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Design of Working Table for Fret Wiring Operators With Nida Method in Guitar Industry Mancasan Sukoharjo

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ABSTRACT

The guitar industry is in Mancasan, Sukoharjo regency is a small medium enterprises which carried out finishing process to produce acoustic guitars. All of the process are done manually without any machine. There is one process called fret wire installation where the operator is in a static work posture for an extended period of time to hold the work piece. Nordic Body Map (NBM) assessment showed that almost all assessed workers have pain in hip and right upper arm. There is indication of Musculoskeletal Disorders (MSDS) risk in left upper arm, back, and waist of workers who conduct fret wires installation process. This indication is confirmed using REBA. REBA Score for fret wiring operator is 10, it indicates that the investigation and modification was needed as soon as possible. This arises to a problem called workers MSDS due to awkward posture. This research aims to design an ergonomic working table to reduce the risk of musculoskeletal disorder for fret wire installation operators. REBA was used to evaluate working posture to find the specific problem. In addition, NIDA product development process and anthropometry concept were also implemented to develop working table based on the problem previously found. The result is the proposed working table which specifications are has adjustable system on the leg of the table, features a lock to hold the guitar head, a support with a pad for the neck and body of the guitar, a work tool area and a half-coil fret wire arrangement, and a curved table base so that the operator is in a comfortable position and is close to the work piece.

INTRODUCTION

Small and medium enterprises play a role in the development of mainstay areas to be able to accelerate economic recovery through a regional approach by selecting regions to accommodate priority programs and development of sectors and potentials as well as increasing community empowerment efforts (Primiana, 2009). With such a big role, the system in small medium enterprises should also develop over time. The guitar industry is in Mancasan, Sukoharjo regency is a small medium enterprise

which carried out finishing process to produce acoustic guitars which uses human labor in carrying out the process. One group of injuries are musculoskeletal disorders which are considered the main health issues associated with the industrial workers (Kalantari, 2016)

According to Punnett and Wegman, common causes that pose a risk of work-related musculoskeletal disorders (WMSD) are unnatural posture, prolonged static work, repetitive movements, manual material handling, and exertion and strong vibrations (Punnet, 2004). These factors are found in the guitar industry in Mancasan where all processes are done manually without machines or proper facilities. Workers sit on the floor barefoot that causes workers to bend over to be able to measure, cut, stick and, install the wire. Workers also use their limbs to support the guitar in the process in long period of time. When the muscle receives static load repeatedly and for a long time, will be able to cause complaints due to damage to joints, ligaments, and tendons (Kroemer, 1997). Prolonged awkward postures were found to be common and may place tattoo artists at an elevated risk for musculoskeletal problems (Keester, 2017). Product design is a process that begins with the discovery of the human need for a product to the completion of the drawings and design documents used as the basis for the manufacture of the product. The results of the design that are made into products will produce products that can meet human needs (Kristanto, 2011). The tools are designed with attention to the anthropometry of the workers. Anthropometry is very important to consider in design process. This is because human body size and shape have a lot of variability (Sari, 2011).

RESEARCH METHOD

Nordic Body Map (NBM) assessment was conducted to confirm the indication since mong several tools used for assessing musculoskeletal disorder, NBM is one of the most popular tools (Anugraha & Sutan, 2015). The Nordic Body Map questionnaire is a form of ergonomics checklist questionnaire which is standardized and neatly arranged. With the Nordic Body Map can identify and provide an assessment of complaints of pain experienced (Ramdhani & Zalynda, 2018)

REBA (Rapid Entire Body Assessment) is an ergonomic technique developed by Sue Hignett and Lynn Mc Atamney in 2000. It is a systematic process to evaluate whole body postural MSD and risks associated with job tasks. A scoring sheet contains group A, group B, and table C is used to evaluate required or selected body posture, forceful exertions, type of movement or action, repetition, and coupling. Group A covered the trunk, neck and legs. This reduces to nine possible scores to which a ‘Load/Force' score is added. Group B covered the upper arms, lower arms and wrists, reducing to nine possible scores to which a ‘Coupling' score is added. The A and B scores are combined in Table C and finally an activity score is added to give the fnal REBA score (Hignett, et. al., 2000)

The design method used in this research is the NIDA method. The NIDA method consists of 4 stages (Need, Idea, Decision, and Action). The first stage is that a designer determines and identifies needs, then continues with the development of ideas that will give birth to alternatives to meet needs, then an assessment and analysis of various alternatives is carried out, so that the designer can decide on the best alternative. And in the end a manufacturing process was carried out (Lakhsita, Astuti, & Suhardi, 2019). The overall research metodhology is shown in Figure 1.

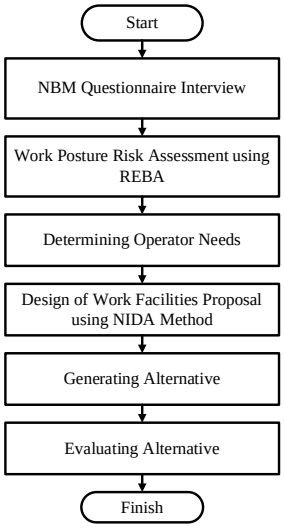


Figure 1. Research methodology flowchart

RESULTS AND DISCUSSION

Nordic Body Map (NBM) assessment was conducted to confirm the indication since mong several tools used for assessing musculoskeletal disorder. Operators were asked to provide an assessment of the part of their body that feels pain during activities work according to a predetermined Likert scale. The assessment showed that almost all assessed workers have pain in hip and right upper arm. In other words, there is indication of MSDS risk in left upper arm, back, and waist of workers who conduct fret wires installation process. This indication is confirmed using REBA to validate the risk of operator work posture.

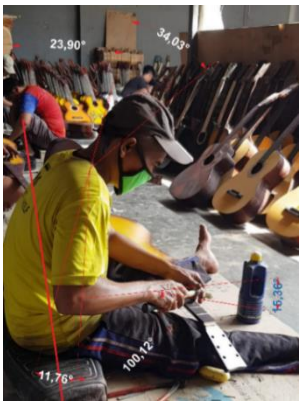


Figure 2. Attaching the wire to the frets using a hammer and glue

The final score of REBA in this research showed that the stamp tools scraping process score is 10. It indicates that the investigation and modification was needed as soon as possible. Therefore, the fret wire installation working table must be designed to reduce workers fatigue and achieve higher productivities. This research was conducted to propose the design of fret wire installation working table. The proposed working table design is expected to reduce workers fatigue and increase operator's productivities. The NIDA method is suitable for designing designs because in using this method the operator's needs are considered. Work table is designed for NIDA

Need

Identification of needs in the design aims to determine the operator's requirements for the design of work facilities. Identification was carried out based on expectation of workers (Suhardi,et.al., 2015) and the results of data collection using the NBM questionnaire and the results of data processing, namely work posture analysis using the REBA method.

Table 1. interview result

No.	Interview Result
1	Operators want to avoid having to hold the guitar in its body for too long.
2	Operators want facilities that can make their back more relaxed while working.
3	Operators want a facility that fits the production floor and does not interfere with the mobility of other operators.
4	The operator wants a container to arrange the equipment, such as wire, pliers and a hammer.
5	Operators want a facility with lightweight and durable materials because each operator's area can move at any time.

Idea

At this stage, considerations are made based on the known and conveyed needs of the operator to design appropriate features in the work facility. The description of generating ideas to meet operator needs is described in tabel 2.

Table 2. Interview result

Identification	Need	Features
The NBM questionnaire showed that the operators experienced many complaints on left upper arm, back, and waist.	Work facilities that do not cause stiffness in body parts such as back	Designing work facilities that can reduce musculoskeletal risks
The results of the REBA assessment show the result of 10 on the work element attaching the fret wire using a hammer and glue because of the high activity score.	Work facility that eases the operator in maintaining a stable guitar position	Designing work facilities that function specifically as work tables for the fret wiring process

Decision

The decision-making stage is carried out as a development of ideas in the form of alternative designs so that work facilities are chosen appropriately and meet needs. The next step is to identify or look for new combinations of elements using the Morphological Chart step. This method is useful for broadening the search for new possible solutions (Sulaiman, 2017).

The results of the Morphological chart show that the design concepts obtained are 6 selected functions. The combination is obtained as many as three alternative concepts based on the color; orange for alternative 1, blue for alternative 2 and red for alternative 3. The three alternative concepts above will be raised as an alternative design as the initial concept. This alternative concept provides information about the drawing or form of the design of the fret wiring workbench facility. An explanation of the alternative concepts proposed is as shown in figure 3 - figure 5.

Table 3. Morphological chart

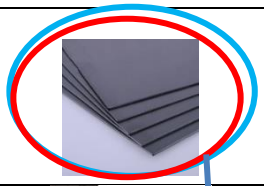
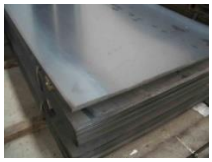
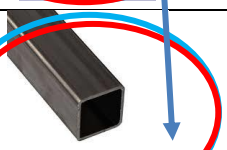
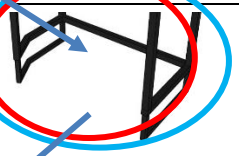
Subfunctions	Solutions		
	A	B	C
Table Cloth Material			
Table Leg Material			
Table Cloth Features			
Table Leg Features			
Table Cloth Design			
Table Leg Design			
	Alternative 1	**Alternative 2**	**Alternative 3**

Figure 3. Alternative 1

Figure 4. Alternative 2

Figure 5. Alternative 3

a. Alternative 1

Table base uses multiplex which has anticipation features for tools and the price of the material is more affordable and lighter so it is easy to move. Table leg uses wood so it should be made straight

so that there is an unnecessary part of the bottom left side of the table base. Fixed table leg so it cannot adjust the operator's elbow height.

b. Alternative 2
Table base uses iron plate so that it is sturdier when it comes to pressure and is durable. The lower left table base design is more efficient, making it easier for operators to fret wiring. Table legs uses hollow steel. There is an adjustable feature on the table legs so that the operator can adjust the guitar body to the left elbow or to a lower position according to comfort.

c. Alternative 3
Table base use multiplex and the table leg uses hollow steel. It is a combination of alternative 1 and 2, so it can accommodate the strengths and overcome the weaknesses of each alternative. But the manufacturing process must be carried out by two different vendors to work on wood as a table base and iron as a table leg.

Action

At this stage an action was taken, namely the design of work facilities. The selected design is the third alternative which a combination between alternative 1 and 2 (Hanifah, 2019). It is a work table for the fret wire installation process with a wooden top and an iron table leg. With this workbench, the operator can work on the fret wiring process with the correct and comfortable posture, reduce the distance between the body and the guitar neck, arrange the equipment in the available case so that it is easy to find and within the reach of the hand so as to reduce ineffective motion elements.

1) Application of Anthropometric and Percentile Data

The construction of a work facility takes into account several anthropometric dimensions as well as the dimensions of the guitars produced in The Guitar Industry. The working table of fret wire installation used anthropometric data of Javanese men at productive age (18-45 years), was obtained from Indonesian anthropometric data because workers in the guitar industry are not permanent and have an age range of 18 to 45 years.

The reach dimension is the principle that is used in this research. It is the determination of the design dimensions where the smallest person in the population can use the design. The reach dimension is intended to accommodate the smallest / shortest user population. The design with the properties of the dimension of reach using the normal standard value (Zx) with small percentile. The least percentile value that is often used is the 5th percentile (Purnomo, 2013).

2) Calculation of Design Dimensions

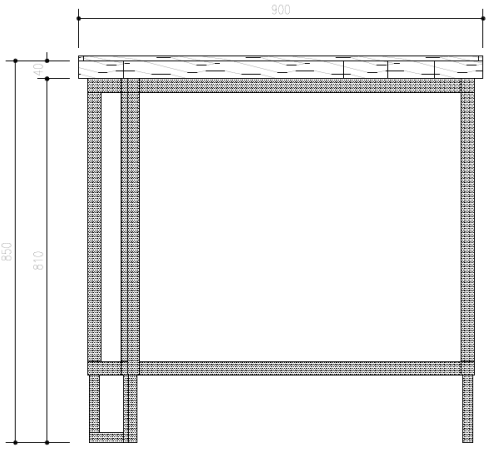


Figure 6. Drawing of 2D front view

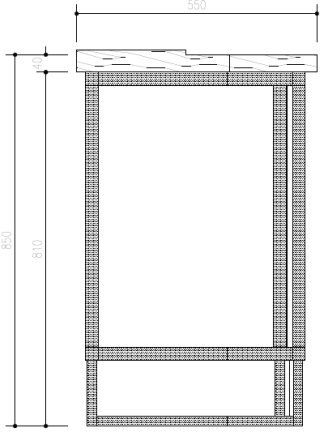


Figure 7. Drawing of 2D rear view

a. Height of Table Leg

According to Wignjosoebroto (2008), if in designing a product there are variations for the actual size, then it should be able to design a product that has flexibility and properties that

are able to adjust (adjustable) with a certain range. The table legs on the fret mount workbench can be operated up and down to adjust the height dimension of the operator's standing elbow. The minimum table leg height is 81 cm and can be adjusted up to 20 cm to reach a maximum height of 101 cm. The determination of this size is based on the 5th percentile of the elbow height dimension, which is 94.16 cm and the 5th percentile of the hip height dimension, which is 89.28 cm so that the total table height (table leg height + table base thickness + guitar support height) is between the operator's hips and elbows.

b. Length of Table Base

The length of fret installation working table is based on the dimension of the length of elbow span at 5th percentile which is 66.17 cm and the height of the guitar with ½ size, which is 135 cm. During the fret wiring process, 2/3 of the guitar must fit onto the workbench so that the table length is 90 cm.

c. Width of Table Base

The width of the fret installation working table is based on the dimensions of forearm at 5th percentile which is 25.08 cm and the width of the guitar, which is 38 cm. Allowance of 12 cm is provided as area for the other worker's tools so that the table width is set at 50 cm.

3) Making Design Plans

SkecthUp software is used to design fret wire installation working table which composed of two components: table base and table leg. There are several features on the table top which include:

a. Guitar head lock & guitar neck support

The guitar head lock helps the operator not to hold the guitar with his feet or elbows, thereby improving high-risk work postures. The guitar neck support plays a role in keeping the guitar in a firm position while the operator hits the fret wire with a hammer along the length of the guitar neck.

b. Guitar body support

The guitar body support is designed in an angled shape to facilitate the operator in the fret fitting process. the operator is not burdened with the weight of the guitar while holding the guitar at one time

c. ½ Roll Fret Wire Container

As a place to place a pile of ½ rolled wire before installing it so it is not scattered in the production area.

d. Container for short and long frets leftovers

Uniformly cut ½ coiled wire often produces residue because it doesn't match the total wire needed for the entire fret on one guitar. This container is used to accommodate the remaining wire so that it is easier to find and use in the next guitar fret wire installation.

e. Work tool area

A work tool area is provided for placing pliers and a hammer so the operator can pick up and place them in the same place after use thereby reducing searching time and getting organized.

f. Anticipate falling tools/materials

The front side of the table is higher than the other one which is act as a precaution so the fret wire or other tools do not fall.

g. Adjustable Table Legs

The table leg on the fret wire installation working table can be operated up and down to adjust the operator's comfort in working. In addition, because the front and rear table legs are connected, the operator only needs to adjust the table height twice using the screws provided on the table legs.

h. Table Legs Adjust the Table Shape

The advantage of iron material is that it remains sturdy even though the table leg structure is not straight. So that the lower left leg of the table can be formed according to the table base where the four corners are not perpendicular.

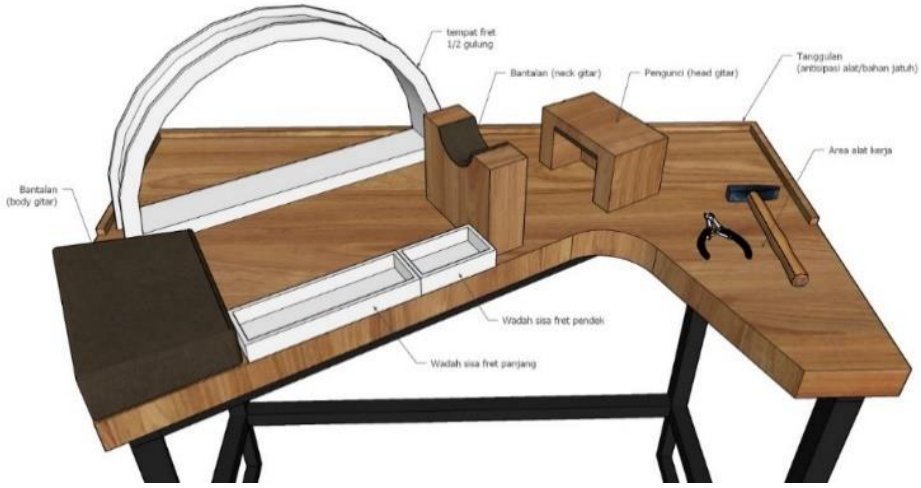


Figure 8. Features on the Base of Fret Wiring Workbench

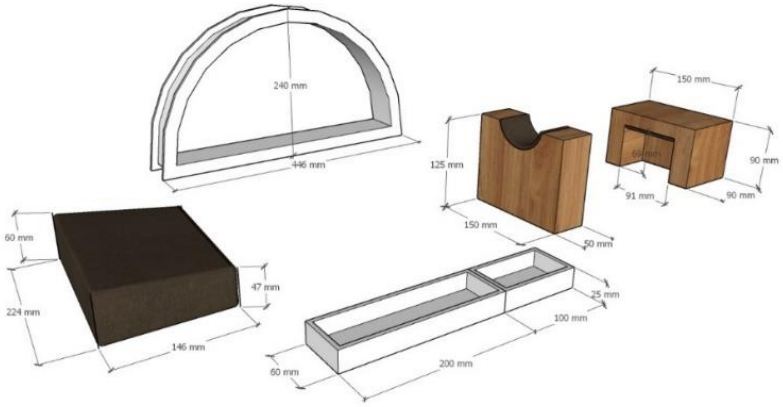


Figure 9. Dimension of Each Features

Figure 10. Guitar Head Lock and Guitar Neck Support

Figure 11. Guitar Body Support

4) Bill of Material

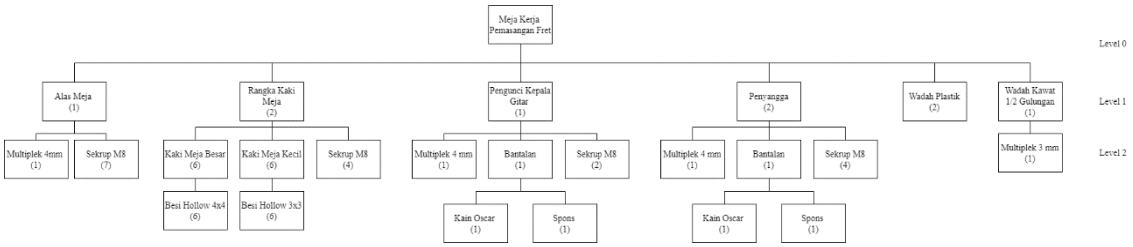


Figure 12. Bill of Material

CONCLUSIONS

The proposed fret wire installation working table involves of some ergonomic theoretical analysis and researches. The proposed design of fret wire installation working table is arranged through the concept development which consists of identifying the customer needs of fret wire installation working table, development ideas, generate product design concept, select product concept and take action to make the product. As a result, the proposed fret wire installation working table which specifications are has adjustable system on the leg of the table, features a lock to hold the guitar head, a support with a pad for the neck and body of the guitar, a work tool area and a half-coil fret wire arrangement, and a curved table base so that the operator is in a comfortable position and is close to the work piece.

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