INTRODUCTION

One of the elements of the logistics system is the subsystem of production, of which the basic elements of each work process are people, means of work and work items [28]. Moreover, production systems are defined as a system composed of physical elements such as machinery and equipment, tools and people. They have to produce goods that meet the expectations of consumers. From the health and safety point of view, the production system is designed to meet the needs of both workers and consumers [2]. In addition, production systems dependent on the human-operator are particularly prone to problems related to work safety, discomfort, maintaining production quality and increases in training costs and absenteeism [10].

Work performed by people is accompanied by physical activity, which may cause the occurrence of musculoskeletal disorders (MSDs) in workers [30, 31] manifesting in the form of health problems [13-15]. Studies have shown that the posture of the employee at work, range of motion, force, repetition and duration of activity must be taken into account when categorizing the level of physical activity [12]. The position and movements of the operator during operation are important variables that must be taken into account in the safety of the work, because they are the two most important factors that determine the workload of the employee. In addition, the posture of the employee at work is affected by factors such as task accomplished, job, tools available and their design and the anthropometric characteristics of workers [30].

Research techniques proposed to estimate the level of discomfort and load associated with the worker taking up different postures during labour can be divided into observational and machine-based devices. In the case of angular deviation of the body segments from the neutral position, information is obtained by visual observation. Techniques based on instruments, in contrast, work on the basis of continuous monitoring of posture performed by devices connected to the worker. Due to the lack of interference with the labour process, low cost and ease of use, observational techniques are more commonly used in industry [3].

Observational methods used to assess postural load on the employee include: Ovako Working posture Analysing System (OWAS) [9], Rapid Upper Limb Assessment (RULA) [24] and Rapid Entire Body Assessment (REBA) [5, 16]. They were each developed for different purposes and therefore are used under different workplace conditions. Each technique has its own classification system for the operator, which differs from other techniques; this may cause differences in the final result for the load, depending on the technique used.

The publication of various scientific studies has shown the usefulness of OWAS in assessing the posture of the employee while working in various environments such as warehouses [29], construction [23], operation and maintenance of ships [8], in metal processing [4], wood [7], processing of fish [26], in the furniture, steel, electronics, automotive and chemical industries [11, 17-22, 25, 27, 31], etc.

In the production process, a sequence of tasks is performed which allows the production of the desired product. The performance of such a system is not determined solely by the technical subsystem, but is also influenced by the human subsystem. From an ergonomic point of view, the key
element are workers and their efficient workflow, which can be affected by excessive load, improper postures taken during work, etc. Disturbances in the human system can lead to problems associated with the provision of production, quality and increased costs of sickness absence due to the negative impact of work on health workers. Hence, it becomes an essential element of ergonomic assessments to detect abnormalities that imply ergonomic interventions to improve the efficiency of the system.

This study focuses on one case involving the production of steel pipes which has allowed a detailed investigation on the interaction of employees with each element of the task. A set of methods was used including: interview, task analysis and OWAS, which is one of the simplest techniques of observation and in conjunction with the method of observation allows for quick execution of assessment and evaluation of the level of ergonomic intervention associated with the risk of MSD’s.

The aim of the study was to assess the posture taken by operators in the production of steel pipes by OWAS. The term ‘Action Categories’ (AC) describes the need for ergonomic intervention.

1 METHODS AND MATERIALS

1.1 Research group

The evaluation was performed in a production plant in western Poland. The research group consisted of 3 males: 35, 40 and 55 years old. The pipe production process was evaluated for three consecutive positions:

– Shaping the sheet: the employee’s task was to collect the sheet metal from the palette, place it in the rolling mill, then remove coiled shapes and place them on a pallet.
– Welding: this job involved taking a shaped coil from a palette, placing it in the welding machine holder, welding fittings and putting the pipe aside on the table.
– Forming: the operator fetches welded pipes from the accumulation bin on the table and transfers the items onto a roller, on which shaping of the ends of the tubes takes place. Following this the pipes are placed in a machine where a single volume of expanded pipe end is fitted. The pipe is then laid on the floor.

The job was performed in a standing position, for 8 hours per shift, 5 days a week. There are 2 rest breaks daily of 15 minutes and no rotation of positions.

1.2 Observation, interview and analysis of tasks

Several techniques were used to gather research material: observation, interview, analysis of tasks and the OWAS method. Observations of tasks performed by employees were preceded by interviews with supervisors and employees, which helped to understand the process of work and activities carried out by operators. A hierarchical task analysis [1] was used to determine the actions performed by the employees.

1.3 OWAS method and evaluation of operator posture

The OWAS method was developed by Finnish authors in the Oy Ovako company [9] and has been disseminated in many countries. It was developed for the assessment of exposure to MSDs risk associated with the operator’s posture during operation. The method comprehensively considers the issue based on the observation technique during performance of the work. It takes into account the posture taken by the operator during operation by highlighting the following body segments: trunk (back), arms, legs and external load in kilograms, which has a significant impact on the risk. The basis for the assessment of exposure to MSDs is the degree of the total postural load with regard to the external load. The OWAS method is focused on the identification of problems and corrective actions which finds its expression in terms of evaluation. The main objective of the assessment therefore becomes disclosure and possible correction of unwanted items.

In this method, the model distinguishes three segments of the human body, which may take different positions and also considers the external load. The OWAS method takes into account the load derived from four factors:

– The position of the back (four coded selections: 1 - straight, 2 - bent forward, 3 - twisted, 4 - bent and twisted).
– The position of the arms (three codes: 1 - both below the shoulder joint, 2 - one above the shoulder joint, 3 - both above the shoulder joint).
– The position of the legs (seven codes: 1 - sitting position, 2 - Standing with legs straight, 3 - standing with one leg extended, 4 - standing with legs bent, 5 - standing with one leg bent, 6 - kneeling on one or both knees, 7 - walking).
– External load in kg (three codes: 1 - less than 10kg, 2 - 10 to 20kg, 3 - over 20kg).

The total operator load code consists of a combination of the codes for back position, the position of the arms, leg position and external load, creating a four-digit code. Their combination creates categories describing the assessment of the risk of exposure to MSDs and categories of necessary action to improve working conditions on the test bench. The authors distinguished:
– AC 1: no risk, correct position, with no particular adverse effects on the musculoskeletal system; operator intervention is not required.
– AC 2: there is little risk; working position has little detrimental effect on the musculoskeletal system. There is a light load; immediate intervention is not required, however ergonomic adjustment should be taken into account in future actions.
– AC 3: significant risk; working position has a significant detrimental effect on the musculoskeletal system. Ergonomic intervention should be carried out as soon as possible.
– AC 4: very high risk; working position has a very large detrimental effect on the musculoskeletal system; ergonomic intervention is required immediately.

Positions taken by each of the operators were assessed during daily routine work. The most unfavourable positions taken by the employees were considered.

2 RESULTS AND DISCUSSION

First, tasks performed at different positions were divided into steps, followed by an assessment of the posture during each using the OWAS method. The evaluation results are summarized in the following tables.

Tab. 1. OWAS evaluation of the formation position

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Back (1-4)</th>
<th>Arms (1-3)</th>
<th>Legs (1-7)</th>
<th>Load (1-3)</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Approach</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Acquisition</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Placement</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Removal</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Storing</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

The formation position (Tab. 1) is comprised of 5 steps, of which one qualified for AC 3. Two steps qualified for AC 2, along with two for AC 1. It was noted that when acquiring and returning items, the employee took an incorrect position (excessively tilted forward when acquiring and depositing the metal sheet on the pallet). Position of the legs was incorrect in three cases: when obtaining the sheet metal from the palette and when placing the sheet in the machine, the worker moved his weight with one leg bent at the knee joint. However, during set-down his weight was moved on one straight leg.
Tab. 2. OWAS evaluation at the welding position

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Body Position Code</th>
<th>Back (1-4)</th>
<th>Arms (1-3)</th>
<th>Legs (1-7)</th>
<th>Load (1-3)</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Approach</td>
<td></td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Acquisition</td>
<td></td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Transport</td>
<td></td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Placement</td>
<td></td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Removal</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Storing</td>
<td></td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

At the welding position (Tab. 2) six steps were highlighted, of which 1 action qualified for AC 3, one for AC 2 and the remaining 4 steps for AC 1. In three cases there was an abnormal position of the back, which was excessively tilted forward in the case of setting down. In two cases (acquiring the pieces from the palette and placing them in the welding machine holder) leg position was incorrect, as the weight of the body was transferred to a straight or bent knee leg.

Tab. 3. OWAS evaluation of the forming position

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Body Position Code</th>
<th>Back (1-4)</th>
<th>Arms (1-3)</th>
<th>Legs (1-7)</th>
<th>Load (1-3)</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Approach</td>
<td></td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Collection</td>
<td></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Transport</td>
<td></td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Placement 1</td>
<td></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Transfer</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Placement 2</td>
<td></td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Storage</td>
<td></td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

In turn, at the forming station (Tab. 3) work consisted of seven steps. Three of them qualified for AC 2 whilst 4 qualified for AC 1. Irregularities were observed relating to the position of the legs. In the case of three steps (acquiring welded fittings, putting on rollers, placing on the instrument machine) body weight was transferred to one dislocated leg at the knee joint.

Postural load analysis on the musculoskeletal system of operators was carried out for three different positions in the production process. It was noted that there was an absence of AC 4, which requires immediate ergonomic intervention. Moreover, operators kept their arms in the correct position - below the shoulder joint - through the entire process of work. Load also had no effect on risk, since at no time did it exceed a value of 10 kg. However, in two cases there was an AC 3 rating, which requires a change in the positions as soon as possible. In six cases, the activities were classified as AC 2, which may require ergonomic intervention. The remaining ten actions were classified as AC 1, which does not require intervention as the risk of MSD’s is minimal. Moreover, incorrect position of the back was observed in five cases and of the legs in eight cases.

3 CONCLUSIONS AND RECOMMENDATIONS

An important element in production systems, in addition to the physical elements, is the human factor which affects performance, cost and quality [6]. Improving the system of production can not only cover the technical sphere, but also the realm associated with the environment and ergonomics. The aim of the study was to assess the posture taken by operators in the production of pipes and define categories of actions.

Of the 18 positions taken by workers that were distinguished, the evaluations were as follows:
- AC 1: 10 actions classified.
- AC 2: 6 actions classified.
- AC 3: 2 actions classified.
The main factors influencing the negative assessment of the position when working were: holding the back tilted and twisted and moving the weight on one leg. Awkward postures were forced by the workplace. Production engineers and specialists in the field of occupational safety and health should pay particular attention to the organization of work and in particular for activities related to the collection and accumulation of items. Ergonomic intervention should be linked to:

- Redesign of positions with particular emphasis on collecting items as well as depositing.
- Development and implementation of a system of rotation of employees to ensure variability in workload.

After making changes on the test positions reassessment with the OWAS method is recommended in order to verify the effectiveness of the changes.

In summary, this work recognized abnormal positions of the operators in the production of steel pipes. It sets out action categories for each item. These findings can be used to develop a system of rotation of employees at work stations and implement ergonomic changes and a prevention program.

Abstract

Systems dependent on the human-operator are particularly prone to problems related to work safety, discomfort, and ensuring production quality. The article presents an assessment of the positions taken by operators in the production of pipes for three workstations: forming, welding and moulding, conducted using the OWAS method. The action categories of activities (AC) describe the need for ergonomic intervention. Of 18 operator positions evaluated, 10 were assessed at AC1, a further 6 at AC2 and 2 positions at AC3, for which urgent ergonomic intervention is required. In five cases, the position of the back was incorrect, and in eight cases that of the legs. The arms were kept below the shoulders, and external load did not exceed 10 kg.

Recommendations: reorganization of work with particular attention to retrieving and depositing items; development and implementation of a system of rotation of employees in order to ensure variation in workload.

Przyjmowane pozycje podczas pracy przez operatorów w procesie produkcji rur – studium przypadku

Streszczenie


ACKNOWLEDGEMENT

The authors would like to thank the Manager and employees for cooperation and help in carrying out the evaluation.

BIBLIOGRAPHY


