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BAZA DANYCH NADDATKÓW WYMIAROWYCH DO ERGONOMICZNEGO PROJEKTOWANIA ŚRODOWISKA PRACY

Streszczenie: Praca ma na celu prezentacje nowego narzędzia wspomagającego projektowanie ergonomicznego środowiska pracy. Jest nim nowa baza danych istotnych z punktu widzenia bezpieczeństwa i komfortu pracy - Baza Danych Naddatków Wymiarowych, które są konsekwencją stosowania środków ochrony indywidualnej (ŚOI).

Słowa kluczowe: środki ochrony indywidualnej, bezpieczeństwo pracy, antropometria, projektowanie ergonomiczne

A DATABASE OF DIMENSIONAL ALLOWANCES FOR ERGONOMIC DESIGN OF THE WORK ENVIRONMENT

Summary: The aim of the work is to present a new tool supporting the design of an ergonomic work environment. It is a new database important from the point of view of work safety and comfort – a Database of Dimensional Allowances resulting from the use of personal protective equipment (PPE).

Keywords: personal protective equipment, work safety, anthropometry, ergonomic design

1. Introduction

1.1. Ergonomic anthropometry

Anthropometric data is used for ergonomic design in various areas of everyday life and professional activity. It is used in the design of spaces, and items. Ergonomic (engineering) anthropometry deals with measurements and data processing, which is then used to ergonomically shape the human living and work environment [1, 2]. It takes into account the dimensions and shapes of the human body as well as motor

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aspects, e.g. ranges of movement of the limbs. Population anthropometric studies are conducted all over the world and are presented in atlases and databases.

Nowadays the development of science and technology has made it possible to take anthropometric measurements based on analysis of three-dimensional images obtained using 3D scanners, in a non-contact and faster way compared to manual methods. Data from the scanned 3D images are used to generate high-quality shape data along with a three-dimensional view of the body called an avatar, used for virtual design. 3D scanners allow the contactless collection of huge amounts of data and their subsequent processing at any time, while a database of electronic anthropometric data enables virtual, cost-free design. The ability to collect large amounts of data from scans has made it possible to create online databases for design, which have become a popular tool supporting the work of designers.

1.2. Dimensional allowances

The terminology "dimensional allowances" is used in everyday and professional life. However, the importance and role of dimensional allowances in these two areas of human activity differ. In everyday life, it is associated with clothing design and fashion, and in professional activity – with ergonomics and safety of the work environment. The concept of dimensional allowances resulting from the use of PPE involves increased dimensions of the human body with implications for the safe access to areas of the work environment with limited access. It has not been the subject of research and publications in the literature.

For the first time, information on dimensional allowances resulting from the use of PPE appeared in the 2001 Atlas of Human Measures by Gedliczka [3]. Since then, this topic has not been the subject of theoretical considerations and experimental research. It requires updating and supplementing (continuation of research). The justification for such research is the constant need to expand knowledge on improving occupational health and safety. The use of knowledge about dimensional allowances resulting from the use of personal protective equipment (PPE) in the design of ergonomic workplaces and the external work environment, is especially important in the so-called limited access. One should be aware of the difficult working conditions of rescue teams and the barriers (man-made and natural) that they must overcome, while their external dimensions are increased by PPE and rescue equipment.

When it comes to designing the work environment: tools, machines and workstations, it is obvious that the use of personal protective equipment should be taken into account.

Dimensional allowances are listed in the EN 547 standard, part 1 and part 2. as well as EN 349 [4-6]. Standards define the current requirements for the dimensions of the human body (anthropometric data) which are required in EN 547-1 and EN 547-2 for the calculation of access dimensions. Part 1 specifies a procedure for designing openings that takes into account "extra space" subsequently called dimensional allowances for width and height. "When determining the value of the dimensions of the holes, it is necessary to add allowances to the anthropometric data, so as to allow conditions for safe and free access and work, taking into account the aspects specific to the operator and the conditions of the operation being performed." Among the mentioned criteria for maintaining safety, the standard provides:

a) ease of movement, influenced by:
- type of clothing, e.g. heavy or light;
- possible relocation of tools for, e.g.., maintenance or repair;
- possibly carrying or wearing additional equipment, such as personal protective equipment (including protective clothing) or portable lighting;
- task-specific requirements, e.g. position, type and speed of movement, line of sight, force exerted;
- frequency of repetitions and duration of the task;
- the length of the passage, e.g. through a relatively thin wall (tank wall) where at the time of exit there is space for traffic, or through a channel-like passage;
- the space necessary to develop the dynamics of movements necessary to escape from danger;
- location and size of body supports, e.g. foot supports, hand rests;

b) environmental conditions (e.g. darkness, heat, noise, humidity);
c) the level of risk in performing the tasks.

The allowances to be taken into account in the above-mentioned cases depend on the characteristics and application of the machine in question. “Several types of allowances are specified for each hole type considered in this European Standard, for the conditions that should be taken into account when determining the dimension of a specific access opening. The conditions of using the holes determine the allowances that should be added to the values of the anthropometric features in order to ensure safety and health when using these holes. The allowances do not constitute mere added value as some conditions are the same. Each of the following conditions should be considered when designing a specific access opening. It must be decided which of these conditions apply to the case under consideration and which are the most critical. Then, an expert should integrate the factors affecting the working conditions to finally obtain the value of the total allowance required for each dimension ”.

1.3. Anthropometric database

Many countries around the world conduct anthropometric research into the development and updating of national sizing systems most commonly used to design clothing, including functional clothing and workplaces in the professional field. I. Fang Cheng and his team [7] report that currently (data as of 2018) there are about 90 large anthropometric databases. The first atlas of human measures was compiled in 1981, and then updated and published in the United States in 1994 by Dr. Farkas – "Anthropometry of the head and face in medicine" [8].

Currently, the Taiwanese electronic database 3-D BodyBank deserves attention [9]. It is the first and probably the only database where PPE appeared but in a very limited range. The Taiwanese 3-D BodyBank database is a rare anthropometric atlas devoted to the anthropometric measurements used to design tailored personal protective equipment, and in particular fitted protective helmets (see Figure 1) and filtering half masks (see Figure 2).

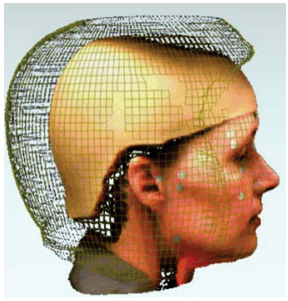

Figure 1. Taiwanese 3-D BodyBank for the design of fitted protective helmets - an example of use, http://3dcrystal.com.tw/webdata/article/21.pdf, accessed on 29.09.2022

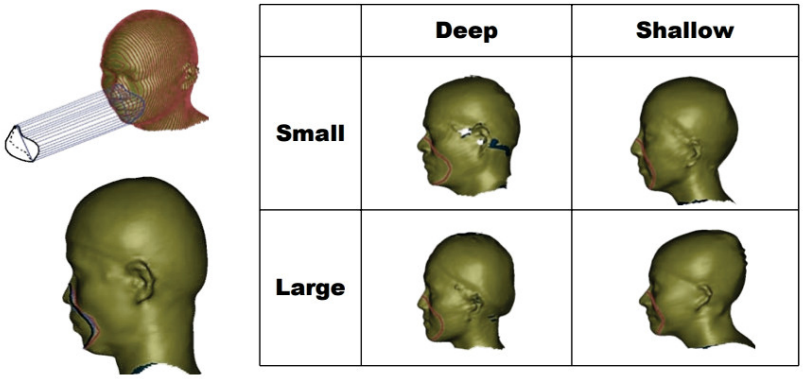

Figure 2. Taiwanese 3-D BodyBank for the design of filtering half masks, http://3dcrystal. com.tw/webdata/ article/21.pdf, accessed on 29.09.2022

In Poland, the best known are three atlases of human anthropometric measures, authored by: A. Bogotowska and J. Słowikowski (Institute of Industrial Design) [10] and E. Nowak (Institute of Industrial Design) [11] and A. Gedliczka (Central Institute for Labor Protection) [3].

2. The dimensional allowances database

In Poland, from 2020, work is underway on a new atlas of human measures for the purposes of ergonomic design. It will be the first tool of its kind to take into account the use of personal protective equipment (PPE) by humans. It includes an extensive chapter on dimensional allowances, understood as the difference in the dimensions of a person wearing underwear and a person wearing PPE, taking into account the dimensions of the PPE construction. This knowledge is particularly important when designing confined or enclosed spaces. it can also be used for designing machines, tools and new PPE constructions.

For the purpose of developing a database of dimensional allowances, 500 people were scanned – volunteers who were professionally active in various occupations (both blue and white collars). The group contained both females and males aged 18–65 years, subdivided into 5th, 50th and 95th percentile groups by body height. The adopted age intervals were: 18–27; 28–37; 38–47; 48–57; 58-65 lat. The sizes of age groups are given in Figure 3.

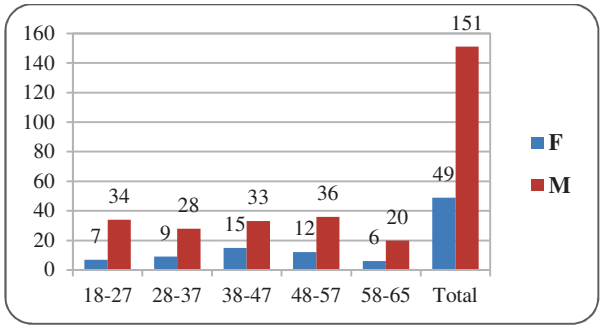

Figure 3. Research sample distribution by age groups and sex (F – females, M – males)

The study sample contained 31.6% females and 68.4% males with the largest age groups being 38–47 and 48–57-year-olds, each accounting for 24% of the sample. The participants were assigned to three body height groups defined by the 5th, 50th, and 95th percentiles, for males and females separately. The percentile groups were determined on the basis of analysis of data from an atlas of human measures [6] and literature data [7,8]. In addition, height groups based on percentile classification were assigned to the size data advertised by the manufacturers of protective clothing. The structure of the sample in terms of sex and size categories is given in Figure 4.

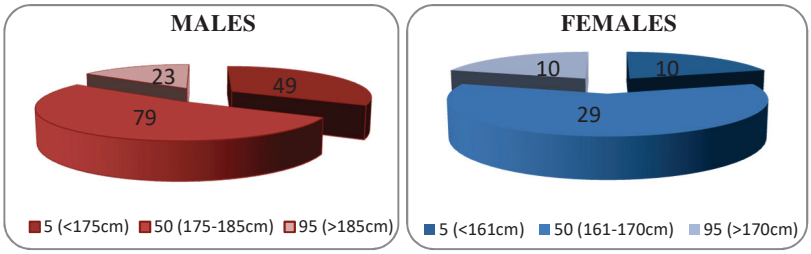

Figure 4. Study sample structure in terms of height percentile groups and sex

Analysis of the sample structure presented above, divided into percentiles, reveals 144 participants in the 5th percentile (28.8%), 262 participants in the 50th percentile (52.4%) and 94 participants in the 95th percentile (18. 8%).

Following the example of the Atlas of Human Measures by A. Gedliczka, the database includes the results of tests for complete protective equipment, determined for the entire human body and for parts of the body, resulting from the use of

individual types of PPE. Hence the justification for dividing the database into 8 parts, namely:

- head protections,
- hand protections,
- leg protections,
- protection of the respiratory system,
- Eye and face protections
- hearing protectors,
- PPE kits,
- integrated PPE.

The structure of the database of dimensional allowances is presented in Figure 5.

Figure 5. Structure of the database of dimensional allowances – an initial selection panel for personal protective equipment categories showing the scope of the database, i.e. dimensional allowances resulting from the use of hand protection, leg protection, head protection, eye and face protection, respiratory system protection, hearing protection, PPE kits and integrated protection

The database contains dimensional allowance calculators and batch files for programs used in PPE design.

The structure and scope of the database are presented on the example of leg protections and dimensional allowances resulting from the use of footwear with protective features. In the case of leg protections, the main division of leg protections into two categories was taken into account. Category I includes safety footwear made of leather and textile materials (1-7), while category II includes all-rubber footwear (8-11). The types of protections selected for inclusion in the database differ in their design and purpose, among them:

1. Protective footwear for steelworkers;
2. General professional safety footwear – made of textiles and polymers;
3. Protective footwear for firefighters;

4. Protective footwear for welders;
5. Protective footwear for the mining industry;
6. General professional safety shoes – made of leather;
7. General professional leather safety shoes, incl. for the food industry
8. Protective footwear for firefighters;
9. Protective footwear for users of hand-held chain-saws
10. Protective footwear for electricians – electrical insulating overshoes;
11. Safety footwear for the food industry

Examples of PPE representing the different types of leg protections used to develop the database of dimensional allowances are provided in Table 1.

Table 1. Personal protective equipment used for developing the database of dimensional allowances for leg protections

Type of PPE	PPE view			
Leg protection of category I.				
	1	2	3	4
				
	5	6	7	
Leg protection of category II.				
	8	9	10	11

Figure 6 shows a view of the selection panel for Category I leg protections with illustrations of safety footwear examples. In turn, Figure 7 presents a view of the selection panel for protective footwear intended for steelworkers.

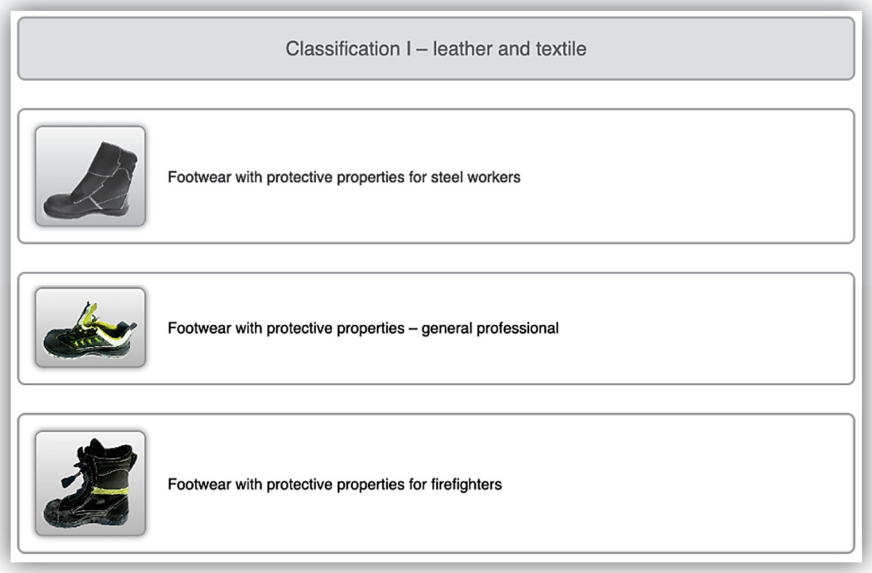

Figure 6. View of the selection panel for data on leg protections in category I

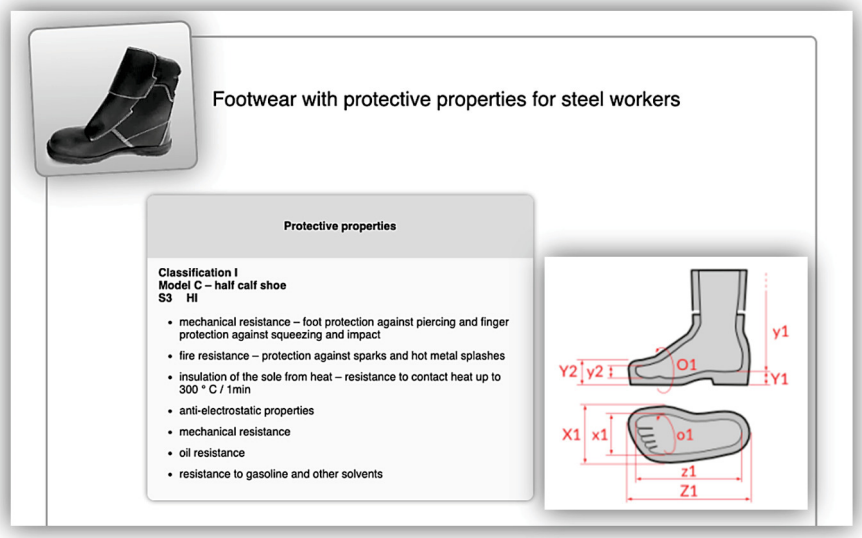

Figure 7. View of the selection panel of detailed data on footwear with protective properties for steelworkers

Figure 7 shows also examples of graphical presentation of the markings of dimensional allowances and the total external dimensions of the human body in the case of protective footwear for steelworkers.

The design of the dimension allowance database includes texts introducing the user to the subject of the database and graphics illustrating the dimensional allowances and the various types of PPE. The database contains the necessary information about the intended use, protective properties, markings, and links to an Internet PPE knowledge base (https://soi-info.ciop.lodz.pl/) in the scope of information relating to the principles of selecting PPE suitable for a given hazard, the comfort of its use, the time of safe use, and the principles of assessing the technical condition resulting from typical use processes.

An example of texts introducing the topic of dimensional allowances is presented in Figure 8.

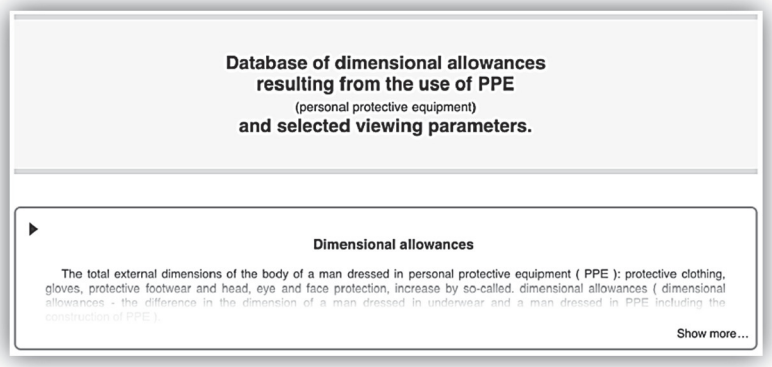

Figure 8. View of the panel introducing dimensional allowances with texts

The online database of dimensional allowances resulting from the use of personal protective equipment contains batch files for designing and algorithms (calculators) for estimating dimensional allowances and total dimensions of a person wearing PPE (to be used online and / or downloaded from the website). Both the batch files and the dimensional allowance calculators were developed on the basis of the results obtained during two years of research. To develop batch files for design programs, minimum, average and maximum values of dimensional allowances were used for each type of protection, integrated innovative safety devices, and PPE kits.

Based on consultations with designers it can be stated that a useful form of batch files and data presentation is a table with the values of dimensional allowances containing their minimum and maximum values. Moreover, independence from the anthropometric features of human body models increases the utility of the data. Such a possibility is provided by the use of statistically compiled results and their presentation in the form of numerical data and percentage increments for anthropometric measures. Algorithms for estimating dimensional allowances have the form of a calculator that allows one to estimate the values of the total dimension [cm] of the human body after the selected PPE is donned, the dimension of the allowance [cm], which is assigned from the coded data relating to the statistical results of dimensional allowances, and the relative increment [%], which shows by how many percent a given anthropometric measure will increase as a result of the selected PPE being worn by a worker. Therefore, the database requires the user to provide the values of the appropriate anthropometric measures (lower-case letters: y_n, x_n, z_n, o_n). After

pressing the "=" sign, the values of the total dimension including the dimensional allowance appear (capital letters: Y_n, X_n, Z_n, O_n). The value of the dimensional allowance and the value of the relative increment are also displayed.

A view of the calculator for determining dimensional allowances resulting from the use of protective footwear for steelworkers is presented in Figure 9.

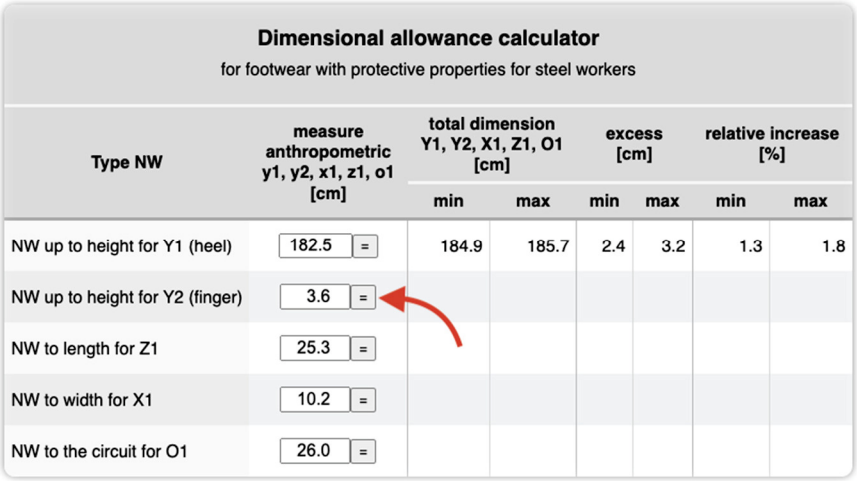

Figure 9. View of the calculator for estimating dimensional allowances and total external dimensions of a person using leg protections – example of footwear with protective properties for steelworkers

The batch files in .xls format discussed above are located under the dimensional allowance calculator, where they are available for download by database users. A view of files to be downloaded is presented in Figure 10 (an example of protective footwear for steelworkers).

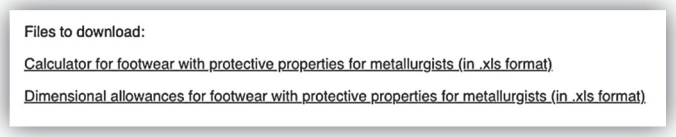

Figure 10. View of batch files for design programs, which are included in the dimensional allowance database

3. Conclusion

The aim of the work was to present a new tool – a database of dimensional allowances – and to draw attention to the need to analyze the total external dimensions of the human body wearing PPE for design purposes.

The database contains the results of the work that should be taken into account by professionals designing both occupational and non-occupational infrastructure, as well as by occupational safety specialists.

The dimensional allowances resulting from PPE use can increase the space needed for work and may create additional difficulties and entail hazardous situations.

The developed database of dimensional allowances, which is a contribution to a new atlas of human measures "Portrait of Polish People PL2030," is the first tool of this type to support the process of designing the work environment.

The database was developed at the Central Institute for Labor Protection - National Research Institute and will be available from December 2022 at *https://baza-nw.ciop.pl*

We encourage manufacturers of innovative PPE to take advantage of testing offer using 3D technology conducted at the Institute.

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