Risk Assessment & Reduction

A machine safety case study from Quebec

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IN QUEBEC, SOME 30,000 PEOPLE work in the plastics industry in about 600 plants. Accident reports of CSST (the province's occupational safety and health commission) indicate that this industry occasionally experiences incidents involving injection molding machines. The types of injuries reported range from small cuts, burns, avulsions, amputations, fractures, sprains and electric shocks to deaths. The accident reports reveal that these incidents occurred because the workers 1) reached around, under, over or through guards into hazardous zones; 2) removed or bypassed guards and safety devices; 3) reached into the machine to remove stuck or jammed material; 4) did not use lockout/tagout procedures; 5) were victims of machine malfunctions; 6) were unfamiliar with the machine and its hazards; and 7) operated insufficiently guarded machines.

The Injection Molding Process

Injection molding is used to produce plastic parts through a cyclic process of rapid mold filling through an injection process. Photo 1 (right) shows the small automated horizontal injection molding machine found in IRSST's machine safety laboratory. A typical injection cycle is as follows:

1) Melted plastic is injected, under pressure, into the cavities of a clamped mold with two parts—a moving part and a stationary part.

2) The screw inside the heating barrel of the injection unit retracts, metering a specified amount of molten material for the next shot. In the meantime, the previous shot that is inside the mold is cooled by the cooling fluid circulating inside the mold.

3) The injection unit retracts from the stationary platen.

4) The clamping unit of the injection machine opens the mold.

5) The ejector unit then forces the plastic parts out of the mold.

Figure 1 (p. 50) reveals hazardous zones associated with such a machine. The zones are numbered as follows: 1) mold area, 2) nozzle area, 3) clamping mechanism area, 4) feed opening area, 5) ejector, 6) heating barrel and 7) part discharge area. A discussion of hazards associated with each zone begins on p. 53.

Photo 1: Injection molding machine at IRSST.

Machine Safety: Familiarization with Risk Assessment & OHSMS

Risk assessment is a technique for evaluating the risk of harm or damage that could result from identified hazards. It involves the complete life cycle of the machine and has been defined in ANSI B11.TR3 as the process by which the intended use of the machine, the tasks and hazards, and the level of risk are deter-

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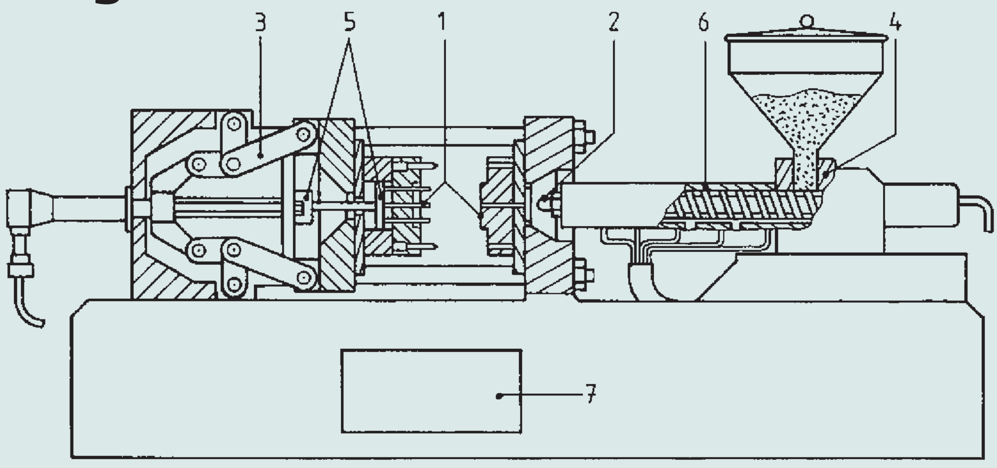
Figure 1

Danger Zones Identified



Abstract: *Many machines are not safeguarded properly because risk assessments are not conducted. This article describes risk assessment and risk reduction using a small automated plastic injection molding machine as an example. Several types of risk reduction methods are discussed as are some basic tools intended to simplify task and hazard identification.*

mined. The four stages of risk assessment are 1) determine the limits and specifications of the machine; 2) identify tasks and hazards; 3) estimate risk; and 4) evaluate risk.

Guidance for conducting risk assessment is detailed in ISO 14121 and ANSI B11.TR3 (Main, 2005; Roudebush, 2005; Tolbert, 2005; Paques, 2005). Risk assessment needs to be applied to industrial machines and processes to ensure worker safety. Information on incident history, energy sources, nature of the machine and affected personnel (e.g., operators, maintenance personnel, technicians, helpers, supervisors, passersby) is needed.

In addition, ANSI/AIHA Z10, Occupational Health and Safety Management Systems (OHSMS), provides an effective tool for continual improvement of occupational safety and health performance. An OHSMS implemented in conformance with this standard can help organizations minimize workplace risks and reduce the occurrence and cost of occupational injuries, illnesses and fatalities. As such, five system activities described in the standard have been identified as 1) management leadership and employee participation; 2) planning; 3) implementation and operation; 4) evaluation and corrective action; and 5) management review. For example, in the planning process, risk assessment is used to identify and prioritize OHSMS issues.

Limits of the Machine

ANSI B11.TR3 describes the process of determining the limits of the machine by 1) intended use, production rates, cycle times, speed, force, material to be used and number of persons involved; 2) space requirements for machine installation and maintenance; 3) temperature, humidity and noise limits; and 4) time limits linked to change of fluids, components, maintenance and wear.

Task & Hazard Identification

All tasks associated with the machine should be identified, and the machine's life cycle needs to be considered. Table 1 describes typical tasks associated with industrial machines.

Hazard identification is a critical step in risk assessment. Based on ISO 14121 and ANSI B11.TR3, some typical mechanical, electrical, thermal, and material and substance hazards are listed in Tables 2 to 5 (pp. 52-53).

Risk Estimation

Risk estimation for a given hazardous situation (task/hazard pair) is based primarily on the severity of injuries and the probability of occurrence of the harm, as explained in ANSI B11.TR3. Table 6 (p. 54) presents a risk estimation matrix from ANSI B11.TR3.

The severity of the harm is categorized into levels as follows:

•catastrophic: death or permanently disabling injury or illness (worker is unable to return to work);

•serious: severe debilitating injury or illness (worker is able to return to work at some point);

•moderate: significant injury or illness requiring more than first-aid treatment (worker is able to return to same job);

•minor: no injury or slight injury requiring no more than first-aid treatment (little or no lost worktime is recorded).

When determining risk, the worst credible severity is to be selected (per ANSI B11.TR3).

The probability of occurrence of harm is estimated taking into account frequency and duration of exposure, level of training and awareness of the hazard. ANSI B11.TR3 defines four levels of risks: high, medium, low and negligible. If the risk level is deemed not tolerable, risk reduction is required. The parameters used for risk estimation may vary and many tools in addition to ANSI B11.TR3 are available for risk estimation (Paques, 2005).

As noted, in the planning section of an OHSMS (per ANSI/AIHA Z10-2005), priorities must be established based on several factors including the level of risk. The standard also provides an example of a risk assessment matrix.

Hierarchy of Risk Reduction

The hierarchy of risk reduction techniques is presented in several sources, including ISO 14121, ISO 12100, ANSI B11.TR3, CSA Z432 and Roudebush (2005). The most effective risk reduction strategy is to eliminate the hazard through inherent design measures. Examples might include removing the need for human intervention; eliminating pinch points through greater clearances; reducing operating speeds; lowering the operating pressures; and lowering operating temperatures.

If the risks cannot be sufficiently reduced, machine safeguarding is required (McConnell, 2004;

CSA Z432). Fixed guards (barriers) provide the highest degree of risk reduction after inherent design methods. They prevent access into danger zones or to parts of a machine that could cause injury. Fixed guards are held in place permanently by welding or by means of bolts, screws and nuts that make their removal or opening impossible without the use of tools. Fixed guards must be sized to cover all means of access to hazardous zones; be made of material that will resist wear, tear and deformation; allow ventilation to prevent overheating of electrical motors; and be of suitable height and positioned far enough away from the dangerous parts as explained in ISO standards 14120, 13852, 13853 and 13854. Gaps (such as round and square openings or slots) in guards can be dangerous if they are large enough to allow access to hazards.

Interlocked mobile guards are effective risk reduction methods. These guards can be mechanical, electrical, electronic, hydraulic or pneumatic in nature. ISO 13849 provides the requirements for safety-related parts of control systems (e.g., circuits involved with the interlocking of guards, light curtains, two-hand controls, emergency stops, safety mats). This standard specifies five categories—B, 1, 2, 3 and 4—representing a classification with respect to the abilities of the safety-related control system to withstand faults, as well as its behavior in the event of faults.

Reliable components and structural architecture of the parts in the control system (e.g., redundant and monitored channels) are the backbone of ISO 13848. In addition, ISO 14119 provides general information on interlocking devices with and without guard locking.

Presence-sensing devices such as light curtains, safety mats, laser scanners and pressure-sensitive edges, as well as the use of two-hand controls are other risk reduction methods. ISO 13855 provides guidelines on these devices, especially in terms of safety distances required for them to function as effective risk reduction methods.

The least effective methods are 1) warning signs and alarms (beepers, sirens, light beacons); 2) training and administrative controls; and 3) PPE. Methods based on human behavior generally are less reliable and more difficult to ensure. Table 7 (p. 54), which is excerpted from ANSI/AIHA Z10, summarizes the hierarchy of risk reduction methods.

Table 1

Typical Tasks for Machine Life Cycle

Tasks	Life cycle of the machine						
	C	T	I	S	O	M	D
Assembly	X						
Testing	X						
Lifting		X					X
Loading/unloading		X					X
Transportation		X					X
Packing/unpacking		X	X				X
Assembly of the different machine parts			X				
Connecting to power supply			X				
Adjustments			X			X	
Trials with no load or maximum load			X				
Exhaust system, waste water system connection			X				
Greasing, adding lubricant			X			X	
Safeguarding (setting of protective devices)				X			
Setting and verifying parameters such as speed, force, pressure				X			
Changing tools				X			
Programming verification (e.g., PLC)				X			
Verify final product				X	X		
Functional tests				X			
Inspection					X		
Driving the machine					X		
Feeding, filling, loading raw materials					X		
Manual loading/unloading					X		
Minor adjustments and setting of parameters such as speed, pressure, force					X		
Minor interventions during operations (e.g., removing waste materials, remove blocked material, cleaning)					X	X	
Restart machine after stopping/interruption					X	X	
Supervision					X		
Dismounting parts						X	X
Cleaning						X	
Replacement of tools, worn-out components						X	
Resetting						X	
Isolation and energy dissipation						X	X
Restoring fluid levels						X	
Repairing						X	
Faultfinding						X	

Note. *C = construction stage of the machine; T = transportation of the machine; I = installation of the machine; S = setting of the machine; O = operation of the machine; M = maintenance done on the machine; D = dismantling of the machine.*

Risk Assessment: Injection Molding Machine

Since risk assessment requires that tasks around the machine be identified and understood, in the course of this research, the authors visited factories operating in the plastic sector in Quebec in order to gather information about the different tasks performed around a typical injection molding machine. The following tasks were identified:

- installing and uninstalling the molds;
- connecting and disconnecting the cooling circuits for the molds;
- connecting and disconnecting electrical cables for certain types of molds;
- purging to remove molten plastic from the heating barrels;
- changing the nozzle of the injection units (e.g., to match with different molds);
- shutting down heat on the barrels;
- unblocking or removing products stuck into the molds or ejectors;
- cleaning the molds;
- reaching into the molds to manually remove finished products when the machines are operating in semiautomatic modes (i.e., one cycle at a time);
- inspecting final product;
- manually feeding raw materials (plastic pellets) into the hoppers;
- performing maintenance or troubleshooting hydraulic or electrical systems;
- setting or changing the operating parameters in the electronic programmable systems (e.g., injection pressures, temperatures in the heating barrels, speeds of rotating screws).

Table 8 (p. 55) illustrates risk assessment and the associated risk reduction method as described in ANSI B11.TR3 when applied to the injection molding machine at IRSST. The task selected for review is as follows: A worker operates the machine in semiautomatic mode and manually removes molded parts at the end of each cycle. Existing safeguards are not considered at this stage. This approach is preferred since it facilitates the identification of all hazards and even possible elimination of those hazards through inherent design measures.

Consider this example of the risk estimation phase. A crushing hazard exists when the mold closes. The hazardous zone is found between the machine's stationary and mobile platens, onto which the two halves of the mold are attached. The probability of harmful occurrence is very likely since the worker frequently enters this zone—approximately each minute when the machine operates in a semiautomatic mode. Also, the accumulated duration of expo-

Table 2

Mechanical Hazards Checklist

Mechanical hazards	Examples of machine types/parts	Possible consequences	Hazard present: Yes	Hazard present: No
Shape—sharp edges	Burrs, cutting blades, milling tools, wood and metal tools	Cuts and lacerations		
Cutting or severing hazard—cutting parts of machines	Band saws, circular saws, fan blades, lathes, milling machines, boring or drilling machines	Cuts, lacerations, severing		
Rotating parts of machines—entanglement hazard	Couplings, cams, clutches flywheels, shafts, spindles, rotating workpieces, mandrels, pins	Entanglement, trapping, fractures		
In-running nip points with rotation in opposite direction—crushing hazard	Intermeshing gears, rolling mills, feed rollers	Crushing, severance injury		
In-running nip point with rotating parts and tangentially moving parts—crushing hazard	Power transmission belt and its pulley, a chain and a sprocket, a rack and pinion	Crushing, severance injury, shearing, entanglement		
In-running nip point between rotating and fixed machine parts	Screw conveyors, periphery of an abrasive wheel, flywheels, mixer and beater arms	Crushing, abrasion		
Rotating parts with projections or gaps—entanglement hazard	Fan blades, spoked pulleys, chain wheels, flywheels, belt fasteners, projecting keys, pins on shafts	Entanglement		
Reciprocating (back and forth or up-and-down) motion of machine parts—crushing hazard	Travelling tables, trapped between moving part and stationary part (wall, bench, floor)	Crushing, impacts		
Masses and stability—effect of gravity	Elements that may move due to gravity, falling counterweights, falling parts from conveyors, failures of holding devices and clamps	Crushing, fractures, death		
Friction and abrasion hazard	Abrasive wheel, belt sanding machine, a conveyor belt, material running onto a reel, fast moving ropes or belts	Friction burns, abrasions at body parts		
Accumulated energy within the machine—projection of fluid under pressure	Compressed springs, hydraulic oil under pressure, gases under pressure including air (pneumatic systems), spray painters, diesel fuel injectors	Tissue damage caused by injection of fluids through skin, impact injuries, eyes injuries, embolism		
Crushing hazard due to motion of machine parts with a part of the body in between	Tools of power presses, closing nip between two platen motions (e.g., injection molding presses), ram of a forging hammer	Crushing		
Impact hazard—caused by objects hitting the body but do not penetrate it	Robot arm movement, transverse motion of a machine part, being struck by projected mechanical parts.	Fractures, impacts		
Drawing-in hazards—can be caused when a part of the body is drawn into a running or in-running nip point	In-running nips such as meshing gears, rolling mills, mixing rolls, press rolls, power transmission belt and pulley, rack and pinion	Shearing, crushing injuries		
Puncturing hazard—penetration of the body	Flying objects including ejection of machine parts (e.g., a loose cutter, broker tooling on a press), projected debris and rapidly moving parts (e.g., sewing machines, drilling machines, nail guns)	Stabbing injuries		
Shearing hazard	Blade of a guillotine, scissor lifts, transfer mechanisms	Shearing		

sure to the hazard is very high. Normally, the severity of the harm is catastrophic since if the mold closes when part of the worker's body is in the danger zone, s/he will suffer crushing injuries. In larger models, the whole body of the worker can fit inside the hazardous zone and s/he might be crushed to death. Therefore, the risk level is high.

Detailed Analysis of Risk Reduction Methods

Two standards—ANSI/SPI B151.1-1997 and EN 201-1997—address the safety of horizontal injection molding machines. The authors studied the electrical and hydraulic circuit diagrams of the machine shown in Figure 1 (p. 50) and in the model at IRSST, as well as machine specifications in order to analyze the risk reduction methods used.

Mold Area

Since the machine used in this study is relatively small, it has a tunnel-shaped guard protecting all sides (front, top and rear) of the mold area. This guard protects the worker from moving parts as well as from the projection of hot plastic. When the gate is opened, the movements (closing and opening) of the mold-clamping mechanisms, of the ejectors, of the injection unit and of the rotating screw are all stopped and prevented from starting.

This was verified by studying the schematics and by tests on the machine. The operator's guard was opened while the machine was running in automatic production mode and semiautomatic mode, and unsuccessful attempts were made to start dangerous movements of different parts of the machine. The interlocked guard has redundant safety-related self-checking control circuits to ensure the continuance of performance in the event of a fault(s) in the circuit.

Risk reduction is achieved by three independent and self-monitored interlocks, based on three different technologies. Hence, the likelihood of common mode failures is reduced. The following discussion describes these risk reduction methods.

Operator's Gate: Electrical Interlock

Although the injection molding machine is fully automated—meaning its operation cycles are controlled by an electronic programmable system—the safety-related electrical interlock is a hardwired electrical interlock circuit (i.e., safety limit switches,

Table 3

Electrical Hazards Checklist

			Hazard present	
Electrical hazards	**Examples**	**Possible consequences**	**Yes**	**No**
Contact of person with live parts—direct contact	Exposed live conductors during maintenance	Electrification, electrocution		
Contact of persons with parts that become live under faulty conditions—indirect contact	Insulation failures, no earth connection, short circuits	Electrification, electrocution, fatal fall triggered by a shock		
Approach to live parts carrying a high voltage	Exposed conductors (high voltage)	Electrification, electrocution		
Electrostatic phenomena	Capacitors	Electrification, electrocution		
Thermal radiation	Explosions, overloads causing fires	Burns		
Ejection of molten particle	Short circuits, electrical explosion melting metal and projecting it	Burns		
Chemical effects from overloads or short circuits	Overloads causing fires around chemicals	Health problems, poisoning		

Table 4

Thermal Hazards Checklist

			Hazard present	
Thermal hazards	**Examples**	**Possible consequences**	**Yes**	**No**
Contact of person with objects or materials at high or low temperatures	Flames, explosions, radiation from a heat source	Burns, scalds and other injuries		
Work in a hot or cold environment	Working outdoors in summer or winter	Dehydration, frostbite and health problems		

Table 5

Materials & Substances Hazards Checklist

			Hazard present	
Chemical or biological hazards	**Examples**	**Possible consequences**	**Yes**	**No**
Inhalation of harmful fluids, gases, mists, fumes and dusts	By-products or waste materials associated with the machinery operation or contact with material product or waste being ejected from machinery	Health problems such as cancer, irritation, poisoning respiratory problems		
Fire or explosion hazards	Inflammable materials and substances processed or used by the machine	Burns		
Biological or microbiological hazard	Material used by the machine (for example, contaminated cutting fluid used in CNCs)	Infections and various health problems		

Table 6

Risk Estimation Matrix

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 7

Hierarchy of Safety & Health Controls

	Controls	Examples
Most effective	Elimination	Design to eliminate hazards such as falls, hazardous materials, noise, confined spaces and manual materials handling
	Substitution	Substitute for less-hazardous materials; reduce energy. For example, lower speed, force, amperage, pressure, temperature and noise
	Engineering controls	Ventilation systems, machine guarding, sound enclosures circuit breakers, platforms and guard railing, interlocks, lift tables, conveyors and balancers
	Warning	Signs, backup alarms, beepers, horns, labels
	Administrative controls	Procedures: safe job procedures, rotation of workers, safety equipment inspections, changing work schedule Training: Hazard communication training, confined space entry
Least effective	Personal protective equipment	Safety glasses, hearing protection, face shields, safety harnesses and lanyards, gloves, respirators

Note. *From ANSI/AIHA Z10-2005, Occupational Health and Safety Management Systems, by ANSI/AIHA. 2005. Alexandria, VA: AIHA.*

cables and safety electromechanical relays, operating independently of the programmable system). This ensures separation of safety-related functions from normal operating functions.

Two electromechanical limit switches—with forced opening contacts and in positive actuation mode (i.e., actuated when the guard opens)—are used to monitor the position of the gate. The limit switches change state each time the guard is opened or closed, and a predetermined state of the two switches is needed to allow hazardous motion. The limit switches are securely mounted so that alignment and switching tolerances are maintained under all expected conditions (e.g., vibration, normal wear, ingress of foreign bodies, temperature).

Technically linked safety electromechanical relays are used to monitor the position of the operator's gate and to detect faults in the internal electrical contacts of these relays, thus increasing the reliability of the safety-related control circuit. The working principle of this interlock is as follows: When the operator's gate is opened, the safety limit switches are actuated and electrical power to the electrical solenoids used to pilot a hydraulic valve is shut off. The hydraulic valve, which is spring-centered, overlapped and closed-centered, and which supplies hydraulic energy to all parts of the machine, prevents all dangerous movements in the machine (e.g., platen closing, injection forward, ejectors, rotation of the screw inside the heating barrel).

Operator's Gate: Mechanical Interlock

The machine's mechanical interlock protection prevents movement of the mold when the safety gate is opened—that is, a mechanical device prevents the moving platen from closing. For example, if the safety gate is opened as the clamping unit is closing, a blocking element is pushed into the grooves of a metallic rod via springs. This inhibits the closing movement of the mold. A proximity switch monitors the position of the mechanical blocking element.

Operator's Gate: Hydraulic Interlock

In addition, a safety hydraulic valve is used to act as a hydraulic interlock. When the operator's gate is opened, a safety limit switch with forced opening contacts and in positive actuation mode interrupts electrical power supplied to the solenoid of the safety hydraulic valve, which is then shut off. Using the de-energize principle (the safe state is obtained by removing the electrical control signal), the spring-centered, overlapped and closed-centered safety valve blocks the hydraulic fluid supplied to the mold closing circuit. This interlock circuit is independent of the electrical and mechanical interlocks. The hydraulic safety valve also is redundant to the machine's main directional hydraulic valve and the position of its spool is self-monitored.

In addition, the machine has the following basic safety principles associated with its hydraulic safety-related control system: 1) pressure limitation by the use of two pressure relief valves; 2) avoidance of contamination of the fluid by using filters to remove solid particles that could otherwise affect safety critical hydraulic components; 3) separation of safety-related functions from other functions; and 4) monitoring of the temperature of the hydraulic oil and shutting down the machine when the oil temperature exceeds a certain value.

Clamping Unit Area

The clamping unit is accessed during maintenance and fixed guards can be used. The machine studied features a mobile interlocked guard that is connected to the same safety control circuit as the operator's gate—it actuates the two safety limit switches as well as its own safety limit switch. The electrical and hydraulic interlocks described earlier apply to the mobile guard protecting the clamping unit as well.

Purging Area Protection

An interlocked guard protects the front, rear, bottom and top sides of the purging area behind the stationary platen. This guard protects the worker from hot plastic coming out of the nozzle, as well as from a crushing hazard that is present when the injection unit advances toward the stationary platen. When this interlocked guard is opened, the screw inside the barrel cannot rotate or advance. The injection unit also cannot advance. These conditions have been tested and verified by studying the machine's schematics. An electromechanical safety relay monitors the position of the mobile guard.

In addition, a fixed guard prevents inadvertent contact with high voltage and high temperature when the injection unit is in the normal operating position. Fixed guards are used at the parts discharge opening to prevent access to hazards in the mold area through this opening. A conveyor belt could eventually act as a barrier.

Table 8

Risk Assessment & Reduction

Hazard	Severity of harm	Probability of occurrence of harm	Risk level (initial)	Risk reduction method
Crushing hazard—mold closes	Catastrophic—death or permanent disabling injury	Very likely	High	Interlocked guard using control systems having redundancy with self checking to ensure the continuance of performance.
Crushing and shearing hazard—clamping mechanism	Catastrophic—death or permanent disabling injury	Very likely	High	Barrier guard preventing intentional exposure of any part of the body and secured with special fasteners or use an interlock guard as above.
High temperature of the mold	Minor—slight injury (superficial burns)	Likely	Low	Use heat-resistant gloves.
Shape—sharp edges of the mold	Minor—slight injury (cuts)	Very likely	Medium	Use protective gloves and clothing. Remove burrs.
Projection of hot molten plastic under pressure	Serious	Likely	High	Use an interlock guard with control systems that have redundancy with self-checking upon start-up to ensure continuance of performance.
Projection of hot fluid used for cooling the mold	Moderate	Unlikely	Low	Inspect hoses regularly for cracks and inspect the connections after each mold change.
Projection of hydraulic oil under pressure	Serious	Unlikely	Medium	Use pressure-relief valve to limit maximum pressure. Inspect hoses regularly.
High temperature of heating barrel	Moderate	Very likely	High	Use a fixed guard.
Crushing hazard—rotating screw in the barrel	Serious	Unlikely	Medium	Use a fixed guard to prevent direct contact with heating barrel.
Electricity—contact with live parts (e.g., heating barrel)	Catastrophic	Very likely	High	Use a fixed guard.
Electricity—conducting part become accidentally live	Catastrophic	Likely	High	Use proper earthing. Inspect electric circuit regularly. Use a circuit breaker detecting earth faults.
Crushing hazard—nozzle presses against fixed platen during injection	Catastrophic	Likely	High	Use an interlocked guard with control systems that have redundancy with self-checking upon start-up to ensure the continuance of performance.
Impact hazard—ejectors	Moderate	Very likely	High	Use an interlocked guard with control systems.
Chemical hazard—fumes from melting plastics	Catastrophic	Likely	High	Ensure proper ventilation or have an extracting hood above the barrel.
Slip and fall of person (e.g., when filling the hopper with plastic pellets)	Moderate	Unlikely	Low	Use an automatic feeder or ensure that the surroundings are not slippery.

Risk Reduction in Larger Models

The risk assessment presented in this article involves a small injection molding machine. Additional safety measures are needed for larger models. For example, it might be possible for workers to stand between the operator's gate and the mold area. An emergency stop button readily accessible from that area, as well as presence-sensing devices, such as safety mats or photoelectric beams, are required. Actuation of the presence-sensing devices will prevent all movements in the machine. The safety circuits need to be monitored and tolerant toward faults for improved reliability.

In practice, safety mats and light curtains are certified safety components. However, the whole safety-related control circuit—including hydraulic valves and electrical contactors if applicable—must be redundant and monitored so that failure of one component does not jeopardize safety. In addition, emergency stops for all injection molding machines and for industrial machines in general should be hardwired independently of electronic programmable systems, using cables and certified safety modules. They should act directly on coils of power elements such as electrical contactors.

Lockout/Tagout

A lockout/tagout procedure is an effective risk reduction method that can be used to prevent injuries resulting from unexpected start-up or release of stored energy in injection molding machines. This method is not technical in nature. It is primarily behavior-based, with specific safety procedures to be

The Four Stages of Risk Assessment

1) Determine the limits and specifications of the machine.
2) Identify tasks and hazards.
3) Estimate risk.
4) Evaluate risk.

Guidance for conducting risk assessment is detailed in ISO 14121 and ANSI B11.TR3. In addition, ANSI/AIHA Z10, Occupational Health and Safety Management Systems, provides an effective tool for continual improvement of occupational safety and health performance.

followed, as explained by ANSI/ASSE Z244.1 and CSA Z460. Workers must be trained to implement effective lockout procedures. The main steps of this procedure are as follows:

•Prepare for shutdown. This includes understanding all the hazards and notifying other workers of shutdown.

•Shut down the machine following the normal shutdown procedures.

•Isolate all energy sources (e.g., open electrical isolators, shut off hydraulic valves).

•Apply locks and/or tags to electrical isolators.

•Verify equipment isolation (e.g., attempt a normal start up, use a voltmeter, use a pressure gauge).

•Release stored energy.

•Perform the task.

•Ensure that the machine is properly assembled and that tools are removed. Also, workers outside danger zones must be notified that locking devices are being removed. Then, workers can remove their locks.

•Reenergize the machine.

In Quebec, lockout procedures are required by province's occupational health and safety regulations for interventions such as maintenance, removal of blocked material and repairs in the danger zones of machines.

Conclusion

Machine safeguarding is an increasingly important issue as risk tolerance continues to evolve. Some machines are imported from countries with different safety regulations. Others may be purchased used and may not be properly safeguarded. In other cases, machines may have been upgraded or customized by engineers who are not familiar with risk assessment and machine safeguarding. These factors, combined with the bypassing of existing protective devices for various reasons, create a potentially hazardous working environment. Comprehensive risk assessment and subsequent risk reduction can help employers remove those hazards and create a safe working environment.

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