TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 65, Issue Special III, November, 2022

SPOT-WELDING POSTURE ANALYSIS USING CAPTIV T-SENS WIRELESS MOTION SENSORS

Mihaela POPA, Anca MOCAN, Sabina POTRA, Luisa DUNGAN, Andrei BORBOREAN, Marian MOCAN

Abstract: *In today's increasingly concerned society for employee wellbeing, ergonomics has started to gain ground and continuously develop by using modern technologies with the final purpose to provide better measurements and corrective actions. In the food industry, many welding tasks are done manually. Thus, the present research aims to analyze the worker's posture in a specific spot-welding situation with the help of CAPTIV 7000 Premier software and motion sensors. The results prove the usability of the proposed technology and opens the door to easier ergonomics analyses for all kinds of operators.*
Key words: *3D avatar, ergonomic task visualization, posture evaluation, workplace conditions, motion capture sensors.*

1. INTRODUCTION

According to the International Ergonomics Association [1], ergonomics 'is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design and optimize human well-being and overall system performance.' Within the wide scope of analysis that ergonomics pertains to, one of the most studied areas is that of musculoskeletal disorders. The reason that this topic is so well studied is the fact that musculoskeletal disorders continue to be one of the leading causes of long disability and lost work time [2] and have a significant economic impact [3, 4]. This is of course a topic of high concern in today's business environment that is looking to increase productivity at any cost. One means of doing that is with the application of ergonomic principles and methodologies in designing the workspace [5].

Welding is one of the major manufacturing processes that still require workers to exude awkward body positions [6]. While in many factories the welding process has been partially outsourced to robots [7], this outsourcing is usually reserved for high frequency mid to low complexity welds. In industries that produce made to order equipment characterized by low volume and high complexity, the welding is usually done by hand. But awkward positions can damage the musculoskeletal system [8].

As welding is a high skill job that is in high demand, there is of course a clear desire to keep welding operators as work fit as possible. Because of this, welding is an area ripe for ergonomic analysis and improvement [9, 10].

From the workstations to the manipulation and positioning of the machines, researchers have tried analyzing the ergonomic impact of welding activities by means of traditional [11, 12] and modern ergonomic assessment tools [13].

One of these modern tools is offered by the CAPTIV T-Sens Wireless Motion full body sensors, a modular solution which senses physiological functions based on a simultaneous synchronization of sensor information and video recordings [14]. Its sensors can simulate a work task in laboratory surroundings [15].

This tool is considered preferable for ergonomic analysis by many scholars [14, 16] due to its accuracy and scalable solutions but also because it collects complex data simultaneously [8], an important aspect to take into consideration for evaluation simplification.

The aim of the present paper is to analyze with the help of laboratory 3D avatar simulations the posture of a worker who needs to weld L profiles in a cylinder and compare the results with onsite observations. In the next section the methodology for the research is detailed, followed by a results and a conclusions and recommendations section.

2. METHOD

The laboratory test is based on a real ergonomic problem first observed in a food industry based private company, namely, the circular spot welding of L profiles in a cylinder that would be further processed for usage in can sterilization. The length of the cylinder can vary but would not be less than 8 meters. The worker needs to enter the tubular construction (1.4 m maneuvering space) and weld the profiles in sequential circular points from the beginning of the cylinder till its end. The ergonomic specialist observed the process and concluded that it represents a real ergonomic problem with consequences on the long term for the worker. Therefore, the specific posture needed to be thoroughly analyzed for accurate conclusions.

In Figure 1 the starting position can be visualized.

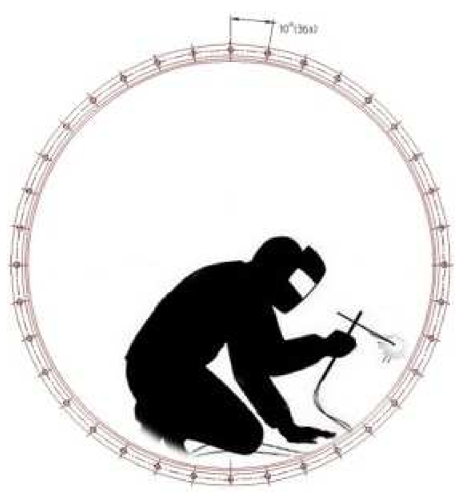

Fig. 1. Worker's starting position when spot welding in a cylinder.

The worker must extend his hand in a circular motion all around the cylinder and spot weld the profile every 10 degrees of the circle. During that activity the hand stays in the needed position for 15-20 seconds in order to prepare and then weld. Ergonomic strain problems should appear in several parts of the body due to the difficult posture.

The welding situation has been simulated in laboratory settings. Measured joints for appropriate motion in the specific analyzed working situation have been defined to be the following: neck, lower back, right and left shoulder, right and left elbow together with the right and left wrist.

Once the sensors have been carefully calibrated, the subject was equipped with 13 CAPTIV motion sensors, one on the head, one on the upper back, one on the lower part of the back, the rest on the arms and legs. If correctly mounted on the subject, the wearable devices start transmitting data into the CAPTIV software. After a short verification of the system, the working position has been repeatedly simulated and in the same time videotaped. Only the most precise simulation has been taken into consideration. The motion measurements have been combined with the recordings and have been displayed as a 3 D avatar which provides all the subject movements easily observable from different angles.

3. RESULTS

The 3D avatar provided useful information regarding the visualization of the analyzed task with an emphasis on specific body segments. Using three different colors: green, orange, and red, the possible problems in the worker's joints are thoroughly presented (Figures 2, 3 and 4) in different positions during the welding process.

The green color signifies that the posture is appropriate, the orange color directs the ergonomic specialist towards a change in the work environment and the red color indicates a clear need for corrections in posture and workload. We can see that in the starting and finishing positions, the lower back is the most impacted by the task. If the welding is done for a long period of time, those postures increase the risk of low back pain.

The positions when the worker needs to weld the upper part of the cylinder, are inappropriate for his neck. Also, the right hand which is used for preparation and welding is very strained. Therefore, in some parts of the welding task the worker also uses the left hand to help him hold the welding device. This action takes over a part of the effort from the right hand but cannot become a solution for a long time.

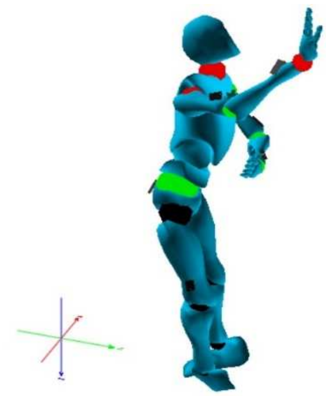

Fig. 3. The middle posture in the welding process.

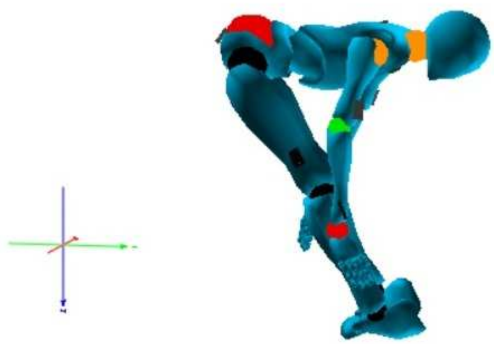

Fig. 2. The 3D representation of the worker posture when starting the spot-welding task.

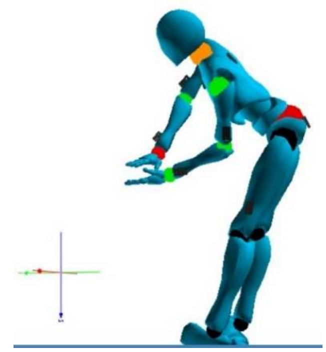

Fig. 4. Lowering down in the final part of the welding.

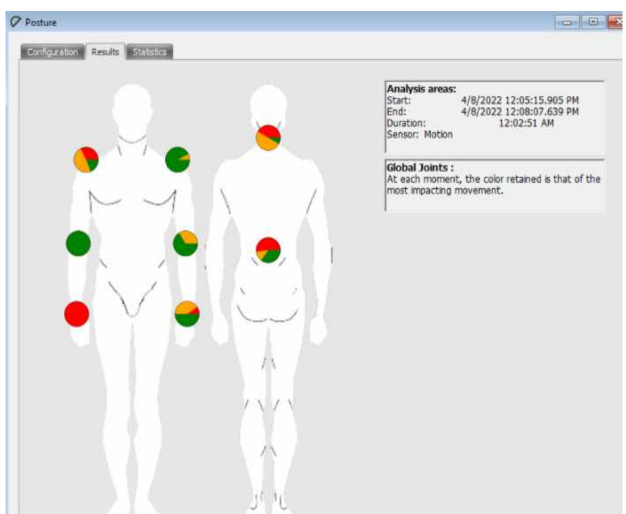

Fig. 5. The posture evaluation results for the spot-welding task.

Table 1

Spot welding posture statistics.

Joints	Green area	Orange areas	Red areas
Neck Flexion/Extension	8%	50.2%	41.8%
Lower back Flexion/Extension	35%	12.9%	52.1%
Right shoulder vertical rotation	19.2%	48.1%	32.7%
Left shoulder vertical rotation	92.4%	7.6%	0%
Right elbow Flexion/Extension	100%	0%	0%
Left elbow Flexion/Extension	66%	34%	0%
Right wrist Flexion/Extension	0%	0%	100%
Left wrist Flexion/Extension	50.3%	40.2%	9.5%

Figure 5 portrays the simultaneous joint angles which indicate using the same three colors which threshold values are exceeding the specific analyzed joints. The results are easily understandable for all company employees and represent a starting point for new management decision making criteria.

As a first deduction, the right wrist and lower back are the most exposed to an incorrect posture during the spot-welding task. The neck is partially impacted by several postures during the welding process as well.

In Table 1 the posture statistics are delineated. With computed percentages, the red areas indicate also towards the neck, lower back, and right wrist joints as being strongly forced during the stages of the working task.

The 3D visualization ergonomics color-based analysis corroborated with the posture statistics and the possibility to study the posture both in laboratory settings and in real work situations makes the CAPTIV 7000 technology suited for easy ergonomic analysis.

7. CONCLUSIONS AND RECOMMENDATIONS

The ergonomic observations gathered with the help of the wireless sensor ergonomic TEA CAPTIV system shows moderate to severe strain in the neck and back area as well as severe strain in the dominant wrist and shoulder area (right sided as the subject was right-handed). This information corroborates the on-site visual observations of the work being done and would match with a possible RULA assessment done by a certified ergonomics specialist.

As the sensors can be placed on the worker and allow them to get on with their job with minimal discomfort this system would provide not just a quicker but a more accurate assessment of the strain the operator manages during a work shift. As there is no secondary party necessary to observe the movements being done this type of analysis can now be freely executed by individuals not specialized in ergonomic analysis – democratizing it as a means of workplace improvement. While training would still be necessary to understand the way in which the software and related sensors need to be calibrated, mounted on the subject, utilized in data processing, and while the final analysis of the results would still require a trained specialist, the job of gathering data and visualizing it would be simplified.

In this spot-welding case, the improvement possibilities are limited. As the diameter of the tube itself cannot be increased and the welding of the L profiles needs to take place from inside the tube, complete elimination of the strain areas is impossible without full job automation. Given the low volume of work for this type of activity, the possibility of job automation is almost inexistent.

Reduction of strain however could be achieved by creating a mixed work environment. Allowing the operator to take frequent work breaks or the instating of rotational jobs would reduce the overall strain.

While in this particular use case the improvements that can be done are relatively small, the information itself is invaluable.

It proves the usability of the technology and opens doors for more frequent and easier ergonomic analyses for all types of operators. It also helps managers of all levels better understand the ergonomic posture consequences by colored 3D posture visualizations. In this way, decisions regarding workload and working time in difficult postures can be made with more ease and faster than in traditional approaches.

Future motion studies will be developed combined other methods and tools as presented by [17-20]. Through university-industry collaborations, based on technical consulting contracts, there could be created a solid based on the adequacy of different methods and tools available for the posture analysis [21, 22].

8. REFERENCES

[1] International Ergonomics Association, available at: https://iea.cc/what-is-ergonomics/.

[2] Buckle, P., *Ergonomics and musculoskeletal disorders: overview*, Occupational medicine Vol. 55 No. 3, pp.164-167, 2005.

[3] Bevan, S. *Economic impact of musculoskeletal disorders (MSDs) on work in Europe*, Best Pract. Res. Clin. Rheumatol., 29, pp. 356–373, 2015.
[4] Sultan-Taïeb, H.; Parent-Lamarche, A.; Gaillard, A.; Stock, S.; Nicolakakis, N.; Hong, Q.N.; Vezina, M.; Coulibaly, Y.; Vézina, N.; Berthelette, D. *Economic evaluations of ergonomic interventions preventing work-related musculoskeletal disorders: A systematic review of organizational-level interventions*, BMC Public Health, 17, 935, 2017.
[5] Gani, A. Zuraini, Mahani Mohd Zamberi, and Muhammad Hafizzuddin Md Teni. *A Review of Ergonomics towards Productivity*, Int. J. Sup. Chain. Mgt 7, p. 306, 2018.
[6] Dinagaran, D., et al. *Discomfort and postural analysis of flux cored arc welding machine operators*, J Erogonomics Stud Res 1, p.103, 2019.
[7] Pires, J. N., et al., *Welding robots*, IEEE robotics & automation magazine 10.2, pp. 45-55, 2003.
[8] Onofrejova D. et al. *Ergonomic Assessment of Physical Load in Slovak Industry Using Wereable Technologies*, Applied Sciences 12, 3607, 2022.
[9] Popescu, M., *Welding Ergonomics-Elements*. na, 2010
[10] Suman, Das, et al. *Postural stress analysis with MSD symptoms of welders and solution for workstation design*, International Journal of Forensic Engineering and Management 1(1), pp. 4-23, 2020.
[11] Singh, B., Piyush, S., *Work related musculoskeletal disorders risk assessment for different welding positions and processes*, 14th International Conference on Humanizing Work and Work Environment HWWE, 2016.
[12] Özcan, A. G., *Ergonomic Risk Assessment in Automotive Welding Lines and Comparison of Method Output*, Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi 12(4), pp. 645-659.
[13] Rahmana, A., Ekambaram P., Ambarish K., *Virtual reality based ergonomic risk evaluation of welding tasks*, Proceedings 19th Triennial Congress of the IEA, 9, 2015.
[14] Kramarova, M., Gaso, M., *Tool of modern ergonomics for measure a psychophysiological human functions*, J. Res. Appl. Prof. Saf., 9, pp.1–5, 2016.
[15] Worobel, R., Čapek, J., Kováčová, L., Bubeník, P., Krajčovič, M., *Improving business processes using simulation tools*, MM Science Journal, p. 2244–2251, ISSN 1803-1269, 2018.
[16] Steinebach, T., Grosse, E.H., Glock, C.H., Wakula, J., Lunin, A., *Accuracy evaluation of two marker less motion capture systems for measurement of upper extremities: Kinect V2 and Captiv*, Hum. Factors Ergon. Manuf. Serv. Ind., 30, pp. 291–302, 2020.
[17] Gajšek, B., Draghici, A., Boatca, M. E., Gaureanu, A., Robescu, D., *Linking the Use of Ergonomics Methods to Workplace Social Sustainability: The Ovako Working Posture Assessment System and Rapid Entire Body Assessment Method*, Sustainability, 14(7), 4301, 2022.
[18] Choong, S. W. J., Ng, P. K., Yeo, B. C., Draghici, A., Gaureanu, A., Ng, Y. J., ..., Selvan, H. K. T., A *Preliminary Study on Ergonomic Contribution to the Engineering Design Approach of a Wheel Loader Control Lever System*, Sustainability, 14(1), 122, 2021.
[19] Dufour, C., Draghci, A., Ivascu, L., Sarfraz, M., *Occupational health and safety division of responsibility: A conceptual model for the implementation of the OHSAS 18001: 2007 standard*, Human Systems Management, 39(4), 549-563, 2020.
[20] Draghici, A., Vaduva, R., Capotescu, S., Banaduc, G., Robescu, D., *Innovations for Tackling Post-Pandemic Related Challenges-A Collaborative Research to Discover New Solutions for Hybrid Work in The Context Of 15-Minute Cities*, Acta Technica Napocensis-Series: Applied Mathematics, Mechanics, and Engineering, 65(1S). 2022.
[21] Draghici, A., Baban, C. F., Ivascu, L. V., Sarca, I. (2015). *Key success factors for university–industry collaboration in open innovation*, Proceedings of the ICERI2015,

ISBN: 978-84-608-2657-6, 7357-7365, IATED, 2015.
[22] Szabó, G., Balogh, Z., Dovramadjiev, T., Draghici, A., Gajšek, B., Lulić, T. J., ..., Zunjic, A., *Introducing the ergonomics and human factors regional educational CEEPUS Network*, Acta Technica Napocensis-Series: Applied Mathematics, Mechanics, and Engineering, 64(1-S1), 2021.

Analiza posturii în timpul sudării în puncte utilizând senzorii de mişcare CAPTIV T-SENS

În societatea de astăzi din ce în ce mai preocupată de bunăstarea angajaților, ergonomia a început să câștige teren și să se dezvolte continuu prin utilizarea tehnologiilor moderne cu scopul de a oferi măsurători mai bune și acțiuni corective. În industria alimentară, multe sarcini de sudare sunt efectuate manual. Astfel, cercetarea de față își propune să analizeze poziția lucrătorului într-o situație, solicitare specifică activității de sudare în puncte, cu ajutorul aplicației software CAPTIV 7000 Premier și a senzorilor de mișcare. Rezultatele dovedesc utilitatea metodologiei propuse și deschid calea către analize ergonomice mai ușoare și mai rapide pentru diverse tipuri de activități manuale.

Mihaela POPA, Lecturer PhD, Politehnica University Timisoara, Engineering Faculty Hunedoara, Electrical Engineering and Industrial Informatics Department, mihaela.popa@upt.ro
Anca MOCAN, Eng. PhD, Project manager JBT Corporation, Sint Niklaas, Belgium, anca.mocan@jbtc.com
Sabina POTRA, Lecturer Eng. PhD, Politehnica University Timisoara, Faculty of Management in Production and Transportation, Management Department, Research Centre in Engineering and Management, sabina.potra@upt.ro, 14 Remus str., 300191 Timisoara, Romania.
Luisa DUNGAN, Associate Professor Eng. PhD, Politehnica University Timisoara, Mechanical Machines, Equipment and Transports Department, luisa.dungan@upt.ro, 2 Mihai Viteazu Bdl, 300222 Timisoara, Romania.
Andrei BORBOREAN, Assistant Professor, Politehnica University Timisoara, Road Vehicles Department, andrei.borborean@upt.ro, 2 Mihai Viteazu Bdl, 300222 Timisoara, Romania.
Marian MOCAN, Professor Eng. PhD, Politehnica University Timisoara, Dean of the Faculty of Management in Production and Transportation, Management Department, Research Centre in Engineering and Management, marina.mocan@upt.ro, 14 Remus str., 300191 Timisoara, Romania.