MACHINE GUARDING – TO IMPROVE SAFETY CULTURE DRIVINGMACHINE SAFETY

N.Panneerselvam*[1], P. Vignesh [2]

[*1]Associate Professor, Department of Mechanical Engineering, Knowledge Institute of Technology, Salem. Tamil Nadu, India. 637 504

[2]PG Scholar, Department of Industrial Safety Engineering, Knowledge Institute of Technology, Salem, Tamil Nadu, India. 637 504

ABSTRACT

Bypassing guards and protective devices on machinery can lead to serious and fatal accidents. Some of the most frequent incentives included the necessity to remove safeguards to perform activities (e.g. adjustment, troubleshooting, maintenance, and installation), a lack of visibility, failures, and a lack of reliability of the safeguards. This journal analysis suggests classifying the incentives into five categories: ergonomics, productivity, machine or safeguarding, behavior, and corporate climate. The solutions, which are related tothe design, manufacturing, and usage phases, are classified into technical, organizational, and individual factors. These are all factors that influence the prevention of bypassing. All the machines in the industry premises were assessed mechanically, electrically and in terms of environmental aspects. The factors including safety switches such as limit switches and interlocks were also assessed for all the machines. Hazards of each machine were identified at the end of the assessment. The identifies hazards are eliminatedby providing machine guards and training the workers to avoid bypassing the safety sensors, switches and interlocking devices which have potential to cause high risk accidents.

Keywords: **Safeguard, bypass, switches, sensors, interlocking devices.**

1. Introduction

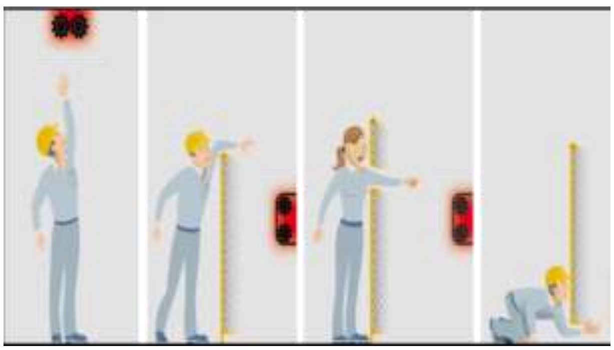
When machine-related mechanical hazards cannot be eliminated through inherently safe design, they must then be reduced to an acceptable level, or the hazards that cause them must be isolated from the workers by guards that allow the minimum safety distances to be respected.

Most of the risks related to mechanical hazards can be reduced to acceptable forces orenergy levels by applying a risk reduction strategy (see Figure 1). If this is impossible, the hazards must be isolated from people by guards that maintain a safety distance betweenthe danger zone and the people, with the main result being to reduce access to the dangerzone. The main factors to be taken into consideration so that guards are effective are:

- the accessibility to the danger zone by the different parts of the human body
- the anthropometric dimensions of the different parts of the human body
- the dimensions of the danger zones as well as their position in space and in relation to the ground or the working platform.

The general risk-reduction principles, the protection principle involving guards, and crushing hazards are also discussed. Finally, protection against some specific hazards, such as risks of entanglement or being drawn into in-running nips. The different situations in which the distance protection principle applies are then discussed.

- Is the danger zone, which is locatedabove, accessible from below
- Is the danger zone accessible fromabove the guard
- Is the danger zone accessible throughone of the openings in the guard
- Is the danger zone accessible frombelow the guard



2. Definitions of the terms used in this report:

Risk Analysis:

- Combination of the determination ofthe limits of the machine, hazard determination (also called identification), and risk estimation

In Running Nip or Convergence Zone:

- Danger points at the rollers, reels, cylinders or drums whose movement creates a narrowing and are the cause of a risk of parts of the body or the whole body being drawn in between two rollers, power-operated or not, turning in opposite directions; a turning roller and a stationary component of the machine;
- Rollers turning in the same direction or conveyor belts moving in the same direction and with different velocities or surfaces (friction); one roller and transmission belts, a conveyor, and potentially, a sheet of material
- There are also convergence zones on the non-powered rollers (guiding rollers) driven by the sheet ofmaterial. The risk level can be related to different factors such as the typeand strength of the material, the winding angle, and the velocity of the sheet of material and the moment of inertia.

Risk assessment:

- Overall risk analysis and risk evaluation process.

Protective device:

- Means of protection other than a guard.

Harm:

- Physical injury or damage to health.

Risk estimation:

- Definition of the probable severity of harm and the probability of this harm.

Interlocking guard:

- Guard associated with an interlocking device and a guard locking device in order to ensure, with the machine's control system, the machine's hazardous functions that are protected by the guard cannot operate until the guard is closed and locked.
- The guard remains closed and locked until the risk attributable to the machine's hazardous functions that are protected by the guard has passed.
- When the guard is closed and locked, the hazardous functions that are protected by the guard can operate. Closing and locking of the guard do

not themselves initiate the machine's hazardous functions

Safeguarding:

- Prevention measures using safeguards to protect the workers from the hazards that cannot be reasonably eliminated or risks that cannot be sufficiently reduced by applying inherently safe design measures.

Risk:

- Combination of the probability ofharm and the severity of this harm.

Hazardous situation:

- Situation in which a worker is exposedto at least one hazard. Exposure to this or these hazards can lead to harm, immediately or over the longer term.

3.Integrated manufacturing system:

- Group of machines operating together in a coordinated way, connected by a material handling system, and interconnected by actuators (namely controls), for the purpose of manufacturing, processing, moving or conditioning different components or assemblies.

Intended use of a machine:
Use of a machine according to the information in the operating instructions.

Problem Identification

Moving machine parts have the potential to cause severe workplace injuries, such as crushed fingers or hands, amputations, burns,or blindness. Amputations, lacerations, and abrasions are costly and have the potential to increase workers compensation premiums.

Amputation is one of the most severe and crippling types of injuries in the occupational workplace, often resulting in permanent disability. Due to this fact, OSHA (Occupational Safety & Health Administration) has established a set of standards around machine guarding. The purpose of machine guarding is to protect the machine operator and other employees in the work area from hazards created during the machine's normal operation. This would include hazards of concern such as: ingoing nip points, rotating parts, reciprocating, and flying chips & sparks.

Any machine part, function, or process that might cause injury must be safeguarded. When the operation of a machine or accidentalcontact with it could injure the operator or others in the vicinity, the hazards must be either controlled or eliminated

4. Mechanical Hazards Occur:

Dangerous moving parts in three basic areas require safeguarding:

The point of operation: that point where work is performed on the material, such as cutting, shaping, boring, or forming of stock.

Power transmission apparatus: all components of the mechanical system which transmitenergy to the part of the machine performing the work. These components include flywheels, pulleys, belts, connecting rods, couplings, cams, spindles, chains, cranks, and gears.

Other moving parts: all parts of the machine which moves while the machine is working. These can include reciprocating, rotating, and transverse moving parts, as well as feed mechanisms and auxiliary parts of the machine.

5.Hazardous Mechanical Motions and Actions:

A wide variety of mechanical motions and actions may present hazards to the worker. These can include the movement of rotating members, reciprocating arms, moving belts, meshing gears, cutting teeth, and any parts that impact or shear. These different types of hazardous mechanical motions and actions are basic in varying combinations to nearly all machines, and recognizing them is the first step toward protecting workers from the danger they present

The basic types of hazardous mechanical motions and actions are:

Motions

a. rotating (including in-running nip points)
b. reciprocating

Actions

a. cutting
b. punching
c. shearing
d. bending

5.1 Motion:

Rotating motion can be dangerous: even smooth, slowly rotating shafts can grip clothing, and through mere skin contact force an arm or hand into a dangerous position. Injuries due to contact with rotating parts can be severe.

Collars, couplings, cams, clutches, flywheels, shaft ends, spindles, meshing gears, and horizontal or vertical shafting are some examples of common rotating mechanisms which may be hazardous. The danger increases when projections such as set screws, bolts, nicks, abrasions, and projecting keys or set screws are exposed on rotating parts.

In-running nip point hazards are caused by the rotating parts on machinery. There are three main types of in-running nips. Parts can rotate in opposite directions while their axes are parallel to each other. These parts may be in contact (producing a nip point) or in close proximity. In the latter case the stock fed between the rolls produces the nip points. This danger is common on machines with intermeshing gears, rolling mills

Nip points are also created between rotating and tangentially moving parts. Some examples would be: the point of contact between a power transmission belt and its pulley, a chain and a sprocket, and a rack and pinion. Nip points can occur between rotating and fixed parts which create a shearing, crushing, or abrading action. Examples are spoked hand wheels or flywheels, screw conveyors, or the periphery ofan abrasive wheel and an incorrectly adjusted work rest.

Reciprocating motions may be hazardous because, during the back-and-forth or up-and-down motion, a worker may be struck by or caught between a moving and a stationary part.

Transverse motion (movement in a straight, continuous line) creates a hazard because a worker may be struck or caught in a pinch or shear point by the moving part.

5.2 Action:

Cutting action may involve rotating, reciprocating, or transverse motion. The danger of cutting action exists at the point of operation where finger, arm and body injuries can occur and where flying chips or scrap material can strike the head, particularly in the eyes or face. Such hazards are present at the point of operation in cutting wood, metal, or other materials.

Examples of mechanisms involving cutting hazards include band saws, circular saws, boring or drilling machines, turning machines (lathes), or milling machines.

Punching action results when power is applied to a slide (ram) for the purpose of blanking, drawing, or stamping metal or other materials. The danger of this type of action occurs at the point of operation where stock is inserted, held, and withdrawn by hand.

Typical machines used for punching operations are power presses and iron workers. Shearing action involves applying power to a slide or knife to trim or shear metal or other materials. A hazard occurs at the point of operation where stock is inserted, held, and withdrawn.

Examples of machines used for shearing operations are mechanical hydraulically, or pneumatically powered shears. Bending action results when power is applied to a slide to draw or stamp metal or other materials. A hazard occurs at the point of operation where stock is inserted, held, and withdrawn. Equipment that uses bending action includes power presses, press brakes, and tubing benders.

5.3 Non Mechanical Hazards:

All power sources for machines are potential sources of danger. When using electrically powered or controlled machines, for instance, the equipment as well as the electrical system itself must be properly grounded. Replacing frayed, exposed, or old wiring will also help to protect the operator and others from electrical shocks or electrocution. High pressure systems, too, need careful inspection and maintenance to prevent possible failure from pulsation, vibration, or leaks. Such a failure could cause, among other things, explosions or flying objects.

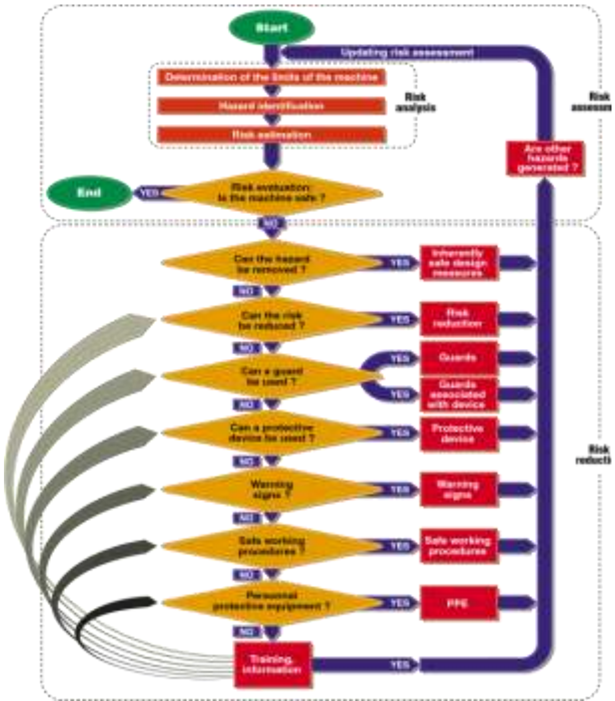
Machines often produce noise (unwanted sound) which can result in several hazards to workers. Noise can startle and disrupt concentration, and can interfere with communications, thus hindering the worker's safe job performance. Research has linked noise to a whole range of harmful health effects, from hearing loss and aural pain to nausea, fatigue, reduced muscle control, andemotional disturbance. Engineering controls such as the use of sound-dampening materials, and personal protective equipment, such as ear plugs and muffs, can help control the harmful effects of noise. Also, administrative controls that involve removing the worker from the noise source can be an effective measure when feasible.

Because some machines require the use of cutting fluids, coolants, and other potentially harmful substances, operators, maintenance workers, and others in the vicinity may need protection. These substances can cause ailments ranging from dermatitis to serious illnesses and disease. Specially constructed safeguards, ventilation, and protective equipment and clothing are possible temporary solutions to the problem of machinery-related chemical hazards until these hazards can be better controlled or eliminated from the workplace.

5.4 HAZARD IDENTIFICATION

Hazard identification involves two major steps namely:

a. Risk assessment and
b. Risk reduction



5.5 Risk assessment:

In general, any improvement to a machine's safety begins with a risk assessment. This operation includes a risk analysis, followed by risk evaluation.

5.6 Risk analysis:

A risk analysis has three steps namely

a. Determining the limits of machine
b. Determining (identifying) the hazard
c. Estimating the risk

5.7 Determining the limits of machine:

The very first step in the risk management process involves establishing the limits of the risk assessment. At the end of this step, you must be able to describe the conditions in which the machine will be used: who will use the machine, for how long, with what materials, etc. The machine's life cycle (design, installation, use unjamming, maintenance, and disposal), foreseeable uses, and the users' expected level of experience are also established. Only once these conditions have been determined can hazard identification and risk estimation

5.8 Determining the hazard:

Hazards are the cause of all hazardous situations. When exposed to a hazard, aworker is in a hazardous situation, and theoccurrence of a hazardous event leads to an accident that can result in harm.

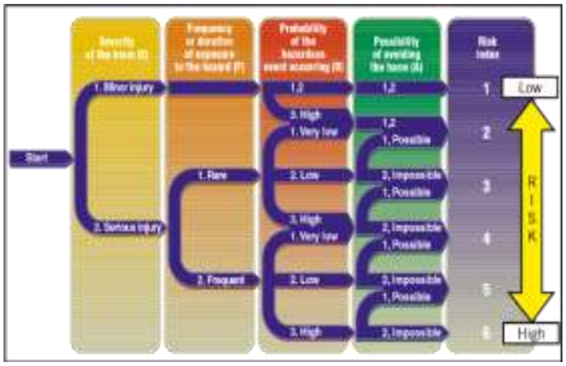
Hazard identification is one of the most important steps in the risk management process. The list of hazards must be carefully established. A list of all the energy sources or all the man-machine interfaces that can affect the health and safety of exposed workers must be carefully established, whether they are moving elements (mechanical hazard), electrified components (electrical hazard), machine components that are too hot or too cold (thermal hazard), noise, vibration, visible (laser) or invisible radiation (electromagnetic), hazardous materials or awkward postures (ergonomic hazard). These hazards are then linked to the hazardous situations to which the workers are exposed.

5.9 Estimating the risk:

Risk estimation consists of comparing the different hazardous situations identified. This relative comparison establishes an action priority, for example the probability of occurrence

a. The frequency and duration of exposure to the hazard **(F)**
b. The probability of a hazardous event occurring **(O)**
c. The possibility of avoiding or reducing the harm **(A)**

To make this estimation easier, a risk index can be defined for each hazardous situation. Document proposes a range of values to be associated with the components of the risk. Once the ranges of values have been defined, risk estimation tools can be used. These can be graphical tools, matrix tools, etc.



The severity of the harm can be estimated by considering the severity of the injuries or adverse health effects. The proposed choices are:

a. **S1** Minor injury (normally reversible). For example: scrape, laceration, bruise, slight injury, etc.
b. **S2** Serious injury (normally irreversible, including death). For example: limb broken or torn out, serious injury with stitches, etc.

5.10 Frequency or duration of exposure to the hazard (F):

The exposure can be estimated by taking into consideration

a. The need to access the danger zone (for example, for normal operation, maintenance, or repairs)
b. The reason for access (for example, manual feeding of materials)
c. The time spent in the danger zone; the number of people that must access it
d. The frequency of access.

6. Probability of hazardous event occurring (O):

The probability of the hazardous event occurring can be estimated by considering

a. Reliability data and otherstatistical data
b. The accident history
c. The history of adverse health effects
d. A comparison of the risks with those of a similar machine (if certain conditions are met).

The purposed choice is:

a. **O1**Very low (from very low to low). Stable, proven technology recognized for safety applications, material strength.
b. **O2** Low (from low to average). Hazardous event related to a technical failure or event caused by the action of a qualified, experienced, trained worker with an awareness of the high risk, etc.
c. **O3** High (from average to high). Hazardous event caused by the action of a worker lacking experience or specific training.

6.1 Possibility of avoiding the harm (A):

The possibility of avoidance allows the harm to be prevented or reduced in relation to

a. The workers using the machine
b. The rapidity of appearance of the hazardous event
c. The awareness of the hazard's existence
d. The possibility of the worker avoiding or limiting the harm (for example, action, reflex, agility, possibility of escape).

By combining the results obtained for the four parameters, the risk index is defined by using the risk graph, which allows six increasing risk indexes.

For example, an air compressor is in the work area; two in-running nips exist between the belt and the pulleys

a. Severity of the harm: **S2**, high (loss of at least one finger)
b. Duration of exposure: **F2**, because the compressor is in the work area where the workers move around
c. Occurrence: **O3** because the worker is not trained in using the targeted machine
d. Possibility of avoidance: **A2**, because the finger cannot be removed from the in-running nip once it has been caught, if the compressor startsautomatically
e. Calculated risk index: Once all the hazardous situations have been estimated

6.2 Risk evolution:

The last step in the risk assessment process consists of making a judgement about the estimated risk level. At this step, it is determined whether the risk is tolerable or not.

When the risk is considered intolerable (high risk index, as in the case of the compressor in the previous example), risk reduction measures must be selected and implemented. To ensure that the chosen solutions fulfill the risk reduction objectives without creating new hazardous situations, the risk assessment procedure must be repeated once the solutions have been applied.

6.2.1 Risk Reduction:

Once the risk assessment step has been completed, if the evaluation prescribes a reduction of the risk (which is considered intolerable), means to be applied to achieve the risk reduction objectives must be selected the hierarchy in the risk reduction measures.

6.3 Hazard Elimination and Risk Reduction:

As stated in the occupational health and safety, eliminating the hazard is the first objective. The risk must be eliminated to makethe situation safe: this is called inherently safe design.

"Inherently safe design measures are the first and most important step in the risk reduction process. Inherently safe design measures are achieved by avoiding hazards or reducing risks by a suitable choice of design features of the machine itself"

It is therefore at the machine design step that the worker's safety is ensured. The designer tries to improve the machine's characteristics creating a gap between the moving components in order to eliminate the trapping zones, eliminating sharp edges, limiting the drawing-in forces or limiting the energy levels (mass, velocity, acceleration) of the moving components.

6.4 Guards and Protecting Device:

Guards, whether they are fixed or interlocking guards or interlocking guards with guard locking rank just below inherently safe design in terms of effectiveness in the hierarchy of risk reduction measures. Protective devices and electro-sensitive protective devices come next, such as safety light curtains, pressuremats and surface detectors or two-hand controls.

6.5 Requirements for Safeguards:

Safeguards must meet these minimum general requirements:

Prevent contact: The safeguard must prevent hands, arms, and any other part of a worker's body from contacting dangerous moving parts. A good safeguarding system eliminates the possibility of the operator or another worker placing parts of their bodies near hazardous moving parts.

Secure: Workers should not be able to easily remove or tamper with the safeguard, because a safeguard that can easily be made ineffective is no safeguard at all. Guards and safety devices should be made of durable material that will withstand the conditions of normal use. They must be firmly secured to the machine.

Protect from falling objects: The safeguard should ensure that no objects can fall into moving parts. A small tool which is dropped into a cycling machine could easily become a projectile that could strike and injure someone.

Create no new hazards: A safeguard defeats its own purpose if it creates a hazard of its own such as a shear point, a jagged edge, or an unfinished surface which can cause alaceration. The edges of guards, for instance, should be rolled or bolted in such a way that they eliminate sharp edges.

Create no interference: Any safeguard which impedes a worker from performing the job quickly and comfortably might soon be overridden or disregarded. Propersafeguarding can enhance efficiency since it can relieve the worker's apprehensions about injury.

Allow safe lubrication: If possible, one should be able to lubricate the machine without removing the safeguards. Locating oil reservoirs outside the guard, with a line leading to the lubrication point, will reduce the need for the operator or maintenance worker to enter the hazardous area.

6.6 Fixed Guard and Guard with Interlocking System:

One of the best ways of reducing exposure to a hazard is to prevent access to it by installing a guard. Ideally, it is "fixed" and a tool must be used to remove it. However, the guard may have to be opened for periodic access to the danger zone, for example, for production, unjamming or maintenance purposes.

These "movable" interlocking guards or interlocking guards with guard locking must send a stopping signal to the machine as soon as they are opened. If the machine stopping time is short enough for the hazard to stop before the worker can reach it, an interlocking guard is used. However, if the hazard stopping time is longer, an interlocking guard with guard locking is used which, in addition toperforming the functions of the interlocking guard, locks the guard in the closed position until the hazard has completely passed.

6.7 Protective Device:

If a guard, either fixed or movable, cannot be considered, one must determine whether a protective device can be used. A protective device is defined as any safeguard, other than a guard. For example, it can be an optoelectronic protective device (safety light curtain, surface detector), a validation device, a pressure mat, a two-hand control, etc. These devices are specially designed to reduce the risk associated with a hazardous situation.

6.8 Warnings, Work Methods and Personal Protective Equipment:

Procedures, warnings, work methods and personal protective equipment are not considered as being the most effective means.

Although essential in situations where no other solution seems to provide satisfactory results, their effects on safety improvement are considered less significant. They are often used with other risk reduction methods.

7. Training and Information:

In all cases where the hazard cannot be eliminated, workers must receive training so that they are informed about the nature of the residual risk to which they are exposed and the means that are used for reducing this risk. This training is in addition to the general training that the employer must provide to the workers for the purpose of using the machine.

Even the most elaborate safeguarding system cannot offer effective protection unless the worker knows how to use it and why. Specific and detailed training is therefore a crucial part of any effort to provide safeguarding against machine-related hazards. Thorough operator training should involve instruction or hands-on training in the following a description and identification of the hazards associated with machines the safeguards themselves, how they provide protection, and the hazards for which they are intended

- how to use the safeguards
- how and under what circumstances safeguards can be removed, and by whom (in most cases, repair, or maintenance personnel only) and
- Contact the supervisor if a safeguard isdamaged, missing, or unable to provide adequate protection.

This kind of safety training is necessary for new operators and maintenance or setup personnel, when any new or altered safeguards are put in service, or when workers areassigned to a new machine or operation.

Protective Clothing and Personal Protective Equipment Engineering controls that eliminate the hazard at the source and do not rely on the worker's behavior for their effectiveness offer the best and most reliable means of safeguarding. Therefore, engineering controls must be the employer's first choice for eliminating machine hazards. But whenever engineering controls are not available or are not fully capable of protecting the employee (an extra measure of protection is necessary), operators must wear protective clothing or personal protective equipment.

If it is to provide adequate protection, the protective clothing and equipment selected must always be:

- Appropriate for the hazards
- Maintained in good condition
- Properly stored when not in use, to prevent damage or loss and
- Kept clean, fully functional, and sanitary.

Protective clothing is, of course, available for different parts of the body. Hard hats can protect the head from the impact of bumps and falling objects when the worker is handling stock; caps and hair nets can help keep theworker's hair from being caught in machinery. If machine coolants could splash or particles could fly into the operator's eyes or face, then face shields, safety goggles, glasses, or similar kinds of protection might be necessary. Hearing protection may be needed when workers operate noisy machines. To guard the trunk of the body from cuts or impacts from heavy or rough-edged stock, there are certain protective coveralls, jackets, vests, aprons, and full-body suits. Workers can protect their handsand arms from the same kinds of injury with special sleeves and gloves. Safety shoes and boots, or other acceptable foot guards, can shield the feet against injury in case the workerneeds to handle heavy stock which might drop.

It is important to note that protective clothing and equipment can create hazards. A protective glove which can become caught between rotating parts, or a respirator face piece which hinders the wearer's vision, for example, require alertness and continued attentiveness whenever they are used

Other parts of the worker's clothing may present additional safety hazards. For example, loose-fitting shirts might possibly become entangled in rotating spindles or other kinds of moving machinery. Jewelry, such as bracelets and rings, can catch on machine parts or stock and lead to serious injury by pulling a hand into the danger area.

8. Verification of the Result:

To ensure that the chosen solutions fulfill the risk reduction objectives without creating new hazardous situations, the risk assessment procedure must be repeated once the solutions have been applied.

9. Conclusion

All the machines in the industry premises were assessed mechanically, electrically and interms of environmental aspects. The factorsincluding safety switches such as limit switches and interlocks were also assessed for all the machines. Hazards of each machine were identified at the end of the assessment. The identifies hazards are eliminated by providing machine guards and training the workers to avoid bypassing the safety sensors, switches and interlocking devices which have potential to cause high risk accidents.

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About author:

Dr.N.Panneerselvam[1] *Associate Professor, Department of Mechanical Engineering, Knowledge Institute of Technology, Salem. Tamil Nadu, India . 637504*