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## ERGONOMIC AND NOISE RISK ASSESSMENT FOR THE OPERATOR OF A DYNAMIC TESTING MACHINE

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**Abstract:** The aim of this study is to determine what posture the operator of the dynamic testing machine should use at work to maintain good health. In the proposed paper, a posture assessment using the Rapid Entire Body Assessment (REBA) ergonomic method is performed for the operator's work when changing the jaws of the dynamic testing machine without or with the use of a step ladder. The documented postures were evaluated using a worksheet and the ErgoFellow 3.0 software suite, applying the REBA method. The research results have been used for recommendations for the operator to take preventive measures and wears hearing protective equipment such as earplugs or earmuffs during the cyclic tests. In addition, it is necessary to carry out regular hearing tests.

**Keywords:** dynamic testing machine, working postures, REBA method, ErgoFellow 3.0 software, noise, monotonic test, cyclic test.

### 1. INTRODUCTION

Workers should understand the level of workload they are able to manage when performing their duties, keeping in mind the natural limits of human cognitive and physical capacity. Although posture may sometimes be overlooked, continuously working in inadequate body positions leads to tiredness, which can eventually cause musculoskeletal disorders (MSDs).

When this occurs, employee performance declines and overall production effectiveness is compromised. Performing a detailed assessment of workplace postures and informing employees of the findings is therefore essential. By doing so, negative effects on productivity and risks to achieving company objectives can be prevented [1].

With the growing relevance of occupational health and safety, several techniques have been designed to detect harmful working postures. A work posture is essentially the physical action carried out by an employee while completing a task.

Analyzing body posture provides a strong ergonomic approach to estimating the likelihood of musculoskeletal injuries, since it examines the working positions adopted during task execution. Postural assessment tools generally combine two contrasting characteristics: they may be broad in scope or highly sensitive [2].

The Rapid Entire Body Assessment (REBA) method is a simple and cost-effective way to evaluate ergonomic working postures. By assigning scores to each body part and analyzing the results, REBA identifies the most problematic ergonomic factors [3].

In REBA, each segment of the body is assessed during task performance, including the operator's neck, back, arms, wrists, and legs. The method also takes into account coupling, external loads applied to the body, and the specific activities performed [4-6].

Carrying out posture assessments can be simplified by using specialized software such as ErgoFellow 3.0 [7,8]. The primary aim of such evaluations is to classify and improve employees' postures during their workday, with the objective of reducing musculoskeletal strain and enhancing performance [8].

Industrial halls often contain numerous machines that generate both noise and vibration, which affect workers inside as well as people outside. Noise is among the most common forms of pollution in occupational and environmental contexts, ranking third after air and water pollution.

It also poses a threat to human well-being and work performance. Its presence is largely a consequence of the widespread use of various industrial machines, technological processes as well as audiovisual and explosive devices [9].

Prolonged exposure to high noise levels is one of the most prevalent occupational hazards, with wide-ranging negative impacts on workers. It can lead to both physiological and psychological changes that compromise productivity, safety, and quality of life [10,11].

To safeguard against hearing impairment, Directive 2003/10/EC [12] defines maximum permissible exposure limits ( $L_{ex,8h} = 87$  dB(A);  $p_{peak} = 200$  Pa), as well as upper ( $L_{ex,8h} = 85$  dB(A);  $p_{peak} = 140$  Pa) and lower action levels ( $L_{ex,8h} = 80$  dB(A);  $p_{peak} = 112$  Pa). These thresholds are designed to trigger preventive interventions that protect workers' health [12-14].

If the noise intensity exceeds these values, this can lead to a weakening of the worker's hearing ability. Noise-induced hearing loss is therefore one of the most frequent occupational illnesses [9].

Noise within industrial halls can also be described using the equivalent noise level ( $L_{Aeq,T_e}$ ) [12]

$$L_{Aeq,T_e} = 10 \cdot \log \left[ \frac{1}{T_e} \int_0^{T_e} 10^{0.1L(t)} dt \right], \quad (1)$$

where  $T_e$  is the time of daily exposure to noise and  $L(t)$  is the instantaneous noise level. The noise level can also be determined by direct measurements with sound level meters.

The first objective of this research is to assess two different operator postures during the replacement of the gripper jaws of the dynamic testing machine, both without and with the aid of a step ladder. These postures were analyzed using the REBA worksheet and the ErgoFellow 3.0 software.

The second objective of this research is to determine the noise intensity during the operation of the dynamic testing machine. The noise measurements were carried out during idling, monotonic test and cyclic tests.

Based on the ergonomic assessment and the noise measurements carried out, it will be possible to make recommendations for the operator to maintain his health.

## 2. ERGONOMIC ASSESSMENT USING REBA METHOD AND A DEDICATED SOFTWARE

The Rapid Entire Body Assessment (REBA) method represents a tool for analyzing ergonomic postures and identifying musculoskeletal risks across different tasks. Originally intended for healthcare workplaces, it can be readily applied to other industries. The approach evaluates positions of the trunk, neck, legs, and arms quickly, assigning higher scores to postures that deviate further from neutral.

Different parts of the body are grouped into two categories: Group A and Group B. Group A consists of the trunk, neck and legs, whereas Group B comprises the upper arms, lower arms, and wrists. In addition, this method takes into account other factors, including the coupling factor, external loads handled by the body, and the nature of the worker's activity [2, 16-18].

The REBA assessment is applied in several stages, as illustrated in Fig. 1, which shows the framework for calculating the REBA score [16]. The assessment can be conducted manually using a worksheet (Fig. 2) or digitally using the ErgoFellow 3.0 software, which also supports other ergonomic assessment methods (Fig. 3).

## 3. DYNAMIC TESTING MACHINE

The measurements in this paper were performed with a dynamic testing machine situated at the Faculty of Metallurgy, University of Zagreb. Fig. 4 illustrates the machine along with its auxiliary components that are necessary for operation.

For the operation of the dynamic testing machine, a hydraulic unit is required, whose hydraulic oil must be additionally cooled with water when it is heated.

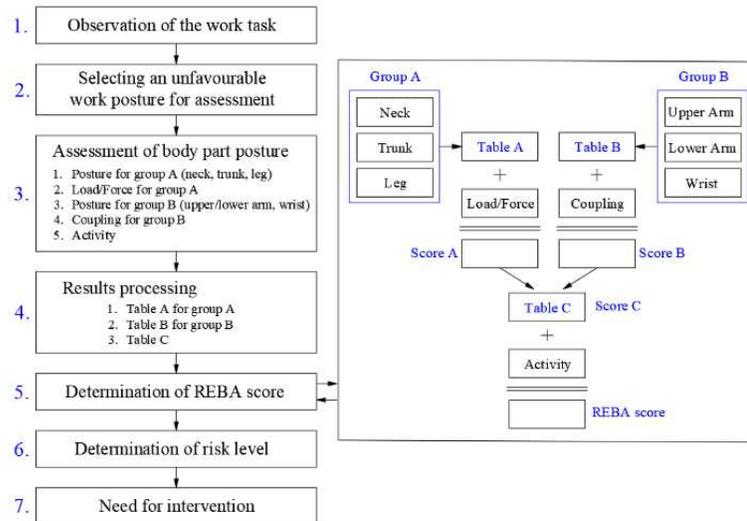


Fig. 1. The procedure of using REBA method - the diagram for the REBA score calculation.

Fig. 2. REBA worksheet [17].

The water circuit is in a closed circuit, which is additionally cooled by a fan. The operation of all the additional equipment generates a lot of noise. The impact of environmental chamber noise was not analyzed in this work.

### 3.1 Working Posture

In the first part of this paper, the working position of the operator of the dynamic test machine is evaluated according to the ergonomic REBA method. The operator must prepare the machine for work, more precisely, he must place

the appropriate jaws on the specimen grips and clamp the specimen in the set jaws. As this is a large dynamic testing machine with jaws at a height of 170 to 190 cm, the operator must raise his hands when changing the upper jaw (Fig. 5i). The operation can be carried out using a step ladder (Fig. 5ii).

By applying the REBA method, the operator's working posture is assessed for these two cases of working posture shown in Fig. 5. When the position of the upper arm is analyzed for posture 1, the arm is at an angle of more than 90° and the

shoulders are raised, while in posture 2 the arm is at an angle of less than 90°. The assessment made was recorded in the ErgoFellow software and shown in Fig. 6.

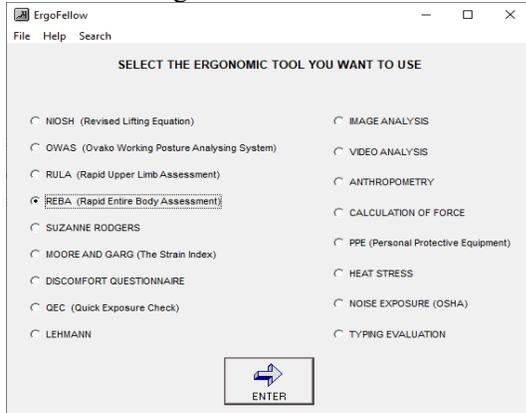


Fig. 3. ErgoFellow software interface.

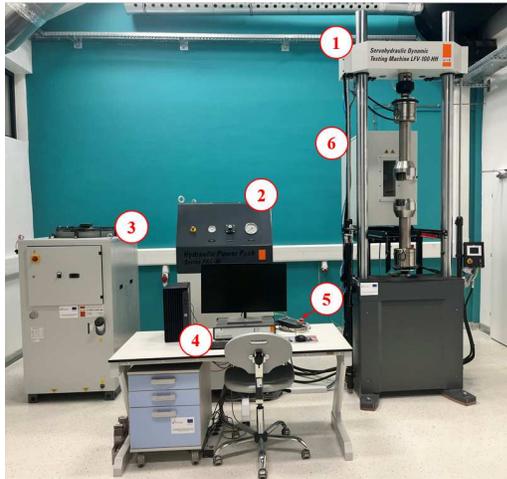


Fig. 4. Dynamic testing machine:  
 1) servohydraulic dynamic testing machine LFV-100-HH, 2) low noise hydraulic power pack, 3) closed loop water re-cooler, 4) digital testing controller with desktop PC, 5) remote control handset, 6) environmental chamber.

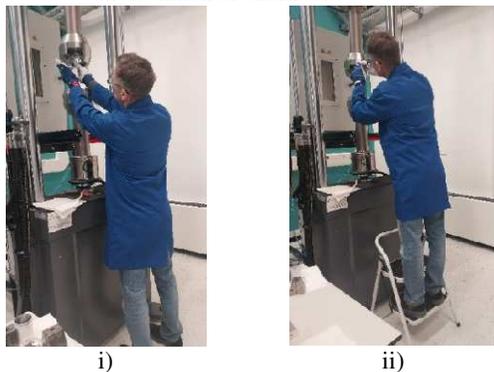


Fig. 5. Operator changing the gripper jaws of a dynamic testing machine: i) without a step ladder (first posture) and ii) with a step ladder (second posture).



Fig. 6. REBA assessment of the upper arm with the ErgoFellow for: i) first posture and ii) second posture.

### 3.2 Noise measurements

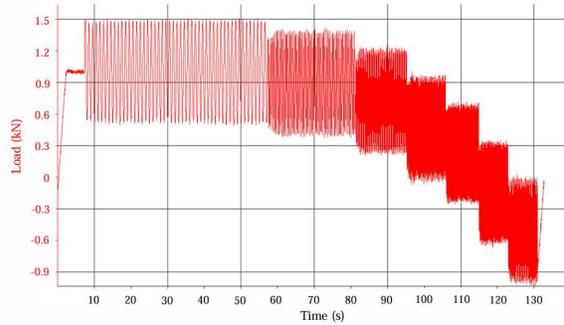
In the second part of the experiment, the noise generated by the device during operation is measured: (i) when idling in mode (without test), (ii) during a monotonous tensile test and (iii) during cyclic tests. All monotonic and cyclical tests were carried out on the mild steel specimen (Fig. 7). The noise measurements were carried out at the operator's sitting position at a height of 1.25 m (Fig. 8). The noise measuring device complies with HRN EN 60804:2002 standard and measurement was done in accordance with the HRN EN ISO 9612 standard. The result of the conducted cyclic test with variation of the amplitude is shown graphically in Fig. 9. In the second cyclic test, the same mean force of 1 kN and an amplitude of 500 N varied with the frequency of the force oscillations of 1; 2.5; 5; 7.5; 10; 12.5 and 15 Hz. The result of the conducted cyclic test with variation of the frequency is shown graphically in Fig. 10.



Fig. 7. Test specimen.



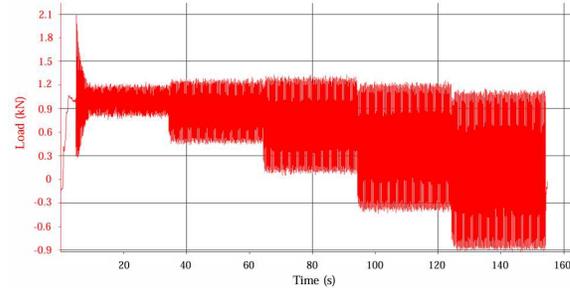
Fig. 8. Sound level meter VOLT CRAFT.



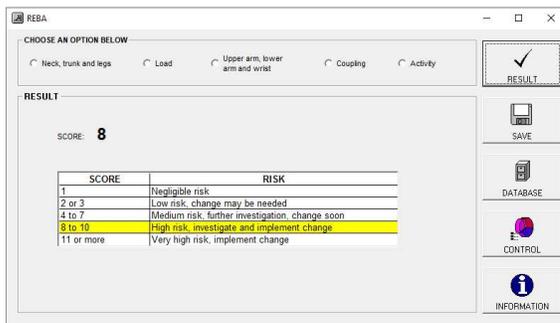
**Fig. 9.** Graphical representation of a cyclic test with varying oscillation frequency.

When performing cyclic tests, the frequency and amplitude of the oscillation of the imposed force load were varied. In the first cyclic test, the

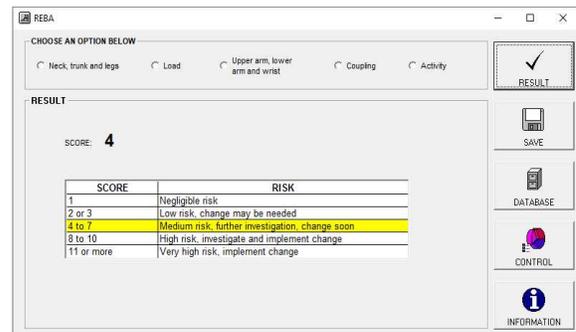
behavior of the test specimen was tested under a cyclic load with an average load of 1 kN and a frequency of 5 Hz and with force amplitudes of 200, 400, 600, 800 and 1000 N.



**Fig. 10.** Graphical representation of a cyclic test with varying oscillation amplitude.

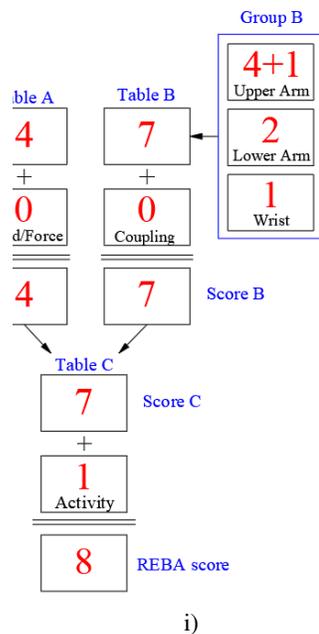


i)

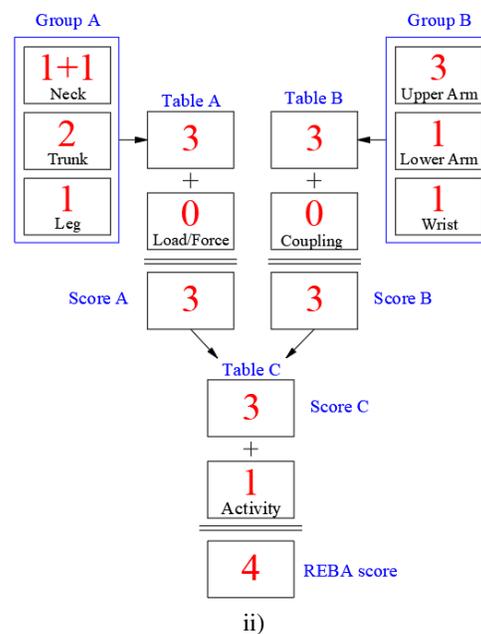


ii)

**Fig. 11.** ErgoFellow REBA scores for: i) first posture and ii) second posture.



i)



ii)

**Fig. 12.** REBA scores using a worksheet for: i) first posture and ii) second posture.

## 4. RESULTS AND DISCUSSION

### 4.1 REBA scores

Following the applied REBA method evaluation of the operator’s postures (Fig. 5), the results achieved through the ErgoFellow 3.0 program are shown in Fig. 11, while Fig. 12 provides a schematic illustration of the worksheet-based calculation.

As presented in Table 1, the final REBA results derived from Figs. 11 and 12 coincide for each posture. This table also links the scores to the corresponding musculoskeletal risk levels, consistent with Fig. 2.

Table 1

REBA scores and risk.			
	Worksheet	ErgoFellow 3.0	Risk
Posture 1	8	8	high
Posture 2	4	4	medium

Figure 12, which details results for specific body segments, provides additional insight into the REBA outcomes. For group A (neck, trunk, legs), scores were higher in the case of the first posture than in the second one. When the operator is not using the step ladder (posture 1), the neck is extended and twisted, but when he is using it (posture 2), the neck is tilted forward by 10°.

As indicated in Table A (in Fig. 2), group A’s total score is greater in the first posture than in the second one: posture 1 scored 4 compared to 3 in posture 2. In posture 1, without the ladder, the upper arm angle exceeds 90° with elevated shoulders, while in posture 2, with the ladder, the angle is reduced to below 90°. In Table B (in Fig. 2), group B also shows a greater score for the first posture than in the second one (posture 1 scored 7, compared to 3 for posture 2).

Table C (in Fig. 2) combines the results of groups A and B, showing a higher total score in the case of posture one than in the second case. Score of table C for posture 1 is 7, while posture 2 is 3. The operator's activity due to holding body parts for longer than 1-minute increases the score achieved by 1 in both cases.

Consequently, the overall REBA value is greater for posture 1 than for posture 2. Specifically, posture 1 scored 8 (Figs. 11i and 12i), while posture 2 scored 4 (Figs. 11ii and

12ii). These outcomes classify posture 2 as medium risk and posture 1 as high risk. Thus, avoiding posture 1 is advisable, and the use of a step ladder is recommended when replacing the gripping jaws.

### 4.2 Noise intensity

The outcomes of the idling noise intensity measurements and the monotonic test are presented in Table 2. Based on the recorded values, it can be concluded that the monotonic tensile test with the fan does not generate additional noise relative to the testing machine operating in idle mode. The noise intensity measurements were carried out for cyclic tests with two test specimens. The vibration frequency varied for one test specimen (Fig. 7) and the amplitude of the vibration force for the other (Fig. 8). The results of the noise measurements during the cyclic tests are shown in diagrams. Fig. 13 illustrates the relationship between the measured noise intensity and variations in vibration frequency, whereas Fig. 14 presents the relationship between the measured noise intensity and variations in vibration amplitude. The measured noise intensities are approximated by quadratic trend line functions.

Table 2

Measurement of noise intensity with monotonic tensile test and without test.

Idling mode (without test)	
without cooling fan	72.5 dB
with cooling fan	74.6 dB
Monotonic tensile test	
with cooling fan	74.7 dB

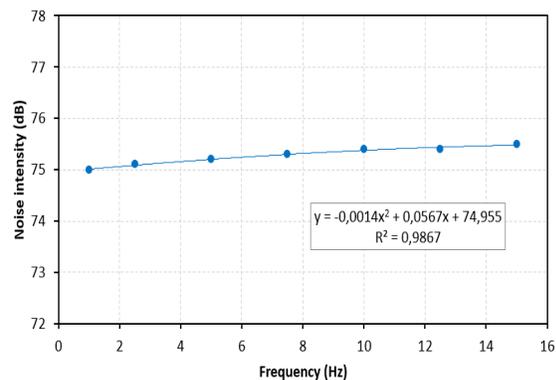
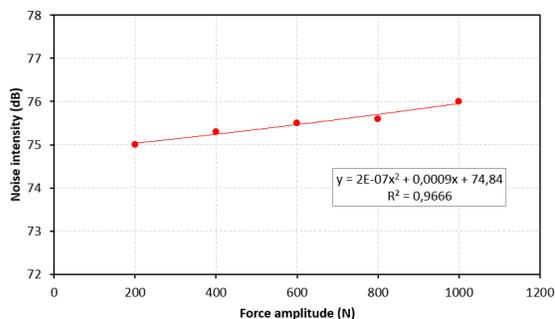


Fig. 13. Dependence of the measured noise intensity on the vibration frequency.



**Fig. 14.** Dependence of the measured noise intensity on the vibration force amplitude.

The diagram shows that the increase in noise intensity with increasing amplitude of the force oscillation is slightly greater than with increasing oscillation frequency. It is evident that, during cyclic tests, the measured noise intensity at higher amplitudes of the applied force oscillations can reach 80 dB(A), corresponding to the lower exposure limit for an eight-hour workday.

## 5. CONCLUSION

The REBA assessment of the operator's working postures during the task of changing the gripping jaws of the dynamic testing machine - without (first posture, Fig. 5) and with (second posture, Fig. 5) the use of a step ladder - indicated that the risk to the worker is higher when the task is performed without a step ladder. The final REBA scores were 8 for posture 1 (without a step ladder) and 4 for posture 2 (with a step ladder), corresponding to high and medium risk levels, respectively. An optimal solution would be to position the test machine at a lower height relative to the floor, thereby eliminating the need for step ladders. A limitation of this study is that the working posture assessment was conducted on only a single operator in both scenarios.

As the noise intensity during the cyclic tests can reach the lower warning limit of 80 dB(A) during an eight-hour working day, it is recommended that the operator wears hearing protective equipment such as earplugs or earmuffs during the cyclic tests. It is also recommended that hearing is tested regularly. The best solution would be to physically

separate the operators when working on the dynamic testing machine.

## ACKNOWLEDGMENT

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### Evaluarea ergonomică a posturii de lucru și a expunerii la zgomot a operatorului mașinii de testare dinamică

Scopul acestui studiu este de a determina ce postură ar trebui să utilizeze operatorul mașinii de testare dinamică la locul de muncă pentru a menține o sănătate bună. În această lucrare, se efectuează o evaluare a posturii utilizând metoda ergonomică de Evaluare Rapidă a Întregului Corp (REBA) pentru munca operatorului la schimbarea fălcilor mașinii de testare dinamică fără sau cu utilizarea unei scări. Posturile înregistrate au fost analizate cu ajutorul unei fișe de lucru și al pachetului software ErgoFellow 3.0 folosind instrumentul REBA. Ca urmare a rezultatelor de cercetare obținute, se recomandă ca operatorul să ia măsuri preventive și să poarte echipament de protecție auditivă, cum ar fi dopuri de urechi sau căști antifonice, în timpul testelor ciclice. În plus, este necesar să se efectueze teste auditive regulate.

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