Framework of modular industrial workstations for neuroergonomics experiments in a collaborative environment

Carlo Caiazzo

Faculty of Engineering, University of Kragujevac. E-mail: carlocaiazzo@fink.rs

Marija Savković

Faculty of Engineering, University of Kragujevac. E-mail: marija.savkovic@kg.ac.rs

Marko Djapan

Faculty of Engineering, University of Kragujevac. E-mail: djapan@kg.ac.rs

Arso Vukićević

Faculty of Engineering, University of Kragujevac. E-mail: arso_kg@yahoo.com

Miloš Jovičić

Faculty of Engineering, University of Kragujevac. E-mail: milos.jovicic@gmail.com

Ivan Mačužić

Faculty of Engineering, University of Kragujevac. E-mail: ivanm@kg.ac.rs

Modern organizations aim to improve key economic parameters (productivity, effectiveness) in order to be competitive in global market. Furthermore, contemporary organizations strive to improve the health and safety of workers. One of the possible solutions to achieve that goal is to modernise production processes through the integration of lean principles and innovative technologies of Industry 4.0. However, in many monotonous and repetitive assembly operations, it is not possible to implement full digitalization. The focus of this research paper is to propose a modular human-robot workstation where the operator and collaborative robot share activities to improve workplace safety and worker's performance. The proposed modular assembly workstation, integrated with a poka-yoke system, is designed in accordance with the individual characteristics of the operator. Authors plan in future periods to conduct researches on this workstation in the field of neuroergonomics using an innovative electroencephalogram system (EEG) during assembly tasks with collaborative robot to prove that it will improve the physical, cognitive and organizational ergonomics and, at the same time, increase productivity and effectiveness.

Keywords: human–robot collaboration; Industry 4.0; lean principles; modular industrial assembly workstations; neuroergonomics; poka-yoke system

1. Introduction

An increasing number of modern production organizations strive to meet the needs, requirements and expectations of customers through the production of quality products, with low costs and minimize time to market. On the other hand, they aim to improve the safety and health of their employees. The main goal of lean production is to ensure a continuous flow of the process while shortening the time between ordering and delivery of products and eliminating all forms of losses (Shah and Ward 2003).

During the first industrial revolution, there was a transition from manual production to work with the help of machines within the production processes. The second industrial revolution, called the technological revolution, was characterized by the development of new technologies and mass production. The third

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industrial revolution, called the digital revolution, was associated with the progress of technology development and involved the digitalization of production processes through the introduction of computers and robots. The Fourth Industrial Revolution (Industry 4.0) implies complete digitalization of production processes. One of the basic characteristics of Industry 4.0 is its focus on workers, which is presented in scientific research through the term Operator 4.0 (Romero et al. 2016).

A special challenge is the improvement of prefabricated workstations where workers perform repetitive, tedious and physically demanding assembly activities.

Swift and Booker (2013) state as basic characteristics of manual assembly activities:

- Production rates vary from low to medium depending on the complexity of the product, the number and size of components
- Production time, i.e. product delivery, is quite long (in some situations this process takes days)
- Assembly activities are quite complex (depending on the size of the finished product being assembled)
- During the performance of these repetitive activities, fatigue and concentration occur, which has a negative impact on the health of workers (physical and mental)
- Operator errors occur especially if the product is complex, if the parts are difficult to insert or if the insertion space is limited, if the installation activities are performed incorrectly
- The quality of the final product largely depends on the abilities and skills of the operators assembling the product.

Prolonged performance of activities in the same (ergonomically inadequate) position (sitting or standing) adversely affects the health of workers. Workers performing activities on a non-ergonomic workstation are particularly exposed to muscle strain and fatigue (Kim et al. 2017; Sun et al. 2018). Excessive stress, stretching, bending can cause the appearance of musculoskeletal disorders (MSDs). Therefore, if activities allow, workers should combine sitting and standing positions when performing activities.

According to Bergman et al. (2001), MSDs are one of the most common causes of operator incapacity. MSDs in working environments cause absenteeism, disability, increased replacement costs (Maakip, Keegel and Oakman 2017), reduced efficiency and productivity (Matos and Arezes 2015; Van Eerd et al. 2016).

Improvement of prefabricated workstations can be achieved by applying Industry 4.0 technologies that enable the transformation of traditional industrial production processes (Henning and Kagermann 2013), such as collaborative robots, cyber-physical systems, Internet of Things, big data, cloud computing, virtual reality, augmented reality, etc (Jeganathan et al. 2018; Phuyal, D. Bista and R. Bista 2020; Pejic-Bach 2019; Aromaa et al. 2018; Belli 2019). Collaborative operation between operators and robots especially contributes to the improvement of prefabricated workstations by improving the safety and health of operators while increasing the performance of operators (Lorenzini et al. 2019).

Advanced application of smart innovative technologies Industry 4.0 (Lee 2015) contributes to the improvement of the working environment and performance of operators who perform monotonous and repetitive activities by improving safety and health of workers, providing greater autonomy to operators, enabling self-development, increasing flexibility and efficiency of production processes (Gorecky et al. 2014; Lasi et al. 2014).

The main contribution of this paper is reflected in the presentation of an innovative prefabricated workstation for collaborative activities between operators and robots, where neuroergonomic research will be conducted in the coming period. The design of the new workstation is in line with the basic principles of ergonomics, taking into account the fact that the workplace, work tasks, instruments and tools must be adapted to the needs and requirements of the operator. The main goal of applying ergonomic principles on prefabricated workstations is to improve workplace and the working environment in order to minimize the risks of injuries at work and improve the health of workers. At the new workstation, the collaborative robot and the operator share a common workspace and perform assembly activities together. The quality of the final product is achieved by means of a built-in poka-yoke device, which guides the operator through the assembly process and a sensor that will inform the operator about the occurrence of an error, the absence of a certain part, etc. The final inspection of the final product is performed by the operator.

The motivation for writing this paper can be found in the fact that it is necessary to redesign traditional prefabricated workstations in order to adapt them to the individual characteristics, abilities and limitations of the operator. The modular prefabricated workstation has been developed with respect to the fact that the zones of the handling area are different for each person. The specifics of the new workstation are reflected in the fact that each operator can adjust the storage containers for parts and components to their needs in order to avoid poor posture and non-ergonomic movements.

A particular challenge is to improve the productivity of workers who perform tedious, repetitive assembly tasks over a long period of time. Many alternatives for improving workers' productivity and the effectiveness of production processes have been presented in scientific research papers. Ergonomic design of workplaces is one of the most important prerequisites for improving production processes (Cimino et al. 2009) and creating a more efficient, safer and more comfortable workplace.

2. Literature Review

High frequency of repetition of tasks in combination with other risk factors such as awkward body positions lead to increased fatigue, decreased concentration and slowing down the production process. Adequately designed workspace allows workers to maintain good posture, to perform fewer movements with less effort. It is of great importance to design a prefabricated workstation where workers will be more satisfied and productive to perform activities (Nielsen et al. 2016).

In two scientific research papers, Brito and his associates showed that it is very important to take into account ergonomic aspects when designing a workstation (Brito et al. 2017a). In this way, productivity is increased, activity time is reduced and the health condition of workers is improved by reducing the risk of musculoskeletal disorders (Brito et al. 2017b).

The improvement of the health status and productivity of workers is the focus of numerous scientific research papers (Gustavsen 2007; Kaiser and Sap 2009).

Numerous studies have analyzed the impact of workplace design and respect for lean and ergonomic principles on productivity level (Vieira et al. 2012; Yusoff, Arezes and Costa 2013; Al Zuheri, Luong and Xing 2014). Also, certain authors pointed out the connection between ergonomic workplaces and lean production (Aqlan et al. 2014) and concluded that integrating lean and ergonomic principles on one hand can improve the safety and health of workers and eliminate non-ergonomic movements (Galante, Costa and Nobrega 2014), reduce stretching, bending, reaching and poor posture and on the other hand increase efficiency and reduce activity time (Yusuff 2016). Adaptation of the workplace to the requirements of the operator is presented in scientific research works by adapting to the physical characteristics of workers and their abilities and skills (Heilala and Voho 2001).

The application of ergonomic interventions could result in large savings and improve productivity, quality and health and safety of workers, as well as increase their satisfaction (Yeow 2003).

The introduction of collaborative robots when performing assembly tasks reduces the execution time of activities (Kinugawa et al. 2017). Palomba et al. (2021) have shown that the collaborative workstation will improve working conditions. By applying the RULA method (Mcatamney and Corlett 2004), the authors concluded that fatigue was reduced for 50% for the left part of the body and 57% for the right part of the body compared with the manual workstation. Pearce et al. (2018) have shown that framework for collaborative cooperation of human and robot minimized task tact time and physical strain of human, reduces physical stress in some tasks. Gualtieri, Rauch and Vidoni (2021) suggested the design of a collaborative workstation to improve the operators' physical ergonomics and concluded that this is how it came about increasing the level of productivity and improvement of workplace conditions.

Fasth-Berglund and Stahre (2013) investigated the occurrence of errors during assembly activities and proved that the application of the "pick to light" system, which is based on the poka-yoke system, reduces errors. Flashing lights on the storage containers for parts and components guide the operator through the assembly process and signal which parts and components to use at which time to avoid making mistakes. Siddhartha (2014) has shown that the application of poka yoke on assembly lines drastically reduces production costs, improves the quality of the final product and increases operator satisfaction.

Cognitive load negatively affects workers' attention, memory ability and reasoning ability (Rabby et al. 2019). In their study, Paas and Van Merienboer (1993) and Sweller, Van Merrienboer and Paas (1998) monitored mental load, performance, and stress levels as cognitive load indicators. Psychological factors can cause musculoskeletal disorders (Mehta 2016). Numerous studies have measured cognitive load via the EEG signal (Fasth-Berglund and Stahre 2013; Fasth-Berglund et al. 2016). In some scientific research papers, the assessment of cognitive load was performed on the basis of subjective self-reporting of workers and measurement of psychophysiological parameters (Rubio et al. 2003; Ustunel and Gunduz 2017). The advantage of using EEG in relation to classical subjective methods of self-assessment of the operator is reflected in the provision of objective data on brain activity and cognitive load.

3. Design of the Proposed Assembly Work Station

In order to be able to solve all the problems faced by workers who perform assembly activities in traditional production systems, the authors proposed a modular assembly workstation. The proposed workstation for collaborative activities between operators and robots, as shown in Fig.1, is designed in accordance with international standards ISO procedures (EN-ISO 6385:2016 2016; EN-ISO 12266:2000/COR 1:2006 2006).

All parts and components storage containers are arranged according to lean principles and taking into account the individual reach and field of view for each operator individually to reduce bending, stress and stretching of the body. The flexible layout of the container for storing components provides the ability to change the layout and organization of the work environment and adapt the material flow to the characteristics of the product being assembled.

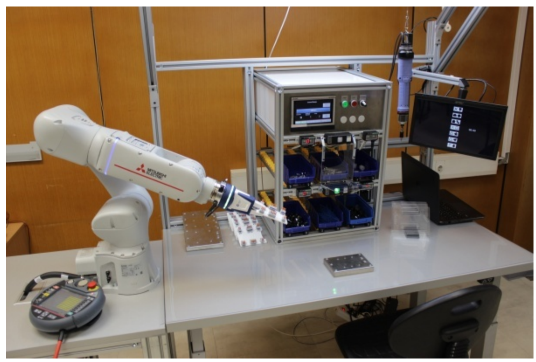

Fig. 1. Prefabricated hybrid assembly workstation

The modular structure of the proposed prefabricated workstation allows the adjustment and adaptation of existing standardized workstation modules and components to operator requirements. The reconfiguration of the workstation and its elements is reflected in the adaptation of the workstation to the requirements of the product itself, assembly activities and the needs of the operator. Tool devices within the modular system allow work activities to be performed by the operator when he needs them and to easily return to the disposal position when they are no longer needed or move to another part of the workspace. The tools that the operator uses are placed closest to the operator in accordance with lean principles.

The combination of performing assembly activities in a sitting and standing position on the new assembly workstation provides an opportunity for operators to perform activities without feeling tired, exhausted and physically stressed.

On the proposed modular workstation, the operator and the collaborative robot create a hybrid workspace in which they jointly perform assembly activities. Collaborative industrial robots are a special type of robot that are able to perform tasks in collaboration with workers in a common workspace in modern industrial environments (International Federation of Robotics 2019). The collaborative robot is in continuous interaction with the operator and provides support during the execution of precise, physically demanding and complex daily activities (Gualtieri et al. 2019). Unlike conventional industrial robots, collaborative robots are safe, flexible, and easy to program (Akella et al. 1999).

In human-robot interaction, operators perform activities that require dexterity, cognitive abilities, reasoning, decision-making and problem solving, and a collaborative robot performs precise and physically demanding activities. By applying cobots in production processes, significant advantages are achieved - increasing the productivity and performance of workers, improving the safety and well-being of workers, etc. Collaborative robots, in comparison with industrial robots, are safer to work with workers as they adjust their activities and speed to the proximity and abilities of workers (Robla-Gómez et al. 2017).

4. Conclusion

Many organizations strive to improve the working conditions of operators performing assembly activities, improve their health and safety, and improve their satisfaction and performance (International Organization for Standardization 2009). The traditional workstation is fixed and not adapted to the individual anthropometric characteristics and abilities of the operator. Furthermore, it is not harmonized with ergonomic principles. Prolonged performing of physically demanding assembly activities in a non-ergonomic position causes the appearance of MSDs and other health problems. Also, performing monotonous and repetitive activities causes a drop in attention and the appearance of fatigue after a certain time.

In order to improve the health condition and performance of the operator, a modular assembly workstation has been proposed as a hybrid production system, in which workers and a collaborative robot perform activities together. This mounting station complies with lean and ergonomic principles and is equipped with a poka-yoke device to prevent operator errors.

In the coming period, the authors plan to conduct various research. Indeed, neuroergonomics research will be conducted in order to monitor brain activity in order to determine when the concentration drops and how often the concentration drops. In addition to the already mentioned neuroergonomics research, in the future, the authors plan to use modern advanced technologies of Industry 4.0 to collect real-time and process data on muscle activity of operators to determine when muscle fatigue occurs and the authors will propose solutions to reduce irregular movements and body position.

All of this research will be conducted without and with the introduction of a collaborative robot to monitor workers' health, effectiveness, and productivity. Also, the authors plan to use sensors to monitor the parameters of the working environment in which operators perform assembly activities (temperature, humidity, noise level, etc.). Some of the other parameters that will be monitored in the coming period are operator satisfaction, stress, well-being of workers in order to determine which factors have the greatest impact on productivity, and the effectiveness and efficiency of production processes.

Through the implementation of these researches and after the application of the proposed modular assembly workstation and with the collaborative cooperation of workers and robot and the application of poka-yoke devices, the authors expect that numerous benefits will be realized for operators performing assembly activities in real industrial environment:

- Reduction of musculoskeletal disorders and other health problems
- Prevention of injuries caused by ergonomically inadequate performance of activities
- Creation of a more pleasant and safer working environment

- Reduction of stress and exhaustion of workers
- Increase of the operator satisfaction
- Increase in productivity
- Improvement in product quality
- Reduction in absenteeism and costs related to sick leave and replacement of workers
- Improvement in the quality of life of workers and prolonging life and working life.

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References

Akella, Prasad, Michael A. Peshkin, J. Edward Colgate, Witaya Wannasuphoprasit, N Nagesh, Jim Wells, Steve Holland, Tom Pearson and Brian Peacock. "Cobots for the automobile assembly line." *Proceedings 1999 IEEE International Conference on Robotics and Automation (Cat. No.99CH36288C)* 1 (1999): 728-733 vol.1.

Al-Zuheri, Atiya, Lee H. S. Luong and Ke Xing. "Developing a multi-objective genetic optimisation approach for an operational design of a manual mixed-model assembly line with walking workers." *Journal of Intelligent Manufacturing* 27 (2016): 1049-1065.

Aqlan, Faisal, Sarah S. Y. Lam, Sreekanth Ramakrishnan and Warren Boldrin. "Integrating Lean and Ergonomics to Improve Internal Transportation in a Manufacturing Environment." (2014).

Aromaa, Susanna, Marja Liinasuo, Eija Kaasinen, Michael Bojko, Franziska Schmalfuß, Konstantinos C. Apostolakis, Dimitrios Zarpalas, Petros Daras, Cemalettin Öztürk and Menouer Boubekeur. "User Evaluation of Industry 4.0 Concepts for Worker Engagement." *IHSED* (2018).

Belli, Laura, Luca Davoli, Alice Medioli, Pier Luigi Marchini and Gianluigi Ferrari. "Toward Industry 4.0 With IoT: Optimizing Business Processes in an Evolving Manufacturing Factory." *Frontiers ICT* 6 (2019): 17.

Bergman, Stefan, Per Herrström, Kjell Högström, Ingemar F. Petersson, Björn Svensson and Lennart T H Jacobsson. "Chronic musculoskeletal pain, prevalence rates, and sociodemographic associations in a Swedish population study." *The Journal of rheumatology* 28 6 (2001): 1369-77

Brito, Marlene, Ana Luísa Ramos, Paula Carneiro and Maria Antónia Gonçalves. "Ergonomic design intervention in a coating production area." (2017).

Brito, Marlene, Ana Luísa Ramos, Paula Carneiro and Maria Antónia Gonçalves. "Combining SMED methodology and ergonomics for reduction of setup in a turning production area." *Procedia Manufacturing* 13 (2017): 1112-1119.

Cimino, Antonio, Duilio Curcio, Francesco Longo and Giovanni Mirabelli. "Improving workers conditions within industrial workstations." (2009).

Cohen, Yuval, Maya Golan, Gonen Singer and Maurizio Faccio. "Workstation–Operator Interaction in 4.0 Era: WOI 4.0." *IFAC-PapersOnLine* 51 (2018): 399-404.

EN-ISO 6385:2016 E (2016). https://www.iso.org/obp/ui/#iso:std:iso:6385:ed-3:v1:en.

EN-ISO 112266:2000/COR 1:2006. https://www.iso.org/standard/44143.html.

Fasth-Berglund, Åsa and Johan Stahre. "Cognitive automation strategy for reconfigurable and sustainable assembly systems." *Assembly Automation* 33 (2013): 294-303.

Fasth-Berglund, Åsa, Filip Palmkvist, Per Nyqvist, Sven Ekered and Magnus Åkerman. "Evaluating Cobots for Final Assembly." *Procedia CIRP* 44 (2016): 175-180.

Galante, Erick B F, D Bordalo and Marcele Nobrega. "Risk Assessment Methodology: Quantitative HazOp." *Journal of Textile Science & Engineering* 3 (2014): 31-36.

Gorecky, Dominic, Mathias Schmitt, Matthias Loskyll and Detlef Zühlke. "Human-machine-interaction in the industry 4.0 era." *2014 12th IEEE International Conference on Industrial Informatics (INDIN)* (2014): 289-294.

Gustavsen, Bjørn. "Work Organization and `the Scandinavian Model'." *Economic and Industrial Democracy* 28 (2007): 650 - 671.

Gualtieri, Luca, Erwin Rauch, Renato Vidoni and Dominik Tobias Matt. "An evaluation methodology for the conversion of manual assembly systems into human-robot collaborative workcells." *Procedia Manufacturing* (2019): n. pag.

Gualtieri, Luca, Erwin Rauch and Renato Vidoni. "Emerging research fields in safety and ergonomics in industrial collaborative robotics: A systematic literature review." *Robotics Comput. Integr. Manuf.* 67 (2021): 101998.

Heilala, Juhani and Paavo Voho. "Modular reconfigurable flexible final assembly systems." *Assembly Automation* 21 (2001): 20-30.

Henning, Kagermann. "Recommendations for implementing the strategic initiative INDUSTRIE 4.0." (2013).

International Federation of Robotics (2019). IFR publishes collaborative industrial robot definition and estimates supply. https://ifr.org/post/international-federation-of-robotics-publishescollaborative-industrial-rob.

International Organization for Standardization. (2009). ISO 9241-210: Ergonomics of human system interaction-Part 210: Human-centered design for interactive systems (ISO 9241-210: 2009). https://www.iso.org/standard/52075.html

Jeganathan, L., A. Nayeemulla Khan, Jagadeesh Kannan Raju and Sambandam Narayanasamy. "On a Frame Work of Curriculum for Engineering Education 4.0." *2018 World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC)* (2018): 1-6.

Kim, Wansoo, Jinoh Lee, Nikolaos G. Tsagarakis and Arash Ajoudani. "A real-time and reduced-complexity approach to the detection and monitoring of static joint overloading in humans." *2017 International Conference on Rehabilitation Robotics (ICORR)* (2017): 828-834.

Kinugawa, Jun, Akira Kanazawa, Shogo Arai and Kazuhiro Kosuge. "Adaptive Task Scheduling for an Assembly Task Coworker Robot Based on Incremental Learning of Human's Motion Patterns." *IEEE Robotics and Automation Letters* 2 (2017): 856-863.

Lasi, Heiner, Peter Fettke, H.-G. Kemper, Thomas Feld and Michael Hoffmann. "Industry 4.0." *Business & Information Systems Engineering* 6 (2014): 239-242.

Lee, J.. "Smart Factory Systems." *Informatik-Spektrum* 38 (2015): 230-235.

Lorenzini, Marta, Wansoo Kim, Elena De Momi and Arash Ajoudani. "A New Overloading Fatigue Model for Ergonomic Risk Assessment with Application to Human-Robot Collaboration." *2019 International Conference on Robotics and Automation (ICRA)* (2019): 1962-1968.

Maakip, Ismail, Tessa Keegel and Jodi Oakman. "Predictors of musculoskeletal discomfort: A cross-cultural comparison between Malaysian and Australian office workers." *Applied ergonomics* 60 (2017): 52-57 .

Matos, Manuel and Pedro M. Arezes. "Ergonomic Evaluation of Office Workplaces with Rapid Office Strain Assessment (ROSA)." *Procedia Manufacturing* 3 (2015): 4689-4694.

Mcatamney, L and Nigel Corlett. "Rapid Upper Limb Assessment (RULA)." (2004).

Mehta, Ranjana K.. "Integrating Physical and Cognitive Ergonomics." *IIE Transactions on Occupational Ergonomics and Human Factors* 4 (2016): 83 - 87.

Nielsen, Izabela Ewa, Ngoc Anh Dung Do, Zbigniew Antoni Banaszak and Mukund Nilakantan Janardhanan. "Material supply scheduling in a ubiquitous manufacturing system." *Robotics and Computer-integrated Manufacturing* 45 (2017): 21-33.

Paas, Fred and Jeroen J. G. van Merriënboer. "The Efficiency of Instructional Conditions: An Approach to Combine Mental Effort and Performance Measures." *Human Factors: The Journal of Human Factors and Ergonomics Society* 35 (1992): 737 - 743.

Palomba, Ilaria, Luca Gualtieri, Rafael A. Rojas, Erwin Rauch, Renato Vidoni and Andrea Ghedin. "Mechatronic Re-Design of a Manual Assembly Workstation into a Collaborative One for Wire Harness Assemblies." *Robotics* 10 (2021): 43.

Pearce, Margaret, Bilge Mutlu, Julie A. Shah and Robert G. Radwin. "Optimizing Makespan and Ergonomics in Integrating Collaborative Robots Into Manufacturing Processes." *IEEE Transactions on Automation Science and Engineering* 15 (2018): 1772-1784.

Pejic-Bach, Mirjana, Tine Bertoncel, Maja Meško and Zivko Krstic. "Text mining of industry 4.0 job advertisements." *Int. J. Inf. Manag.* 50 (2020): 416-431.

Phuyal, Sudip, Diwakar Bista and Rabindra Bista. "Challenges, Opportunities and Future Directions of Smart Manufacturing: A State of Art Review." (2020).

Rabby, Md Khurram Monir, Mubbashar Altaf Khan, Ali Karimoddini and Steven Xiaochun Jiang. "An Effective Model for Human Cognitive Performance within a Human-Robot Collaboration Framework." *2019 IEEE International Conference on Systems, Man and Cybernetics (SMC)* (2019): 3872-3877.

Robla-Gómez, Sandra, Victor M. Becerra, José Ramón Llata, Esther Gonzalez-Sarabia, Carlos Torre-Ferrero and Juan Pérez-Oria. "Working Together: A Review on Safe Human-Robot Collaboration in Industrial Environments." *IEEE Access* 5 (2017): 26754-26773.

Romero, David, Peter Bernus, Ovidiu Noran, Johan Stahre and Åsa Fast-Berglund. "The Operator 4.0: Human Cyber-Physical Systems & Adaptive Automation Towards Human-Automation Symbiosis Work Systems." *APMS* (2016).

Rubio, Susana, Eva Maria Carro Diaz, Jesus Martin and José Puente. "Evaluation of Subjective Mental Workload: A Comparison of SWAT, NASA-TLX, and Workload Profile Methods." *Applied Psychology* 53 (2004): 61-86.

Shah, Rachna and Peter T. Ward. "Lean manufacturing: context, practice bundles, and performance." *Journal of Operations Management* 21 (2003): 129-149.

Sharma, Siddhartha. "Implementation of Poka-Yoke Using Electronic Sensors." (2014).

Sweller, John, Jeroen J G van Merrienboer and Fred Paas. "Cognitive Architecture and Instructional Design." *Educational Psychology Review* 10 (1998): 251-296.

Swift, K. G. and Julian Booker. "Manufacturing Process Selection Handbook." (2013).

Sun, Xiaoguang, Rémy Houssin, Jean Renaud and Mickaël Gardoni. "A review of methodologies for integrating human factors and ergonomics in engineering design." *International Journal of Production Research* 57 (2019): 4961 - 4976.

Ustunel, Zeynep and Tulin Gunduz. "Human-robot collaboration on an assembly work with extended cognition approach." *Journal of Advanced Mechanical Design Systems and Manufacturing* 11 (2017): n. pag.

Van Eerd, Dwayne, Claire Munhall, E Irvin, David M. Rempel, Shelley Brewer, Allard J. van der Beek, Jack Tigh Dennerlein, Jessica M. Tullar, Kathryn Skivington, Clint Pinion and B Amick. "Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence." *Occupational and Environmental Medicine* 73 (2015): 62 - 70.

Vieira, Leandro, Giles Balbinotti, Adriano Varasquin and Leila Amaral Gontijo. "Ergonomics and Kaizen as strategies for competitiveness: a theoretical and practical in an automotive industry." *Work* 41 Suppl 1 (2012): 1756-62 .

Yeow, Paul Heng Ping and Rabindra Nath Sen. "Quality, productivity, occupational health and safety and cost effectiveness of ergonomic improvements in the test workstations of an electronic factory." *International Journal of Industrial Ergonomics* 32 (2003): 147-163.

Yusoff, Sabariah Mohd, Pedro M. Arezes and Nélson Costa. "The integration of lean manufacturing and ergonomics approach in workplace design." (2013).

Yusuff, Prof. Dr. Rosnah Mohd. "As a Lean Manufacturing Tool for Improvements in a Manufacturing Company." (2016).