CASE STUDIES

Improving maintenance work safety by inherently safe design of a reeling machine

1. Organisations involved

Central Institute for Labour Protection – National Research Institute, 00-701 Warsaw, ul. Czerniakowska 16, MAWOS **co. Ltd.**, Industrial Automation and Drive Systems, 92-614 Łódź, ul. Rokicińska 299/301

2. Description of the case

Key points

- manufacture of machinery and equipment n.e.c.
- safety of machinery,
- safety function,
- functional safety,
- safe maintenance

2.1. Introduction

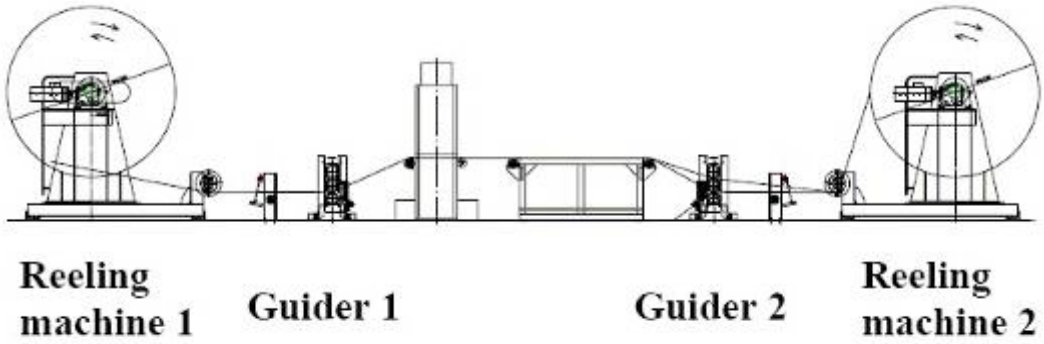
A re-winder of the rubber strip used to make conveyor belts (Fig.3) was designed and built for an individual customer.

Figure 1: Rewinder of the rubber strip

MAWOS Sp. z o.o.

The machine is composed of two reeling machines (fig.4), two pushing devices, a maintenance table and two series-connected guiders to guide the strip onto the reels.

Figure 2: Two reeling machines



*SEMPERTRANS BECHATW Sp. z o.o.
*97-427 ROGOWIEC
Ul. Transportowa 5
POLAND

The machine is used to check and repair rubber conveyor belt strips. It can work in the following configurations:

- Rewinding of the strip from reeling machine 1 to reeling machine 2
- Rewinding of the strip from reeling machine 2 to reeling machine 1
- Independent control of each of the reeling machines

The machine can operate in three modes:

- Mode 0, system shut off - in this mode no device can be set in motion apart from the driving of the holders of the reels
- PREPARATION mode – used when preparing the machine to work in the checking mode. Preparation involves putting on a new strip, changing a reel, manual correction of potential irregularities, and a number of other procedures.
- CHECKING mode –used when checking the strip and repairing it, when both reeling machines are working in a coordinated manner. One reel works as a winding machine the other as an unwinding machine.

Strip guiders are controlled manually and independently of the selected mode. The machine can be used for making repairs and for carrying out maintenance work on strips of various widths, so the spacing of the holders of the reels is adjustable.

In order to adjust them, it is necessary to:

- Stop the line using the “STOP” button
- Set the mode switch to “0” position
- Unscrew the holder mounting screws of the reels
- Switch on the ‘move the holder/guide’ switch
- Move the holder by turning and holding the ’move the holder/guide’ switch
- Re-tighten the holder mounting screws
- Switch off the ‘move the holder/guide’ switch

2.2. Aims

The risk assessment carried out by the designer showed that during the process of adjusting the spacing of the holders of the reels, the unpredictable start-up of the reeling machine can cause its instability and, as a consequence, seriously injure the operator.

Design solutions were needed to prevent such incidents.

2.3. Scope of the project

In order to prevent unexpected start-up of the reeling machine when performing adjustment of the guides, safety functions using fail-safe device were applied. The risk assessment showed that when mounting screws were unscrewed during adjustment the main hazard consisted in the loss of holder stability. Therefore, the safety function had to control the position of the mounting screws to ensure general supervision over the screwing attachment of the holder using fail-safe device.

If one of the mounting screws is left undone or not tightened up sufficiently, the fail-safe device makes it impossible for the reeling machines to be set in motion. If the safety system detects a missing mounting screw, it triggers an emergency stop of the entire machine.

The safety function monitoring holders mounting screws position is implemented by means of limit switches linked to a control system of the machine.

Because unintended easing of the mounting screws during the standard operation of the machines can also put operators at risk, two safety measures were designed.

1. An emergency stop is automatically turned on if the screw mounting the holders is loosened. The mounting screws are monitored by means of limit switches. This function is active in the 'checking' mode, during normal operation of the machine, and shuts off the whole machine.
2. An automatic emergency stop of the main drives of the reeling machines when a loose or missing screw in the strip guides is detected. This function is active in all three modes while the machine is stopped.

The first of these fail-safe functions overrides the second.

A risk assessment was carried out to identify the fail-safe functions needed to improve the safety of the machines. Given that the machines had a programmable electronic control system, this assessment was carried out in accordance with the EN 62061:2005 standard, "Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems".

The risk assessment process analysed information acquired from users of similar machines as well as data on the incidents and accidents which had occurred at particular workplace. The crucial role in the design stage, however, was given to the machine operators. Their feedback and informed opinion based on first-hand experience with similar machines enhanced the quality of the risk assessment.

The following values of risk parameters were set:

Severity of the harm – possibility of fatality or serious injury, Se = 4.

Exposure frequency –adjustments made on average once a week, Fr = 4.

Probability of occurrence of hazardous event – accidental start-up of the machine happens rarely, Pr = 2.

Probability to avoid the harm – if the hazardous event does take place, avoiding harm is highly unlikely – Av = 5.

Class of probability of the harm – Cl = 11

Required Safety Integrity Level according to the Table A6 in EN 62061:2005 – SIL 3

Table 1: SIL assignment matrix IEC 62061:2005, table A6

Severity (Se)	Class (Cl)				
	3-4	5-7	8-10	11-13	14-15
4	SIL 2	SIL 2	SIL 2	SIL 3	SIL 3
3		(OM)	SIL 1	SIL 2	SIL 3
2			(OM)	SIL 1	SIL 2
1				(OM)	SIL 1

The table indicates the SIL assigned as the target for the safety function. The lighter shaded areas should be taken as recommendation that other measures (OM) be used.

This required Safety Integrity Level was fulfilled by use of the certified elements and subassemblies of the control system (safety limit switches, programmable electronic control system certified according SIL 3 requirements).

2.4. Results and evaluation

Machine operating accidents occur mostly when performing repairs, maintenance work or adjustment of the machine, rather than when it is being operated. It is for this reason that in the risk assessment phase a machine designer should also consider these aspects of a machine's use. The reeling machine case demonstrates how accidents can be effectively prevented by the design of fail-safe devices and systems that protect workers when the machine is being adjusted - the manufacturer of the reeling machine has met the safety requirements included in the 98/37/EC directive which states that machinery must be designed and constructed so that it can be operated, adjusted and maintained without putting persons at risk.

Furthermore, the use of fail-safe devices that detect potential risks during the adjustment and maintenance of the machine ensures the safety of the operators in compliance with the 89/655/EEC directive and framework directive.

2.5. Success factors

The described case demonstrates clearly that good design, taking into account all potential risks, helps to ensure safety during repair and maintenance work. It also shows how effective cooperation between a machine designer and its users can be achieved. The end users of the machine were actively involved throughout the whole risk assessment process and played a crucial role in ensuring that the new machine was safe to operate.

2.6. Contact information

Marek Dźwiarek, Central Institute for Labour Protection – National Research Institute, ul. Czerniakowska 16, 00-701 Warsaw, POLAND.

2.7. Transferability

The described methodology, which reduces risk by applying appropriate machine design solutions, can be used in the design of the majority of machines. Almost every machine requires maintenance and adjustment, and this is often when accidents are most likely. This should be considered at the design stage so that appropriate fail-safe measures can be included from the start.

Appropriate risk assessment proves to be fairly problematic in the case of machines where a product standard is lacking and, as a result, there are no guidelines to help the designer include all the safety devices and precautions a particular machine may need.

The practical example presented here shows how the need to regularly adjust a machine can be taken into account during the design stage.

When designing safety into a machine, the designer needs good information about where the dangers lie and exactly what devices are needed to make it safe to operate.

The case described here demonstrates how, in a simple way, hazards can be identified and effective risk assessments can be carried out.

3. References, resources:

author's report, not published.