Assessment and recommendations about the risk of nip points on roll-coaters.

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Table of contents

1. What is a nip point? 5

2. Why is there a risk with a roll-coater? 6

3. Why is there still a risk if the danger has been identified for ages? 10



1. What is a nip point?

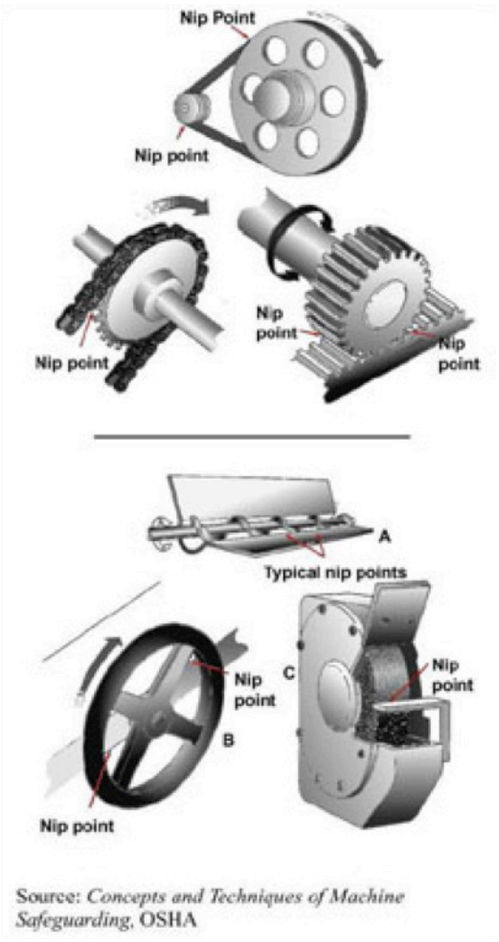
A nip point is a point of convergence between two rolling parts, or a rolling part and a stationary part, where all or part of the human body could become trapped and injured.

In most countries, safety regulations about machine design give recommendations about this specific risk. A well-known example of such a guideline is the OSHA “Concepts and Techniques of Machine Safeguarding”.

In our industry, nip points are very common on all coil coating lines. Conveying a strip with rotating rolls invariably means that the contact zones between rolls and strip (or in between rolls) generate nip points.

On some lines the process can be fully controlled from a remote room and the risk of injury is then relatively low. On other lines, however, some operations are routinely performed by people close to potential nip points. For example, accidents related to nip points (or more generally related to pinch points) are still common on slitting and profiling lines.

This paper focuses on the nip points of roll-coaters. Roll-coaters are used on coil-coating lines but are also used on other continuous units such as can-coating lines.



Source: *Concepts and Techniques of Machine Safeguarding*, OSHA

2. Why is there a risk with a roll-coater?

What is the origin of the risk?

In a roll-coater, paint is transferred to the moving strip via rotating rolls. There are at least two rolls of relatively low diameter (typically 250-300mm) and when the line is running, the rolls are rotating with a high tangential speed (typically a few 10m/min).

Because of the rotation of the rolls, there is often at least one nip point, a point where the hand won't be expelled from the contact zone of the rolls, it will be driven into this contact zone by the rotation. The pressure between rolls is sufficient to crush a limb if it becomes trapped in the space between the rolls.

A good example of a nip-point is the one that is created during the application of a primer where both rolls are in forward mode. In this configuration, the pick-up roll and the applicator roll create a nip point:

Figure 1:
example of an obvious nip point in a very common production situation: the "forward mode"

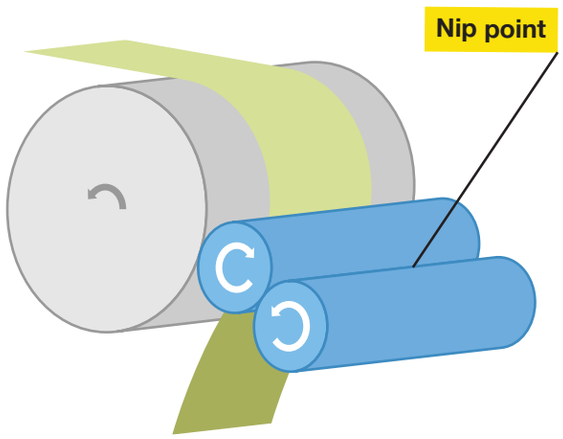
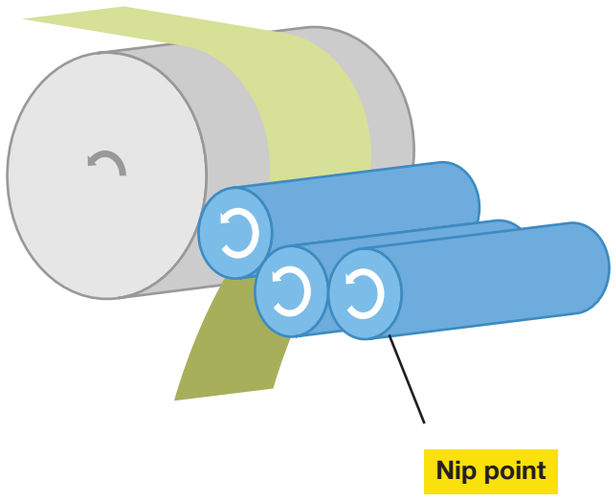


Figure 2:
example of a "hidden" nip point.



There are a number of different configurations that are possible with a roll-coater in coil-coating. In some of these configurations, the risk is not as obvious as in the forward mode example because the rolls rotate in the same direction, which gives an illusion of safety. In such a case, it is the difference in the rotation speed that creates a nip point.

In all the possible configurations of a roll-coater, as soon as the rolls do not rotate in the same direction and with the same speed, there is a risk of being trapped between the two rolls. If two rolls rotating at different speeds are safe from one side, it means that there is a nip point on the opposite side!

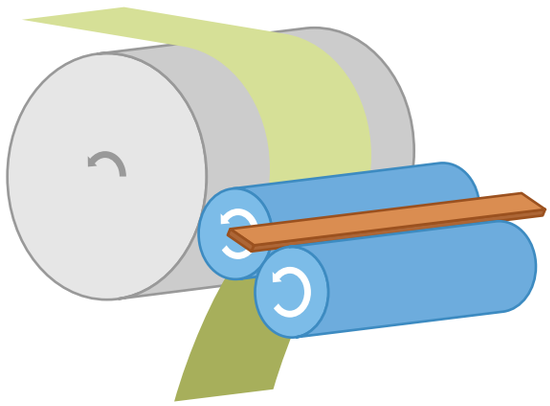
During production, the operator usually does not stand in the direct vicinity of the rotating rolls. However, a roll-coater is a machine that the operators regularly need to work on, especially when a new order is launched or when the coater needs to be cleaned. It means that in normal production conditions, some routine operations potentially expose the workers to the risk of being trapped by a nip point.

What are the usual methods for preventing from the risk of being trapped?

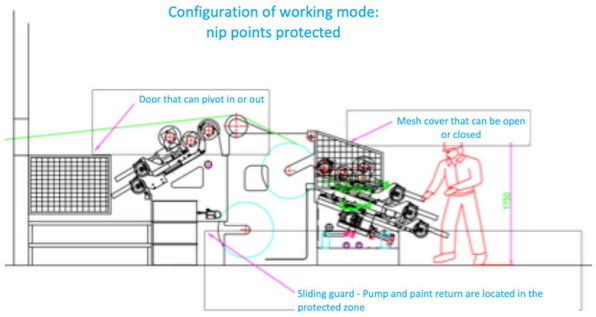
Nip points are a well-known hazard (not only on roll-coaters!) and in most countries there are laws or regulations that define strict rules – or at least recommendations – about how to minimise the risk of entrapment. The most obvious method for preventing operators from this risk is to make it impossible to touch the danger zone when the coater is running in a hazardous configuration. In the above example of an application in forward mode, it is possible to physically prevent the worker from touching the zone close to the nip point as long as the line is producing. With appropriate guards, for example, there is no more risk.

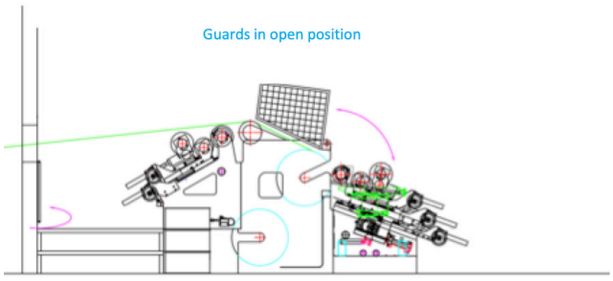
The most common and simple guard is typically a metallic bar, 10-15 cm wide, placed a few mm away from the rolls. Nowadays some more sophisticated systems are also available but simple guards are still the most widely used solution.

Figure 3:
example of a guard to avoid contact with the nip point. To be efficient, the distance between the guard and the roll cannot exceed 5mm, or else another nip point is created between the guard and the rolls.



Another method for protecting not only the nip point itself but also all of the surrounding zone is to enclose the coater in a cage. In such cases, it is generally considered important to be able to see the rolls. The most efficient balance between safety and the necessity to see the rolls is then usually achieved with a mesh, as illustrated below.





This is one of the important points to consider in the design of a guard: operators need to be able to see the rolls or even work on the rolls during the shift. Operators may clean the coater 5-10 times a day … and that the guard needs to be removed. The design of a guard must enable it to be removed in safe conditions, or more generally the global design of the roll-coater and its guards and the operating procedures need to consider a "safe" mode which is defined for the unavoidable cases when the operator needs to (or is likely to) touch the rolls. The safest possible mode is obviously when all rolls are stopped, but for most coil-coating production lines, the continuous operation means it is not realistic to have stopped rolls. So, in most cases, a "safe" mode generally means:

The rotation of the rolls is minimised
The pressure between the rolls is released and a gap of a few centimetres is set
A current limit is set to the motors to limit the torque. With such a limit, if something becomes trapped, the pressure on the roll increases and its motor immediately stops.

There is not one single design and/or procedure that can be used in all situations, deployment depends on the kind of coater and on the existing procedures and safety devices. The common approach is to have two different operational configurations or working procedures for the roll coater:

(a) one configuration or procedure is used in production mode, where the hazard exists and where the safety devices are active in order to minimise the probability of a contact with the risky zone, and

(b) another "safe" configuration where the selected operation of the rolls significantly reduces the hazard from nip points and the safety devices are not active (guard removed, light barrier switched off, door opened, …).

Of course, it is essential that no confusion can occur between the two modes. Ideally, it should not be possible to run any other mode than the "safe" one if the guards are removed or disabled. In most lines, this is at least stated in the procedures but the risk of a mistake or a wrong operator decision is still present if no other barrier exists. This is one of the major difficulties, to find a barrier that would make it compulsory to activate "safe" mode as soon as the safety devices are off. It is increasingly common to use safety interlocks that disable any other mode than the "safe" one (or stopped rolls) if the roll-coater is not correctly guarded.

3.
Why is there still a risk if the danger has been identified for ages?

The "absolute" safety device doesn't exist.

Coil-coating is a sector where the product diversity is higher than in most other coating industries. The product range is wide, very wide... Hundreds of colours, different types of paint systems, one or two layers, a continuous range of coil widths from a few 100mm up to more than 2000mm, … there are thousands of possibilities for the customers who take advantage of this diversity, the coil-coating lines produce each coil as a tailor-made product!

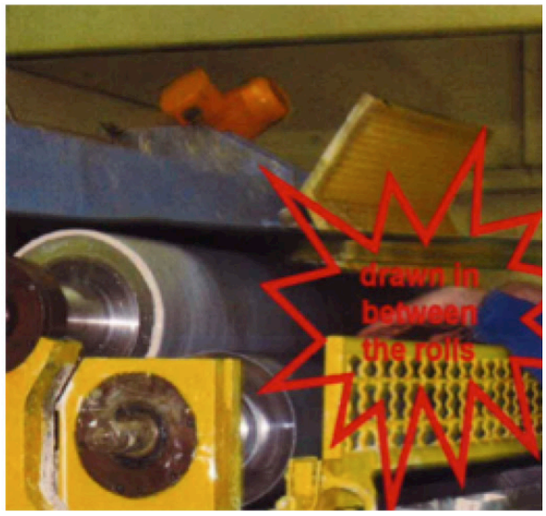
- The consequences for the coil-coating line are that:
- It is necessary to frequently change colour and then to clean at least one coater (5-10 times a day as an average for Europe, sometimes even more)
- It is necessary to frequently replace the applicator roll when the line needs to start a new "width cone". The applicator roll is rubber-coated, and it is cut by the edges of the coils. Once cut at a given width, running wider coils is only possible if the roll is not changed.
- A coater is usually designed in such a way that various configurations are possible: 2 or 3 rolls, in line or V-shaped, with a doctor blade… Changing roller configuration is normally something the workers don't have to do so often but it happens.
- It is common to have fast change coaters. For instance, a shuttle that moves the whole coater from a stand-by position to the strip and vice-versa, or two coaters on both sides of the same deflecting roll (one coater is operating while the other is out of the production line).

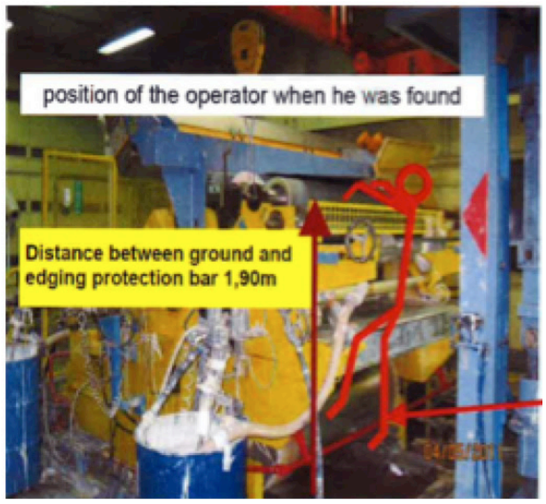
From a "safety" perspective, an absolute safety guard would need to be effective for all the possible configurations of the roll coater, when it is operating but also when it is off-line, and it would need to be easily removable for cleaning or changing rolls. Such an absolute guard is virtually impossible to design with conventional guards because the geometry and/or the position of the roll-coater change. The guards, to be effective, must be located a few millimetres away from the danger zone otherwise the guard is either ineffective or even as dangerous as the nip point it is supposed to protect. When the geometry or location of a machine is changing so frequently, the main mistake is to design a guard that is loose enough to allow some slight changes without any major impact on the design or location of the guard. Case Study 1 is a good example of such a mistake. In this situation, there is a guard, but it is still possible to overpass it. Because of the existing culture amongst operators of touching the rolls, this situation is more dangerous than the situation where there is no guard: whenever some operators decide for any (bad!) reason to go close to the machine, they can still do it, and, because of the guard, they may be forced to stretch or bend to reach it.

Case Study 1: Both hands are caught in the nip point of the back-side coater.

When it is impossible to have protection very close to the machine, the other option is to have it far enough from the machine to create a distance between the safety boundary and the machine that is longer than a leg or an arm.

This option is possible with the use of light barriers. If light barriers are too close to the roll-coater, they will not be effective because the reaction time of such equipment is too long to stop the rolls before the accident happens. But where there is a reasonable distance between the roll-coater and the light barriers, it can be achieved. A major advantage of this approach is that the light barriers do not affect the ability of the operator to correctly see the roll-coater, including the nip point itself (some quality defects are a result of what happens in the transfer zone between the rolls). Moreover, it is not necessary to physically remove the guard when contact with the rolls is required. However, light barriers are not widely adopted across the





The coater had been cleaned 16 hours prior to the accident and had been switched off since then (but the line was running).

When the operator started the coater, he activated the "cleaning mode", which means:

- *it is possible to stop the machine with one hand because of the limited torque imposed to the roll*
- *the rolls rotate in such a way that there is no nip point as seen from above*

When the accident occurred, the coater was no longer in cleaning mode but in production mode.

The operator touched the rolls from below the strip, putting his hands above the guard

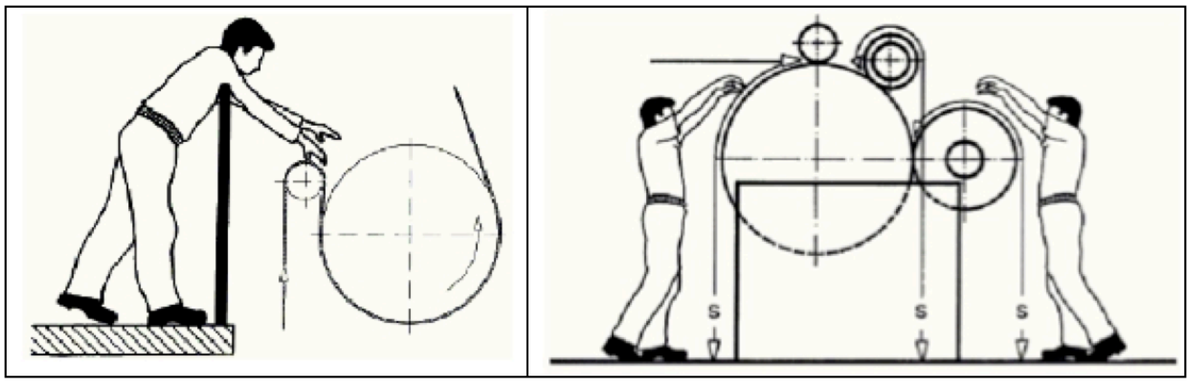
A colleague stopped the lines with the emergency stop when he realised what was happening.

industry. The main reason is that the risk of frequent, unexpected line stoppages with this equipment is unacceptable. The probability that an operator crosses the barrier in normal operation is generally seen as too high as they would need to be placed, in a zone where workers need to be.

In summary, a light barrier doesn't work if it is too close to the roll-coater and as soon as you increase the distance, the risk of unexpected stoppages becomes too high.

The question of the correct distance between a guard and the danger zone is valid not only for light barriers, it is crucial and needs to be correctly addressed with all types of guards.

In an ideal case, the coating room itself can be used as a safety room where it is only possible to enter when the coater runs in "safe" mode! But even if theoretically possible, such options ultimately fail because of the engrained habit of the operators to regularly work close to the machine.



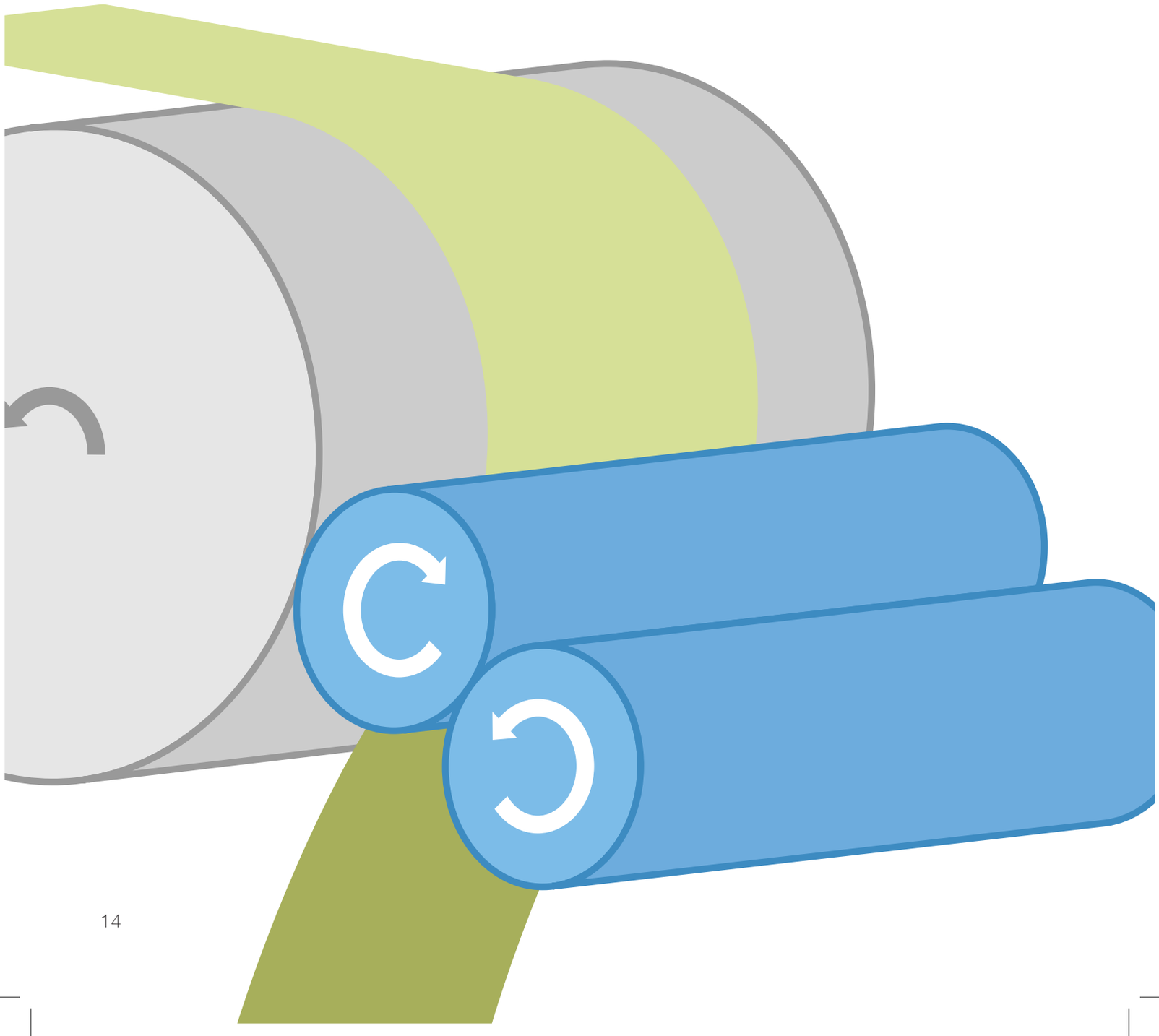
Some plants have deployed light barriers as the primary safety technology in some risky zones around the coating machines. Initial results have been encouraging and it is worth monitoring this deployment and to share good practice across the industry.

One focus to improve safety is to envisage a safety barrier far away from the coater.

One focus to improve safety is to envisage a safety barrier far away from the coater. This is only possible if a preliminary study about the actions of the worker around the machine is completed. Their actions must be questioned, in order to assess the relevancy of certain activities inside the coating room. Perhaps some actions can be eliminated, replaced by other actions performed outside of the coating room, or simply postponed until a time when the coater can run in safe mode.

Increasing safety: a step-by-step process!

It takes time and resources to set-up appropriate safety devices, especially on old coaters where such safety devices were not considered at the very beginning of the design. It takes even longer to change the culture and the way of thinking of people who believe that touching the rolls is necessary… and safe if correctly done!!!



The older coil-coating lines were built at a time when safety requirements were significantly lower than today. In addition, a production line is not a static facility! There are always continuous improvements initiated by maintenance or technical development teams and some of these improvements sometimes have consequences on the design of the roll-coater or its associated equipment. As a result, the "normal" situation is usually one where there is a gap that needs to be closed to reach the perfect safety conditions.

Everybody agrees on the effectiveness of a system that makes it impossible to touch the roll if you consider only safety aspects. However, finding the appropriate way to deploy such a system or to have it adjusted to a new situation when the line evolves, and then have the safety system understood and accepted by people, is not so easy and generally follows a step-by-step process.

"People" can be the managers of the lines who generally need to continuously drive their unit with a balance between cost and production efficiency on the one hand, and the necessary constraints (including safety constraints) on the other hand. It is impossible to change everything from one day to the other and most lines have a "safety improvement plan" which defines the priorities among the safety actions. All safety actions are relevant, but it is not realistic to implement all these actions at the same time.

"People" can also be the operators themselves. In most cases, a safety device will generate a constraint for the operators who will not be able to touch or simply see the machine as they used to. The risk of a nip point on a roll-coater is usually underestimated by operators. When trying to convince a team to stop touching the rolls for safety reasons, it is quite common to hear sentences like "everybody always works like that and there has never been an accident" or "it is impossible to correctly work without touching the machine". Workers usually tend to have a false view of their exposure to the risk, and also of the balance "Risk versus Constraints". Their vision can be further unbalanced by experience because when a risk is regularly taken without facing any serious consequence, one will spontaneously tend to underestimate the risk level.

Increasing safety: a step-by-step process!

Case Study 2 is a good example of what can happen with a machine is partly protected and a worker has a long history of operating the equipment. In this example, the operator had been working in the company for more than 40 years and 18 years in his position on the coil-coating line when the accident occurred. As the pictures show, it is obvious that safety has been seriously managed in this plant, with guards and clear painting of dangerous zones. However, what happened shows that there were still “easy to reach” nip points and neither the procedures nor the equipment was 100% effective to prevent contact with these nip points.

The coater guards have apparently been designed with the main access way to nip point as the only target. Protecting the main access is of course crucial but recent examples also show that an already partly protected coater remains dangerous because of possible access from the sides or from the back. When a machine is still accessible, the risk turns critical if the workers are not aware of it. The absence of clear pictograms at the specific point of the accident, the low visibility because of the shadow below the strip and the long experience of the worker contributed to the unawareness of the risk at the moment of the accident.

Case Study 2: Hand caught by the edges of the rolls of a back-side coater.







The coater needed to be cleaned but there was no necessity to do it quickly because it was not going to be used for the following production batch.
The operator however decided to clean the coater immediately and was alone during this operation.

He used the safe mode for cleaning the coater: max space (2mm) between the rolls and rolls rotating outwards.

When he finished, he didn't switch the rolls off, he just removed the safe mode. Because the rolls were still geared with motors, they started rotating inwards, creating a nip point. It did not appear as a problem for the worker because the cleaning was over and because there is a guard that makes it virtually impossible to reach the nip point.

Some minutes later, after doing other tasks, the worker realized that the rolls' edges were still dirty. He decided to clean the edges with a rag, without changing anything in the machine configuration and he got immediately caught by the nip.

Three areas for further thinking:

The first one is about people's awareness of the risk. Specific training where real cases are regularly shown would probably help, even if most people consider that such accidents are only likely to happen with people they don't know and not on their line. Showing pictures is also a way to make people aware of potential consequences of an accident.

The second area is in the design of the guards, which needs to consider all possible access points, including the edges.

The third area is about the visibility of the risks.

- Pictograms are important, but people generally tend not to see them anymore after a while. Changing them regularly could be an option.
- Some zones are dark, especially below the strip. Improving the way these zones are illuminated can significantly lower the risk level.

Cleaning is still a risky operation.

The most efficient method for changing colour on a roll-coater is still to clean it manually. This method of cleaning is however clearly stated as dangerous by most equipment suppliers.

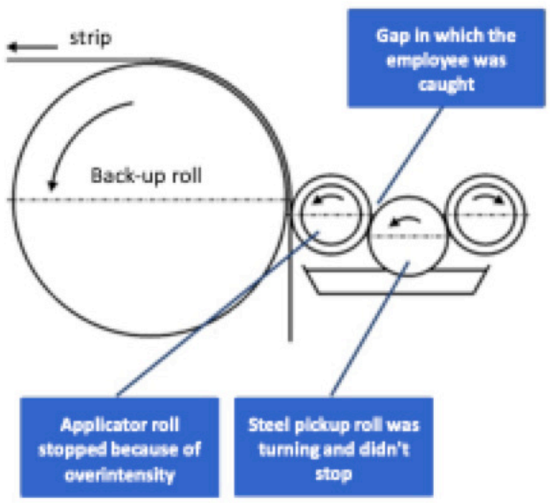
Several devices have been tested to replace manual cleaning with an automatic cleaning process where the hand is not needed anymore, with relative success. For example, “washing-machines” have been installed on some roll-coaters. They are made of a shell that is fully closed around the rolls and inside the shell, nozzles spray the solvent onto the rolls for automatic cleaning. It is difficult to convince people of the relevancy of a washing machine, mainly because it is not possible to see the rolls with such a shell and because the distribution of the nozzles cannot be efficient for all possible coater configurations. The design of a washing-machine is obviously easier in the case of a coating unit where the configuration doesn’t change often (or, even better, doesn’t change at all). This is the case of most back-coaters and some lines have already started to use washing-machines in these simple cases. The most advanced lines are in the process of developing washing machines for the top-coaters.

Another example of how to clean a roll-coater in safer conditions than doing it manually is to use a mechanic arm that replaces the hand of the worker to wipe out the roll with a rag. Such equipment generally fails in cleaning the edges of the roll and in cleaning the ink tray.

Today most coil-coating line still work with colour changes and manual cleaning. This operation is the riskiest one for the operators, even in the case where a procedure is followed, and an active “safe” mode is deployed. Case Study 3 is an example of what can happen even in a situation where everybody believed that there was no more risk for cleaning the coater.

Some companies are trying to develop the “hands-free” concept for cleaning the roll-coaters. The most recent attempts are based on the use of special brushes which can also be used as a solvent dispenser. The operator still needs to clean manually but his hand is not supposed to touch the roll because he uses the brush for either dispensing the solvent or for wiping the roll.

Case Study 3: Two fingers caught while cleaning a coater in “safe” mode.



The coater was equipped with a “safe” mode for cleaning operations. This “safe” mode corresponds to a small gap in between the rolls and a torque limitation on each roll.

With three rolls (and a back-up roll) it is impossible to have a rotation mode that repels the hand from all the inter-rolls. In the described case, the third roll (the “doctor roll”) and the second roll (the “pick-up roll”) rotate in a direction that makes this inter-roll safe but in between the applicator roll and pick-up roll, the safety of the nip point is only possible if the applicator roll rotates faster than the pick-up roll. The strip also needs to run faster than the tangential speed of the applicator roll to secure the nip point between the applicator roll and the strip.

While cleaning the rolls, the worker made a mistake and over-splashed the coating rolls. Because of this over-splash, the torque increased significantly on the applicator roll and this roll then stopped.

The rolls were not interlinked, and the pick-up roll didn’t stop at the same time as the applicator roll exceeded its torque limit.

The rotation of the pick-up roll while the applicator was stopped created the nip point in which the left hand of the worker was caught.

One option is to develop fully efficient alternative solutions for cleaning the coater without involving either a hand or a rag. Equipment suppliers are focused on improving the effectiveness (better thickness control, longer lifetime of the rolls, shorter colour change, …). The coil coating sector believes that increasing operational safety of the equipment is an equally important consideration when designing and developing this equipment.

One option is to develop fully efficient alternative solutions for cleaning the coater without involving either a hand or a rag.

Recommendations

For the design of guards, access to the nip point should be prevented from all possible sides – top and bottom, front and rear, and most importantly the edges. Meshes are recommended to enable the machines to be seen.

Respecting the correct distances is important. If a guard cannot be located no more than a few millimetres away from the risky zone for all working conditions, the barrier must be located more than one metre away. A loose guard is worse than no guard. It makes an accident more likely and/or more serious if it happens.

A "safe" mode is never 100% safe unless the rolls are fully stopped. The design of the safe mode is important: the distance between rolls (the gap should be wide enough (>15mm) to prevent a finger becoming trapped, the way they rotate (direction, speed), the maximum pressure to stop the rolls, the consequences in case of an anomaly (and the interlinks between safety of each roll) must be thoroughly studied. Some lines successfully changed the habits of the operators and some operations that were formerly considered impossible without touching rotating rolls are now performed routinely in a perfectly safe mode, either by a machine or, when the hand is still needed, on a fully stopped coater.

In most cases, such a strict rule is not (yet) realistic and the "safe mode", even if not perfect, is the safest realistic mode. So, it is important that it is selected every time a worker is likely to touch a roll. Procedures are not enough; it is strongly recommended to deploy safety interlocks.

Any alternative to the manual cleaning of the rolls that would be as efficient, effective and without constraint on the production volume is welcome! Some lines have not waited for the perfect alternative and already significantly improved their safety performance, based on the principle that touching a rotating roll with the hand is strictly unacceptable.

There is no situation in which touching a rotating roll with the hand is safe. There is still this belief that it is necessary to touch the rolls for some operations (or for diagnosis in the case of a defect) but this is wrong and should be firmly prohibited. Most operations that require a contact with a roll can be achieved via a tool. Where it is not possible to use a tool, rolls must be stopped for touching them with the hand.

A guard that can be easily removed for cleaning is often also a guard that can be easily by-passed, intentionally or not. In the design of a guard, a specific focus is required on the ability to remove it easily but also on the mechanisms that make it difficult to do so when it is not required to remove it.

Procedures can be improved:

- They should clearly state that cleaning a coater is a risky operation that needs to be performed by the team leader or by any other operator that is given the authority to do so and supervised. It must be explicit that cleaning a coater without following the rules is a breach of procedures.
- In addition, cleaning a machine is safer when a second worker officially watches the operation.
- Procedures should describe what can be done or not when a coater is on stand-by.
- Operator awareness should be regularly renewed..
- The initial training of the operators in the coating room should give detailed explanations about the risks and how to operate safely (especially about cleaning -). An official list of trained people must be available and only these trained people should be allowed to work on the roll-coater.
- Periodic training with real case studies are useful. In these real case studies, showing pictures of accidents is a way to deliver a strong message. A participative management of safety is also efficient: workers can be asked to contribute and regularly update the mapping risks in the coating room, for instance. This safety mapping can then be used in the periodic safety talks within the teams.
- Improvement of visibility with paint and appropriate lighting is useful, especially in the zones of the back-coaters.

Finally: the coating machines are all different; cleaning procedures are all different - rules for personal protective equipment in the coating room are very different from one company to another. There is a room for a better consistency and for a global approach of safety. Today, a worker who is trained on one roll coater could be faced with different safety rules on another roll-coater, even sometimes on another line in the same plant…

ECCA Objectives:

- Increasing the awareness of prepainted metal through promoting its environmental, cost, quality and design benefits.
- Stimulating market, application, product and process development
- Setting quality performance standards and developing test methods
- Granting of Quality and Sustainability Labels for prepainted metal on the basis of the technical and sustainability requirements defined in the ECCA Premium® Label manual and based on independent third party control
- Creating an industry network and forum for the development and exchange of ideas
- Representation of the Industry in its contacts with Public Officials, Public Authorities, other Trade Associations and Professional Bodies.

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