ETIKUM 2021

INTERNATIONAL SCIENTIFIC CONFERENCE
NOVI SAD, SERBIA, DECEMBER 2-4, 2021

Savković, M., Jovičić, M., Vukićević, A., Mačužić, I., Todorović, P.

RESEARCH ON THE POSSIBILITY OF IMPROVING THE SAFETY AND HEALTH AND EFFECTIVENESS OF WORKERS WHO PERFORM MANUAL WORK ACTIVITIES USING EXOSKELETONS

Abstract: *The main focus of the paper is to explore the possibilities of improving the occupational safety and health and effectiveness of workers who perform manual work in the automotive industry using industrial exoskeletons. Exoskeletons are mechanical devices that workers carry and that support workers and strengthen their physical abilities (strength and endurance) when performing difficult, manual and physically demanding tasks that cannot be automated (such as lifting loads and handling loads, positioning and using tools, handling objects, etc.), and enable them to perform their work activities more effectively.*

The analysis of numerous examples from practice concluded that the use of exoskeletons contributes to the reduction of injuries at work and the improvement of the general health of workers through the reduction of musculoskeletal disorders, neck, shoulder, back pain, stress and fatigue. Also, the application of industrial exoskeletons increases the efficiency, productivity and effectiveness of workers.

Key words: *Effectiveness, Exoskeletons, Improving safety and health*

1. INTRODUCTION

One of the important goals of modern companies is to improve the safety and health of workers. This goal is achieved through reduction of occupational injuries, occupational diseases and diseases related to work and creating prerequisites for full physical, mental and social well-being of employees.

The application of new innovative technologies of Industry 4.0 and the automation and digitalization of production processes contribute to the improvement of working conditions and the improvement of safety and health of workers [1]. Despite the automation and digitization of the process, many workers who performing manual, repetitive and physically demanding work activities are still exposed to physical strain (more than 30% of workers in the EU face this problem). Also, 63% of workers perform activities that involve repetitive movements and 46% of workers perform activities in non-ergonomic body positions [2].

Exoskeletons are one of the innovative supporting technologies of the fourth industrial revolution, which is applied to provide help and support to workers who are exposed to physical load while performing daily repetitive and physically demanding work activities in non-ergonomic body positions. Workers who perform these activities are exposed to the dangers of musculoskeletal disorders due to frequent bending, twisting, body strain, manual handling of large and awkward objects and loads.

Musculoskeletal disorders are one of the most common occupational diseases, considering that these diseases affect millions of workers globally. Also, in the European Union, more than 40% of workers experience pain in the lower back, neck and shoulders that occur as a result of performing these professional tasks [2]. An analysis of numerous studies has concluded that performing 70% of repetitive work tasks in industry such as assembly of components and parts can cause musculoskeletal disorders and 60% of physically demanding professional activities performed by workers cause back and shoulder pain [3].

This is especially pronounced in the automotive industry, where workers perform repetitive, tedious professional tasks in non-ergonomic positions over a long period of time, which negatively affects their health [4]. Musculoskeletal disorders make it difficult and in some cases impossible to perform professional tasks and are one of the main causes of workers' absence from work and can lead to temporary or permanent incapacity for work.

Taking into account the fact that musculoskeletal disorders cause high costs for employers and the state as a whole, due to the costs of sick leave, costs associated with rehabilitation of injured workers and the cost of hiring and training replacement workers, modern companies show great interest in applying innovative Industry 4.0 technologies to reduce workers' exposure to risk factors that can cause

musculoskeletal disorders. Exoskeletons, unlike other Industry 4.0 technologies used to reduce the physical workload of workers (eg collaborative robots), do not require large financial investments and therefore find application in the industrial environment.

The paper is structured as follows: after the introduction, exoskeletons are presented in detail and several examples from the practice of applying exoskeletons in industry are given. After that, the paper points out the possibilities of improving the occupational safety and health and effectiveness of workers who perform manual work activities using exoskeletons in an industrial environment. Concluding remarks are given in the conclusion.

2. INDUSTRIAL OCCUPATIONAL EXOSKELETONS

The appearance of the first exoskeletons is related to the period 1960-1970. These wearables were first used in the military to improve the physical capacity and strength of soldiers, and medicine to provide support to people with disabilities or handicapped people during the rehabilitation period and later began to be used in industrial environments.

Exoskeletons began to be used preventively in industry (production, construction, mining, etc.) in order to improve the health of workers when other preventive measures did not prove effective in reducing fatigue and physical exertion of workers and reducing musculoskeletal disorders.

Exoskeletons are mechanical and medical support devices that have the role of providing support and assistance to workers in performing difficult, manual and physically demanding work tasks that cannot be automated. Exoskeletons support the musculoskeletal system, applying the principle of mechanics. In this way, they contribute to the prevention or reduction of the risk of musculoskeletal disorders due to the performance of difficult manual tasks such as manipulation, lifting and carrying heavy objects.
Exoskeletons enhance the physical abilities of workers (e.g., strength and endurance), reduce the compression of force on the lower back, shoulders, elbows, and joints, and thus protect workers from injury to these parts of the body. The use of exoskeletons reduces fatigue and strain on the muscular system of workers and improves their general health. They provide support to the worker's body during positioning or tool use. Also, exoskeletons support to workers who have some physical deficiency. Exoskeletons make it easier for workers to perform activities with their arms raised above their heads for extended periods of time (such as when using a drill overhead or in the process of assembling components and parts) (Figure 1.).

Fig. 1. Ford 75 ExoVest exoskeleton [5]

Exoskeletons are classified into passive (their goal is to provide support and protection) and active (they have a role to increase strength and endurance of workers). Active exoskeletons use starters (mechanical components that consist of electric motors or have hydraulic or pneumatic drive, etc.) to support the movement and activities of workers, give them extra strength and endurance, and increase their performance. An example is the active exoskeleton for the upper body, which was used in Fiat in Italy to provide support to the hands of workers so that workers could lift heavy objects with ease. In this way, the load on the joints and muscles is reduced and the health condition of the workers is improved.

Unlike active passive exoskeletons use the force of a spring or shock absorber to store energy collected during the movement of workers or perform activities and use it as needed to support the position or movement of workers. For example, when a worker leans forward, energy is collected that later helps him maintain that position or lift his body when lifting an object [6]. So, the power is redistributed in order to protect certain parts of the body.

Passive exoskeletons that support the back are most commonly used in industry and are designed to prevent lower back pain [7]. The passive exoskeleton for the lower part of the body is placed as a "chair" and is applied when workers often change positions or stand for a long period of time. By using this exoskeleton, the load in the legs is reduced and it is easier to adopt the correct positions on the one hand, and on the other hand, the flexibility and mobility of the body parts are maintained.

Also, exoskeletons differ depending on the parts of the body on which they are applied. These

support devices can provide additional strength or support to the lower limbs of workers (exoskeletons applied to the lower body), upper extremities (exoskeletons applied to the upper body) or can provide support to the whole body (both upper and lower extremities). In October 2018, Hyundai Motor Group at the North American plant Hyundai-KIA began testing the Hyundai Vest Exoskeleton, which aimed to reduce pressure on the neck and back of workers, and the Hyundai Chairless Exoskeleton used by workers who have to perform standing activities for a longer period of time. This exoskeleton is placed as a "chair" so that the worker can rest. In this way, the load on the legs and back is reduced and the mobility of the worker is facilitated (Figure 2.).

Fig. 2. Example of an exoskeleton that takes on the role of a "chair" [8]

After the application of these exoskeletons, injuries at work and occupational diseases were reduced and the efficiency and productivity of workers was increased. Exoskeletons enable older workers to perform their work tasks more efficiently. Also, exoskeletons are used by workers who were injured during the rehabilitation period.

Exoskeletons are flexible, ie. they are adapted to the individual characteristics of workers - their age, gender, health status, etc. Exoskeletons also differ depending on the material from which they are built and the accompanying technologies. Rigid exoskeletons, ie. exoskeletons made of rigid materials due to their weight and unnatural body position when worn can cause stress and fatigue. Therefore, exoskeletons made of soft, light and flexible materials are mostly used in the industrial environment.

The use of exoskeletons is regulated by the European Union Machinery Directive (2006/42/EC). Also, the application of exoskeletons must be harmonized with the general international regulations for robots and robotic devices (ISO 10218-1:2011 and ISO 13482:2014). The international standard ISO 8373:2012 (ISO, 2012) is related to the application of robots and robotic devices in an industrial environment.

3. IMPROVING THE SAFETY AND HEALTH AND EFFECTIVENESS OF WORKERS WHO PERFORM MANUAL WORK ACTIVITIES USING EXOSKELETONS

Analysis of numerous studies can conclude that the application of exoskeletons contributes on the one hand to improving working conditions and improving the safety and health of workers and on the other hand to increasing the efficiency and productivity of workers, reducing errors and improving the quality of work. Exoskeletons contribute to the reduction of injuries at work and the improvement of the health condition of workers who perform manual repetitive tasks for a longer period of time in a continuously in an incorrect position [9].

In large production systems such as Toyota, Ford and Boeing, positive effects of exoskeleton application have been observed in the form of reduction of effort and muscle fatigue, reduction of discomfort, reduction of injuries at work and reduction of sick leave costs. Numerous experimental results have shown that the use of exoskeletons in most cases reduces the load on the spine [6]. Also, the application of exoskeletons has resulted in increased worker productivity and improved work quality.

In the past period, there has been an increase in the use of passive exoskeletons on assembly lines. The application of these exoskeletons has led to numerous benefits. For example, after the application of ExoVest exoskeletons in the Ford Motor Company during 2015-2016, there was a reduction in injuries of workers on the production line by 83% [10]. Several scientific research papers have indicated a reduction in muscle fatigue from 10 to 40% after the application of exoskeletons [11, 12]. The study [13] proved the positive effects of the application of exoskeletons on the back muscles (muscle fatigue decreased by 10-25%) and the spine (spine load was reduced by 12-13%).

In some cases, exoskeletons can be used instead of collaborative humanoid robots because, unlike robots, exoskeletons do not require large financial resources and do not need to be programmed.

4. CONCLUSIONS

Workers who perform manual, repetitive,

precise, physically demanding professional activities that cannot be automated (such as material handling, lifting and moving objects) and workers who perform activities in a non-ergonomic body position are often exposed to musculoskeletal disorders. The application of exoskeletons in these workers aims to improve safety and health through the reduction of musculoskeletal disorders, reduction of pain in the neck, shoulders, back, reduction of fatigue and strain of workers. On the other hand, the application of exoskeletons contributes to the improvement of economic indicators in the form of increasing the efficiency and productivity of workers, reducing errors and improving the quality of work.

5. REFERENCES

[1] Aazam, M., Zeadally, S., Harras, K. A.: *Deploying fog computing in industrial internet of things and industry 4.0*, IEEE Transactions on Industrial Informatics, pp. 4674-4682, 14 (10), 2018.

[2] Eurofound: *Fifth European working conditions survey*, Luxembourg: Publications Office of the European Union, 2012.

[3] Aziz, F. A., Ghazalli, Z., Mohamed, N. M. Z., Isfar, A.: *Investigation on musculoskeletal discomfort and ergonomics risk factors among production team members at an automotive component assembly plant*, IOP conference series: materials science and engineering, 257 (1), 2017.

[4] Landau, K., Rademacher, H., Meschke, H., Winter, G., Schaub, K., Grasmueck, M., Schulze, J.: *Musculoskeletal disorders in assembly jobs in the automotive industry with special reference to age management aspects*, International Journal of Industrial Ergonomics, pp. 561-576, 38(7-8), 2008.

[5] *Exoskeletons boost productivity and safety for manufacturers*, available at: https://www.controleng.com/articles/exoskeletons-boost-productivity-and-safety-for-manufacturers/

[6] de Looze, M. P., Bosch, T., Krause, F., Stadler, K. S., O'Sullivan, L. W., *Exoskeletons for industrial application and their potential effects on physical work load*, Ergonomics, pp. 671- 681, 59(5), 2016.

[7] Huysamen, K., Bosch, T., de Looze, M., Stadler, K. S., Graf, E., O'Sullivan, L. W.: *Evaluation of a passive exoskeleton for static upper limb activities*, Applied Ergonomics, pp. 148-155, 70, 2018.

[8] *Industrial exoskeletons expand worker capabilities to help healthcare*, https://www.therobotreport.com/industrial-exoskeletons-expand-capabilities/

[9] Savković, M., Dašić, M., Đapan, M., Vukićević, A., Mačužić, I., Stefanović, M.: *Improving workplace safety using advanced Industry 4.0 technologies*, XI International Conference Industrial Engineering and Environmental Protection 2021 (IIZS 2021), pp. 553-560, Zrenjanin, Serbia, October 07-08, 2021.

[10] Dave B. *Exoskeletons unveiled at Ford manufacturing plant*, 2017, available at: http://www.thedrive.com/sheetmetal/15921/exoskeletons-unveiledat-ford-manufacturing-plant

[11] Abdoli-Eramaki, M., Agnew, M. J., Stevenson, J. M.: *An On-body Personal Lift Augmentation Device (PLAD) Reduces EMG Amplitude of Erector Spinae during Lifting Tasks*, Clinical Biomechanics, pp. 456-465, 21 (5), 2006.

[12] Godvin H. Y., Muramatsu M.: *Wearable Lower-limb Assistive Device for Physical Load Reduction of Caregiver on Transferring Support*, Advanced Intelligent Mechatronics, IEEE/ASME International Conference, pp. 1027-1032, 2013.

[13] Graham, R. B., AgnewM. J., Stevenson, J. M.: *Effectiveness of an On-body Lifting Aid at Reducing Low Back Physical Demands during an Automotive Assembly Task: Assessment of EMG Response and User Acceptability,* Applied Ergonomics, pp. 936-942, 40 (5), 2009.

Authors: **Marija Savković, Miloš Jovičić, Arso Vukićević, Prof. dr Ivan Mačužić, Prof. dr Petar Todorović**, University of Kragujevac, Faculty of Engineering, Sestre Janjić str. 6, 34000 Kragujevac, Serbia, Tel/fax: +381 34 331-772.
E-mail: marija.savkovic@kg.ac.rs
milos.jovicic@gmail.com
arso_ kg@yahoo.com
ivanm@kg.ac.rs
petar@kg.ac.rs