Ergonomics In Asia: Development, Opportunities, and Challenges

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Analysis of productivity with an ergo-mechanical approach for making banten elements

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ABSTRACT: One activity that can be found in the lives of Bali people is making banten elements such as tumpeng and penek. Tumpeng and penek are done in home industry and are used in religious ceremonies. Manufacturing processes are done manually sitting on the floor. Production process is sped up by gas-fired dryer to make the products ready to be marketed. One of the goals of industrial activities is productivity. How do our efforts increase productivity for making banten elements? Increasing the productivity of the production process will be achieved through an ergo-mechanical approach, because the ergo-mechanical can be a simultaneous problem solving approach. The ergonomics aspects are oriented to human performance and the mechanical engineering aspects are oriented to the production process of dryer performance.

Keywords: productivity, ergo-mechanical, banten elements

1 INTRODUCTION

Bali is an unique area in respect of religious ceremonies, works of art, a variety of foods and other things. Religious ceremonies are offered as banten form and are very important in the life of Hindus in Bali. They are always available every day, there are not many days without a religious ceremony. The first ceremony can be created when a baby's birth is greeted with penang as a rare ceremony, breaking the umbilical cord is the kele ceremony, then the three months ceremony, otonan ceremony (six months), haircut ceremony and on to adulthood ceremony (Swartika, 2010).

Components of the banten are tumpeng and penek. Tumpeng is shaped like a cone as the Mountain symbol. Mountain is a symbol of Purusa (male) prosperity and also as a symbol of Sang Hyang Akasa as protection or guidance. Penek is rather flat-shaped symbol of ocean (sea) or a lake. Sea or lake is a symbol of Prawanda (female/Sang Hyang Ibu Pertiwi) that gives immediate (existence) of life (Wijayantana, 2003).

The tumpeng and penek are the result of home industry activities created manually by hand and dryer tools. One of the goals in industry activity is continuity of productivity. Productivity generally implies comparison between the results achieved (outputs) with all the resources used (inputs). Competitive businesses can’t just rely on cheap human resources to increase production, but should optimize existing resources and infrastructure to support production activities.

How do our efforts increase the productivity of banten elements industry? One of the efforts to increase productivity can be conducted through an analytical approach using an ergo-mechanical method. In the ergo-mechanical method of solving the problem, ergonomics is mechanical oriented to the human process and simultaneously, engineering is oriented to the production process of dryer tools.

2 PRODUCTION PROCESS

The production processes of tumpeng and penek are done manually by hand and the drying process by dryer tool. Rice is cleaned, soaked and then steamed. Rice that has been steamed
is mixed with warm water, and starch is added as an adhesive; then the resulting dough is the raw material for manufacturing the tumpong and penek. The dough has been cold-formed by mold manually to fit the desired shape of either the tumpong or penek. The result of the production process of forming just manually has not been marketed yet. What is needed further is a simple process to dry using a dryer which has been marketed already. The production process can be shown as in Figures 1 to 4 below.

3 DISCUSSION

Production process of tumpong or penek will be influenced by the performance of workers and the dryer performance. To know the factors that affect worker and dryer tool performance an analysis approach by ergo-mechanical method is employed. The ergo-mechanical approach is solving a simultaneous problem, with ergonomics oriented to human processes and mechanical engineering oriented to the production process which aids drying.

In the ergonomics of performance a person will be influenced by the balance between the demands of the task and the capabilities and limitations of humans (Manuaba, 2006). Performance of a person can be seen from changes in productivity. One of the variables that can affect productivity is the workload. The workload is greatly determined by the working posture at the time of doing the activity. Working posture in Figures 1 and 2 in the production process is not natural or not physiological, so it needs an ergonomic intervention. These interventions are hoped to result in changes to work posture which becomes physiologically natural so it can reduce the workload. This includes external workload (stressor) and internal workload (strain) (Manuaba, 1996 and Adiputra, 1998).

3.1 External workload (stressor)

Stressor is the workload that comes from outside the body such as tasks, organization, and environment. Tasks include static and dynamic muscle activity, frequency and speed of use of assistive devices, as well as quantity and quality of production. Organization involves working

![Image 1](image1.jpg)  ![Image 2](image2.jpg)  ![Image 3](image3.jpg)  ![Image 4](image4.jpg)

Figure 1. Sitting with one leg crossed and asymmetric position.  Figure 2. Sitting with both legs folded.  Figure 3. Penek and tumpong in dryer conditions.  Figure 4. Walls dryer without insulator.

3.2 Internal workload (strain)

Strain is the workload of the body, and psychological and nutritional state is related to the strain, causing a strain on the body and is associated with emotion, satisfaction, and mental health.

The workload of the worker is calculated per minute of work based on the difference in the consumption of oxygen required on a job making between the first and second palpation of the pulse between the first and second palpation of the pulse.

Some of the factors that influence the workload, oxygen consumption, and energy expenditure (calculated using the equation above) are the time used for the activity.

Mechanical exercise can be an indicator of the effectiveness of the production process. The energy balance of the fuel can be calculated using the formula:

\[ P = \text{workload} \times \text{time} \]

where \( P \) = productivity, \( \text{workload} \) = expenditure (calculated using the equation above), and \( \text{time} \) = time used for the activity.

Table 1. Workload Categories

<table>
<thead>
<tr>
<th>Workload</th>
<th>Light</th>
<th>Moderate</th>
<th>Heavy</th>
<th>Very heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
together (team work), turn (shift), and scheduled work breaks. The working environment is associated with physical barriers, microclimate, lighting, noise, aspects of anthropometry, range, high, and low working facilities.

3.2 Internal workload (strain)

Strain is the workload that comes from inside the human body, including: somatic factors and psychological factors. Somatic factors include: gender, age, body size, health condition, nutritional status and others. Psychological factors include: motivation, perception, desire, emotion, satisfaction, confidence, self esteem, responsibility and others.

The workload can be known based on changes in resting pulse rate with beating pulse rate per minute of work. When the workload is increasing, the pulse per minute rate is calculated based on the difference between working and resting pulse rate. The pulse rate after working on a job making offerings was measured by ten beats. The resting pulse rate before the job is also measured by the method of ten beats. The method of ten pulses is the method involving palpation of the radial artery on the left hand, and is calculated based on how long it takes between the first pulse and the eleventh, the results given in seconds.

Some of the indicators for determining the severity of the work will be the pulse rate at work, oxygen consumption, and the person’s energy needs. Pulse relationship to workload, oxygen consumption and energy expenditure can be seen in Table 1 below.

According to Sutjiana (2000) productivity is the ratio between the amount of output with input which can be calculated on the formula:

\[
P = \frac{O}{I_1 \times t_1}
\]

where \(P\) = productivity of workers; \(O\) = (output) the average weight banten element (tumpeng and penek) in kg; \(I_1\) = (input) the average energy expenditure for activity doing banten element workloads (beats/min); and \(t_1\) = (time) the average time expenditure to make banten element (hours).

Equation 1 above can be converted to inputs (I) based on oxygen consumption and energy expenditure (cal/min) with help of appropriate methods interpolation (Table 1). From the equation above the productivity of workers will be affected by the production, energy and time used for the production process.

Mechanical engineering, especially the energy conversion performance of dryers, is a better indicator of productivity performance, and is also a more productive process. The drying production process used an LPG gas-fired dryer. Performance of the dryer is determined by the effectiveness of the process of drying and the utilization efficiency of energy contained in the fuel. The amount of energy that is used in the drying process will be determined by the balance of energy in the combustion process such as equation 2 as follows:

\[
q_s = NKA - X_{H,O} \cdot LH_{H,O} - q_a - q_b = q_c
\]

<table>
<thead>
<tr>
<th>Workload</th>
<th>Oxygen consumption (lit/min)</th>
<th>Energy expenditure (cal/min)</th>
<th>Heart rate during work (Beats/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>0.5-1.0</td>
<td>2.5-5.0</td>
<td>60-100</td>
</tr>
<tr>
<td>Moderate</td>
<td>1.0-1.5</td>
<td>5.0-7.5</td>
<td>100-125</td>
</tr>
<tr>
<td>Heavy</td>
<td>1.5-2.0</td>
<td>7.5-10.0</td>
<td>125-150</td>
</tr>
<tr>
<td>Very heavy</td>
<td>2.0-2.5</td>
<td>10.0-12.5</td>
<td>150-175</td>
</tr>
</tbody>
</table>
where $q_i$ = useful heat (kcal/kg); $NKA =$ calorific value of fuel (kcal/kg); $X_{H,0} =$ total mass of $H_2O$ produced during combustion (kg $H_2O$/kg); $LH_{H_2O} =$ latent heat of vaporization of $H_2O$ (kcal/kg H$_2$O); $q_{ex} =$ heat carried by the exhaust gas (kcal/kg); $q_{w} =$ heat which are not burned (kcal/kg); $q_d =$ heat exposed to the outside of the system (kcal/kg).

An energy balance such as the above to dry tumpeng and penek can be achieved by minimizing the energy lost with isolation wall dryers so that the wall temperature is approximately equal to the air temperature working environment. Isolation is expected to reduce the heat energy that is exposed to the outside of the system. Lesser energy exposed to the outside of the system will improve the performance of dryers so that the drying rate is faster and the rate of fuel consumption decreases and heat lost to the environment is reduced. This situation will also be able to reduce the additional workload due to thermal effects of environmental influences.

The drying process does not only depend on the amount of energy that is available but also on how the phenomenon of water vapor existing in the offerings moves into the air so that the drying process becomes effective. The process of drying involves heat and mass transfer phenomena simultaneously. Heat transfer occurs when there is a difference in temperature while the mass movement occurs when there are differences in concentration. This process can work well when there is air movement. The air movement can be improved if a natural draft is added on the dryer.

The drying process will depend on the process above. The combustion process will depend on the effectiveness of the fuel while drying and will affect the drying time. If both these variables can be minimized then productivity will be better. The productivity of the dryers can be estimated as follows:

$$P = \frac{O}{I_1 \times I_2}$$

where $P =$ productivity of dryer tool working; $O =$ (output) the weight of banten element (tumpeng and penek) in kg; $I_1 =$ the total energy spent in fuel during the drying process kg/hour (cal/min); $I_2 =$ the total time used to dry the banten elements (hours).

Analysis of the productivity process by the ergo-mechanical approach can be formulated as follows:

$$P = \frac{O}{(I_1 \times I_2)(I_2 \times I_3)}$$

where $P =$ productivity of production process; $O =$ (output) the weight of banten elements that can be made weight (kg); $I_1 =$ the total energy expenditure for activity in making banten element workloads (cal/min); $I_2 =$ the total time expenditure to make banten element (hours); $I_3 =$ the total energy which is spent as fuel during the drying process for banten elements kg/hour (cal/min) and $I_4 =$ the total time used to dry the banten elements (hours).

4 CONCLUSIONS

1. Increased productivity of production process for making banten elements is achieved to through the ergo-mechanical approach.
2. The equation used in the ergo-mechanical approach is as in equation 4 above:

$$P = \frac{O}{(I_1 \times I_2)(I_2 \times I_3)}$$
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