STUDY ON THE APPLICATION OF THE 3D MODELLING IN EXPLOSION PROTECTION IN WOODWORKING INDUSTRY

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Abstract: The study deals with explosion protection in the operation of a production hall for processing wood material, using the CAD visualization of the 3D modelling program SketchUp. The wood operation is focused on the production of children's playgrounds and processes exclusively agate wood. The starting point for the elaboration of a written document on explosion protection for 3D modelling was ATEX 137 [1] on the minimal requirements for ensuring safety and health at work in an explosive atmosphere. Assessment the risk of explosion in the production hall, the classification of areas with explosive atmospheres into zones was modelled in 3D. To minimize the likelihood of explosion and mitigate the impact, devices have been designed to reduce dust in the workplace by means of air-conditioning equipment and air-humidification equipment. The benefits of 3D modelling are supported by Industry 4.0 and the upcoming Industry 5.0, which in practice means a faster and more efficient display of individual contexts in space. The result of the study is a digital three-dimensional project of an object exported in 3D format (.skp), which is an important part of creating a virtual model of explosion protection.

Key words: ATEX 137, ATEX 2014/34/EU, Industry 4.0; SketchUp; Wood processing

1. THE CURRENT STATE OF THE PROBLEM OF EXPLOSION PROTECTION IN WOODWORKING INDUSTRY

1.1. Introduction

The job of an engineer in security services is to properly assess the risk and design a system for the operation of work in technological operations to reconcile often conflicting goals. Legal or safety correction is often at odds with the demands and needs of company employees and their management. Therefore, setting the correct safety limits is not easy and no longer costly. It is of the utmost importance to know the risk and apply safety measures to achieve the level of residual risk that is tolerated by the company.

Correct risk assessment in the technological processes of working with wood includes, among other things, fire safety, but no less important role is to establish the fact of the risk of explosion of agitated dust, even materials that do not normally pose a fire risk.

The explosion itself can have a negative impact on life and human health, the destruction of property, animal lives and damage to the production process. It is essential that in operations where there is an increased likelihood of an explosion, employees are informed and properly trained to work in hazardous environments.

The aim of the study is to identify the danger of explosion when working in a woodworking hall and to propose measures to minimize the occurrence of an adverse explosion event. 3D modelling of the production hall project helps to determine technological, organizational, and legal measures more easily for fire and explosion protection.

1.2. Implementation of the latest technologies in the woodworking industry

The use of the latest technologies in the wood industry in our country and in the world is still at a relatively low to very low level. The bulk of the inclusion of the 4.0 technological revolution includes

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modern wood processing equipment and a support team for controlling these devices. These are mainly computer-controlled machines (CNC), robotic production lines, intelligent technological spaces capable of controlling the flow of material, ordering system or security system.

The problem of the absence of autonomous technologies may be insufficient use of the economic, or educational potential of the country, as well as the strategic position of the state or other factors that affect the maturity of IT in the country. Finally, it is a politically, autocratically, or humanely motivated intention to leave work to people and not to machines. In this sense, Gazquez et al. assessed the lack of skills in the areas of key enabling technologies (KET) following the 4.0 (14.0) industrial revolution in higher education. The evaluated sectors include the skills of university graduates in the wood and furniture industry and their level of implementation regarding the latest technological trends. [2]

According to Kropivšek and Grošelj, the situation in Slovenia is at an advanced level of use of information technology and artificial intelligence. The research examined the digital development of the Slovenian wood industry, in particular the implementation of the Industry 4.0 and the upcoming Industry 5.0 concept in practice. Within this, the implementation of specific technological pillars with an emphasis on intelligent factories and intelligent innovative products was studied. [3]

2. MATERIAL AND METHODOLOGY

The production of children´s playgrounds can be realized using various materials. The material used is metal, plastic or wood. In the given operation, children´s playgrounds are mainly made of agate wood, due to its relatively good availability in the Central Europe, affordability, and very high durability.

2.1. White agate *(Robinia pseudoacacia)*

The authors Maľová et al., states that the original occurrence of this wood is in the southern part of the North American continent. The tree grows to a height of 25 m. Agate wood consists of three parts, bark, white and marrow. The agate white wood is hard and heavy. [4] It is suitable for carpentry processing, splitting but also for surface treatment. During impregnation, it shows a high absorbency of the impregnated substance. Drying is slow. It is resistant to most types of biotic pests. Wood Agate white *(Robinnia Pseudoacacia)* is one of the most durable species of wood that will last 80 years without treatment. If the agate wheel is under water, its shelf life exceeds 300 years.

2.2. Machinery in the wood hall to produce children´s playgrounds

For the purposes of wooden constructions, agate tree trunks are stripped of bark and white, which is the purpose of the debarking device. Horizontal band saw, this frame horizontal is a movable band saw used to cut the entire log along the horizontal direction. Angle grinder a tool used to smooth a surface by grinding by rotating a grinding wheel. Tail saw, the type of saw a straight cut but is mainly used for cuts with an atypical motion trajectory.

2.3. Classification of areas with explosive atmospheres

When wood lumber is treated with machinery, wood dust is created which, when mixed with air, creates an explosive atmosphere. To assess the risk of explosion, areas with an explosive atmosphere must be classified as areas with a risk of explosion into three zones. Zone 20 is a space in which an explosive atmosphere composed of a mixture of combustible dust and air in the form of a cloud occurs continuously, for a long time or frequently. Such places generally occur only inside the wood sawdust extraction line, inside the wood dust extraction pipe or the fine wood waste container and near the wood dust production plant in its vicinity. An example of zone 20 is shown in Figure 1.

Zone 21 is an explosive environment forming agitated combustible dust mixed with air, the occurrence of which is occasional. The occurrence of such places is within the production hall where combustible dust with air swirls and includes the entire interior of the production hall. Above all, however, these are places around the working machines.

Zone 22 is an explosive atmosphere forming turbulent combustible dust in admixture with air which is not expected to occur, but even if it does, it is only for a short time. Such a place represents the space of the production hall where the dried lumber shown in Figure no. 2.

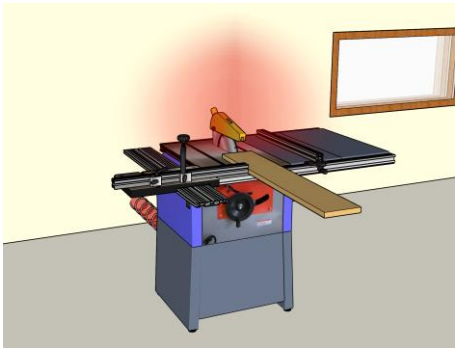


Figure 1 - Circular saw, Zone 20

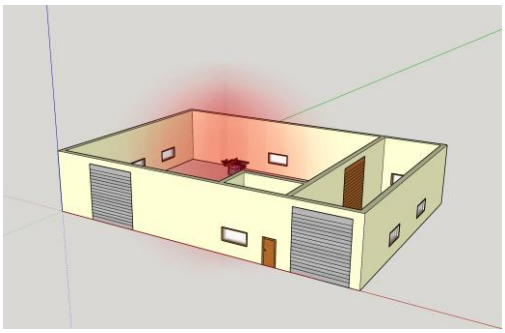


Figure 2 - Production Hall Zone 22

Table 1 Categories of equipment for explosive atmospheres ATEX 2014/34/EU [5]

Group	Cate-gory	Use	Degree of protection	Explosive zone
II.	1	gas and dust explosive atmosphere lasting continuous or long period of time	Very high degree of protection	zone 0 (G) zone 20 (D)
	2	gas and dust explosive atmosphere occurring occasionally	high degree of protection	zone 1 (G) zone 21 (D)
	3	gas and dust explosive atmosphere occurring rarely and for a short time	normal degree of protection	zone 2 (G) zone 22 (D)

2.4. SketchUp Modelling Program

SketchUp is a 3D modelling program owned by software company Trimble Inc. based in Sunnyvale, California, USA This program is used to obtain detailed product diagrams and model three-dimensional sculpture diagrams. It is characterized by a simple user interface and orientation in space (SketchUp,). [6] SketchUp is a highly intuitive program, it is possible to download a plethora of add-ons (plugins) that help create better models in a more efficient way. [7]

SketchUp is a user-friendly open-source program. It can be widely used at the educational level as well as at the professional level. It offers demonstration of real objects in a virtual environment to understand and present the relationships needed to create the most virtual reality of real projects at the time of their development to minimize costs and time. Example of use in practice in modelling a woodworking workshop Figure no.3.

3. RESULTS

When assessing the risk of explosion, it is necessary to consider potential locations of hazardous atmosphere by including places in the relevant explosion hazard zones, re-evaluate the production process, equipment used and a system of preventive measures to minimize the risk of explosion. An important part is also to acquaint employees with the presence of an explosive atmosphere by proper training and behaviour in the workplace according to the principles of health and safety.

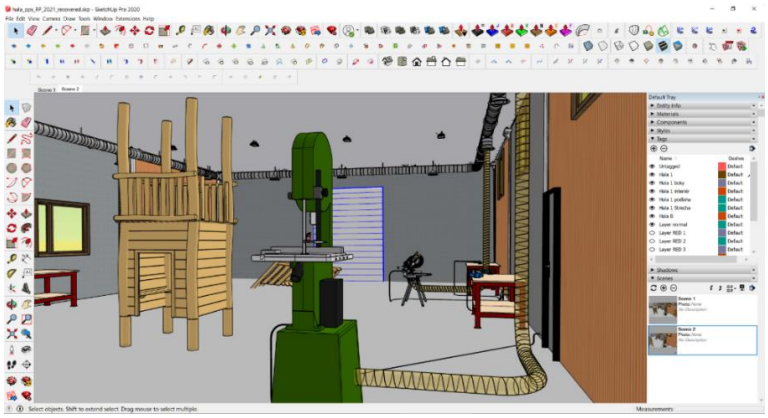


Figure 3 - SketchUp model Wood workshop

3.1. Classification of carpentry workshop premises

When assessing the risk of the probability of the occurrence of an explosive atmosphere and considering the points of procedure according to ATEX 137. I designed the occurrence area of zone 20 in the 3D environment using the modelling program SketchUp. The presence of an explosive atmosphere in this zone is continuous or almost continuous during operation of the machinery.

Zone 20 is in model Figure no.4. In the woodworking workshop, it is depicted with a pink-red area. This area is formed by a space 1.5 m from the center of emitting dust particles.

Figure 4 - Production Hall model, Zone 20

Zone 21 is an area with an explosive atmosphere formed by a mixture of agate wood dust with air and the occurrence is occasional. Such a space is visualized in the present hall of the production building by the area of faint red colour in Figure no. 5 in the vicinity of 3 m from the point of dust production.

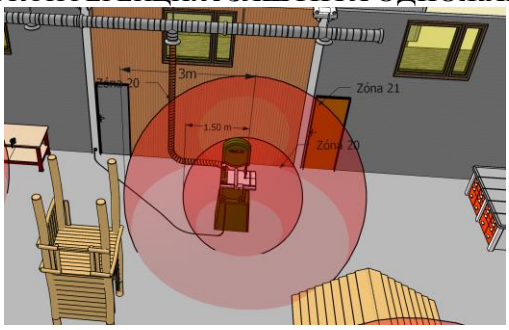


Figure 5 - Production Hall model, Zone 21

The area shown in Figure no. 6 is a zone 22 in which a hazardous atmosphere is not expected to occur and, if such a situation occurs, it is only for a short time.

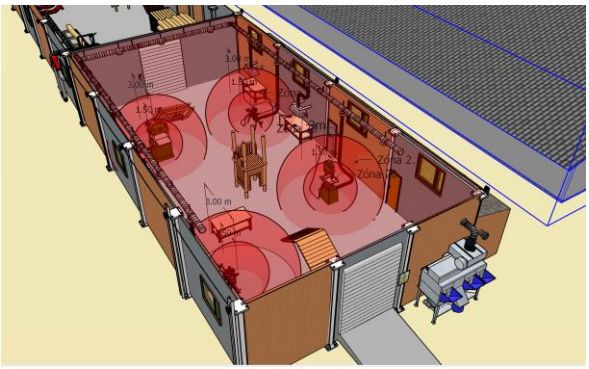
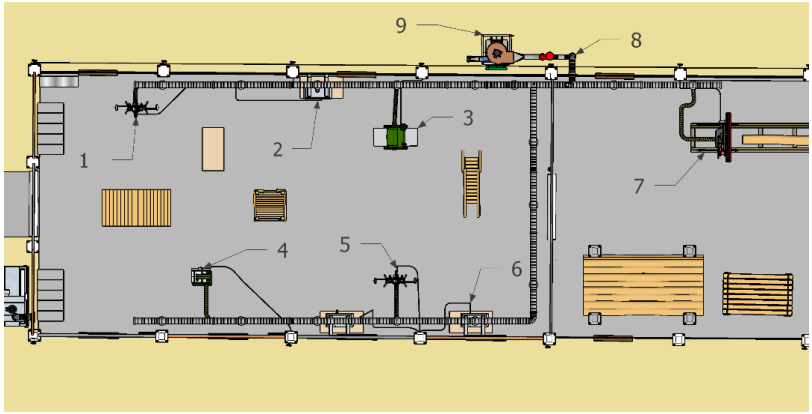


Figure 6 - Production Hall model, Zone 22

3.2. Design of equipment intended for zones according to the probability of the occurrence of a hazardous explosive atmosphere

For devices where many residues in the form of wood dust is generated during work and their position is anchored within the hall, a central dust extraction by means of a vacuum airline is designed. Three manual extraction stations connected to a central extraction are reserved for manual woodworking equipment.

Within the production hall, a band saw, a woodworking planer and two circular saws, two stations for work with hand tools are equipped with this air extraction device Figure no. 7. Suction of machinery is ensured by means of a polyurethane flexible hose reinforced with a steel wire in the shape of a spiral. It is primarily intended for sawdust extraction, capable of withstanding vacuum, connected to a galvanized steel pipe. This air duct opens from the outside of the hall at the location of the cyclone separator. The arrangement of the machinery within the hall is shown in Figure no. 7.



1. Circular saw
2. Tail saw
3. Planer
4. Vertical saw
5. Circular saw
6. Angle grinder
7. Horizontal saw
8. Air conditioning
9. Cyclone separator

Figure 7 - Production hall, top view

The horizontal band saw located in the eastern part of the hall and is also part of the proposed air conditioning. A dangerous explosive zone has not been designed for the given facility, as raw wood is processed here, the moisture of which is many times higher compared to dried lumber. Such wood does not create an explosive atmosphere during processing.

Ventilation extraction of sawdust and small pieces of wood works on the principle of a vacuum system, the operation of which is ensured by an 18-kW electric motor. It is part of a cyclone sawdust separator. It is designed for dust-explosive environments. This device is also equipped with a relief membrane which, in the event of an explosion in the cyclone separator, ruptures and mitigates the deformation effects of the pressure wave.

An anti-explosion chimney is designed on the exhaust pipe, located outside the building and its function is to alleviate the explosion by releasing the pressure wave of the explosion front into the safe zone due to a change in the direction of the exhaust air flow.

Humidification system within the hall, ensures high-pressure spraying of water in the form of water mist. (Figure 8) Its main task is to create water particles that bind dust and thus significantly reduce the risk of explosion in the atmosphere.

Other advantages of such air humidification include in particular:

• reduction of the probability of static electricity

• increase of comfort of inhaled air, which has a significant impact on the health of employees

• increase of functionality of machines operating in significantly less dusty environment.

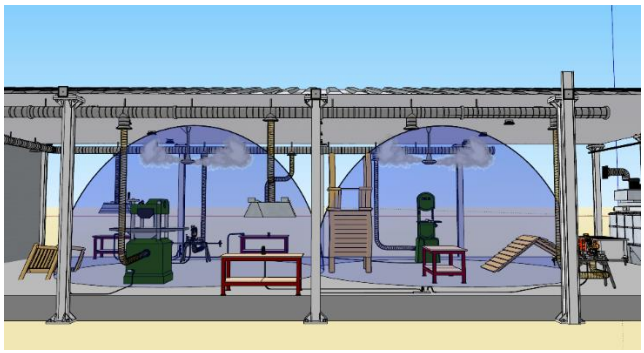


Figure 8 - Humidifying equipment

3.3. Evaluation of the measures taken

In table 2, there are machines that are used in the production hall for processing lumber and their classification into the appropriate category of explosion protection according to the environment in which they are located during the production process.

Table 2 - Summary table of machinery in the production hall

Device number	Machinery	Created explosive environment	Device category
1	Band saw	zone 20	1D/ IP64
2	Circular saw 1	zone 20	1D/ IP64
3	Circular saw 2	zone 20	1D/ IP64
4	Planer	zone 20	1D/ IP64
5	Angle cutter	zone 20	1D/ IP 64
6	Tail saw	zone 20	1D/ IP64

The adoption of technical and organizational measures in the woodworking workshop to produce children´s playgrounds involve the inclusion of machinery in individual danger zones with the appropriate certification, which declares safe use in the given environment. Explosion-proof protection elements, such as a relief membrane and an explosion-proof chimney, have been designed for the suction device to minimize the consequences of a possible explosion. The entrance to the hall is marked by the appropriate danger zone, which clearly defines the area with an explosive atmosphere. We considered that the knowledge of employees working in an explosive environment is insufficient and therefore training of employees in terms of explosion protection and health and safety was proposed. For machinery that does not have a fixed location within the production hall and creates an explosive environment, a local exhaust device was designed, the efficiency of which within the hall was significantly supported by the proposed air humidifier, which largely eliminated the occurrence of frequent static sources of static electricity. In the partition of the separated eastern part of the production hall, we did not mark the horizontal machinery of the band saw as the cause of an explosive atmosphere, as the cross-section of the raw log reaches many times higher humidity than the dried lumber. Applying paint within both parts of the hall also does not pose a risk of explosion, as the paint is water-soluble and does not create an explosive atmosphere.

4. CONCLUSIONS

The European Directive 99/92 /EC (ATEX 137) was used for the elaboration of a written document on explosion protection and ATEX Directive 2014/34/EU. On minimum requirements for ensuring safety and health protection at work in an explosive environment.

Real space modelling while maintaining the dimensions of the actual hall and interior, with the support of CAD 3D technology in the modelling tool SketchUp Pro 2020, significantly helped to achieve the assessment of the risk of explosion in the space. The production process of processing wood parts takes place within the production hall and poses a significant risk of explosion of wood dust due to mechanical processing of wood raw material to produce playgrounds. The model of the hall contains proposals for technical and organizational measures. The individual explosion hazard zones were modelled and graphically represented. By minimizing the risk, we protect the life and health of employees, technology and thus the production process itself.

The use of modern 3D modelling technology in industry, provides a realistic idea in the construction and modification of buildings and in the implementation of safety designs. It provides accurate plotting of areas and helps determine the occurrence of hazardous areas of explosion. It enables verification of proposed measures and implementation of changes in the virtual environment with minimization of financial and time costs.

Acknowledgments

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REFERENCES

[1] ATEX Directive 99/92/EC (ATEX 137): 1999 sets out the minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres.

[2] Gázquez J. L. R., Delgado M. V. B., Gras J. J. O., Lova J. G., Gómez M. V. G., Zbie M. (2021) Lack of skills, knowledge and competences in Higher Education about Industry 4.0 in the manufacturing sector.

[3] Kropivšek J., Grošelj P. (2020) Digital Development of Slovenian Wood Industry. University of Zagreb: Licensee Faculty of Forestry.

[4] Maľová M., Sujová K., Longauerová V., Túčeková A. (2018) Agát biely hospodárska drevina s inváznym charakterom. Zvolen: Národné lesnícke centrum – Lesnícky výskumný ústav Zvolen.

[5] ATEX Directive 2014/34/EU: 2014 on the harmonisation of the law of the member states relating to equipment and protective systems intended for use in potentially explosive atmospheres

[6] SketchUp (2021) Trimble. Available at: http://www.sketchup.com (Accessed: 17 February 2021)

[7] Saymote, P. (2017) A Powerful Tool for 3d Mapping and Modelling. Available at:https://www.researchgate.net/publication/308968859_Google_Sketch_up_A_Powerful_Tool_for_3d_Mapping_and_Modelling?enrichId=rgreq3670685a2cdea5d3b004b176556c15c4XXX&enrichSource=Y292ZXJQYWdlOzMwODk2ODg1OTtBUzo1NDM5ODA0OTY4NjczMjhAMTUwNjcwNjQ2NTUzMg%3D%3D&e (Accessed: 29 February 2021)