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REDUCING ACCIDENT RISKS DURING PAPER PROCESSING BY ERGONOMICALLY DESIGNING THE PROTECTION PANELS

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Abstract: *The paper studies measure to reduce the risk of accidents in paper processing by ergonomically designing protective panels to safely separate the work cylinder area between the operator and the production machine. It is important to comply with the principles of safety integration in the design and construction of work equipment, as well as ergonomic design principles. At the end of the paper, the results of the research on the design, construction and installation of ergonomic protection panels are presented, located in two planes, to eliminate the risks of accidents of the operators.*
Key words: *machinery security, risk of accidents, ergonomic design, protection panels.*

1. INTRODUCTION

As our contemporary society has evolved over the years, the demand for paper has grown exponentially. Probably because we use it a lot. It's no surprise, then, that the world is creating sustainable processes and innovations to increase yields and support the ever-growing demand for paper globally [1-3].

The pulp and paper industry are reinventing itself: many companies are evolving from simple papermaking to integrated pulp processing, generating many new products along the way, such as biodiesel fuels or advanced composite materials. But, as with any progress, those who venture into these new territories face difficult demands. After all, more diversified production processes and varied operating conditions require the machines used to deliver maximum efficiency and performance. And traditional pulp and paper producers also face the need to increase their profitability and productivity [4-6].

The pulp and paper industry are one of the largest in the world. Despite the increase in operating income and production volumes, the field is going through a period of transformation, with megatrends such as globalization, environmentalism, digitalization and e-commerce. These trends, along with tougher competition and increasingly stringent health, safety and environmental regulations, are bringing about big changes that drive up costs. Producers are finding it increasingly difficult to work profitably [7-10].

Competition also reduces the ability of many companies to invest in capital. As a result, machine efficiency and reduced downtime are essential for organizations pursuing prosperity. A traditional source of cellulose is wood, which is obtained from trees such as pine, spruce, beech or oak. The manufacturing process of this material is complex and involves several stages, namely: Obtaining the raw material, Grinding the wood, Treating the material with chemicals. Transforming it into pulp, Forming, pressing and drying the paper, Finishing and rolling [6, 7].

All types of work can pose health risks to workers [1]. Therefore, through a series of measures taken or at all stages of the production activity, the general principles of prevention must be defined. It is necessary to identify, evaluate and act on all existing occupational risks, both those that can cause accidents and / or illnesses, such as situations caused by mental fatigue, dissatisfaction at work, etc. and, in general, any possible deterioration of the health of workers. Nowadays we live in an almost

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permanent change, imposed by the growing competition, which means a continuous effort of companies to adapt to their survival in the market. With this development, there can often be improvements in working conditions, but also, as is often the case, new dangers. It is known that the prevention of occupational accidents and diseases is a set of techniques and /or procedures that have the function of eliminating accidents [2-5].

Accidents at work are not the result of chance but are caused by natural and foreseeable causes. By identifying and eliminating the causes of accidents, they will not happen so easily. It is essential to collaborate with all the company's employees in the activities of Prevention of occupational hazards. To avoid many accidents and occupational diseases, it is necessary to adequately plan prevention actions and to organize an infrastructure that allows for the change, as far as possible, of processes over time, so that appropriate measures are taken to control the risks that produce them [1].

Safety and health at work is one of the most important areas of social policy in the European Union. Statistics at European Union level show that every three and a half minutes, a person dies in the EU due to accidents at work; this means over 150.000 deaths annually, resulting from work accidents (8.900) or occupational diseases (142.000) [8]. For these reasons and not only, it is necessary to study occupational safety and health as a discipline and it must start by knowing the general problems, focused on the risks of accidents and occupational diseases that may occur in work processes and on the main measures to eliminate or diminish them**.**

2. WORK ACCIDENTS

An accident at work can be defined as an accident that occurs at the workplace during the working day and that causes direct or indirect damage, functional disorders or illness leading to a reduction in the ability to work or earn or death [1]. The following are also considered to be work accidents:

a) Trips to and from the workplace;
b) Implementation of services provided spontaneously, and which may lead to economic benefits for the employer;
c) At the workplace, when exercising the right of assembly or activity of the workers' representative, in accordance with the law;
d) At the workplace, in case of attending a professional training activity in progress or outside the workplace, if there is an express authorization from the employer to do so often;
e) During the job search activity during the hours granted by law to workers in the process of terminating the current employment contract;
f) outside the place or working hours, when verifying the performance of certain services by the employer or by an appointee.

Accidents at work, no matter how unexpected and unwanted they are, do not happen by chance. They are the consequences and effects of natural situations, which are sometimes difficult to find. And they will happen again if we do not discover and control the causes. It is said that there is an accident at work if it causes an injury. To avoid this situation, the idea of safety arises, which is a set of techniques and procedures that aim to eliminate or reduce the risk of accidents that occur in the workplace [4, 11, 12].

3. MACHINE SAFETY RISKS

During the production process, situations sometimes arise that can cause injury to workers, as well as defects and losses in products, machinery and jobs. In the workplace, there are numerous accidents, and sometimes the causes of these accidents are clearly visible, it just did not directly affect the performance of workers, and therefore their resolution was delayed. There is also sometimes a certain lack of knowledge on the part of workers about the risks to which they are exposed, which leads to a lack of their prevention [2].

The workplace must be equipped with good security, which is essential to prevent accidents at work and thus make it more convenient. Therefore, it is important to know the environmental hazards. To have a safe workplace, the following recommendations should be considered:

- Machinery must have a safe distance, which would allow workers sufficient space to access and move safely around them;
- The workplaces must be properly directed and provided with a permanent location for the storage of utensils and tools;
- Raw materials should be easily accessible at the workplace, as well as finished products and waste, so as not to interfere at any time with the worker's movements;
- Traffic areas, corridors and stairs must be of appropriate size and must be free of any obstacles;
- Corners and fixed obstacles must be properly sealed;
- Lighting conditions must be adequate;
- Buildings and general facilities should be subject to periodic and appropriate maintenance work to ensure good technical conditions.
- The movement of workers and vehicles at the workplace must be done in different traffic passages, which must be properly marked;
- The floor should be slip-resistant, and the footwear used should be suitable for it;
- In holes and walls that are likely to cause the fall of materials or people, suitable protection must be inserted.

Preventive measures aim to reduce the risk of an accident at work or occupational disease. Preventive measures can be of two types:

1. Technical measures - intended to act directly on the source of risk, to eliminate, reduce or replace it. One possible example of a technical measure is water washing of dust deposits to prevent exposure to silicon particles;
2. Organizational or administrative measures - have the role of changing behaviors and attitudes and promoting a positive security culture.

Harmful factors are largely related to the type of processes, technologies, products and equipment in the workplace, but they can also be influenced by the way work is organized. Preventive measures must be complemented by protective and mitigating measures.

Vision of Zero Accidents is based on the belief that all accidents can be prevented. Vision Zero is a philosophy rather than a quantitative goal: according to the principle behind it, no one should be injured or killed in an accident. People make mistakes, but they shouldn't lead to injury. This is one of the reasons why, when planning any work or living environment, the focus must be on security.

4. PRINCIPLES FOR INTEGRATING SAFETY INTO MACHINE DESIGN

Any machinery must be designed and constructed in such a way that it is fit to perform its function and can be used, adjusted and maintained without exposing operators to a risk. In accordance with the provisions of SR EN ISO 12100:2011, the prevention measures are a combination of the measures implemented by the designer and the user (Fig. 1).

The measures that can be included in the design phase are preferable to those implemented by the user being usually more effective. The goal is to achieve the most important possible risk reduction, considering the following 4 factors:

- Machine safety, during all phases of its work;
- The ability of the machine to perform its function;
- The convenience of using the car;
- Costs of production, operation and maintenance.

For the safe operation of the machine to be sustainable, it is necessary that the protective measures taken allow it to be used easily and do not impede its intended use.

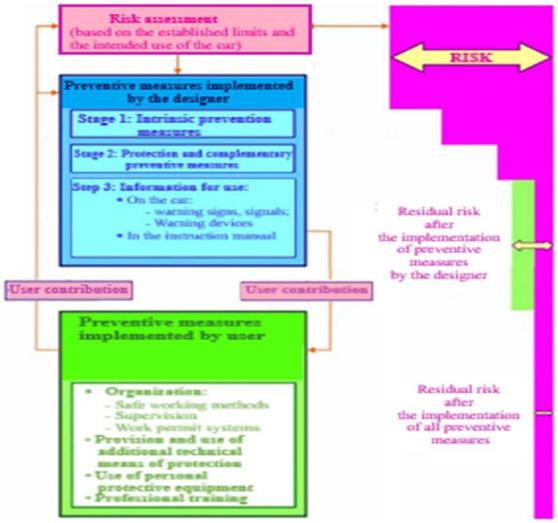


Fig. 1. Procedure for reducing the risk in the design phase (according to SR EN ISO 12100:2011).

5. PROTECTION OF MACHINERY. SAFETY MEASURES TO PROTECT OPERATORS

The protection of machinery and machinery at the workplace is crucial for the reduction or complete avoidance of accidents at work caused by poor safety measures implemented at the level of the organization [3].

5.1. Protection of machines and machinery, a measure imposed by OSH legislation

Every year there are many accidents at work, and people die due to inadequate protection of machines. The countless cases of severe injuries such as lacerations, crushed appendages, abrasions, blindness, and even amputations are recorded as incidents. The safety measures of machinery and machinery must first comply with the strict minimum to guarantee a safe working environment for personnel [5]. These premises are as follows:

- Prevention of contact - The safety measure must protect personnel from meeting any part of their body during potentially lethal movements of machines and machinery.
- Safety - The protection and safety equipment must be firmly fixed on the car and be difficult to handle. They must be constructed of a sturdy material to withstand the use of the machine.
- No additional risks should be introduced. Any protection used must not endanger employees in any way. This can appear in the form of ragged pieces, sharp edges, etc.
- Allows for safe lubrication - If possible, the protective device should nevertheless facilitate the lubrication of the machine

5.2 How do machinery guards work?

Any company can maintain compliance with the requirements of occupational safety and health regulations for the protection of machinery and machinery if it uses any of the fundamental mechanisms and follows the best practice guidelines.

Fewer hazards in the workplace are beneficial for both the organization and the employees. The hazards of unprotected machines could lead to accidents that cost money, decreased productivity, and the possibility of damage to equipment or the product.

Machinery and machinery protection is a design measure designed to protect employees from moving machine components. Most of the time, machine and machinery protection is applied in environments where manufacturing work is widespread.

5.3 Identification of the type of protection of machinery

Three areas around heavy machinery and machinery hold most of the risks considered dangerous for workers. These are the points of operation, the means of power transfer and the moving parts. Because personnel are frequently assigned responsibilities in these dangerous locations, those three areas tend to have the best car protection systems. There are several movements and behaviors that machines make that could endanger operators.

The first step in identifying the type of machine and machinery protection to be installed is to determine the types of risks that exist in the car. Movements that could be dangerous include:

- Spinning movements;
- Alternating movements;
- Transverse movements.

While the following machine operations can become dangerous: cutting, trimming, bending.

5.4 Eliminating hazards using machine guards

To keep operators safe, it is necessary to identify and eliminate or at least reduce certain types of hazards. The elimination of hazards can be achieved by using one or more fundamental methods of protecting machinery.

There are still some good practices to consider for keeping personnel safe while working with heavy machinery and machinery, in addition to providing proper training on the machine to which workers will be assigned.

Employees should not operate equipment that they have not been taught to use. It is the employer's responsibility to ensure that all employees have received the necessary training in the machinery they will be using during the day.

Machine tagging is the next best practice technique to apply in a situation like this. Simply

marking machine hazards can save lives by making threats to workers obvious.

6. ERGONOMIC DESIGN OF SOME PROTECTION PANELS - CASE STUDY

Before becoming a paper roll, paper pulp travels a long way through the paper machine:

- Forming sieves area: the paste is jet deposited on the forming sieves. The sieves have a movement that facilitates the formation of the paper strip and dehydration.
- The area of the presses: here the paper strip picked up on an absorbent pad is compressed between two cylinders.
- Drying area: the tape is dried on some cylinders that are heated inside with steam.
- Surface treatment: the surface of the sheet is covered with materials that improve its properties.
- Calendar: here the surface of the paper is uniformed by compression between steel waves
- Surface treatment with mineral pigments (chalking): the paper strip can be coated on one or both sides with a layer of mineral pigments (kaolin), to improve the printability of the paper.
- Winding: the paper strip is wound into coils. From the rolls the paper can then be cut into sheets or small rolls can be cut.

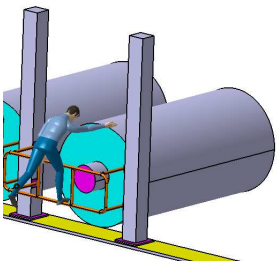
One of the operations that has been proven to lead to accidents at work is the passage of paper through a space containing several steam-heated drying cylinders. The cylinders are heated up to 130 ℃, using the heat generated by steam, to ensure that the paper dries up to 80-85%. The wet gluing solution is now applied to the paper to add a thin layer of starch to the surface, which contributes to the stiffness and bonding of the fibers in the sheet of paper. After applying the gluing solution, the paper passes through another set of heated drying cylinders.

It has been found that the operator is tempted to climb onto the existing panel and reach towards the machine during the operation of the machine, for various small adjustments in the installation, or other short interventions, in order to grasp the paper/cardboard by hand or to help the sheet of cardboard to pass further through the cylinders (see Fig. 3 a and b). This is dangerous, whenever there is a risk of an acident at work.

The new proposed variant is to replace the existing exterior panels with other panels located in two planes (see Fig. 4). Some are of the gate type located towards the operator and the others are fixed, mounted at the limit towards the inside of the machine. In this way, the operator no longer has to climb the protection panel and does not get very close to the cylinders. Also, if it needs to intervene, the gate panel allows it to make various adjustments during the operation of the machine with the gate closed. Moreover, if necessary, the gate type panels can be opened at an angle of up to 1800 making it possible to approach the machine with another 0.5 m. The second row of panels are for the protection of the operator from falling into the machine tub / shredder or at the base, being a level difference of about 7m.

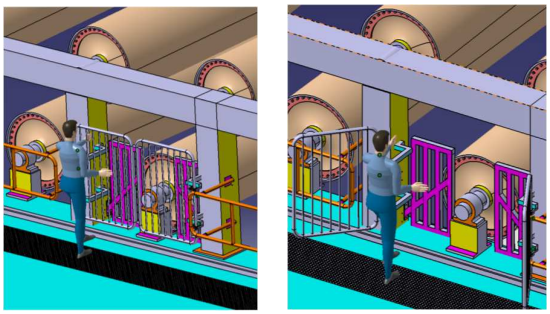
Fig. 2. Production hall (personal photo gallery).

3.a) Personal photo gallery



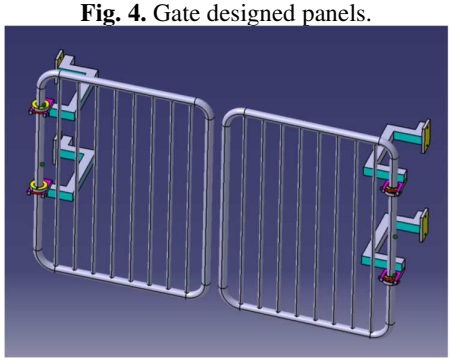
3.b)

Fig. 3. Existing panels on the machine that allow climbing.



a) b)

Fig. 4. Gate designed panels.



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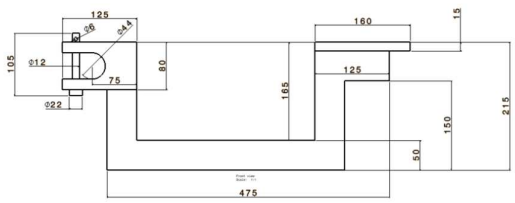

b)

Fig. 5. Mounted gate panels.

Gate type panels have dimensions of approximately H x W - 1200 x 1000mm. They are made of aluminum and are made of round pipe, frame - Ø 48x3mm and the lattices of Ø 20x1.5mm arranged vertically (see Fig. 5). Also, in case of longer maintenance, or if a longer intervention is required, these panels can be removed from the rotary hinges in a simple way, by removing two bolts from the fork-type piece. For the installation of the gate panels, the clamping holes already existing on the machine will be used. In this way, the time required for the installation of new panels is reduced.

The fixed panels are also made of aluminum and are made of 50x50x3mm rectangular pipe. The laying plate is 200x60x8mm, it is provided with 2 holes for mechanically attaching the panel to the machine structure. For fixed panels, two M12 threaded holes will be drilled for each panel in the existing metal structure. In addition, sliding "fixed" panels.

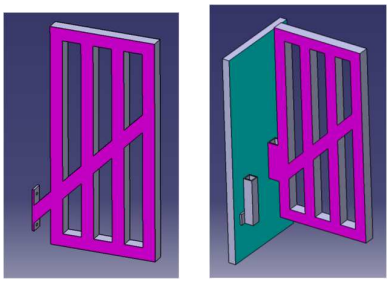

Fig. 6. Fixed and sliding panels

Depending on the installation location, the removable version of these panels can also be mounted on these panels. The clamping system on the pole is the same, instead on the side of the panel there is a sliding system, sliding the square pipe into the square pipe. The fixed part on the pole is made of stainless steel and an aluminum pipe is welded to the panel, see Fig. 6.

The clamping arms for the gate type panels are made of stainless steel, square pipe 40x40x4. The fork-type element is made of sheet metal with a thickness of 15 mm, also made of stainless steel. The arms fixing feet are made of 150 x 60 x 8 stainless steel sheet Bushing – the hinge is an assembly of 2 bushings, stainless steel + aluminum. The speed between them is done mechanically, by screws. The aluminum bushing is welded to the gate frame. The stainless-steel bushing will be placed in the fork and will ensure the rotation of the gate.

The bolts, with a diameter of Ø10 x 120mm, for fixing the gates in the hinges are also made of stainless steel. The current panels are made of non-alloy steel and are painted with small signs of rust; the new panels will be made of aluminum. The approximate weight of the old panel is 20.4 kg and the new one bears about 11.7 kg. Upon eventual disassembly, the new panel is lighter. Mounting vertical lattices in the gate panel at less than 80 mm will prevent the operator from occasionally climbing. Locks - For closing / fixing the gates in the closed position, mechanical locks with a special key will be mounted, see Fig. 7. The locks, the mechanical system are made of stainless steel, and the housing is made of aluminum.

Both the fixed and gate panels will have different sizes for each of the two pillars. There are configuration differences due to the different positioning of the main and auxiliary machines and the need to adjust them.

Fig. 7. Images of mounted panels (personal photo gallery)

When designing the protective panels, ergonomic principles were observed, which involved considering the following parameters: dimensions of the human body; efforts and positions; range of motion; frequency of cyclical actions. To choose the optimal solution, the following elements were considered:

- Elimination or reduction of risks as much as possible (design and construction of protection elements with intrinsic security);
- Adopting the necessary protection measures for risks that cannot be eliminated;
- Informing operators about the remaining risks, about the need for special training.

The risk reduction procedure from the design point of view was carried out according to the requirements of SR EN ISO 12100:2011 and consisted of going through the three stages: intrinsic prevention measures, protection and complementary prevention; information for use.

7. CONCLUSIONS

Work equipment can create hazardous areas for the worker, both inside and around them. The presence of the workers in these areas exposes him to a risk to his safety and health. For these reasons, safety and health requirements for the worker are laid down from the design phase. These requirements are designed in such a way as to ensure the safety of the worker, including in the execution and exploitation phases.

Protective devices must: eliminate or reduce risks; to be of robust construction; not to generate additional risks; not to be easily removed; be located at an appropriate distance from the danger zone; not to limit the observation of the work cycle more than necessary; to allow interventions for the replacement of some elements of the equipment; to allow interventions for maintenance activities. Protective devices are elements that can be included in the composition of work equipment or can be placed around it.

- Every year there are a lot of accidents at work, and people die because of the inadequate protection of cars. The countless cases of severe injuries such as lacerations, crushed limbs, abrasions, blindness and even amputations are recorded as incidents. The safety measures of machinery and machinery must first comply with the strict minimum to guarantee a safe working environment for personnel. These premises are as follows:
- Prevention of contact. The safety measure must protect personnel from encountering any part of their body during potentially lethal movements of machines and machinery.
- Safety. The protections and safety equipment must be firmly fixed on the car and be difficult to handle. They must be constructed of a sturdy material to withstand the use of the machine.
- Safety measures must be put in place to ensure that there is no chance of tools falling into the machine and getting stuck inside it or becoming projectiles.
- No additional risks should be introduced. Any protection used must not endanger employees in any way. This can appear in the form of ragged pieces, sharp edges, etc.

To keep operators safe, it is necessary to identify and eliminate or at least reduce certain types of hazards. The elimination of hazards can be achieved by using one or more fundamental methods of protecting machinery and machinery. If proper safety measures are taken to protect machinery and machinery, workers will have the tools they need to get through the day without accidents [11, 12].

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Reducerea riscurilor de accidentare la procesarea hârtiei prin proiectarea ergonomică a panourilor de protecţie

Lucrarea studiază măsuri privind reducerea riscurilor de accidentare la procesarea hârtiei prin proiectarea ergonomică a unor panourilor de protecţie, pentru a separa în mod sigur zona cilindrilor de lucru între operator şi utilajul de producţie. Se prezintă importanţa respectării principiilor de integrare a securităţii în proiectarea şi construcţia echipamentelor de muncă, precum şi a principiilor ergonomice de proiectare. In finalul lucrării sunt prezentate rezultatele cercetărilor privind proiectarea, construcţia şi montarea unor panouri de protecţie ergonomice, situate în două planuri, care să elimine riscurile de accidentare ale operatorilor.

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