood procurement price and wood wastage in thick V/S. thin logs. The average splint charging in match bars is around 90-91% of the splints reached to this stage and hence it constitute the major share of wastage at splint processing.

Match sticks are the only wood component in match boxes, though inner and outer of boxes are made up of card board which is mainly made from trees. Match sticks are closely monitored for over a dozen quality parameters and there is a tolerance range for each traits over which the splints are considered defective and are rejected. Splint defects in match industry are broadly divided into two viz., wood related defects and process related defects. There have been reports of clone variation in anatomical features of wood (7, 8) that leads to variation in splint quality in match industry (9). There are even efforts to breed new clones specifically suitable for making match splints (10).

A large number of machines and operations affect wood use efficiency and process based splint processing. For example, in one of the main section of wood wastage *i. e*, peeling section, the efficiency depends on quality of peeling knife, position of pressure bar on peeling lathe and skill of the operator. Peeling knife has to be of good quality, timely sharpened, changed at least thrice a shift and is cleaned to remove the sap which deposits with dirt. A pressure bar applies pressure immediately above the knife edge and is meant to prevent splitting and cracking of the veneer surface. The correct setting of pressure bar is about one tenth of a mm above the knife edge. Operator needs to load billets by centering and peeling down as far as possible. Similarly, drier for drying the splints to 7-8% moisture content needs to have a continuous feeding of splints into the drier, have the conveyer speed and the splint layer thickness according to capacity need, adjust the dryer temperature, adjust the fan capacity (speed, number of fans used), regulate the moist air dampers and regulate the fresh air dampers. Heat supply is regulated by sensors and the moisture content of the air by dampers. For optimum functioning dryer needs to be cleaned and dust free, transport conveyor to be cleaned once in a week and also the heaters to be inspected and cleaned often.

Of the different wood wastage components, most of them find use as firewood and some are sold to other wood based industry. Wastage from bark, cut ends, peeling, chopping and subsequent operations in splint processing are normally used in the in-house boiler which generate energy for self consumption. Centre core which constitute 11.39 % of the total wood consumption is sometimes sold to paper units as pulpwood for manufacturing paper. This is also used as firewood when the prices for pulpwood in local markets are low and it becomes costly to transport the centre core to paper factory located around 200 km away. It is therefore inferred that there is no absolute wastage and all the left over wood and bark components in match manufacturing are used for firewood and/or pulpwood. The firewood price in the market is very low instead of matchwood and from wood consumption perspective, around 50% of the original costly wood get wasted and used as firewood. There are alternate sources of energy which could be considered for energy efficiency by improving wood use efficiency and be keeping wood wastage to the lowest possible extent. Wood wastage in relation to interaction between machines and wood; between wood and human skills and also between machines and human skills are also important as this sector deals with one of a very small and solid wood product (40 mm X 2 mm X 2 mm: length X thickness X width) in direct use. Some controls could be created for effective procurement of quality wood, developing human skills for effective human-machine-wood inter-phase in this low value but high volume wood based industry and therefore in reduction of wood wastage.

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