Chapter 3

Making Table M unted Circular Saw perati ns Safer in C nstructi n Industry: A Practical Appr ach

1 verview

In view of serious accidents in circular saw operations in civil engineering construction projects, the need for finding an effective and sustainable solution was felt While administrative control measures such as training of the operator, good housekeeping, professional supervision etc, makes positive influence in promoting accident prevention, they had limitations in achieving it effectively While exploring higher level of control measures, various engineering options were reviewed

As Circular saw is mainly used for cutting wood materials, including plywood for shuttering work, involving high level of precision such as crosscut, rip, and bevel cut etc the exposure of the operator with the high speed running blade becomes a possibility, unless effectively guarded Severe cuts and even amputations of upper extremities may occur in case the operator accidentally contacts the saw blade, moving at a very high speed Chances of injuries occurring are high when any blade is fully exposed during cutting operation Existing guards are not really effective due to technical limitations and not operator friendly, hence frequently removed from the equipment by the operator

Case study 1

A ply wood was placed on the table of a circular saw for cutting as per a specific design, in angular form The ply wood was being pushed in to the machine, while pressing the same on the table Operator missed to remove his hand from the material while the end portion of the plywood came in contact with the moving blade It resulted in thumb amputation

Case study 2

A small long piece of wood was being cut to make few wooden chisels which is supposed to be used for alignment of beam formwork As the length became shorter the worker's finger came in contact resulting in deep cut injury on the

2 Intr ducti n t research pr blem

Study of various types of existing guards on table mounted circular saw machines and related deficiencies were carried out Total thirty table mounted circular-saw machines were covered under this study at various construction site locations Those machines were classified in three types according to the type of guard provided on the same

It was found that existing guards poses various operational challenges including visibility All of these guards had restricted visibility of the cutting point as existing design of guards restricted vision of the operator – where operator may not be able to see the cutting points clearly in most situations

On detailed survey, the following reasons emerged for not using conventional circular saw guards:

- Overall arrangement of the guard is not user friendly
- Restricted visibility during operation
- Operational access to saw blade is hindered
- Frequent damage of hinges and fittings
- Difficulties in assessing the cutting operation

3 Restricti n t versatile perati ns when using c nventi nal saw guards:

Construction work is associated with various shapes of structures and to achieve the required form, various types and shapes of wooden material are required This requires handling of a wide range of wood material including full length ply wood to long logs The guards provided to a circular saw should be able to accommodate all sorts of varying shapes and sizes without creating hindrance Otherwise the operator might tend to remove the guard for operational convenience which is rarely re-fitted

International studies also highlights that more than 80% of accidents concerning circular saws related to injuries results in serious harm, are due to missing or poorly adjusted guards, or push sticks not being used

Most significant hazards associated with the circular saw operations are as given below:

- Entanglement from contact with blade
- Contact or impact from poor tooling
- Noise
- Dust
- Slips, trips & falls
- Contact or impact from unexpected movement (during maintenance, cleaning & repairs)

Table 31 highlights the potential harm associated with these hazards and its control measures

1 Potential harm associated with some hazards and their control measures			
Sl No	Hazards	Harm	Controls
1	Entanglement from contact with blade	▪ Serious injuries – amputation of fingers; bone fractures and deep cuts to hands and fingers	▪ Fixing adjustable hood guards to all benches, large enough to cover the blades, to prevent contact with blade and access underneath the machine table ▪ Push sticks for each machine (at least 300 mm long and pointed to grip the work piece) ▪ Steel riving knife to every circular saw ▪ Knives are securely mounted, have a smooth surface, slanting leading edge, and curved to the shape of the saw blade ▪ Extension tables and roller stands on the in-feed and out-feed sides to support larger work pieces
2	Contact or impact from poor tooling	▪ Bruises ▪ Fractures	▪ Tools safely maintained ▪ Marking tools with their maximum rotational speed ▪ Any woodworking machines should have a braking device fitted ▪ Retro-fit older machines with a braking device where possible ▪ Isolate saws to minimize the chance of a person being hit by timber
3	Noise	▪ Hearing damage or ▪ Loss	▪ Reduce noise levels by isolating machines or enclosing within noise barriers ▪ Monitor noise levels ▪ Always wear hearing protection
4	Dust	▪ Eye irritation or damage ▪ Breathing problems, lung damage or cancer ▪ Worsening of existing ▪ health problems	▪ Dust extraction equipment to minimize dust getting in the operator's breathing zone ▪ Using respiratory protection ▪ Eye protection
5	Slips, trips & falls	▪ Trapping ▪ Cuts ▪ Bruising	▪ Regular housekeeping ▪ Area around saws clear of slip and trip hazards
6	Contact or impact from unexpected movement (during maintenance, cleaning & repairs)	▪ Bruising ▪ Fractures	▪ Lock-out / Tag-out all power supplies before maintenance, cleaning or repairs ▪ Ensure regular maintenance and testing, in accordance with the original manufacturer's specifications

In view of the hazards and serious consequences as narrated above, it is required to mitigate the risks through effective and sustainable control measures While administrative control measures such as training of the operators, safety inspection, audit etc could be applied for reducing risk potential, implementation of effective engineering controls measures could be the best option, in this case However, engineering interventions need to be effective in terms of versatility accommodating diverse functional requirements of the job In this paper our focus of research is on exploring most suitable and effective guarding arrangements for table mounted circular saw machine deployed for wood cutting operations at construction sites

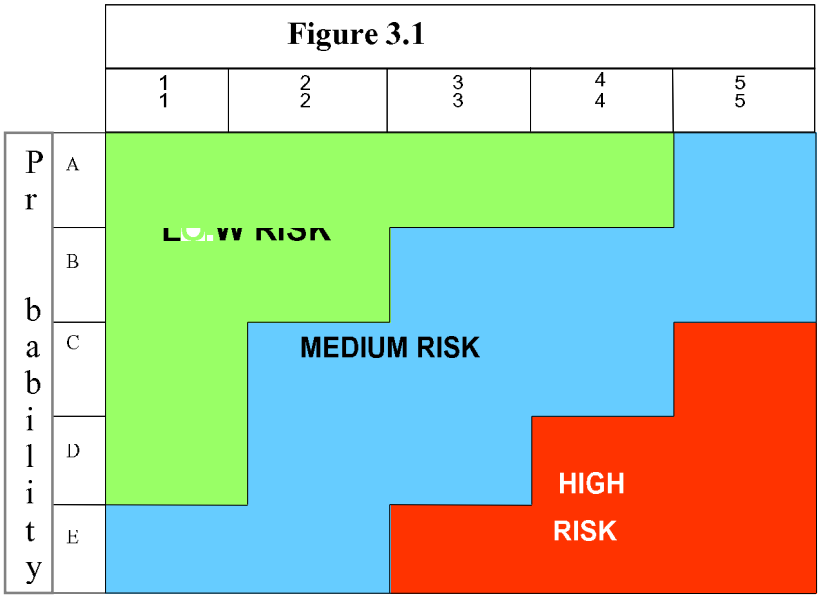
Important step towards evaluation of risk in various types of circular saw machine is done through Hazard identification and risk assessments (HIRA)

According to the hazards at various stages of operation risk are evaluated for its probability of occurrence as well as severity of consequence In order to bring down the risk to acceptable level, additional control measures are be implemented While doing so, hierarchy of control is followed through the following preferred sequence: Elimination, Substitution, Engineering Control, Administrative control and usage of PPE Table given below provide the detail on risk matrix associated with the same

Table 2 Impact Description (The highest category will be used)		
Value	Description	Result of Hazard to Assets/ Progress
5	Single or multiple fatality	Catastrophic Damages, Critical Delay
4	Serious injury requiring hospitalization	Major Damages, Serious Delay
3	Lost Time Accident	Serious Damage, Moderate Delay
2	Injury requiring Medical treatment but not lost time	Moderate Damage ,Minor Delay
1	First Aid treatment only	Minor Damage, No Delay

Table 3.3 : Pr bability Descripti n (The highest categ ry will be used)		
Value	Status	Descripti n
E	Inevitable	Happens regularly n this site
D	M st likely	Kn wn t have ccurred n this site in the past
C	Likely	Kn wn t ccur n ther sites
B	Unlikely	Kn wn t ccur in the Industry
A	M st Unlikely	Min r Damage, N Delay

Figure 3.1



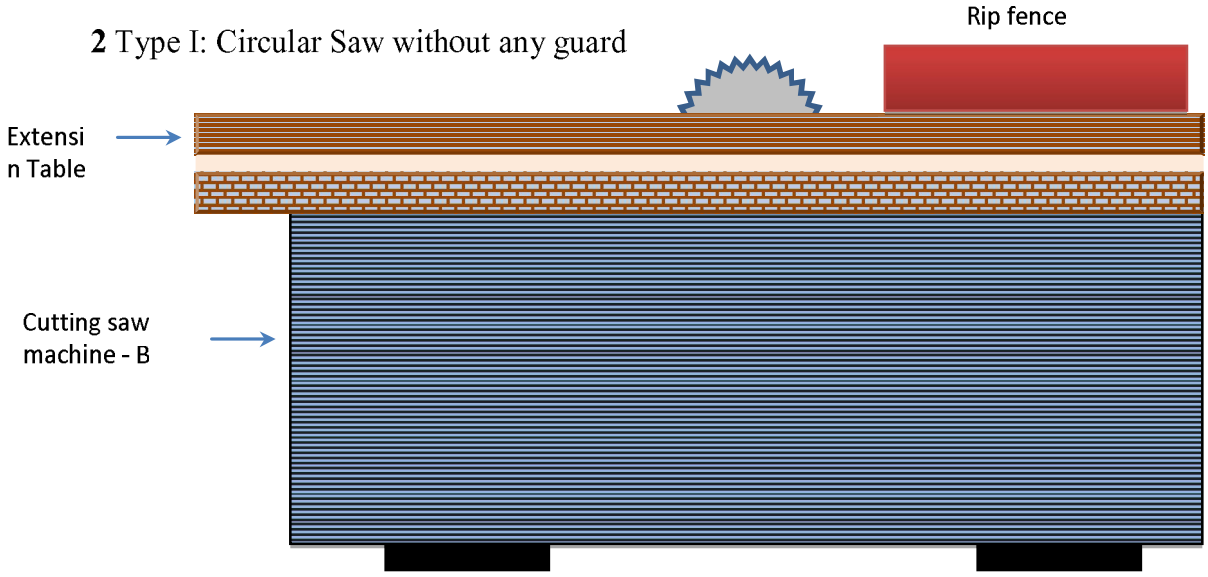
A typical HIRA for woodcutting operation using table mounted circular saw is given below in the table 34

Hazard Identification and Risk Assessment for Wood Cutting Operations

Sl No	Sub Activity	R / NR / E / L	Hazard	Risk	Existing Control Measures (As per company defined procedure)	Risk considering existing control measures			Additional Control Measures to bring Risk to ALARP Level (A-Elimination, B-Substitution, C-Engineering, D-Signage /Warning/ Administrative, E- PPEs usage)	Residual Risk After applying Additional Control Measures		
						Impact Rating	Pr bability Rating	Risk Level		Impact Rating	Pr bability Rating	Risk Level
1	Woodcutting	R	Physical	Injuries	Guarding for circular saw	2	C	Medium	Supervision	2	B	Low
2	Woodcutting	R	Physical	Injuries	Riving knife	2	C	Medium	Supervision	2	B	Low
3	Woodcutting	R	Physical	Injuries	Braking device to bring the blade to rest	2	C	Medium	Supervision	2	B	Low

4 Vari us types f guarding arrangements & Features:

2 Type I: Circular Saw without any guard



Descripti n f guarding

3. Guard not provided
4. Guard provided but removed by the user

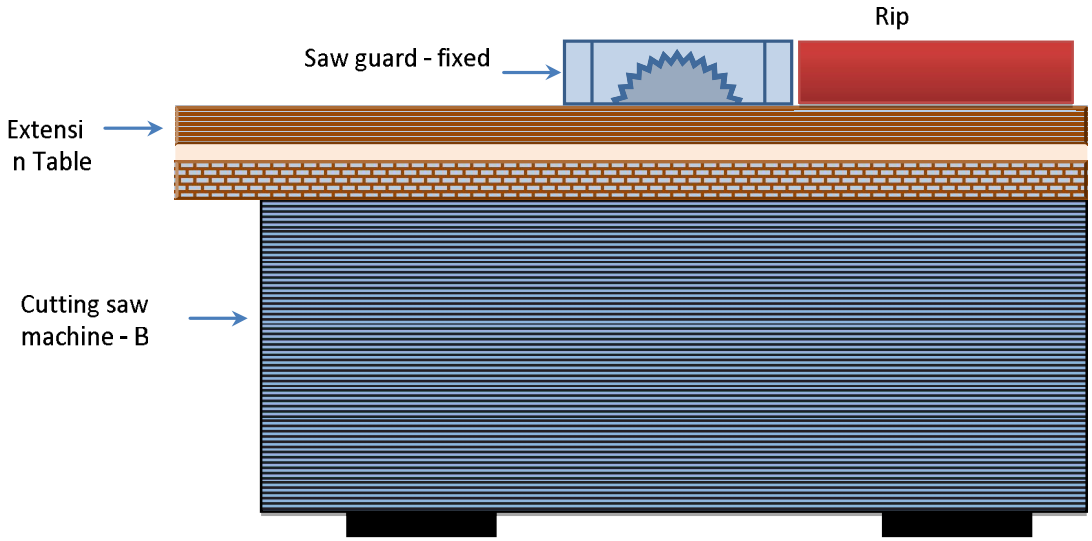
Features

5. Ease of operation, can handle various jobs without hindrance
6. Chances of kickback is high
7. No containment of generated saw dust resulting in poor housekeeping and
8. Increased exposure to wood dust particles causing health hazards

Hazard Identification and Risk Assessment for Wood Cutting Operations

Table 5 Type I - Circular Saw without any guard

Sl No	Sub Activity	R / NR / E / L	Hazard	Risk	Existing Control Measures (As per company defined procedure)	Risk considering existing control measures			Additional Control Measures to bring Risk to ALARP Level (A-Elimination, B-Substitution, C-Engineering, D-Signage /Warning/ Administrative, E- PPEs usage)	Residual Risk After applying Additional Control Measures		
						Impact Rating	Pr bability Rating	Risk Level		Impact Rating	Pr bability Rating	Risk Level
1	Wood cutting	R	Physical	Injuries	Guarding for circular saw	4	D	High	Not Implemented	4	D	High



F **3** Type II: Fixed type saw guard made of steel plate

Descripti n f guarding

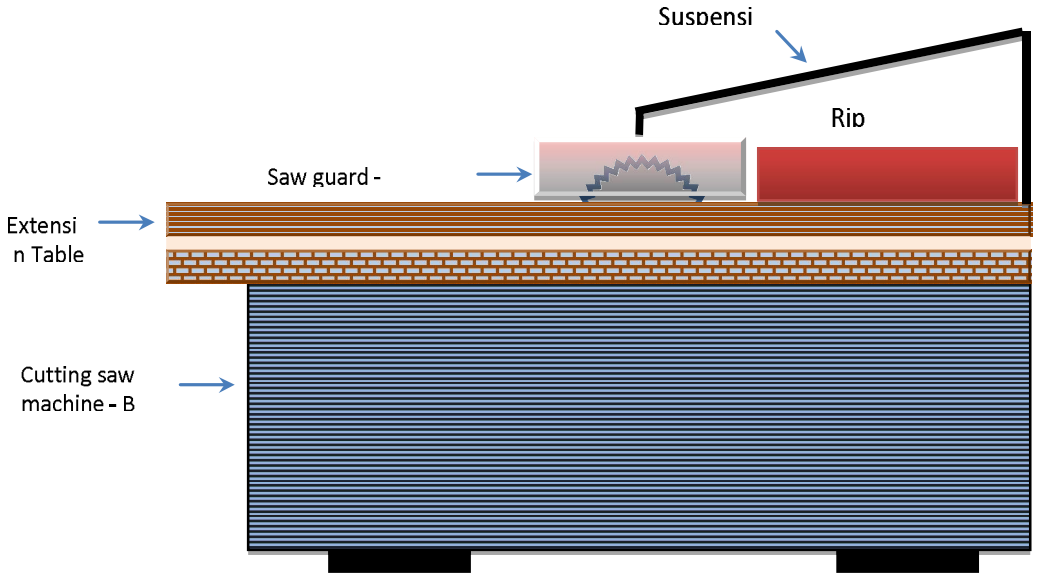
- Fixed guard, limited adjustment
- Metallic guard made of 2 mm steel plate
- Rip fence

Features

- Obstruction caused by the guard blocking visibility
- Chances of kickback is very high
- Ergonomic deficiencies
- Frequent removal of the guard by the operator

Table 6 Type II- Fixed type saw guard made of steel plate

Sl No	Sub Activity	R / NR / E / L	Hazard	Risk	Existing Control Measures (As per company defined procedure)	Risk considering existing control measures			Additional Control Measures to bring Risk to ALARP Level (A-Elimination, B-Substitution, C-Engineering, D-Signage /Warning/ Administrative, E- PPEs usage)	Residual Risk After applying Additional Control Measures		
						Impact Rating	Probability Rating	Risk Level		Impact Rating	Probability Rating	Risk Level
1	Wood cutting	R	Physical	Injuries	Guarding for circular saw	4	D	High	Inspection & Training	4	D	High
		R	Ergonomic - Vicinity	Injuries	-	4	D	High	Inspection & Training	4	D	High



Type III: Suspended saw guard made of steel plate

Descripti n f guarding

- Metallic guard made of 2 mm steel plate
- Suspension arrangement made of 20 mm mild steel rod to hold the saw guard
- Rip fence

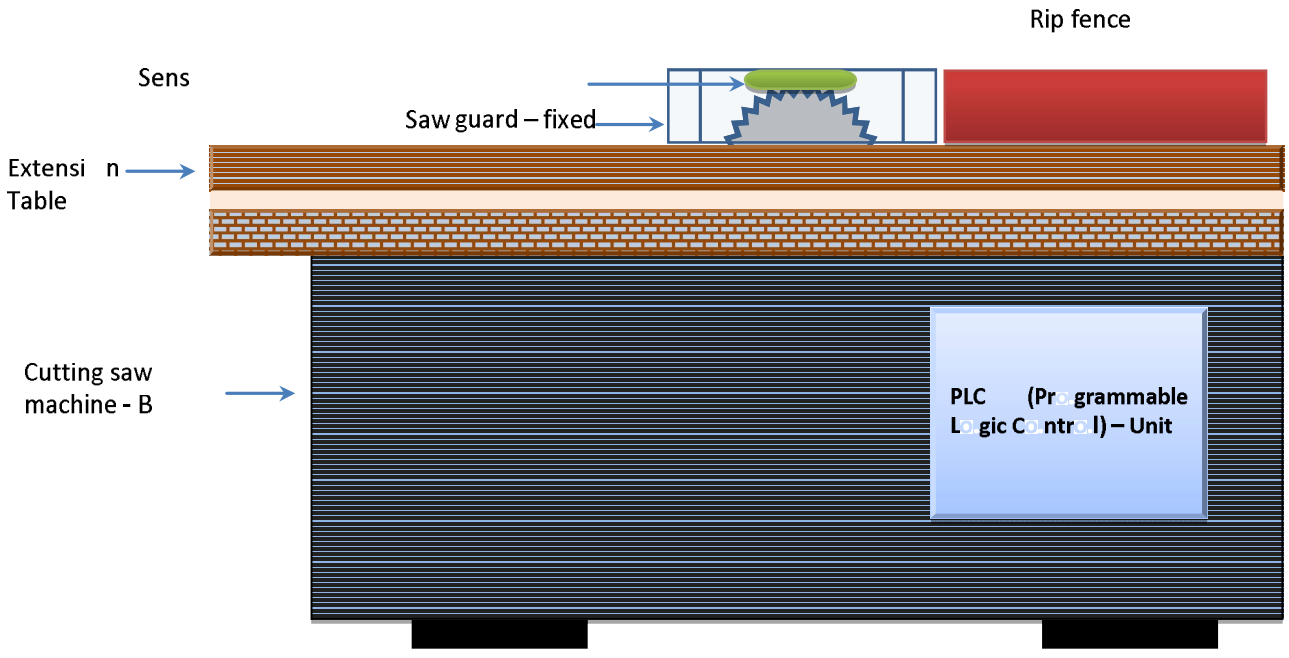
Features

- Obstruction caused by the guard blocking visibility
- Chances of kickback reduced
- Ergonomic compliance improved

- Suspension arrangements using rod was hindering the work place
- Frequent removal of the guard by the operator
- Though wasn't unsafe, the set up doesn't cater with requirements of workplace

Table 7 Type III - Suspended saw guard made of steel plate

Sl No	Sub Activity	R / NR / E / L	Hazard	Risk	Existing Control Measures (As per company defined procedure)	Risk considering existing control measures			Additional Control Measures to bring Risk to ALARP Level (A-Elimination, B-Substitution, C-Engineering, D-Signage /Warning/ Administrative, E- PPEs usage)	Residual Risk After applying Additional Control Measures		
						Impact Rating	Pr bability Rating	Risk Level		Impact Rating	Pr bability Rating	Risk Level
1	Wood cutting	R	Physical	Injuries	Suspended guarding	4	D	High	Inspection & Training	4	D	High
		R	Ergonomic - Vicinity	Injuries	Suspended guarding	4	D	High	Inspection & Training	3	D	Medium



Type IV: Saw guard with integrated sensor

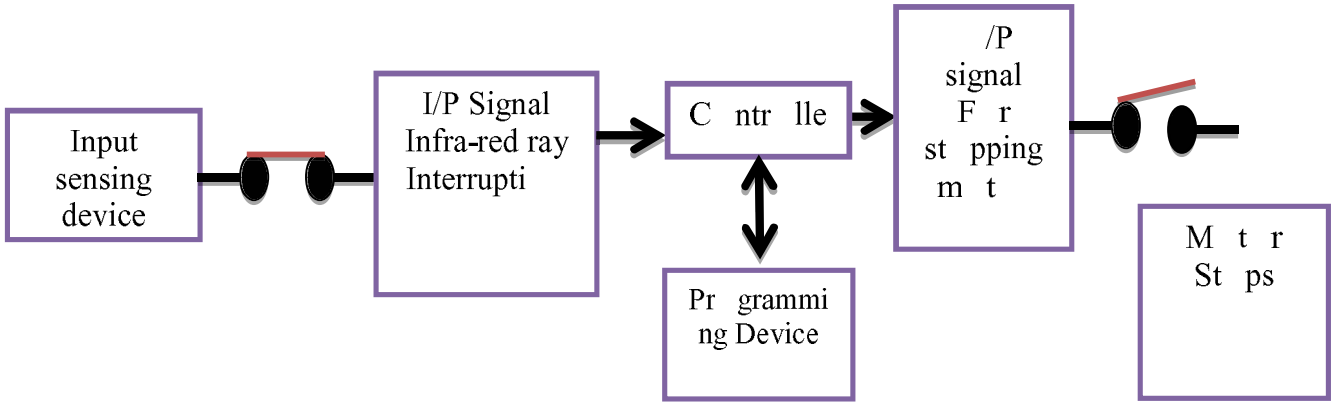
Descripti n f guarding

- Metallic guard made of 2 mm steel plate
- Acrylic Sensor with inbuilt : Infra-red (IR) rays
- Infra-red rays signal linked to PLC
- PLC cuts motor if IR signal gets interrupted

Features

- Aspect of vicinity while cutting was improved
- Chances of Kickback reduced
- Ergonomically convenient
- Since the tip of cutting saw had an infra-red sensor, any accidental disturbance to the signal cuts the machine operation frequently
- Though wasn't unsafe, the set up doesn't cater with requirements of workplace

Programmable Logic Control: Emitter is provided just above the tip of circular saw which emits infra-red rays When the same gets interrupted by any object the logic controller sends output signal to stop electric supply to the motor and subsequently the entire equipment stops functioning



6 Flowchart for automatic sensor based guard

Table 8 HIRA for Type IV- Saw guard with integrated sensor

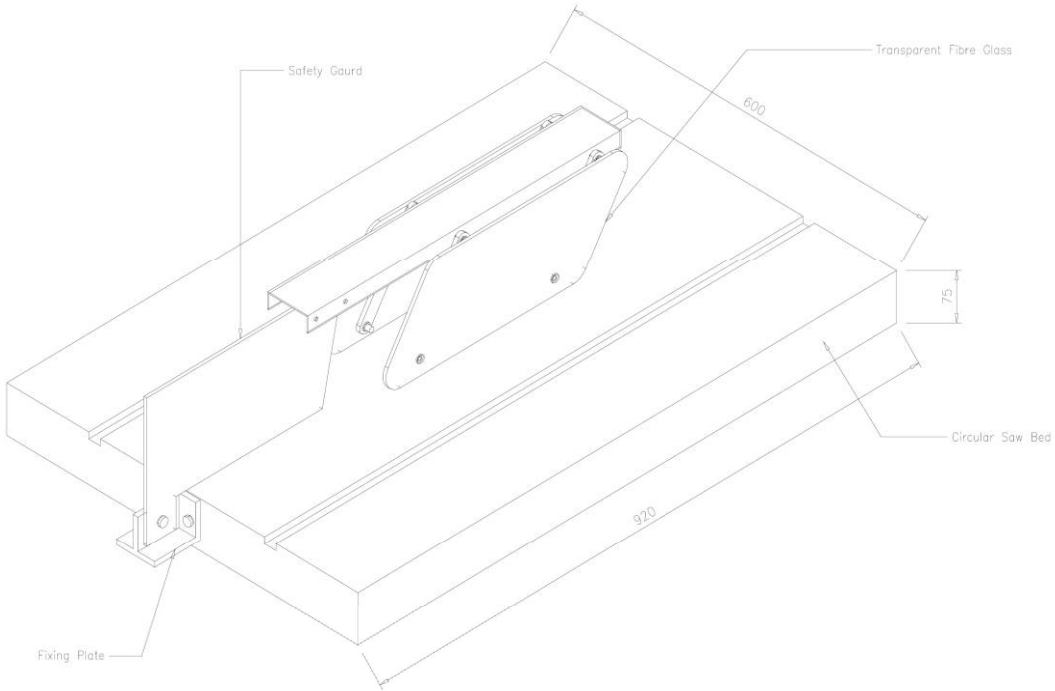
Sl No	Sub Activity	R / NR / E / L	Hazard	Risk	Existing Control Measures (As per company defined procedure)	Risk considering existing control measures			Additional Control Measures to bring Risk to ALARP Level (A-Elimination, B-Substitution, C-Engineering, D-Signage /Warning/ Administrative, E- PPEs usage)	Residual Risk After applying Additional Control Measures		
						Impact Rating	Pr bability Rating	Risk Level		Impact Rating	Pr bability Rating	Risk Level
1	Wood cutting	R	Physical	Injuries	Acrylic guarding with sensor	2	C	Medium	Inspection & Training	2	C	Medium
		R	Ergonomic - Vicinity	Injuries	Acrylic Guard	2	C	Medium	Inspection & Training	2	C	Medium

Considering the findings of various conventional models (Type I to III) and improvised model (Type IV), further improvement in the configuration of the circular guard was felt required Subsequently the new design was developed While developing the new circular saw guard, the following factors were considered

- Arrangement for fixing it on the table (**213(a)(6)**)
- Slide in grooves or tracks that are accurately machined (**213(a)(7)**)
- Hinged saw tables with true-alignment with saw(**213(a)(8)**)
- Covering the possibility of contact of saw either beneath / behind the table(**213(a)(12)**)
- Vicinity of blade

Type V: Circular saw guard with flap type acrylic material

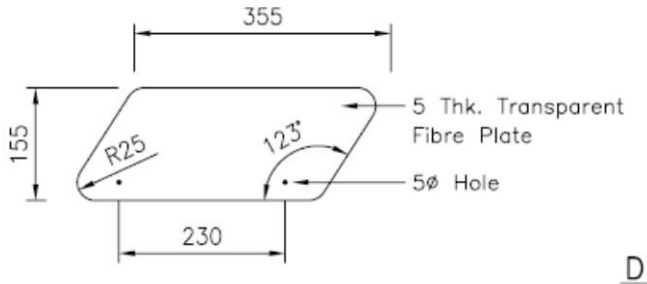
Finally, acrylic guard is developed in-house which is connected with the rip fence eliminating various deficiencies experienced in previous models Refer figure 37



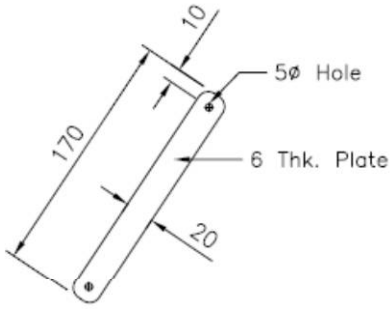
Type V: Circular saw guard with flap type acrylic material

Table 9 Type V - Circular saw guard with flap type acrylic material

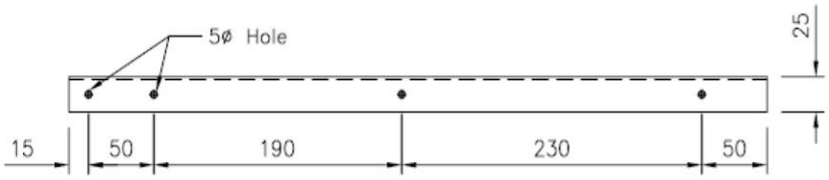
Sl No	Sub Activity	R / NR / E / L	Hazard	Risk	Existing Control Measures (As per company defined procedure)	Risk considering existing control measures			Additional Control Measures to bring Risk to ALARP Level (A-Elimination, B-Substitution, C-Engineering, D-Signage /Warning/ Administrative, E- PPEs usage)	Residual Risk After applying Additional Control Measures		
						Impact Rating	Probability Rating	Risk Level		Impact Rating	Probability Rating	Risk Level
1	Woodcutting	R	Physical	Injuries	Acrylic guarding with sensor	2	B	Low	Inspection & Training	2	B	Low
		R	Ergonomic - Vicinity	Injuries	Acrylic Guard	2	B	Low	Inspection & Training	2	B	Low



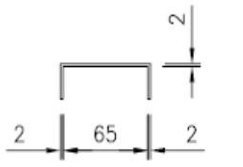
DETAIL OF ITEM NO.3



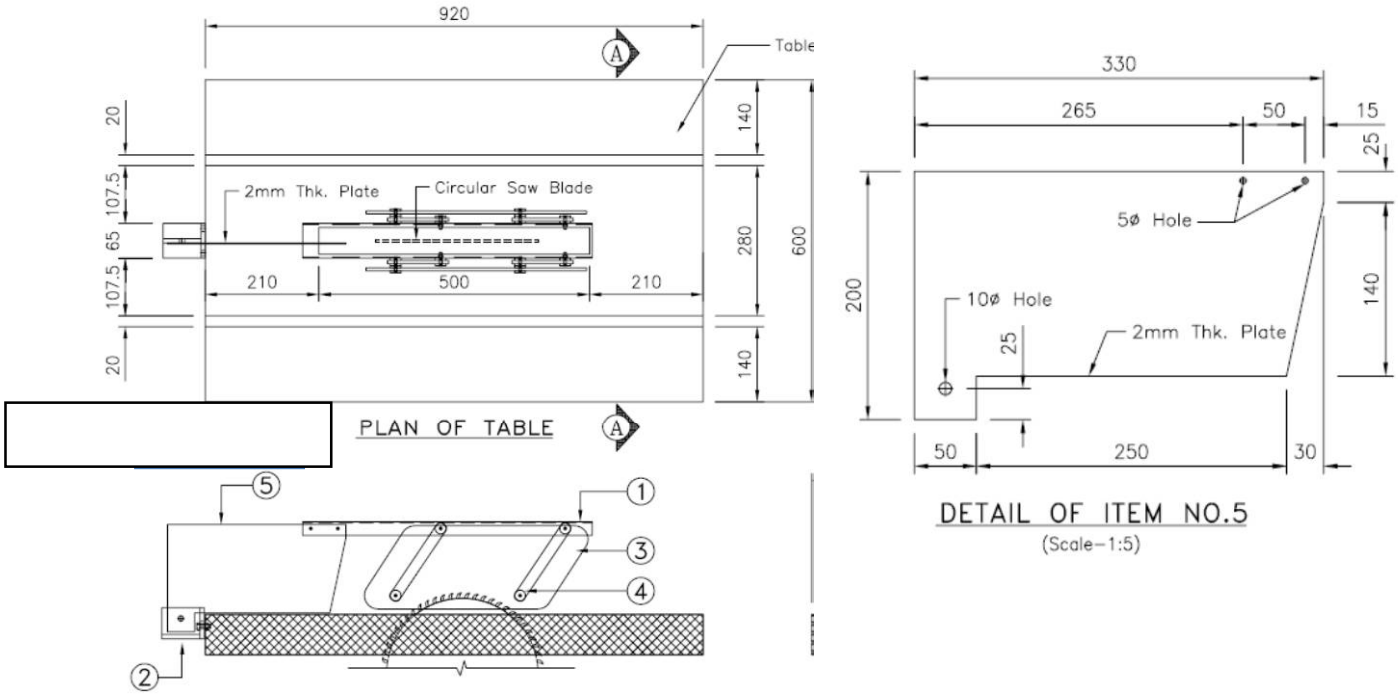
DETAIL OF ITEM NO.4
(Scale–1:5)



DETAIL OF ITEM NO.1
(Scale–1:5)



CROSS SECTION



Details of various components of guard

Distribution of incidents associated with various type of guards on circular saw machine is as indicated in Table 310

10 Distribution of incidents associated with various type of guards

Descripti n	Injury Causatives				perati nal feedback fr m perat rs n ease f perati n
	Near miss fr m C ntact with blade	C ntact with blade	Near miss fr m Kick back	Injury due t Kick back	
Type I: Circular Saw without any guard n=215	**60%**	**8%**	**7%**	**3%**	▪ Visibility of the job during cutting operation is satisfactory (73%)
Type II: Fixed type saw guard made of steel plate n=27	**9%**	**7%**	**3%**	**37%**	▪ Visibility is blocked during cutting operation hence we remove the guards while operation (62%)
Type III: Suspended saw guard made of steel plate n=31	**3%**	**4%**	**9%**	**2%**	▪ Suspension arrangements hindering (59%) ▪ Visibility during cutting operations get restricted (28%) ▪ Hinging arrangement frequently gets damaged and needs to be regularly maintained (13%)
Type IV: Saw guard with integrated sensor	**Data N t Available**				▪ Sensors are hindering the cutting operation (72%)
Type V: Circular saw guard with flap type acrylic material n=23	**Nil**	**Nil**	**7%**	**2%**	▪ Visibility is very good (61%) ▪ Acrylic material needs replacement after prolonged operations (22%)

From the above details we infer that Type 5 is considerably safe in operations as well as perceived as a better option by the operators as given in another picture below

Photo of Type V circular saw guard

Checklist to identify checkpoints of circular saw machines

Sl No	Description	Status (Ok / Not Ok)	Remarks
1	Is the machine stable and unlikely to move during operation		
2	Are the machine guards installed and functioning correctly		
3	Are push sticks available and used to move the timber through the saw		
4	Are the operating controls easily accessible to the operator		
5	Do the operating controls prevent accidental start-up?		
6	Are the control functions clearly marked		
7	Hinged saw tables with true-alignment with saw		
8	Visibility of circular blade		
9	Are the transmission drive and other moving parts totally enclosed or guarded		
10	Are there systems in place for the machine to be isolated		
11	Is there an appropriate emergency stop which is easily accessible and labelled?		
12	Is there a clear work space around the machine?		
13	Is the illumination adequate		
14	Are sharp and well maintained blades used to reduce noise level		
15	Is the floor area regularly cleaned, and all off-cuts and other debris removed		

5 Result and Discussi ns related t circular saw guards

Study of circular saw without guard and two with conventional type guards were initially studied Then two modified type of circular saw guards with better visibility and protection for operators were evaluated to ensure that while operating the circular saw machine, improvement safety as well as cutting operation is achieved During the process, productivity and operational were kept in mind During the development of guard focus was on providing better visibility for cutting operation which is the main aspects associated with prevention of kickbacks

Summary of inference derived from hazard identification and risk assessment (HIRA) of wood cutting operation using table mounted circular saw machine with different types of guards is given below in table 13

Table 13 Summary of Hazard Identification of Risk Assessments : Wood cutting operations with various types of guards

Type of guards	Risk Matrix						Remarks
Type I: Circular Saw without any guard	**High**	✓	**Medium**		**Low**		Non guarded and high potential for cut injuries
Type II: Fixed type saw guard made of steel plate	**High**	✓	**Medium**		**Low**		Hinders cutting operation Guard being removed for convenience and has high injury potential
Type III: Suspended saw guard made of steel plate	**High**	✓	**Medium**		**Low**		Visibility slightly improved Suspended arrangements hinders cutting arrangement Has cut injury potential
Type IV: Saw guard with integrated sensor	**High**		**Medium**	✓	**Low**		Visibility improved through acrylic guard Infra-red sensors to stop motor Hinders job frequently
Type V: Circular saw guard with flap type acrylic material	**High**		**Medium**		**Low**	✓	Flap type acrylic guard Doesn't hinders cutting operation Improved visibility Safe operation

Type V guard of circular saw is made of acrylic material is good for high visibility of the blade and cutting process, however, it require replacement after prolonged usage due to the impact of saw dust / wooden chips on surface of the

guard In fact, over period of time the visibility get reduced due to scratches caused by flying saw dust Depending on the type of hardness of the wood being processed, longevity of the guard gets decided