Ergonomics Assessment and Design Intervention on Removing Drudgery in Jaggery Making Process

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Abstract : This paper reports work towards the ergonomic assessment of a jaggery (unrefined sugar) production unit. To understand the physiological load imposed on the jaggery making workers, attempts have been made to understand the physiological cost of the entire work content and their time-based relation by following the Time-Motion analysis and Heart Rate measurement techniques. Energy expenditure of the workers were found out by using the conversion equation for determining calories burnt using heartbeat. Heart Rate is an effective measure of the physiological strain undergone by an individual. To perform the study, the entire production process was divided into a number of smaller tasks such as crusher feeding, baggase handling, scum removal, stirring and mould-making. Based on the severity of strain suffered by workers, measured as sum of work pulses, these tasks were ranked. The measurements and ranking reported here will be of immense help in design, fabrication and testing assistive devices in this 'manually-intensive" production activity being threatened in many states of India due to labour disinterest.

1 Introduction

Jaggery is unrefined sugar made from sugarcane and palm juice. The production is essentially decentralized and the units are operated by farmers in different states of India. Earlier survey by the research group indicates that some 900 Jaggery making units exist in single Kolhapur district of Maharashtra (India) of which approximately 40% have been shut down in last decade. In the year 2002, about 9.97 Million tons of jaggery was produced in India (Rao et al., 2007). Each jaggery unit, crushes approximately 10 tons of sugarcane/day, engages about 25 people (of which about 12 for cane harvesting and 13 for Jaggery making). High level of drudgery involved in the process of jaggery making operations is one of the principle reasons in shutting-down of jaggery making units (Shiralkar et al., 2014). Research is being carried out to improve both the qualitative and quantitative aspects of jaggery production, and to lower its production cost by modernizing the jaggery making process based on food technology approach (Shiralkar et al 2014). The authors are convinced that along with technology development, there is a need to develop worker related conducive environment (Joshi., 2012; Salokhe and Jaitip., 2001; Kundu et al., 2014), for increasing the work system productivity by reducing the physiological, biomechanical and psychological inconveniences and related issues.

2 Methodology

In order to perform the ergonomic study, field visits were conducted at the jaggery making units located at Shiroli, in Kolhapur district of Maharashtra (India). Minute observation of all the steps involved, starting from the unloading of raw sugarcane to the storage and

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packaging of finished products, were done. The entire production process was segmented into smaller tasks such as crusher sugarcane feeding, baggase handling, scum removal, stirring and mould-making. A Questionnaire was prepared to interview workers. In two jaggery making units, a total of 18 workers in the age group of 21-60 years were selected for HR measurement and Time-motion based study.

2.1 Time Motion study

This study was done to find the time required to complete individual tasks, and conduct a postural analysis of workers performing these tasks. For this, a SONY Handycam was used. The time study was done using a properly calibrated stopwatch. The inbuilt on screen time display feature of the video camera was also selected so that the standard time of shooting would be displayed in the video.

Based on our field observations, the entire jaggery making process is divided into different unit operations, each such unit operation being further divided into a number of tasks. Jaggery making is a batch process, and each unit operation is associated with a 'Batch time'. This Batch time is further divided in between different tasks as 'Task time'. It was observed that some of the tasks which demanded a very high degree of muscular activity were shared by multiple workers alternatively in the time frame. The effective time taken by a worker to complete his part of task, excluding the rest taken in between, if any, is defined here as 'Work-Time'. It is obtained by finding the effective time of all the workers performing a task and taking average of all of them.

2.2 Heart Rate measurement

Heart rate (HR) is an effective tool to determine the physiological workload of a worker (Kundu et al, 2014). Classification of the physiological workload based on heart rate (in bpm) obtained from previous researches conducted in India has been shown in Table (Sen, R.N., 1969)

Heart Rate measurement of sampled workers were done using POLAR FT80

Heart Rate monitor, which comes with an inbuilt data logging facility. It has two components, a POLAR H1 heart rate sensor which transmits the heart rate signal to a POLAR FT80 training computer using 5kHz transmission. Heart rate sensor has a heart belt strap which is worn on the ribcage of the subject, below the pectoral muscles. The training computer, which looks like a wrist watch, has the receiver element and receives the signal transmitted from the sensor. It has features like displaying and logging the transmitted heart rate data and was worn on the wrist of the subject.

Heart Rate sensor and training computer was worn by the subject and was allowed to sit in resting mode for 10 minutes so that its heart rate normalizes. This Resting HR was noted down. Then the subject was allowed to start his work in a normal manner. HR data logging was started 10 minutes after the start of the work so that the HR normalizes in working mode. It is stopped after 10 minutes of the start. Average value of the data obtained is calculated to get the average working HR value. Average Work-Pulse rate was calculated by subtracting the resting HR from the average HR.

Average work-Pulse rate = Average working HR - Resting HR, (1)

Average Work-Pulse rate for each task was multiplied with their respective work-time

obtained from time-motion analysis to get 'sum of work-pulse'.

Sum of Work-Pulse = Average Work-Pulse Rate × Work-Time, (2)

Sum of work-pulse can be taken as a measure of physiological strain undergone by a worker (Kundu et al, 2014). From the data obtained for sum of work-pulses obtained for different tasks, a task ranking was done based on the physiological strain involved.

2.3 Human Energy Expenditure

Average HR data can be used to measure energy expenditure of a person using the conversion equation for determining calories burnt using heartbeat (Reddy and Achary, 2015). Equations for Determination of Human Energy expenditure in Kcal:

Human Energy Expenditure (Kcal) [For Male]=
(-55.0969 + (0.6309 x HR) + (0.1988 x W) + (0.2017 x A)) /(4.184 x 60 x T) .. (3)

Human Energy Expenditure (Kcal) [For Female]=
(-20.4022 + (0.4472 x HR) - (0.1263 x W) + (0.074 x A)) /(4.184 x 60 x T) (4)

where
HR = Average Heart rate (in bpm)
W = Weight (in kg)
A = Age (in years)
T = work-time (in hours)

Weight and age were taken during the interview as a part of the questionnaire while work-time is obtained from the time and motion study.

3. Field Measurements and Analysis

Time-Motion study and heart rate measurements were done for the sampled workers. Time of execution of different tasks has been obtained from the time-motion analysis using stop watch and video recordings. From this, batch time, task time and work-time has been obtained as discussed in section 2.1

3.1Segmentation of Jaggery making process and measurement of Work-Time

Based on our observation, the entire jaggery making has been divided into different unit operations. Each such unit operation is further divided into a number of tasks. Table 1 shows the segmentation of the jaggery making process into unit operations and tasks. Batch time, Task time and the Work-Time has also been given as obtained from the field measurements. The whole process starts with the unloading of sugarcane from the transportation vehicle, usually a tractor. At the unit studied this operation was performed using the hydraulic system of the tractor itself and did not involve much of human labour, and has not been included in this article.

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3.2 Analysis of field data

From Figure 1, it can be seen that the highest value of working HR, as well as the average Work-Pulse rate, were highest for Crusher feeders, owing to their continuous bending of trunk and legs, and lifting of heavy weight. Hence, it turns out to be the most strenuous task. However, because of the sharing of the work by 2 workers in the time frame, effective working hour per worker reduces to only 1 hour. Hence, in figure 2, it comes down in ranking, when sum of work-pulses with a time element as one of the parameter is considered. From figure 2, it can be seen that the stirring work by Gulvya (master-craftsman) ranks highest. This is because of the continuous, and longer hours of work. Scum removal, which involves similar kind of work, follows this. Figure 3 shows the demand of human energy for different tasks.

4. Conclusion

Of all the unit-operations conducted by the workers, sugarcane crusher-feeding has the maximum average heart rate, it comes down in ranking because of the alternate sharing of job by two workers, and hence, reducing the effective work time of each by half. Based on sum of work-pulse, which considers both the stress value, and the duration of undergoing stress, different tasks can be ranked as below:

Table 1 List of tasks with their sum of Work-Pulse and Average Human Energy consumption

Unit operation	Batch Time (in hrs/ batch)	Name of Task	Task Time (in hrs/ batch)	No. of workers sharing task with time	Work-Time (in hrs/ person /batch)	Average work-pulse rate (±SD) (in bpm)	Sum of work-pulse (in beats/ person /batch)	Average Human Energy consumption (in Kcal/person/batch)
Crushing	2.0	Feeding sugarcane to crusher	2.00	2	1.00	53 (8)	3180	601
Bagasse Drying	2.5	Wet Bagasse Transport to dry	2.00	2	1.00	48 (7)	2880	541
		Bagasse Turning	2.00	1	2.00	28 (5)	3360	941
		Dry bagasse Transport towards furnace	2.00	2	1.00	22 (11)	1320	369
Boiling	2.5	Bagasse feeding	2.50	1.25	1.25	41 (6)	3037	677
		Juice stirring (by Gulvya)	2.00	1	2.00	33 (7)	3960	1191
		Scum removal	2.00	1	2.00	30 (4)	3600	769
Mould making	1.0	Stirring molten jaggery in the cooling pan	0.10	1	0.10	15 (9)	90	23
		Moulding	0.50	1	0.50	18 (2)	540	157

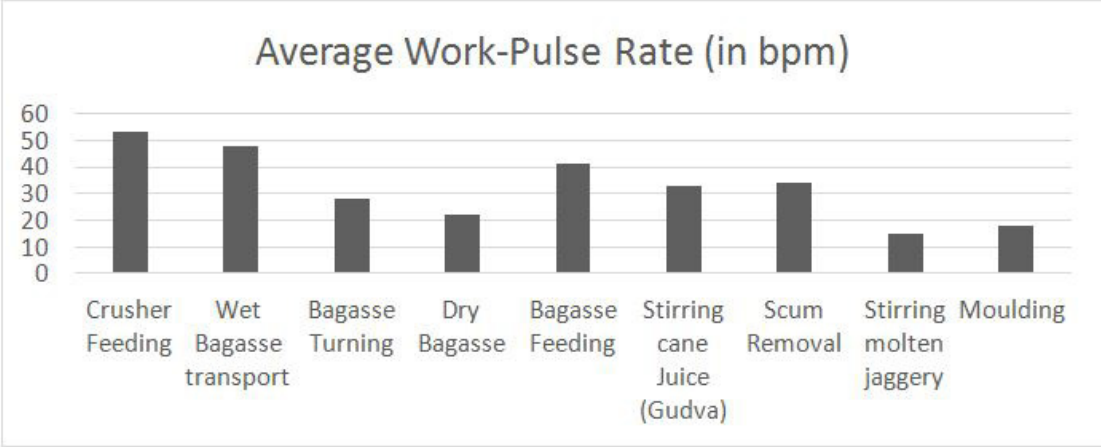

Figure 1 Average Work-Pulse of different tasks

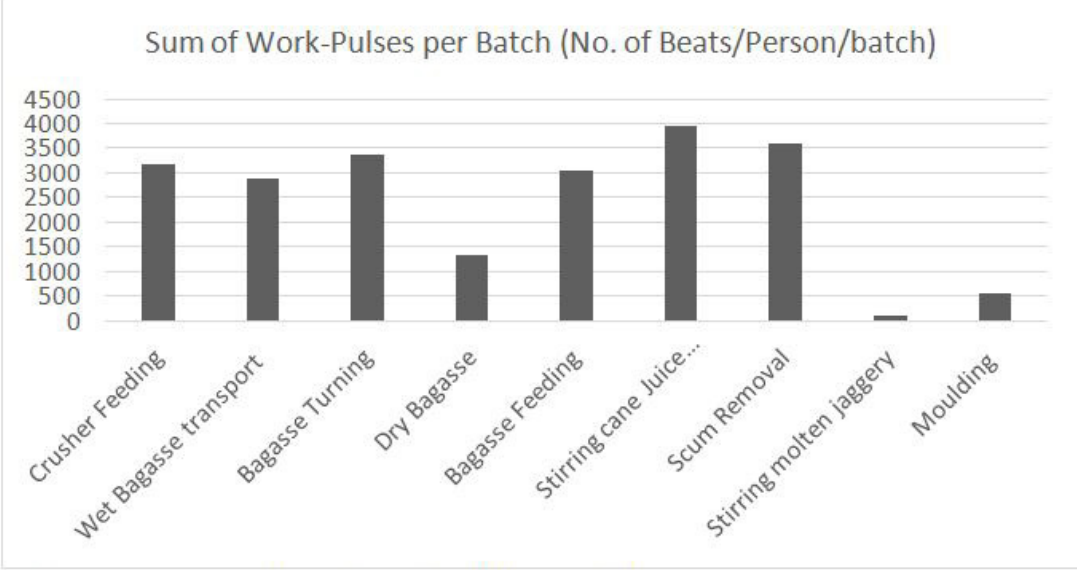

Figure 2 Sum of Work-Pulse for different tasks

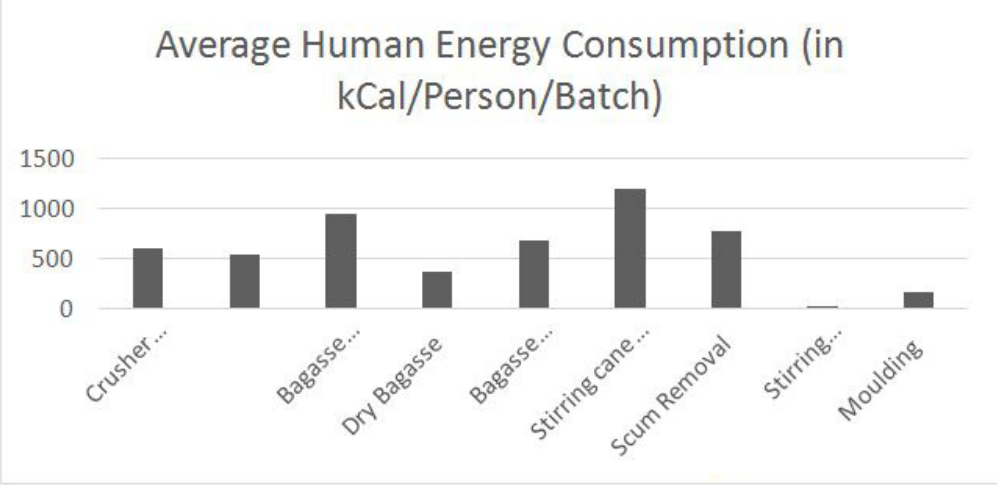

Figure 3 Average Human Energy consumption for different tasks

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