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MACHINE SAFETY IN SHEET METAL FABRICATION INDUSTRY

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Abstract: The sheet metal fabrication industry is using various thickness of sheets for making the components as per the drawing requirement. This sheet metal fabrication process is complex by physical phenomena, process fluctuations and complicated parameter and dimensions in the production processes. In this modern industrialization, man machine interaction is expected more and more collaborations during machine operation. Machine are considered as the prime for engineering industry in development and speed up of products that are required to meet the market requirement. They play a key role in transforming the raw material to intermediate components and finally as product to various customer. The efficiency of machine depends on their type, capacity, operator skill and many more.

There are many improvements developed in Machine designs but still the control measures implemented in the Machine is not making the effectiveness in many engineering industries. After the analysis of all Machine accidents, we identified that most of the accidents are during machine operation and having lack of control measures. So, this research aims for a detailed study of Machine operation and maintenance for a safe work methodology by considering the hazard and risk associated with the machine.

Keywords: Fabrication, Safety, Hazard & Risk.

1.INTRODUCTION

Machine safety covers the different safety aspects of using machinery and maintaining plant and equipment in the workplace of fabrication industry.

Metal fabrication is a process of forming products from sheet metal. Metal fabrication is a step by step process of designing, cutting, bending, shaping, and joining metals. Machines is one of key factor for the fabrication engineering industry and is one of the industrial mainstays of the Community economy. The social cost of the large number of accidents caused directly using machinery can be reduced by inherently by safe design and construction of machinery and by proper installation and maintenance of the machine.

Machines can help improve production efficiency in the workplace. However, their moving parts, sharp edges, and hot surfaces can also cause serious workplace injuries such as crushed fingers or hands, amputations, burns, or blindness. Hazard identification is the key factor of identifying the hazards related to all activities carried out during fabrication of sheet metal. Risk assessment can be taken up for the identified hazards. All the inherent risk for the machine to be identified and effective measures to be planned to reduce the risk level. While identifying the control measures, new hazard shall not be generated. Risk control measures to be implemented as per the hierarchy of controls.

Sharp edges can cause cuts and severing injuries, sharp-pointed parts can cause stabbing or puncture the skin, and rough surface parts can cause friction or abrasion. People can be crushed, both between parts moving together or towards a fixed part of the machine, wall, or other object, and two parts moving past one another can cause shearing. Parts of the machine, materials, and emissions (such as steam or water) can be hot or cold enough to cause burns or scalds, and electricity can cause electrical shock and burns. Injuries can also occur due to machinery becoming unreliable and developing faults or when machines are used improperly through inexperience or lack of training.

2. LITERATURE REVIEW

Integrity assessment in complex control systems demands a logical approach, and in the international and European standardisation organisations, technical committees and working groups are beavering away to create guidance on the standards to be achieved. The creation of the Machinery Directive and its contribution towards achieving the single

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European market by the end of 1992 has significantly increased the importance of this, and new standards work, during 1989. With reference to manufacturing machinery control systems this paper describes how this work is being integrated into the programme of European Harmonized Standards to support the Machinery Directive and consider the significance of the Directive for machine designers and users in the UK

This guide identifies some tasks undertaken in the metal fabrication manufacturing industry that are hazardous and have resulted in injuries. However, it is not a comprehensive list of all tasks that may pose a hazard. Combined solutions can be proposed & will determine if they are right for your workplace or if further modifications or different controls are required. It is necessary to monitor the success or otherwise of any controls implemented.

This guide mainly discusses the prevention of mechanical hazards. It describes methods for eliminating hazards at source or for reducing them, as well as ways to protect against them by using fixed guards. The risk reduction or distance protection principles presented in the guide are general and are appropriate for most machines. For some machines (for example, conveyors, metal presses, drills, rubber machines, etc.), before applying the generic solutions proposed in this guide, one should consult Québec regulations, standards relating to these machines (ISO, CSA, ANSI, etc.), or the technical guides published by the CSST or by other organizations (ASP, INRS, IRSST, etc.), which can provide details on how to ensure the safety of these machines.

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 or energy levels by applying a risk reduction strategy. If this is impossible, the hazards must be isolated from people by guards that maintain a safety distance between the danger zone and the people, with the main result being to reduce access to the danger zone.

3. EXISTING SYSTEM

The accidents in the fabrication industry during the handing, machine operation, maintenance & material movement to be identified. The analysis of each type of accidents to be made and corrective actions to be taken appropriately. All activity related hazards to be identified and risk to be evaluated. Control measures to be taken effective for the risk reduction as per below hierarchy of controls.

These require the following actions to be taken:

1. Eliminate the risk
2. If it is not practicable to eliminate the risk, reduce the risk so far as is practicable.
3. Engineering controls
4. Administrative controls
5. Personal protective equipment

The method shall implement for following factors

1. Man – Training, competence, awareness evaluation of the work force
2. Machine – Implementation of safety guard, sensors, & control system
3. Method – Working procedures for use of machine
4. Material - Material handling

Following are main contribution factor in industry to safety incidents & were identified as the root causes for the Lost time injury

1. Lack of Risk Assessment & Verification in Safety Management
2. Safeguards missing/defeated & lack of periodic inspections
3. Safety critical machine is not having Safety System
4. Lack of training & operator is not competent enough to operate the machine
5. Lack of awareness
6. Non-compliance to PPE Usage\

4. METHODOLOGY

4.1 Machine

What is a machine?

An assembly of linked parts or components, at least one of which moves, and which are joined for a specific application

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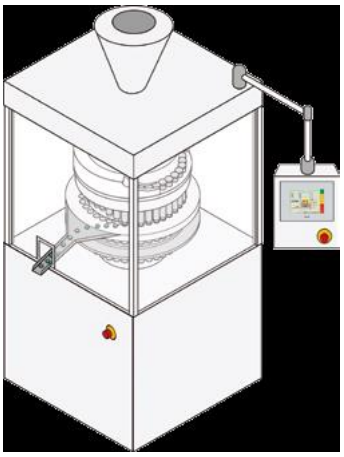

Figure – 1 – Basic Machine Sample Image

4.2 Risk Assessment of Machines

Risk assessment is to assess the hazardsto identify where risk controls are required.

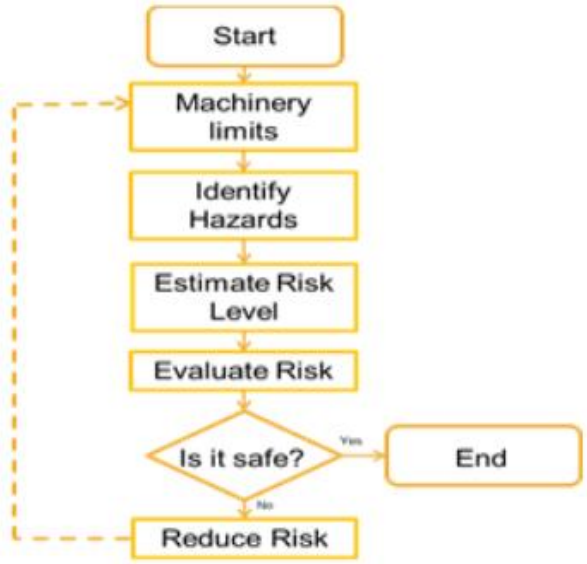

Figure – 2 -Risk Assessment process flowchart

Types of Hazards

1. Electrical
2. Mechanical
3. Thermal
4. Ergonomics
5. Noise
6. Radiation
7. Vibration
8. Materials & Substances

After risk assessment, identify areas of risk controls. Develop the concepts required to achieve the compliance & safety. At the design stage the following should be defined:

- safety requirements specification (SRS) Function of emergency stops
- Function of interlock devices Function of presence sensing devices
- Function of Guarding
- generation of detailed designs e.g. guarding, electrical, pneumatic, and hydraulic circuits
- planning System Implementation and System Validation stages

Safety Validation

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Validation of safety features on machinery should be performed by a person independent of the design and installation phases. It should be performed by a competent person with suitable vocational education, practical experience and knowledge of relevant legislation and standards. The results of the validation should be documented and kept as design records

Probability of occurrence of harm	Severity of harm			
	Catastrophic	Serious	Moderate	Minor
Very likely	High	High	High	Medium
Likely	High	High	Medium	Low
Unlikely	Medium	Medium	Low	Negligible
Remote	Low	Low	Negligible	Negligible

Table - 1 - Estimation of severity

Table 1 estimates the severity of harm or its consequences for each possible hazard.
The severity levels in Table1 are:
Catastrophic - death or permanent disabling injury or illness (unable to return to work)
Serious – severe debilitating injury or illness (able to return to work at some point)
Moderate – significant injury or illness requiring more than first aid (able to return to same job)
Minor – no injury or slight injury requiring no more than first aid (little or no lost work time)
The left column of this table – "estimation of probability of occurrence of harm" is subjective and thus brainstorming of knowledgeable people is considered advantageous.
Like severity, there are many scales used to estimate the probability of occurrence of harm. Some methods do not provide descriptions other than the
terms used.
Other matrices provide additional descriptions as in Table 1:
- very likely – near to certain to occur
- likely – can occur
- unlikely – not likely to occur
- remote – so unlikely as to be near zero
The probability should be compounded to one kind of interval, like lifetime of the machine. By using this kind of a risk matrix for judging all the possible risks that can occur, the severity and occurrence together give us an understanding about the risk level.

4.3 Hazard Rating Number

There are in the market several methods for scoring risks numerically. One numeric method; Hazard Rating Number System is presented hereunder.
Hazard Rating Number system – often abbreviated as HRN, gives numeric rating for different dangers. If performed in a chart and using different colours for scoring, HRN can be very visual, easy to read way to assess different risks. In HRN method there are eight different risk levels that are used: acceptable, very low, low, significant, high, very high, extreme, unacceptable. HRN takes into
HRN is got by calculating LO: Likelihood of Occurrence, FE: Frequency of Exposure, DPH: Degree of Possible Harm and NP: Number of Person at risk. Thus, the formula is relatively simple as shown in below.

$$HRN = LO \times FE \times DPH \times NP$$

Formula of Hazard Rating Number (HRN)

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Likelihood of Occurrence (LO) is scored in accordance with the following Table

LO (Likelihood of Occurrence)		
0.033	Almost impossible	Only in extreme circumstances
1	Highly Unlikely	Though Conceivable
1.5	Unlikely	But could occur
2	Possible	But unusual
5	Even Chance	Could happen
8	Probable	Not surprising
10	Likely	To be expected
15	Certain	No doubt

Table –2 - LO (Likelihood of Occurrence)

Frequency of Exposure is scored in accordance with the following Table 3.

FE (Frequency of Exposure)	
0.5	Annually
1	Monthly
1.5	Weekly
2.5	Daily
4	Hourly
5	Constantly

Table – 3 – FE (Frequency of Exposure)

Degree of possible harm (DPH) is scored in accordance with the following Table 4.

DPH (Degree of Possible Harm)	
0.1	Scratch or bruise
0.5	Laceration or mild ill-effect
2	Break of minor bone or minor illness(temporary)
4	Break of major bone or major illness(temporary)
6	Loss of one limb, eye, hearing (permanent)
10	Loss of two limbs or eyes (permanent)
15	Fatality

Table – 4 – DPH (Degree of possible harm)

Number of persons that are exposed to danger (NP) is scored in accordance with the following Table 5.

NP (Number of Persons at risk)	
1	1-2 persons
2	3-7 persons
4	8-15 persons
8	16-50 persons
12	50+ persons

Table – 5 - NP (Number of Persons exposed to danger)

HRN	Risk
0-5	Negligible
5-50	Low, significant
50-500	High
Over 500	Unacceptable

Table – 6 - HRN (Hazard Risk Number)

If by making the calculation in accordance with formula: LO x FE x DPH x NP zero (0) or 1 is given as a result, the risk has no significance. Numbers from 2 to 5 stand for a very low risk. Numbers from 6 to 10 signify that the risk is low. Scoring numbers from 11 to 50 show a significant risk. Numbers from 51 to 100 show a high risk, from 101 to 500 signify a very high risk, numbers from 501 to 1000 an extreme risk. Numbers over one thousand show that the risk is impossible, i.e. not acceptable.

RISK REDUCTION

If there are any risks noted that are at the level that is not acceptable, there should always be done measures to reduce

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this particular risk. Best result is achieved if these measures can be considered already in the design phasis of machinery. So called naturally safety designing of machinery means that hazards are eliminated or reduced by designing and building machine safe by following the principle of safe technology; choosing naturally safe technology and processes, taking into account 14 ergonomic principles, by applying safety principles when designing control systems and by mechanising or automating manual work steps.

4.4 Hierarchy of Controls for identified risk

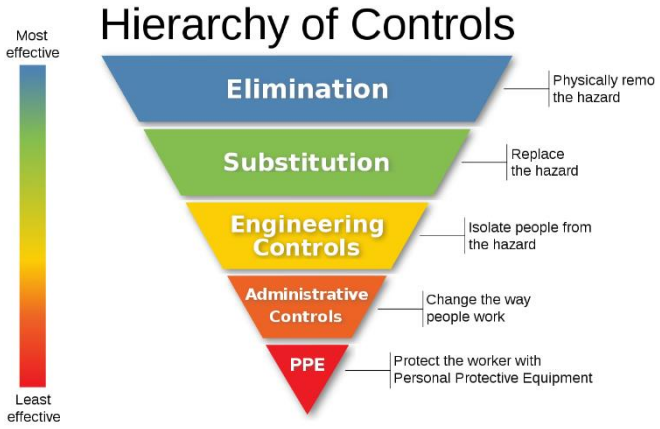

Figure – 2-Hierarchy of Controls

Based on the activity carried out by operator, control measures shall be taken to ensure machine safety.
Guards and protective devices (also known as “safeguarding” or “engineering controls”) shall be used to protect persons wheneveran inherently safe design measure does not reasonably make it possible either to remove hazards or to sufficiently reduce risksComplementary protective measures involving additional equipment (forexample, emergency stop equipment) may also be provided and used for emergency situation.
Administrative Controls
Safe work procedures and training shall be provided to operator &implemented for high critical machines to reduce risk where guards, safeguarding devices, and awarenessmeans are insufficient to achieve acceptable risk for a task related to an operation of high critical task or equipment.

Personal Protective Equipment
Personal protective equipment (PPE) shall be used in addition to other safety measures but not as a substitute for other risk reduction measuresor when no other control method is available or feasible.

4.5 Machine Safety Guard selection

Guards and protective devices must: • be of robust construction
• be securely held in place
• not give rise to any additional hazard
• not be easy to by-pass or render non-operational
• be located at an adequate distance from the danger zone
• cause minimum obstruction to the view of the production process, and
• enable essential work to be carried out on the installation and/or replacement of tools and for maintenance purposes by restricting access exclusively to the area where the work has to be done, if possible without the guard having to be removed or the protective device having to be disabled.
• Guards must, where possible, protect against the ejection or falling of materials or objects and against emissions generated by the machinery.

Fixed guards

Fixed guards must be fixed using systems that can be opened or removed only with tools. Their fixing systems must remain attached to the guards or to the machinery when the guards are removed. Where possible, guards must be incapable of remaining in place without their fixings.

Interlocking movable guards

Interlocking movable guards must:
• as far as possible remain attached to the machinery when open
• be designed and constructed in such a way that they can be adjusted only by means of an intentional action
Interlocking movable guards must be associated with an interlocking device that:

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• prevents the start of hazardous machinery functions until they are closed and gives a stop command whenever they are no longer closed Where it is possible for an operator to reach the danger zone before the risk due to the hazardous machinery functions has ceased, movable guards must be associated witha guard locking device in addition to an interlocking device that:
• prevents the start of hazardous machinery functions until the guard is closed and locked, and
• keeps the guard closed and locked until the risk of injury from the hazardous machinery functions has ceased Interlocking movable guards must be designed in such a way that the absence or failure of one of their components prevents starting or stops the hazardous machinery functions.

Adjustable guards restricting access

Adjustable guards restricting access to those areas of the moving parts strictly
necessary for the work must be adjustable manually or automatically, depending on the type of work involved, and
Protective devices must be designed and incorporated into the control system in such a way that:
• moving parts cannot start up while they are within the operator's reach
• persons cannot reach moving parts while the parts are moving, and
• the absence or failure of one of their components prevents starting or stops
the moving parts.
They must be adjustable only by means of intentional action.
A guard is part of a machine which is specifically required as a form of physical barrier to protect persons from the hazards of machinery. In some cases, the same safeguards can simultaneously protect the machine from persons, for example,
if time-critical processes may not be interrupted by persons approaching at random. The study below considers the first scenario only.
A “guard” forms a physical barrier between the machine operator and the hazard, in contrast to “protective devices” or “electrosensitive protective equipment” such as light curtains and light beam devices, which are covered later.
Safeguards of this type do not prevent access to a hazard but detect a person or part of a person’s body when a hazard is approached. In this case, the hazard is shut down via a downstream controller so that the danger is removed before
the hazard zone is reached. Depending on its design, a guard may be implemented as housing, casing, shield, door, cover, or some other format.

4.6 PPE Matrix

PPE usage is the last option to be used in safety control measures. PPE usage is wholly depending upon the operator behaviour. There shall be proper training & understanding shall be provided to operator for usage of PPE. The use of personal protective equipment (PPE) as a final measure must be considered to ensure safety. PPE is a lower order control and can only be used where higher order controls are not possible or are not totally effective. Selection and use of PPE requires careful consideration, as there are many different types that reduce the risk of injury of contact or exposure to a hazard. Incorrect use of PPE, or purchasing inappropriate PPE, can contribute to serious workplace incidents. PPE that is uncomfortable, restrictive, or heavy may create secondary hazards, and, as a result, constant supervision may be necessary to ensure it is usedeffectively.
1. Safety Shoe
2. Cut-Resistant Gloves
3. Safety Goggles
4. Ear Plug

4.7 Lockout tagout

Removing and controlling energy sources during access People performing tasks, such as maintenance, repair, installation, service and cleaning, are highly vulnerable, and have a higher risk of being killed or maimed through inadvertent operation of machinery and equipment they are working in, on or around. It is essential that people who work in, on or around machinery and equipment are not exposed to hazards due to accidental start-up or movement of the machine mechanism.

Identifying energy sources

All energy sources likely to activate the machinery and equipment and expose people to hazards should be identified prior to work beginning.
Such energy sources include:
• electricity (mains)
• battery or capacitor banks
• fuels

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- heat
- steam
- fluids or gases under pressure (water, air steam or hydraulic oil)
- stored energy
- gravity
- radiation

Isolation procedures

Isolation procedures in each workplace vary in detail because of differences in machinery and equipment, power sources, hazards, and processes. However, if adequate interlocking is not possible, or the maintenance, repair, installation, service, or cleaning requires the method of guarding or interlocking to be bypassed or removed, an isolation procedure should be implemented.

Tag and lock Valve lock and tag

Figure –3-LOTO Lock images

5. CONCLUSION

Man, machine interaction in the sheet metal fabrication is inevitable. A systematic approach to be made for the human safety while operating the machine. Using machinery and work equipment exposes workers to multiple risks. While initiating the hazard identification all the hazard related to the activities to be considered and the maximum possible risk to be identified. This will lead effective control measures for each individual operation. The factors for the incident like man, machine, material & method to be addressed properly to ensure safety. Proper training & PPE for operator safety, Machine guarding system for machine safety, material handling to be done as per the written down procedure & Standard operating procedure to be maintained & implemented for each process and activity. Effective implementation of safety control system for CNC machine will lead to operator safety, even operator can't bypass. Technological development allows for designing more and more effective protective devices. The role of control systems as applied to risk reduction becomes more and more significant. Both manufacturers and users of the machine should apply the afore mentioned measures to ensure the operator safety. The only way to reduce accident rates in machine operations is through proper application of technical safety means by the machine manufacturer and proper monitoring of them by the user, combined with adequate organizational procedures. Fixed guard system for CNC punching machine will reduce the accidents due to material movement & sharp edge. Wherever access required, Interlock guard provided for lubrication & maintenance activity. Fixed guard provided on back side of Bending machine; Interlock shall be provided for the side guard & Laser beam system shall be implemented for the front side as there are more varieties were processed in the machine.

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