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Application of Malaysian Anthropometric Data in Dummy Welder Design

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***Abstract** - The design of dummy welder by incorporating the Malaysian anthropometric data with ability to replicate the common body posture during welding works is presented. Dummy welder is used in the experimental study to investigate personal welding fumes exposure during controlled welding. In this study, 16 out of 55 standard anthropometric measurements for technological design were selected for the design of the dummy welder. The selected anthropometric measurements were based on the mean value of anthropometric data for Malaysian male industrial workers database. Experimental set-up for personal welding fumes exposure would highly consider the distance of welder breathing zone with the source of welding fumes exposure. The dummy welder design also considered standing and sitting position of the welder for variation of data collection. In conclusion, dummy welder design by considering Malaysian anthropometric data and welder body posture shall give more reliable and valid experimental results concerning welding fumes exposure to the population of Malaysian male industrial worker.*

Keywords – Anthropometric data, Dummy welder design, Malaysian design, Welder position, Welder mannequin.

I. INTRODUCTION

Experimental set-up to represent human exposure to dangerous element must be carefully designed to obtained results that represent the actual condition. In this study, experiments regarding welding fumes exposure towards welders were investigated. The welding was carried out by a welding machine attached to a Computer Numerical Control (CNC) workbench for a programmable welding route. The welding machine was connected to software for monitoring welding parameters such as voltage, current and wire feed speed parameters during each welding route programmed. Personal sampling of welding metal fumes were taken according to National Institute of Occupational Safety and Health (NIOSH) method [1].

Sampling pump connected to sampling media was attached to the breathing zone (0.3 m in radius hemisphere extending in front of the human face) or usually on the welder neck collar during sampling. During experiment, a dummy welder was put near the welding equipment to replicate actual welders during work. In order to make sure the experiment results represent the true underlying risk of welders in Malaysian, the dummy welder need to be designed by taking into account the anthropometric data of Malaysian citizen.

II. RELATED WORKS

Experimental welding works by using dummy, mannequin or also called manikin was carried out by several researchers [2, 3]. Examples of the dummy used are as shown in Figure 1 and Figure 2.

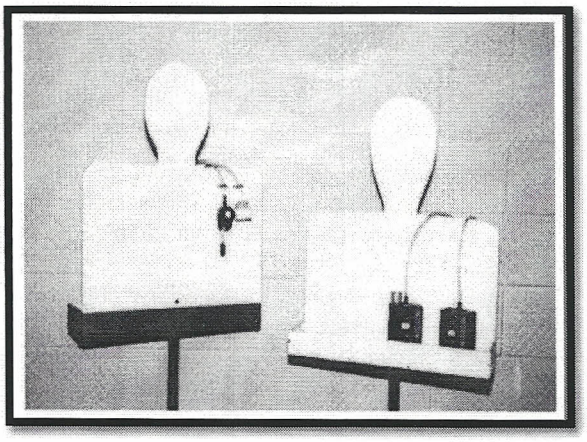

Fig. 1: Mannequin welding fumes sampling system [3].

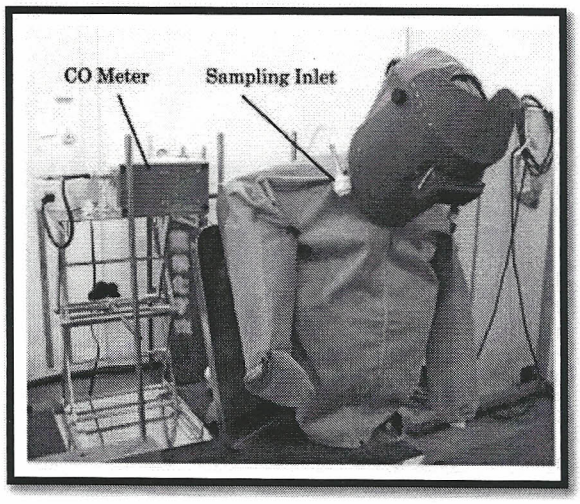

Fig. 2: Dummy welder for welding experimental set-up [2]

However, there is very limited information discussing on the development of the dummy welder itself. Depend on the objective of the welding experimental conducted, development of the dummy welder need to be incorporated with the anthropometric data on the investigated population for reliable and valid experimental results. Thus this study is conducted to develop a full size dummy welder for welding fumes collecting platform.

III. METHODOLOGY

Currently, our experimental set up of dummy welder was done without considering the anthropometric data of Malaysian citizen. Only a body height of 170cm and a shoulder height of 150cm from floor were considered as shown in Figure 3. The dummy welder was also put in approximately of 20 degree inclination from the floor to replicate welder posture during welding as shown in Figure 3. The existing dummy welders have setbacks that need to be improve for better experimental result purposes. Incorporating anthropometric data and adapting the actual posture of welder during welding task either during standing or sitting should benefit in terms of more reliable and valid data collection to represent the risk of welding fumes towards Malaysian welder.

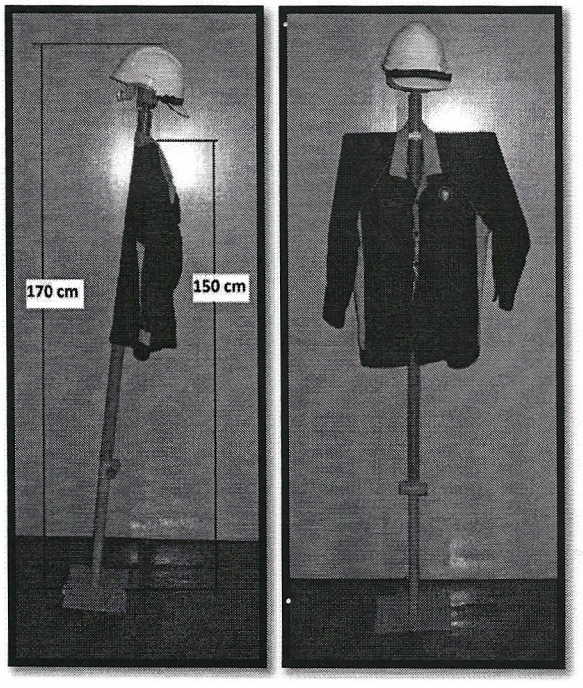

Fig.3. Current dummy welder use in the experimental set- up.

In order to improve the current design, a systematic design process need to carried out as shown in Figure 4. The study begins with gathering information on the Malaysian anthropometric database along with the information on the body posture during welding works before the determination of the design requirements.

The important stage of designing starts with concept generation process using morphology chart to generate and arrange main function and criteria. Weighted objective method was used for evaluating the concept ideas before a final concept design was select for detail design and fabrication.

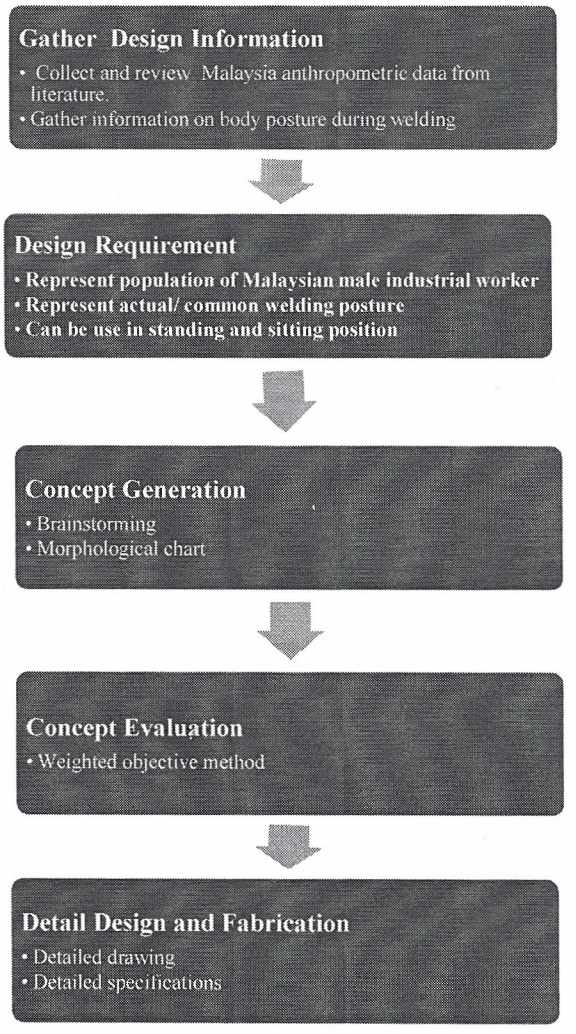

Fig 4: Research Methodology Flowchart

IV. RESULT AND DISCUSSION

According to the research methodology flow chart, the results were discussed in the next sub-chapter.

A. Gather Design Information

Anthropometric databases of Malaysian citizen build by previous researcher [4-6] were collected and reviewed. The most appropriate data to be incorporated in this study

would be the anthropometric data of Malaysian Industrial Worker [6]. Out of 55 standard anthropometric measurements [7], only 16 were selected for the dummy welder design. The selected anthropometric measurements were as shown in Table 1.

Table 1. Selected anthropometric measurement for dummy welder.

No	Standing Welder	Sitting Welder
1	Stature (body height)	Sitting height
2	Shoulder height	Sitting eyes height
3	Eyes height	Sitting shoulder height
4	Head breadth	Sitting knee height
5	Head length	Knee height
6	Shoulder breadth	
7	Chest depth	
8	Chest circumference	
9	Shoulder elbow length	
10	Forearm hand length	
11	Standing elbow height	

There are various type of body posture of welders mainly because of the industrial setting, types of ventilation, type of welding processes and materials used. There is critical need to design a dummy welder that has flexibility on the movement of the spine to replicate the actual posture of the welder especially during standing or sitting. Since the welder breathing zone is the crucial part in taking personal sampling of welding fumes, the actual size of head and torso need the highest consideration.

The 50th percentile (mean) value of the anthropometric measurement was used to design the dummy welder. Although only the mean anthropometric data were considered and applied in the design, the collection of the welding fumes sample are applicable anywhere in breathing zone area which span from 0.3 m in radius hemisphere extending in front of the human face. Thus the difference in the anthropometric measurements between the 5th percentile and 95th percentile on the selected anthropometric measurements are still within the 0.3 meter radius as shown in Table 2.

Table 2. Difference between the 5th percentile and 95th percentile selected anthropometric measurements.

Anthropometric Measurement	5th Percentile (mm)	95th Percentile (mm)	Difference (mm)
Body height	1527	1734	207
Shoulder height	1245	1438	193

Figure 5 illustrated the breathing zone of the 5th, 50th (mean) and 95th percentile of anthropometric measurement of Malaysian male industrial workers. The circle dotted lines represent the breathing zone of the welder. Although the dummy welder was designed only by considering the 50th percentile (mean) anthropometric measurement, the sample cassette attached to the dummy welder's neck collar is acceptable for both 5th and 95th percentile measurement attached on the same location since its located within the breathing zone. Thus, the dummy welder design is acceptable for welding fumes sample collection attached to the neck collar to represent welding fumes exposure to Malaysian male industrial workers.

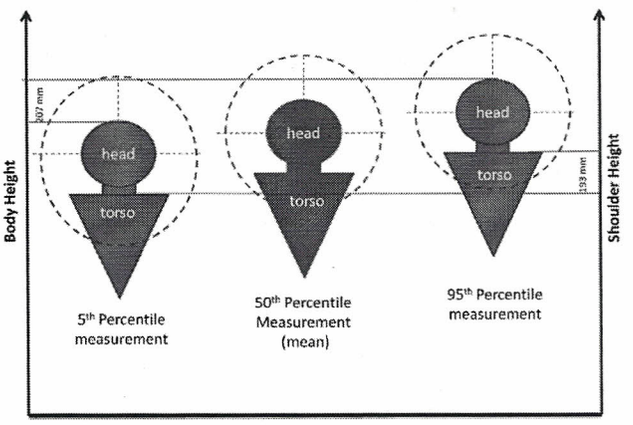

Fig.5. Illustration of the 50th percentile (mean) measurement breathing zone compared to 5th percentile and 95th percentile breathing zone measurement.

A. Design Requirement

Based on the design information gathered, there are 3 main design requirements that need to be fulfilled at the end of the designing process of the dummy welder.

i) Dummy welder to represent population of Malaysian male industrial workers.
ii) Dummy welder has to represent actual/common welding posture.
iii) Dummy welder that can be use in standing and sitting position.

From these three primary design requirements, an objective tree was developed to identify the secondary and tertiary objective of the welder dummy design as shown in Table 3. This objective tree was used to derive the weight factor in the concept evaluation phase.

Table 3. Objective tree of dummy welder design

No	Primary	Secondary	Tertiary
1	Represent population of Malaysian male industrial workers.	Incorporated the design with anthropometric data.	-Sitting and standing anthropometric data. -Actual size head, torso, arms and feet.
2	Represent actual/common welding posture.	Flexibility on spine.	-Adjustable spine.
3	Can be use in standing and sitting position.	Easily change leg component.	-Have interchangeable leg for standing purpose. -Have interchangeable legs for sitting purpose.

B. Concept Generation

During concept generation, brainstorming is done to generate a large number of ideas regarding the design of the dummy welder. The team include technical person that will fabricate the dummy welder with researchers that will conduct the welding experimental works. A few technical persons doing welding works in the laboratory were also taking part in the brainstorming session. From the brainstorming session, the main function and design criteria were shortlisted with possible solution of each main function. Three design concepts were shortlisted in morphological chart as shown in Table 4.

Table 4. Morphological chart for dummy welder.

No	Sub-Function	Concept		
		I	II	III
1	Main Material	Wood	PVC	Metal + chicken wire
2	Fixed Joining	Screw	PVC connector	Bolt and nut
3	Flexible Joining	Ball and socket	Fastener + metal plate	Metal/ plastic hinges
4	Neck, torso and arms padding	Sponge + tape	Shell+ stuffing	Recycled paper + tape
5	Head	Styrofoam	Chicken wire	Paper Mache

C. Concept Evaluation

Each of the concept design was evaluated according to the design objective and multiplies with the weight factor as shown in Table 5. The design concept II with highest cumulative marks was chosen to be the final design. 5 point scale was used to evaluate the concept design (0: inadequate, 1: weak, 2: satisfactory, 3: good, 4: excellent).

Table 5. Evaluation chart for dummy welder concept design

No.	Objective	Weight factor	Concept		
			I	II	III
1	Sitting and standing anthropometric data.	0.20	3	3	3
2	Actual size head, torso, arms and feet.	0.20	2	3	2
3	Adjustable spine.	0.20	1	2	2
4	Have interchangeable legs for standing purpose.	0.20	2	3	2
5	Have interchangeable legs for sitting purpose.	0.20	2	3	2
Total sum		1.00	10	14	11
Total weight			2.0	2.8	2.2

D. Detail Design and Fabrication

The main material used in construction of the dummy welder is the PVC hollow. PVC with inner diameter of 50mm was chosen because the availability of the size in common hardware shop. The UPVC hollow type was used due to the characteristic of UPVC more resistant to heat compare to PVC. The dummy welder was constructed from foot as shown in Figure 6.

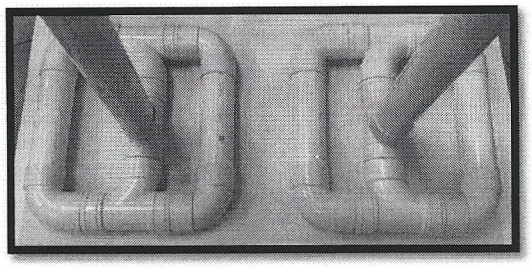

Fig.6. Dummy welder feet

The spine of the dummy welder was constructed from UPVC with additional component of metal plate and fastener to give more flexibility of the spine in replicating different posture. These additional components are shown as in Figure 7.

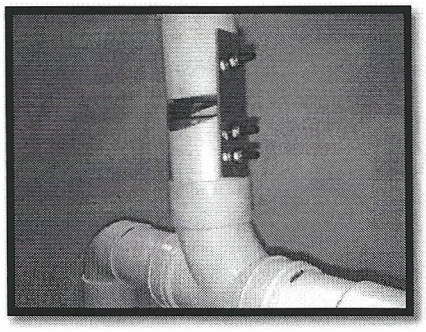

Fig.7. Adjustable spine

The torso of the dummy welder was constructed in square shape by using UPVC shown in Figure 8.

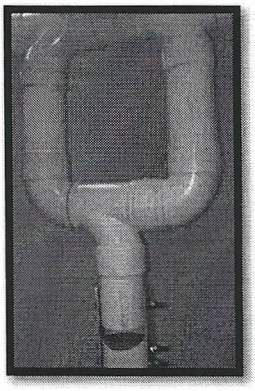

Fig.8. Torso

The body figure as standing and sitting posture is as shown in Figure 9. The designed dummy welder feet components can be changed for standing and sitting purpose.

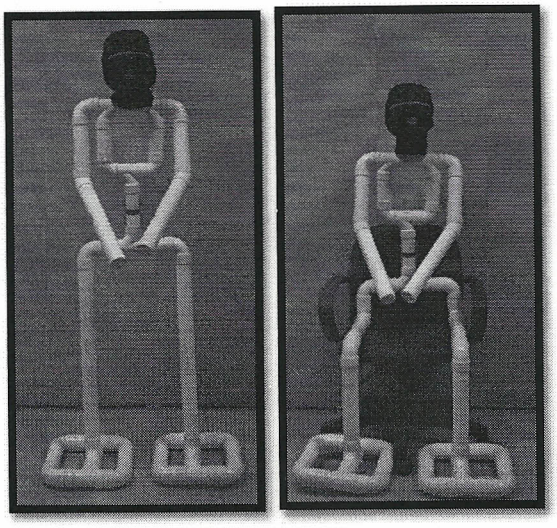

Fig.9. Standing and sitting position.

In order to replicate the actual chest measurement, a chest shell constructed from chicken wire and duct tape was fastened around the square torso shape as shown in Figure 10. The anthropometric data for chest depth and chest circumference were applied to the chest shell.

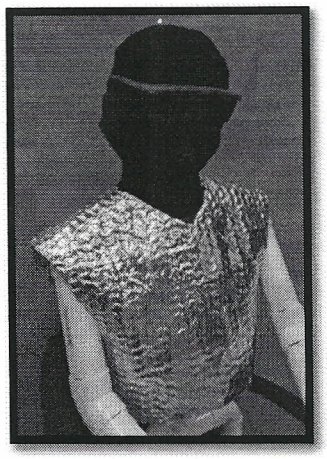

Fig.10. Chest shell.

Figure 11 shows the fully attired dummy welder for experimental purpose. A sampling cassette to collect welding fumes was attached within the breathing zone usually on the collar of the dummy welder.

V. CONCLUSION

The developed dummy welder successfully fulfills the design requirements and applied the anthropometric data of Malaysian male industrial worker into its design. Although only the mean anthropometric data were considered and applied in the design, the collection of the welding fumes sample are applicable anywhere in breathing zone area which span from 0.3 m in radius hemisphere extending in front of the human face. Thus the difference in the anthropometric measurements between the 5^{th} percentile and 95^{th} percentile on the selected anthropometric measurements are still within the 0.3 meter radius.

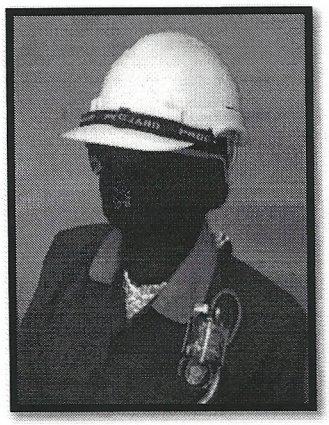

Fig.11. Welding fumes sampling.

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