Analysis of the statodynamic load on workers in the technological cutting process

Snježana Kirin[1,*]; Anica Hursa Šajatović[2]
[1] Karlovac University of Applied Sciences, Karlovac, Croatia
[2] University of Zagreb, Faculty of Textile Technology, Zagreb, Croatia
*Corresponding author: snjezana.kirin@vuka.hr
Received January 26, 2023
UDC 689.022:159.944

Original scientific paper**

Work in the technological cutting process requires a high degree of visual acuity and is performed in a standing posture, resulting in significant stress on the lumbar and cervical spine, as well as the legs, arms, and hands. The workload of workers in the technological cutting process was investigated using the RULA approach at two typical workplaces. The RULA method was used to determine the body load resulting from the work posture in relation to the requirements of the work task. The results of the analysis show a load on the legs, the presence of increased flexion of the spine and head, and a high proportion of hand and finger work, leading to worker fatigue. A proposal was made to redesign the current workplaces in order to reduce awkward working postures and increase work productivity.

Keywords: *technological cutting process; RULA method; workload*

Izvorni znanstveni rad**

Rad u tehnološkom procesu krojenja izvodi se u stojećem položaju uz znatno opterećenje nogu, ruku i šaka te slabinskog i vratnog dijela kralješnice, pri čemu je potreban visoki stupanj usredotočenosti vida. Primjenom RULA metode analizirano je opterećenje radnika u tehnološkom procesu krojenja za dva karakteristična radna mjesta. RULA metodom utvrđeno je opterećenje tijela uzrokovano radnim položajem s obzirom na zahtjevnost radnog zadatka. Rezultati dobiveni analizom ukazuju na optrećenje nogu, prisutnost pojačane fleksije kralješnice i glave te visok udio rada ruku i prstiju što dovodi do zamora radnika. Dan je prijedlog za preoblikovanje postojećih radnih mjesta čime bi se smanjili nepovoljni radni položaji i povećala produktivnost rada.

Ključne riječi: tehnološki proces krojenja; RULA metoda; radno opterećenje

*Paper presented at the *15th Scientific-Professional Symposium Textile Science And Economy*, Jan 26, 2023, Zagreb, Croatia

1. Introduction

In contemporary clothing manufacturing processes, significant emphasis is placed on optimizing work organization to minimize the duration of technological operations, uphold required quality standards, maximize equipment utilization, ensure efficient material flow, and alleviate worker fatigue [1]. Each technological activity requires proper workplace design, including the selection of the most suitable work method to significantly minimize workers' psychophysical workload.

Cutting constitutes the initial phase of the clothing production process, representing approximately 20% of the total garment production time. The process of technological cutting involves the interaction of workers, machines, and the environment, resulting in a complex system of actions. These actions depend on factors such as human ability, the type of technological operation, the type and technical equipment of the machine, and the body posture adopted by the worker during the work [2]. The work is conducted while standing, and the worker employs their torso and hands to manage the material and/or the machine during the cutting process.

In the technological cutting process, layers are cut using machines that are controlled manually. This includes the use of straight-knife cutting machines for coarse cutting and band knife machines for fine cutting. When utilizing a straight knife, the cutting layer remains stationary as the operator navigates the machine along the curves of the cutting sections. Conversely, band knife cutting machines require the worker to manually move the layer along the contours of the cutting parts while the machine remains in place. In the process of cutting layers, the worker utilizes straight knife and band knife machines while standing, which can lead to a strained posture of the spine and head. This is necessary to accommodate the motor activity of the hands and visual focus required to accurately guide the cutting process along the contours of the parts. The efficiency of band knife cutting machines is enhanced through the utilization of a nozzle system on the working surface, which generates an air cushion to minimize friction between the working surface and the cutting layer. This ultimately leads to increased cutting accuracy [3].

Research on the workload of workers engaged in technological cutting operations has indicated that workers tend to work in a disadvantageous standing posture, exhibiting a back flexion of more than 15° and a head flexion with a curvature angle exceeding 30° [4, 5]. The angle of curvature of the cervical and lumbar spine is influenced by the manner in which technical tasks are carried out and the height of the worker. Inadequate working posture can result in heightened fatigue, diminished work quality, and extended task completion durations. The workload of workers is a consequence of a mismatch between their physical, mental, and health capabilities and the requirements of the workplace, coupled with inadequate work organization and unfavourable microclimatic conditions. This issue can be attributed to a lack of adherence to ergonomic principles in the design of workplaces. It is essential to ensure that the man-machine-environment achieves dimensional harmony during the cutting process, allowing for a favourable standing posture that facilitates coordinated movement and correct spinal and head positionning. To meet the demands of the work process, it is recommended to slightly bend the upper back by up to 15° and flex the head forward by up to 30° for an optimal working posture. In the workplace design process, the height of the work surface should be adjusted to accommodate the static and dynamic proportions of the workers. This adjustment allows for the optimal arrangement of work zones and promotes proper dynamism and rhythm during work [6].

2. RULA (Rapid Upper Limb Assessment) method

The RULA (Rapid Upper Limb Assessment) method was developed by McAtamney L. and Corlett E.N. (1993) with the aim of determining the degree of exposure of workers to unfavourable working postures that can lead to musculoskeletal disorders. The RULA method is employed to assess and analyze the biomechanical postures of the whole body, encompassing the arms (upper arm, forearm, hand), neck, trunk, and legs, along with the movement of the muscles in these body regions. The findings are a result of a subjective survey carried out among observers at a specific workplace [7-9].

To assess the working body postures while carrying out work tasks, visual aids are used to depict the posture of the hands (Fig.1) and the posture of the body (neck, trunk, legs) (Fig.2).

Based on the assessment, the degree of worker load in the technological process, as well as the need for redesigning the workplace to lower worker workload and fatigue, are determined and presented in Table 1.

Using the RULA method, workplaces can be assessed to determine which body parts are experiencing elevated strain due to unfavourable workplace design and inadequate work methods.

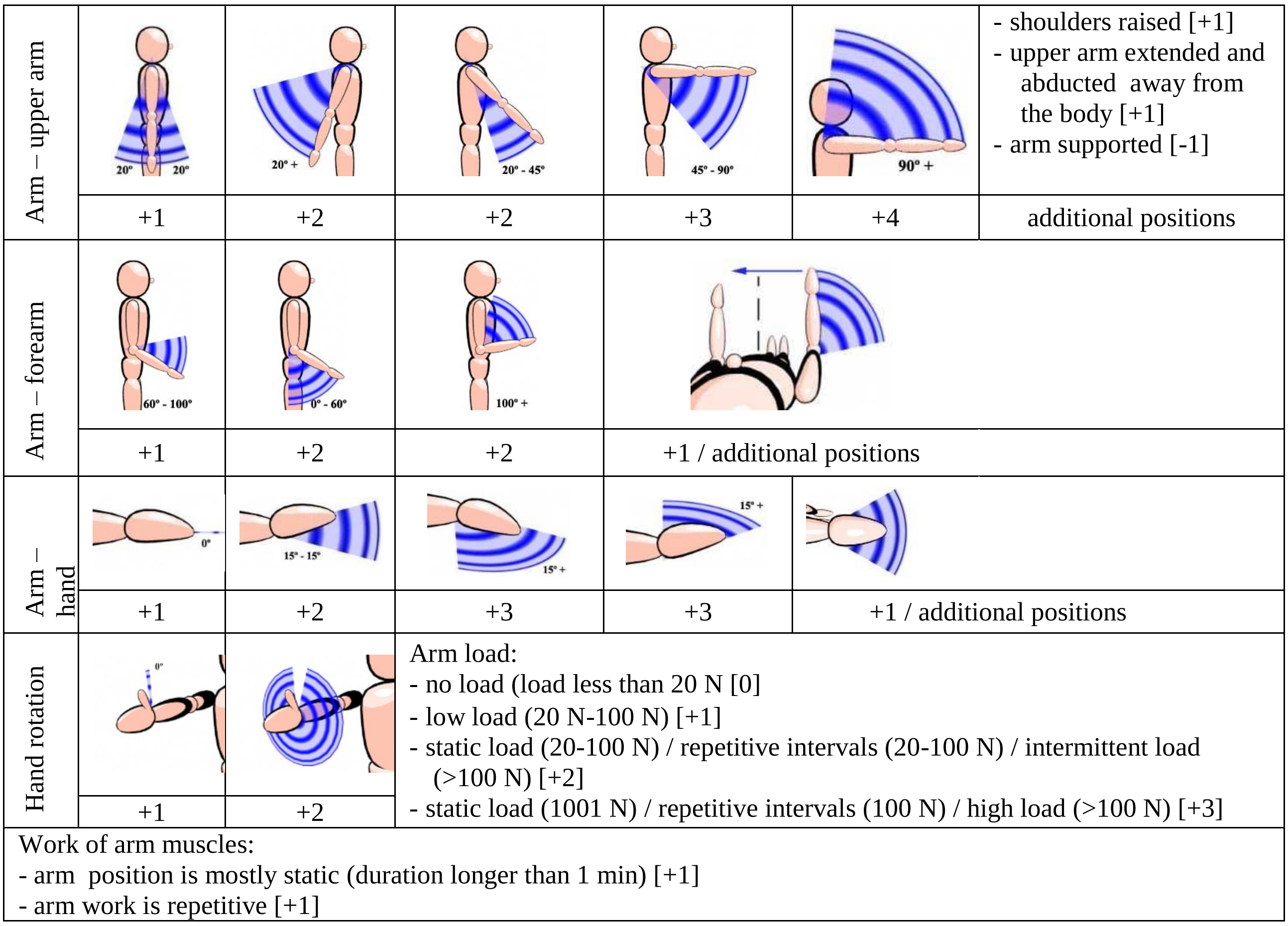

Fig.1 The working arm positions following the guidelines of the RULA method [9].

Observing undesirable working postures or motions while doing technological tasks provides important information for the optimal ergonomic design of the workplace and favourable working techniques. Through the development of computer systems, the RULA computer program was developed, which enables the analysis of ergonomically unfavourable working postures in real production processes.

Tab.1 Presentation of the assessment of the body load according to the RULA method [9]

Score	Risk	Description of load
1-2	1	Negligible risk; body posture acceptable; redesign of the workplace is unnecessary
3-4	2	Low risk; postural load; more detailed examination; redesign of the workplace in the foreseeable future
5-6	3	Medium risk; medium postural load; more detailed investigation; redesign of the workplace required soon
7+	4	High risk; high postural load; more detailed investigation; immediate redesign of the workplace required

3. Experimental part

Two workplaces from the actual manufacturing process were chosen to analyse the workload of workers in the technological process of cutting:

– Cutting the cutting layer with the AYANG CZD 108 straight knife, which has a 12 cm blade length and can cut the layer up to 10 cm (RM1). The cutting table height is 95 cm. A 190 cm tall worker used mechanical clamps to secure the cutting layer with the cutting pattern. After finishing the cut, he places the cut piece on the side table by rotating the trunk 180° while walking approx. 2-3 steps.
– The KURIS band knife, identified by plate number RBS 300, boasts a table height of 95 cm and a knife length of 4.92 m. This model is capable of cutting through layers up to 20 cm thick, and does not feature a nozzle system for producing an air cushion on the work surface. From the auxiliary table, the worker takes the cutting layer pieces, walks a distance of 4-5 steps to the band knife, completes the fine cut, and then returns the cut pieces to the original table. This task is performed by a worker with a height of 190 cm (RM2).

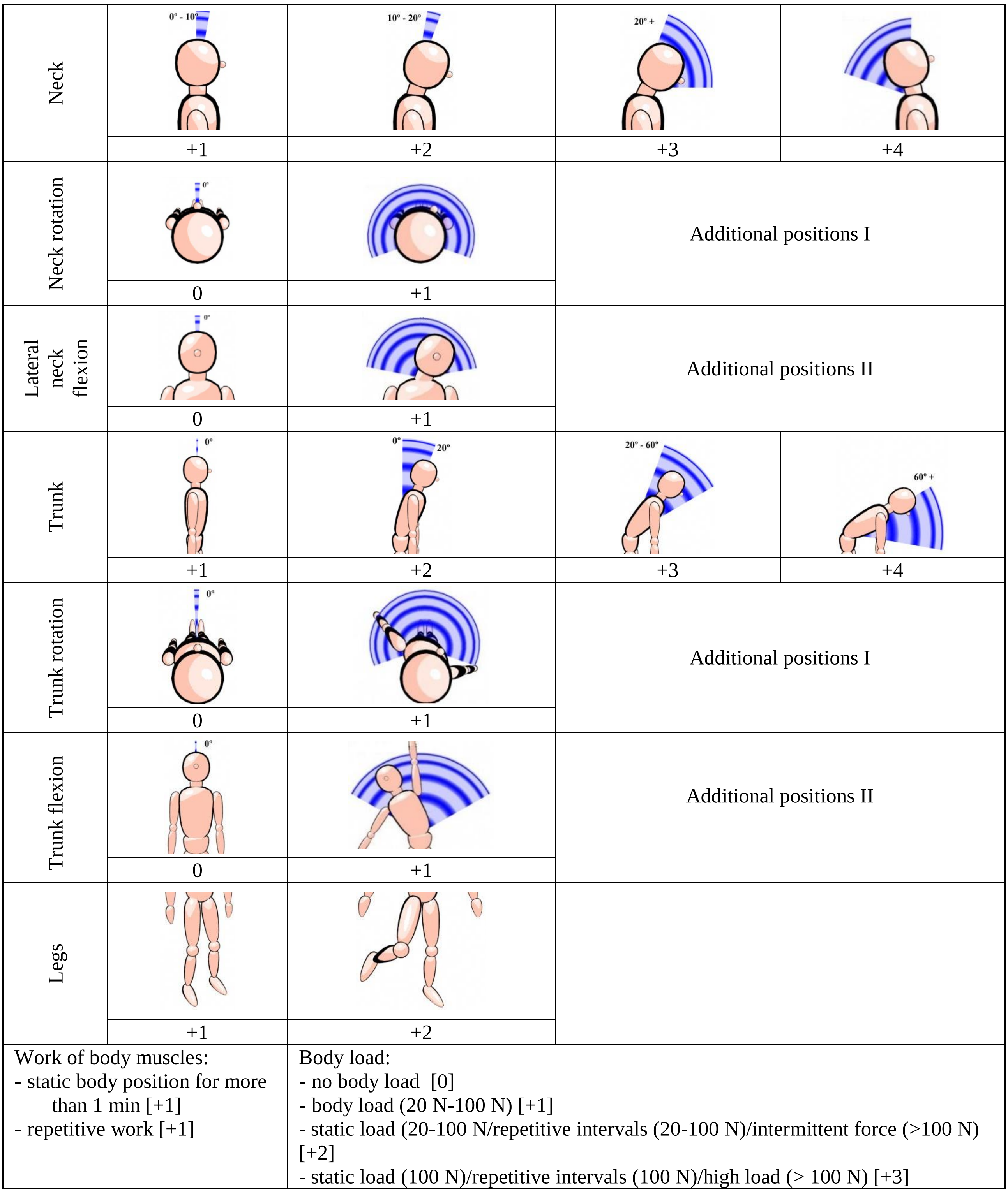

Fig.2 Illustration of the arm working positions as per the RULA method [9]

A camera with a built-in EF-S 18-135 mm lens, such as the EOS 750D, was utilized for the video recordings. The recording showed 17 minutes of cutting with a straight knife and 11 minutes of cutting with a band knife. The size of the recording is calculated using the workplace's stability coefficient (Ks) with a 95% probability (t=2) and a relative inaccuracy of 5%. The worker was captured in a photo from the right side in the sagittal plane.

4. Results and discussion

The worker's workload analysis is detailed in Table 2, providing insights into three distinct working postures for cutting with a straight knife and three distinct working postures for cutting with a band knife. This includes information on the angles of curvature of the back and neck parts of the spine, the required rotation of the head and eyes, as well as the angles of movement of the upper arm and forearm for both the right and left arm. Fig.3 shows the characteristic postures of the workers when cutting with a straight knife (RM1), while Fig.4 shows the characteristic postures of the workers when cutting with a band knife (RM2).

Through the analysis of the characteristic working postures using the RULA method for the technological task of cutting with a straight knife, it was observed that the worker stands while performing the task, with forward flexion and torsion of the spine exceeding 20°. The head of the worker is flexed forward at an angle greater than 30°, typically with a lateral tilt and rotation of the trunk.

During the cutting of cutting layers, the worker often works with an unfavorable arm position (upper arm-forearm-hand). A score of 7 was assigned to all three characteristic work postures using the RULA method, highlighting the urgency for workplace analysis and redesign.

To achieve more favourable working postures, it is necessary to adjust the height of the work surface from 95 cm to 106 cm to the height of the worker. Furthermore, it is suggested to purchase a console version of the straight knife cutting machine, which enables more accurate and easier cutting, and contributes to a lower level of workload for the workers, because the console takes over part of the weight of the machine and facilitates the control of the straight knife cutting machine and the worker's work.

According to the RULA method analysis results, it was observed that the worker assumes a standing posture with a spinal flexion of more than 15° during band knife cutting operation. The worker's head is tilted forward, and the worker's arms (upper arm, forearm, hand) are in an unfavourable posture. The total load for characteristic working postures was rated 7, which requires an immediate redesign of the workplace.

Tab.2 The curvature angles of the back (T) and cervical (C) spine, the required head and eye rotation (E), and the movement angles of the upper arm (F) and forearm (W)

Technological suboperation	Curvature angles of back (T), neck (C), head and eye rotation (E) [°]	Upper arm movement angles [°]		Angles of movement of the forearm [°]	
		Right arm	Left arm	Right arm	Left arm
RM1 – cutting with straight knife					
Position 1	31/54/50	50	30	50	45
Position 2	57/40/45	45	45	100	100
Position 3	30/50/0	20	20	30	45
RM2 – cutting with band knife					
Position 1	22/28/30	20	45	35	45
Position 2	36/24/0	25	45	45	45
Position 3	31/30/0	45	20	45	45

Tab.3 Presentation of the scores achieved by characteristic positions for RM1 and RM2

Technological suboperation/load	**RM1 – cutting with straight knife**						**RM2 – cutting with band knife**					
	Position 1		Position 2		Position 3		Position 1		Position 2		Position 3	
Arm (right/left)	D	L	D	L	D	L	D	L	D	L	D	L
Arm	7	6	6	5	6	5	4	6	4	6	6	4
Body		10		10		9		9		7		7
Total	7		7		7		7		7		7	

Fig.3 The characteristic working postures when cutting with a straight knife (RM1)

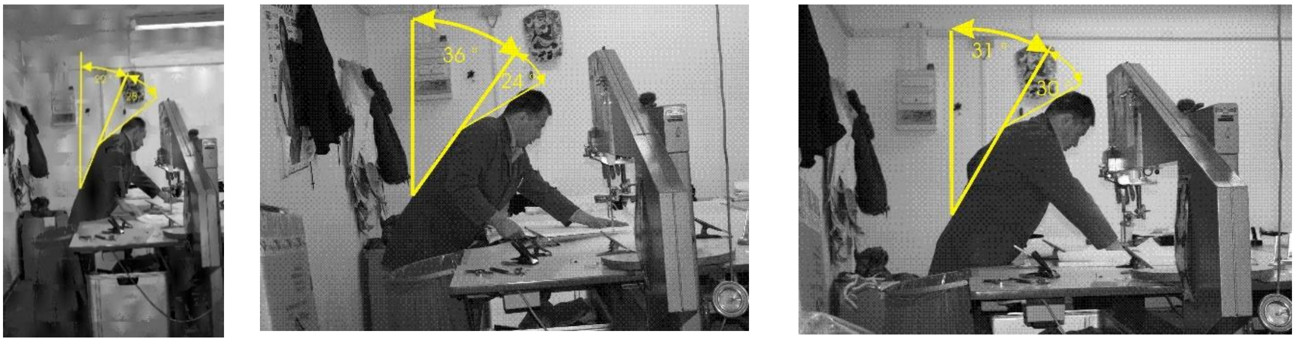

Fig.4 The characteristic working postures utilized for band knife cutting (RM2)

Redesigning the workplace for band knife cutting operations involves enlarging the working surface from 95 cm to 106 cm to ensure it is ergonomically suitable for the worker's height. To reduce strain on the worker's body, especially the spine, head, and arms, it is advised to buy a band knife cutting machine that offers adjustable work surface height and a built-in nozzle system to create an air cushion. This feature enables smoother handling of the cutting material and enhances cutting precision.

5. Conclusion

The technological cutting process is a complex system that requires good motor, tactile and visual abilities of the worker, which includes high mobility and coordination of body movements and the upper arm-forearm-hand system. By utilizing the RULA method, the assessment of work places during the technological cutting process involving straight knife and band knife identified the level of strain on workers and indicated that the work places were not ergonomically designed. There is a difference in the body height of workers in both workplaces, resulting in static and dynamic loads caused by unfavorable working postures. Therefore, it is recommended to adjust the height of the work surface to the body height of the worker. Redesigning the workplace can reduce the strain on the upper arm-forearm-hand system and minimize the forward flexion angles of the back and neck spine. Positive angles found in kinematic chains aid in smooth motor movements, accurate task execution, improved coordination of movements, and enhanced flexibility. This ultimately decreases physical strain and allows for higher levels of productivity on an hourly and daily basis.

References:

[1] Šaravanja, B.; Hursa Šajatović, A.; Dragčević, Z. Istraživanje uvjeta radne okoline u tehnološkim procesima proizvodnje odjeće, *Tekstil*, **2018**, 67(5-6), pp. 146-154. https://hrcak.srce.hr/229012

[2] Kirin, S.; Dragčević, Z.: Investigation of Workload in the Technological Sewing Process Using the RULA Method. In: *Proceedings of the 9th International Textile, Clothing & Design Conference - Magic World of Textiles*, Dragčević Z. Ed, pp. 197-202, Dubrovnik, Croatia, October 7th-10th, 2018,University of Zagreb Faculty of Textile Technology, Zagreb

[3] Rogale D.; Ujević, D.; Firšt Rogale, S.; Hrastinski, M. *Procesi proizvodnje odjeće*, Sveučilište u Zagrebu, Tekstilno-tehnološki fakultet, Zagreb, Hrvatska, 2011, pp. 12-18.

[4] Žunič Lojen, D.; Polajnar, A.; Camlek N. Ergonomsko oblikovanje delovnih mest pri krojenju usnja, *Tekstilec*, **2002**, 45(11-12), pp. 341-354.

[5] Verhovnik, V.; Polajnar, A. *Oblikovanje dela in delovnih mest*, II izdanje, Univerza v Mariboru, Fakulteta za strojništvo, Maribor, Slovenija, 2007, pp. 45-60.

[6] Žunič, D., Geršak J. Oblikovanje delovnih mest v konfekcijski industriji, *Tekstilec*, **1991**, 34(2-3), pp. 79-84.

[7] Balantič, Z.; Polajnar, A.; Jevšnik, S. *Ergonomija v teoriji in praksi*, Nacionalni inštitut za javno zdravje, Ljubljana, Slovenija, 2016), pp. 120-125.

[8] Stanton, N.A.; Hedge, A.; Brookhuis, K.; Salas, E.; Hendrick, H.W. (Eds.). *Handbook of Human Factors and Ergonomics Methods* (1st ed.). CRC Press. 2004. https://doi.org/10.1201/9780203489925

[9] McAtamney, L., Corrlett, E.N. RULA: a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics*, **1993**, 24(2), pp. 91-99. https://doi.org/10.1016/0003-6870(93)90080-S