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# Visualization of Anthropometric Measures of Workers in Computer 3D Modeling of Work Place

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**A B S T R A C T**

*In this work, 3D visualization of a work place by means of a computer-made 3D-machine model and computer animation of a worker have been performed. By visualization of 3D characters in inverse kinematic and dynamic relation with the operating part of a machine, the biomechanic characteristics of worker's body have been determined. The dimensions of a machine have been determined by an inspection of technical documentation as well as by direct measurements and recordings of the machine by camera. On the basis of measured body height of workers all relevant anthropometric measures have been determined by a computer program developed by the authors. By knowing the anthropometric measures, the vision fields and the scope zones while forming work places, exact postures of workers while performing technological procedures were determined. The minimal and maximal rotation angles and the translation of upper and lower arm which are basis for the analysis of worker burdening were analyzed. The dimensions of the seized space of a body are obtained by computer anthropometric analysis of movement, e.g. range of arms, position of legs, head, back. The influence of forming of a work place on correct postures of workers during work has been reconsidered and thus the consumption of energy and fatigue can be reduced to a minimum.*

## Introduction

Contemporary methods of industrial engineering and automation of technological processes have a great significance in technological systems. They changed the way of working and in this process it was noticed that a worker had limited possibility of action and adaptation to such changes and that such changes should be followed by suitable work humanization[1].

The damages and degenerative changes of bone-joint structures are a consequence of discordance between the requirement for organism burdening and the possibility of the organism to react to

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these requirements[2,3]. Psychic disturbances, such as general fatigue, slowness and exhaustion are frequently related to unsuitably formed work place in relation to the individual worker, i.e. the negligence in applying ergonomic principles while forming a work place[4].

While forming the total working space in accordance with total criteria of the standing posture, it is necessary to know the anthropometric characteristics of a worker. The dimensioning of a work area should be in accordance with anthropometric sizes of a worker. Rudan[5] states the anthropometric sizes for men with average value of the total height of 175 cm and limits of 163 cm up to 187 cm, and for women with values of 165 cm and limits of 153 cm up to 177 cm. Muftić[6] points to the methods of harmonic anthropometrics as a basis for applied dynamic ergonomy. In that process it is assumed that during the implementation of certain task the individual parts of the human body do not function independently one from another, but as a functional whole.

By introducing computers and computer 3D program solutions a prototype can be replaced by 3D models where it is possible to carry out interactively all the necessary forming and changes in real time. Computer 3D model used for testing should be versatily studied and checked, since otherwise each of its deficiencies would be found in all realized final elements of the implemented project. The making of biomechanic model of human body requires a thorough preparation and analysis of each individual segment the human body consists of[7]. This means that the authenticity of the presentation of the human body depends on an in-advance-defined number of sections, at which process the segments of the human body should be divided into smaller parts. In forming segments of body symmetry of bodybuilding is assumed in order to get symmetrical value of burdening for the left and right extremities.

In the human organism none of the properties are constant for a longer period of time. The human body consists of heterogeneous material and all of it and its properties are different for various parts. The sex is also a very important factor for the modeling of computer 3D character. During the modeling of segments of a female body by geometric bodies it is necessary to introduce hypothesis and simplification, which means that in the breast and hips area it is necessary to widen the trunk in relation to the appearance of a male body[8].

On the basis of an inner kinematic model of a human body an outer kinematic model is made which presents the muscle system of the body, where inner kinematic model is used as a basis for construction. By computer even the most complex movements of 3D character consist of various basic movements in individual parts and individual joints similarly as in the human locomotor system. The human body can be presented by means of a computer 3D analysis as a system of shafts and corresponding forces that are its moving parts (muscle in a man). In this process forces towards the shafts, that is muscles towards the bones, act as on shafts and the center of rotations is in joint shafts and towards force of gravity represent forces of opposite direction.

In ergonomically functionally studied and implemented working postures or working environment, where a worker carries out his work, the balance of static and dynamic burdening of the human body is attained and the fatigue which occurs because of an active use of muscle is reduced. Working postures should be such as to enable change of postures within the limits in which a worker redistributes his weight during work, without changing his general working postures.

Current research shows that ergonomically functionally studied working postures and working environment facilitates the working effect and prevents fatigue, slowness, exhaustion and permanent reduction of worker's working capability.

*Theory*

A worker cannot take correct or wrong postures while standing, but standing can be either comfortable or uncomfortable. Standing with equal burdening on both legs is the optimal postures for the spine and especially for its lumbal part. Adverse postures of a worker are manifested through increased coefficient of tiredness because of overcoming the burden at corresponding body postures. Those unfavorable postures can be professionally dangerous where the burdening of the spine is excessive and at the limit of physiologically accepted sizes[9].

The motion between spine joints is realized by means of intervertebral disc and the direction and scope of motion by means of small joints. The pressure force effected on the trunk during various tasks cause an increase of pressure in the abdominal cavity. The pressure is distributed on the diaphragm and downwards on the pelvis, on the breast part of the spine and the pelvis muscles[10]. According to results of Mairiaux at. al.[11,12] the intraabdominal pressure IAT (kPa) depends on lumbal moment $M_L$ (N m) at the level of lumbal spine L4/L5 vertebrae and is calculated according to:

$$IAT = 0.079\ M_L - 1.127\ kPa \qquad (1)$$

where:

IAT (kPa) = intraabdominal pressure;
$M_L$ (N m) = lumbal moment.

The surface of the model of abdominal section and other sizes according to Figure 1 are calculated according to Muftić and Jurčević-Lulić[10] by means of:

$$S = (86.5 \text{ to } 104.72)\ 10^{-4}\ h^2\ m^2 \qquad (2)$$

$$AD = \frac{h}{8} \qquad (3)$$

$$\frac{AB}{2} \quad \frac{CD}{2} \quad \frac{h}{36} \qquad (4)$$

$$BC = FE = \frac{h}{72} \qquad (5)$$

where:

S ($m^2$) = total surface of section of abdomen,
h (m) = body height,
AD (m) = length of complete lumbal area,
AB (m) = length of left lumbal area,
CD (m) = length of right lumbal area,
BC = FE = length of umbilical area.

Total area where intraabdominal pressure is applied is calculated by means of:

$$S = S_1 + S_2 + S_3 + S_4 + S_5 \qquad (6)$$

where:

S ($m^2$) = total area of abdominal section,
$S_1 = S_5$ = areas of abdominal section,
$S_2 = S_4$ = areas of abdominal section,
$S_3$ = areas of abdominal section.

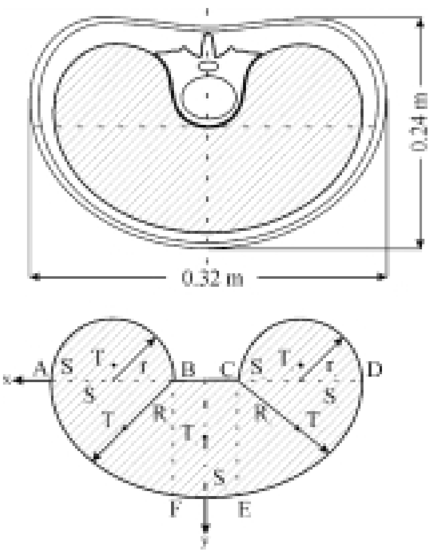


*Fig. 1. Section through the abdomen with marked areas.*

For different workers' heights (h) it is possible to calculate total section area in the field of abdominal section (S) on which intraabdominal pressure is applied. According to Morrisu[13] the pneumatic mechanism should be reduced by 30% calculated on compressive force. Davis & Stubbs[14] propose that in cases where intraabdominal pressure is 13.07 kPa and even more, an increase of spinal damage occurs.

*Experiment: Anthropometric sizes of a worker during forming the working area*

The determination of anthropometric measures in a conventional way is complex and longstanding. The introduction of new computer methods enables a quick and accurate determination of all important body sizes so that dimensions and shapes of elements of the environment are adapted to a human being. Regarding that a computer program has been developed which with incoming data of sex and body heights of people, establishes twenty -two characteristic anthropometric sizes. Figure 2 presents a screen presentation of position characteristic, computer-obtained anthropometric measures of a 195 cm tall man. Table 1 presents characteristic anthropometric measures for separated cases of 160.0 cm, 170.0 cm and 180.0 cm tall women, and 165.0 cm, 180.0 cm and 195.0 cm tall men.

On the basis of human height, weight and sex and necessary accuracy of work and posture during work it is possible from the point of ergonomy to determine precisely the dimensions of ideally formed space for each individual worker. Calculation results in this work have only been taken for male subjects. Being informed on anthropometric measures and by application of computer equipment and computer 3D graphic programs it is possible to implement ergonomic modeling of dimensions and elements of environment very effectively and quickly so that they can be adapted to a man. In order to determine relation in dimension between a man and machine recording by camera of a worker on steam pressure for final ironing of a cuff Schödt & Krebs GmbH, model X – G – 36 was carried out with this work. The stated machine has been presented on Figure 3.

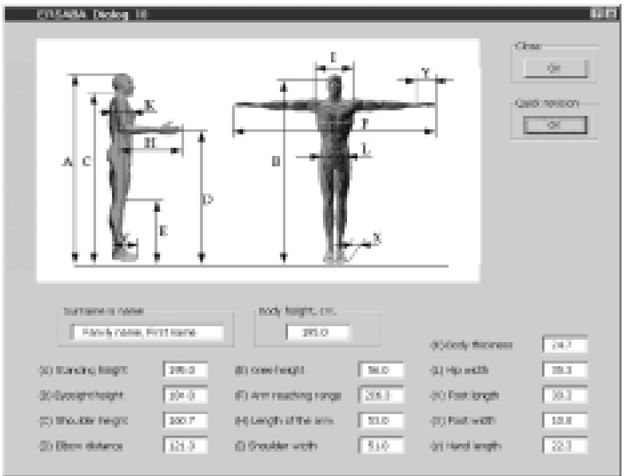


*Fig. 2. Screen presentation of characteristic anthropometric measures for standing position.*

**TABLE 1**
CHARACTERISTIC ANTHROPOMETRIC MEASURES OF MALE AND FEMALE WORKERS IN STANDING POSITIONS

| Marking and name of anthropometric measure | Anthropometric measures (cm) | | | | | |
|---|---|---|---|---|---|---|
| | Male | | | Female | | |
| | I | II | III | I | II | III |
| A Standing height | 165.0 | 180.0 | 195.0 | 160.0 | 170.0 | 180.0 |
| B Eyesight height (standing) | 154.8 | 169.0 | 184.0 | 149.4 | 158.6 | 167.8 |
| C Shoulder height (standing) | 135.7 | 148.2 | 160.7 | 129.8 | 138.2 | 146.5 |
| D Elbow distance from the floor | 102.2 | 111.3 | 121.3 | 99.7 | 106.3 | 113.0 |
| E Knee height (standing) | 47.7 | 52.3 | 56.0 | 47.8 | 50.7 | 54.0 |
| F Arm reaching range | 175.2 | 191.0 | 206.0 | 160.0 | 170.0 | 180.0 |
| H Length of the arm from the elbow (including hand) | 44.7 | 49.3 | 53.0 | 41.8 | 44.3 | 46.8 |
| I Shoulder width | 42.7 | 47.3 | 51.0 | 38.8 | 40.8 | 42.5 |
| K Body thickness (chest) | 21.3 | 23.4 | 24.7 | 24.2 | 25.8 | 27.5 |
| L Hip width | 29.5 | 32.8 | 35.3 | 33.2 | 35.3 | 37.8 |
| V Foot length | 25.3 | 27.8 | 30.3 | 24.2 | 25.8 | 27.5 |
| X Foot width | 9.6 | 10.2 | 10.8 | 8.8 | 9.2 | 9.6 |
| Y Hand length | 18.2 | 19.8 | 22.3 | 16.9 | 17.9 | 18.8 |

*Fig. 3. Photo presentation of an iron for final cuff ironing.*

### *3D visualization*

3D modeling, design, animation and scientific visualization of this work was made on high-end workstation by using various 3D graphic animation programs. On the basis of recorded worker and working posture in the manufacturing process, computer model of 3D work, machine and working posture was made. Received computer 3D model has been compared and put in accordance with realistic model of working posture and a worker. According to realistic data on received 3D scene a biomechanic analysis of working motions of workers bodies was carried out by scientific visualization. 3D model of a worker, machine and working posture make a 3D scene under which in computer graphic oriented part of space is understood to which coordinated system is merged in relation to which posture and orientation of entity, primitive, objects or their group. On the basis of these parameters dynamic anthropometric measures are calculated which are used as a basis for simulation character animation.

By using existing realistic or computer made maps and materials and by analyzing its parameters like: Ambient Color, Diffuse Color, Specular Color, Glossiness, Self–Illumination, Opacity, Bump, Reflection, Refraction, etc. it is possible after implementation of a more complex procedure of rendering to obtain very realistic (that is photo–realistic) results of virtual space of working posture that is a worker. Photo-realistic analysis of frame of perspective wire presentation of simulation model of a worker on working posture new frame was obtained and presented on Figure 4. Individual elements, group of elements, frame or complete visualization with stated and presented wire frame and photo realistic presentation can be also made in the following presentation: Cartoon, Carton Wire Line, Flat Lined, Flat shaded, Hidden Line, Lit Wireframe, Outline, Silhouette, Smooth Lined, Smooth Shaded, Texture Shaded etc.

In dependence on the change of burdening of the machine its operating possibilities are calculated and worker engagement operating the machine depends on that. In the stated steam pressure for final cuff ironing (pictorial presentation on Figure 3 and computer photo-realistic presentation Figure 4) one portion of the operation is performed manually.

Before a worker begins to work his position is under the pressure. A worker position of a subject on the lower part according to the technological purpose -formed pedestal for ironing and then he moves the upper part of the pressure downwards and this results in holding the chosen part of the cuff by upper and lower ironing object. In dependence with the technological requirements of processing a worker holds the upper part of the pressure for a certain time maximally closed. Following that operation he returns the upper part of the pressure in the initial maximally opened position and

*Fig. 4. Perspective computer photo-realistic presentation of simulation model of a worker on working posture.*

by putting of the piece of manufacturing at the place which is predicted for that he finishes the working operation.

Within the stated a worker can by combined motions of legs and arms determine the time, the intensity and the duration of steam and vacuum on the article of clothing. The sequence, frequency and scope of the operation are conditioned by the technological process.

## Results

The two-dimensional working posture of a worker in sagital plane put in a coordinated system with burdening (weights of body parts and weights of G working parts of the machine) and forks during the lifting of the upper parts of a machine more simplified kinematic pair in which reference position of vertebrae L4/L5 in the starting point is O, have been shown on Figure 5.

The upper part of a worker with inserted positions of burdening of body parts, was burdened with forces $F_1$ up to $F_7$ which cause lumbal moment. During standing the pressure force within the disc is from 785 up to 980 N. The force in the disc during bending increases to 1470 N, and during lifting or transferring of the burden may go up to 9807 N (Mairiaux at. al.[11,12]).

For a worker in the upper part of burdening by weights of the corresponding parts of the body and G working part of a machine (Figure 5), and its forks and moments, a lumbal moment $M_L$ = 150.41 N m was determined, and intraabdominal pressure IAT = 10.76 kPa is its result. This value IAT = 10.76 kPa is satisfactory since it is lower than the allowed values 12 kPa[10].

Weights of corresponding parts of worker's body of 165 cm body height weighing 740 N and G of working part of a machine, and its distance from lumbal vertebrae L4 and/L5 and lumbal moment obtained by multiplying of weights and distance have been stated in Table 2.

On the basis of burdening by weights of corresponding body parts (forces), and extremities and moments the lumbal moment was determined $M_L$ = 150.41 N m, where from the intraabdominal pressure $IAT_M$ = 10.76 kPa results which is within the permitted limits (up to 13 kPa for men[13]).

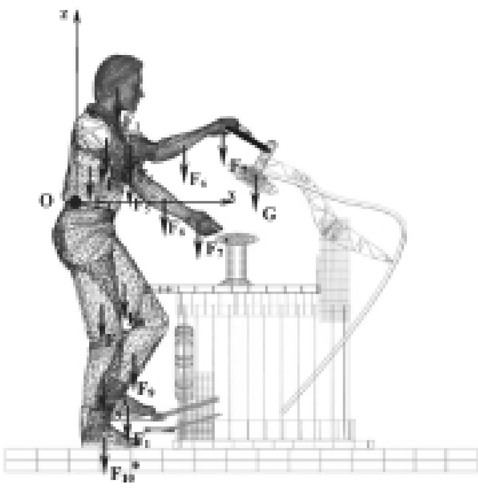


*Fig. 5. Work posture of a worker with corresponding weights.*

**TABLE 2**
WEIGHTS OF CORRESPONDING BODY PARTS AND G WORKING PART OF A MACHINE IN SAGITAL PLANE IN DEPENDANCE WITH ARM SHIFT

| Marking | Part of worker's body and G of machine | Weight | Distance | Lumbal moment |
|---|---|---|---|---|
| | | F (N) | a (m) | F  a (N m) |
| 1. | Head and neck | 51.36 | 0.06 | 3.08 |
| 2. | Upper part of trunk | 118.07 | 0.09 | 10.63 |
| 3. | Middle part of trunk | 120.82 | 0.07 | 8.46 |
| 4. | Lower part of trunk | 82.69 | 0.04 | 3.31 |
| 5. | Right upper arm | 20.03 | 0.12 | 2.40 |
| 5.* | Left upper arm | 20.03 | 0.09 | 1.80 |
| 6. | Right lower arm | 11.96 | 0.41 | 4.90 |
| 6.* | Left lower arm | 11.96 | 0.26 | 3.11 |
| 7. | Right fist | 4.54 | 0.55 | 2.50 |
| 7.* | Left fist | 4.54 | 0.44 | 2.00 |
| 8. | Right upper leg | 104.82 | 0.22 | 23.06 |
| 8.* | Left upper leg | 104.82 | 0.12 | 12.58 |
| 9. | Right lower leg | 32.04 | 0.22 | 7.05 |
| 9.* | Left lower leg | 32.04 | 0.12 | 3.84 |
| 10. | Right foot | 10.15 | 0.16 | 1.62 |
| 10.* | Left foot | 10.15 | 0.14 | 1.42 |
| 11. | G of machine | 85.00 | 0.69 | 58.65 |

Sum lumbal moments $M_L \quad {}_{i\,1}^{7} F_i \quad a_i \quad 150.41$ Nm

The activity of a men is related to the corresponding working burdening and thus with strain. Burdens, which occur in man's work, are frequently connected to his non-ergonomic posture. Non-ergonomic posture of workers body is harmful and especially so if it is compulsory.

The description of human body's motion is done in various ways depending on requirements for which they are made. Three characteristic working postures that is frame are separated within animation, depending on the motion of an arm of a worker and upper part of a machine and thus as maximally opened $\upsilon = 0°$, maximally closed $\upsilon = -30°$ and interposture $\upsilon = -15°$ with presentations in sagital plane.

Figure 6 presents 3D wire model of a worker with body height of 165 cm, in the upper part of the figure of erect closed kinematic chain where the angle of trunk slope axis is $\varphi = 0°$, and in the lower part of figure for angle of dip is $\varphi = 8°$ trunk slope according to the position of the operating part of a machine.

Rotation angles and arm translation have been determined on the basis of upper and lower arms of a worker, with presentation of received results in Table 3 for a worker with body height 165 cm, in Table 4 for a worker with body height 180 cm and in Table 5 for a worker of body height 195 cm. In this process angle $\alpha$ between vertical axis and upper arm, and angle $\beta$ is angle between horizontal axis and lower arm. Clockwise direction is taken as positive value of an angle and counterclockwise direction as negative value of an angle.

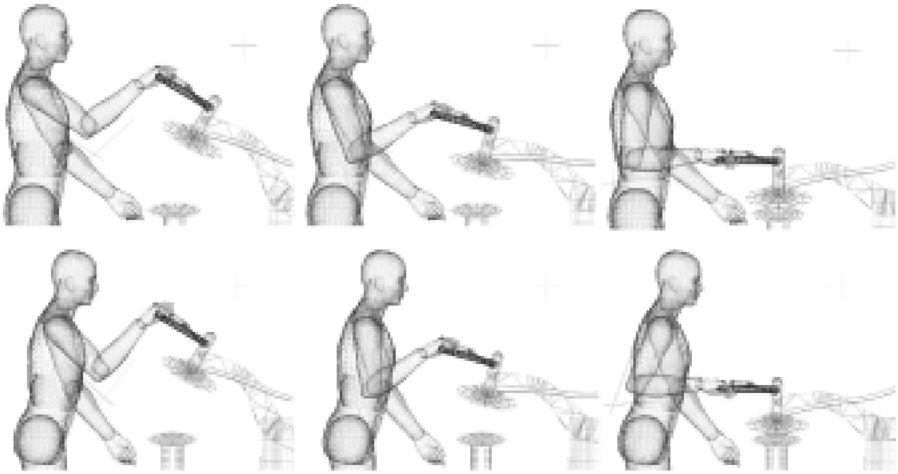

*Fig. 6. 3D wire presentation of characteristic postures during visualization of work of a worker with body height of 165 cm.*

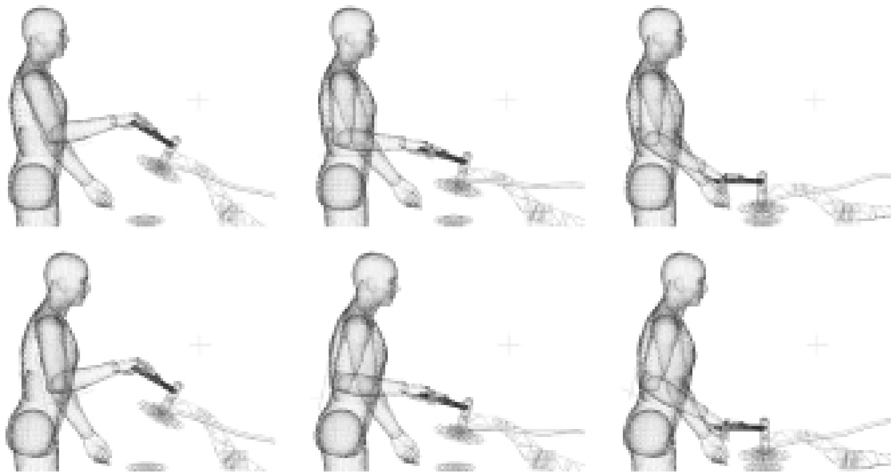

*Fig. 7. 3D wire presentation of characteristic postures during visualization of work of a worker with body height of 180 cm.*

According to the results from Table 3 and Figure 6 in erect posture the smallest angles $\alpha$ and $\beta$ are obtained at maximally closed working position of a machine and at maximally closed position of a machine, and the biggest at maximally opened. During the dip of a trunk by $\varphi$ = 8° in relation to erect axis angle of upper arm $\alpha$ is reduced and lower arm angle $\beta$ is increased.

Figure 7 represents 3D wire model of a worker with body height of 180 cm, where working postures as on Figure 6 are taken. According to Table 4 and Figure 7

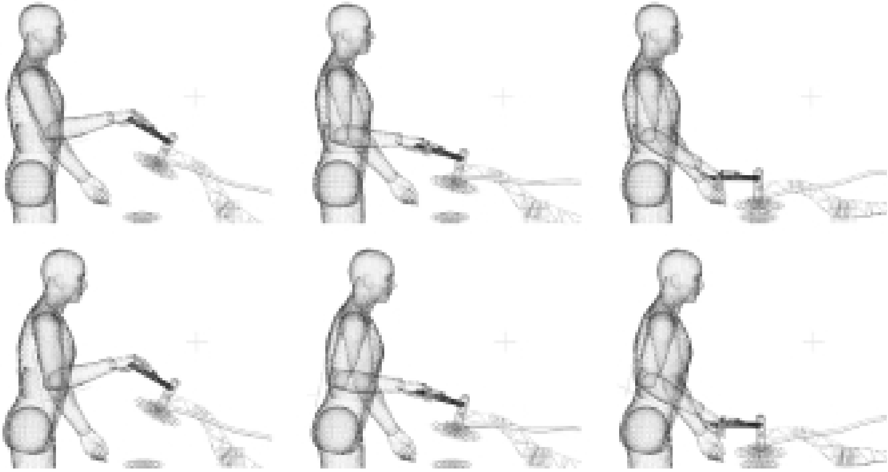

*Fig. 8. 3D wire presentation of characteristic postures during visualization of work of a worker with body height of 195 cm.*

lower values are obtained $\alpha$ and $\beta$ in relation to Figure 6 and this is connected with anthropometric sizes and results in machine construction getting closer to anthropometric measures of a worker. In all postures angle $\alpha$ is reduced, and angle $\beta$ is increased.

3D wire model of a worker with body height of 195 cm with working postures as on Figures 6 and 7 are presented on Figure 8. According to Table 5 and Figure 8 equal angle $\alpha$ is obtained for working interposition and maximally closed position of a machine in erect position of a trunk where $\varphi$ = 0°, for a worker with the body height of 195 cm. This is unfavorable for a worker since there is a bigger burdening of the upper arm. With trunk dip by $\varphi$ = 8° towards the working part of a machine the angle $\alpha$ is increased and this results in increase of angle $\beta$.

## Discussion

On the basis of the received measurement results the angles of rotation and translations of worker's arm at certain spine posture have been analyzed. According to the results presented on Figures 6, 7 and 8 the ergonomic position of a worker during work can be evaluated.

**TABLE 3**
ANGLE SLOPE OF UPPER AND LOWER ARM IN RELATION TO VERTICAL AND HORIZONTAL AXIS OF A WORKER OF 165 CM BODY HEIGHT

| Working posture of a worker of 165 cm height | Working posture of a machine | | | | | |
|---|---|---|---|---|---|---|
| | Maximally opened ($\nu$ = 0°) | | Inter posture ($\nu$ = – 15°) | | Maximally closed ($\nu$ = – 30°) | |
| | Angles of upper arm $\alpha$ (°) and lower arm $\beta$ (°) | | | | | |
| | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ |
| $\varphi$ = 0° | –58 | –43 | –22 | –33 | + 02 | –07 |
| $\varphi$ = 8° | –48 | –51 | –10 | –37 | + 20 | –08 |

**TABLE 4**
ANGLES OF SLOPE OF UPPER AND LOWER ARM IN RELATION TO VERTICAL AND HORIZONTAL AXIS OF A WORKER WITH BODY HEIGHT OF 180 CM

| Working posture of a worker of 180 cm height | Working posture of a machine | | | | | |
|---|---|---|---|---|---|---|
| | Maximally opened ($\nu = 0°$) | | Inter posture ($\nu = -15°$) | | Maximally closed ($\nu = -30°$) | |
| | Angles of upper arm $\alpha$ (°) and lower arm $\beta$ (°) | | | | | |
| | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ |
| $\varphi = 0°$ | –41 | –30 | –10 | –18 | + 03 | +11 |
| $\varphi = 8°$ | –28 | –37 | +01 | –19 | + 15 | +10 |

**TABLE 5**
ANGLES OF SLOPE OF UPPER AND LOWER ARM IN RELATION TO VERTICAL AND HORIZONTAL AXIS OF A WORKER WITH BODY HEIGHT OF 195 CM

| Working posture of a worker of 195 cm height | Working posture of a machine | | | | | |
|---|---|---|---|---|---|---|
| | Maximally opened ($\nu = 0°$) | | Inter posture ($\nu = -15°$) | | Maximally closed ($\nu = -30°$) | |
| | Angles of upper arm $\alpha$ (°) and lower arm $\beta$ (°) | | | | | |
| | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ | $\alpha$ | $\beta$ |
| $\varphi = 0°$ | –26 | –16 | –03 | +03 | –03 | +27 |
| $\varphi = 8°$ | –11 | –18 | +10 | +01 | +11 | +26 |

According to the Tables 3, 4 and 5 with the maximally opened working position of a machine ($\upsilon = 0°$) the highest angles of rotation and upper arm and translation of lower arm at bend working position for $\varphi = 8°$ are found in a worker with body height of 165 cm, and the lowest in a worker of body height 195 cm. With maximally closed working position of a machine ($\upsilon = -30°$) a worker with body height of 180 cm has the most favorable position at work. On the basis of the results presented on Figures 6, 7 and 8, the rotation of the upper arm and the translation of the lower arm can be evaluated at erect position of the body using in this process results from Tables 3, 4 and 5. In working position of a worker where the trunk dip $\varphi = 8°$ towards the operating part of the machine (according to Tables 3, 4 and 5) the angle of the upper arm $\alpha$ is reduced and the angle of the lower arm $\beta$ increased. The size of angle change $\alpha$ and $\beta$ depends on anthropometric measures of workers and is visible on considered realistic and computer 3D modeled and scientifically visualized worker with body height of 165 cm, 180 cm and 195 cm.

The results that values of curving angle of the upper arm and the translation of the lower arm are different in workers and this show that they depend on technological process. On the basis of this it can be evaluated that also the burdening of workers in the technological process of clothes ironing differs too.

The minimal and maximum rotation angles and the translation of working posture of arm depend on the change of burden on a machine. The determination of working space has special importance in defining the working area in this example, which means a working surface where manual activities are performed.

The working position should be such as to enable change of posture within the limits where a worker redistributes his weight during work without changing his general working position[15,16]. A better forming of work place, a correct posture of body trunk and a technical equipping of machines, will reduce the burdening in the lumbal part of spine[17]. The purpose is to maintain the body posture and biomechanically more correct movement and in this process skill should be used more than strength.

## REFERENCES

1. SCHOENMARKLIN, R. W., W. S. MARRAS, S. E. LEURGANS, Ergonomics, 37 (1994) 1449. — 2. BAILEY, R.-W.: Human performance engineering: A guide for system designers. (Prentice-Hall, Englewood Cliffs, 1982). — 3. YOSHITAKE, H., Ergonomics, 14 (1971) 175. — 4. BLICKE, M., U. HOLDERIED, Bekleidung Waesche, 35 (1983) 98. — 5. RUDAN, P., Dimenzije tijela i tjelesni položaj pri radu. In: Medicina rada. (Medicinska knjiga, Zagreb, 1984). — 6. MUFTIĆ, O., Method of man's figure drawing, Coll. Antropol. (Supll.) 18 (1994) 27. — 7. KING, A. I., C. C. CHOU, J. Biomech., 9 (1976) 301. — 8. DOOLEY, M.: Anthropometrics modeling programs – A survey. (Institute of Electrical Engineers (IEEE), Computergraphics & Application, 1982). — 9. RADWIN, R. G., M. L. LIN, Ergonomics, 34 (1993) 379. — 10. LABAR, J., MUFTIĆ, O., Modelling of the head and cervical spine in biomechanical analysis, Coll. Antropol. 14 (1994) 123. — 11. MAIRIAUX, P., J. MALCHAIRE, Ergonomics, 31 (1988) 1331. — 12. MAIRIAUX, P., R. P. DAVIS, A. D. STUBBS, D. BATY, Ergonomics, 27 (1984) 883. — 13. MORRIS, M. J., J. Bone Joint Surg., 43 (1961) 327. — 14. DAVIS, D. R., S. A. STUBBS, Appl. Ergonomics, 8 (1977) 141. — 15. MIJOVIĆ, B., M. SKOKO, M. PERČINLIĆ, Coll. Antropol., 22 (1998) 229. — 16. REBER, J. G., W. GOLDSMITH, J. Biomechanics, 12 (1979) 211. — 17. BAKSA, S., M. SKOKO: Investigations of the impact of human anthropometric measures on computerised determination of optimal working postures. (DAAAM, Vienna, 1999).

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## VIZUALIZACIJA ANTROPOMETRIJSKIH DIMENZIJA RADNIKA RAČUNALNIM 3D MODELIRANJEM RADNOG PROSTORA

## SAŽETAK

U radu je provedena računalna 3D vizualizacija radnog mjesta pomoću računalno izvedenog 3D modela stroja i računarske animacije radnika. Vizualizacijom 3D karaktera u inverznoj kinematičkoj i dinamičkoj vezi sa upravljačkim dijelom stroja određene su biomehaničke značajke tijela radnika. Za utvrđivanje dimenzija stroja proveden je uvid u tehničko – tehnološku dokumentaciju stroja, izvršena je radna izmjera stroja i provedeno je snimanje kamerom. Na osnovu izmjerenih tjelesnih visina, pomoću računalnog programa razvijenog od strane autora određene su sve relevantne antropometrijske veličine radnika. Poznavanjem antropometrijskih mjera, vidnih polja i zona dosega pri oblikovanju radnih mjesta utvrđeni su točni položaji radnika pri izvođenju tehnoloških postupaka. Pri tome su analizirani minimalni i maksimalni kutovi rotacija i translacija nadlaktice i podlaktice koji su baza za izučavanje opterećenja radnika. Računalnom antropometrijskom analizom pokreta dobivene su dimenzije zahvatnog prostora tijela, kao npr. dohvati ruku, položaji nogu, glave, leđa itd. Razmotreni su utjecaji oblikovanja radnih mjesta na pravilan položaj radnika pri radu, čime se njegov utrošak energije i zamor svode na razmjerno mali iznos.