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*Research Paper :*

# Product optimization of graters using Taguchi technique

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## ABSTRACT

Proper selection, evaluation and use of kitchen tools is a major ergonomic concern. As grater is one of the most vital and essential tools in Indian kitchens, a need was felt to conduct a study on graters. Three models of graters identified from the household and market survey in twin cities of Hyderabad and Secunderabad were ergonomically evaluated. To enhance the quality of process, the present study was taken up to conduct analysis of ergonomic evaluation using Taguchi technique. Experiments with four 3-level factors were designed using L-9 array considering the three graters as three levels. The optimum conditions derived from the analysis was the shape of the grater at Level 1/Level 2, wrist angle at Level 2 and energy expenditure at level 2/level 3. It was found that the factors affecting the comfort, efficiency and safety, most significantly in the present study were shape of the grater and wrist angle of the user.


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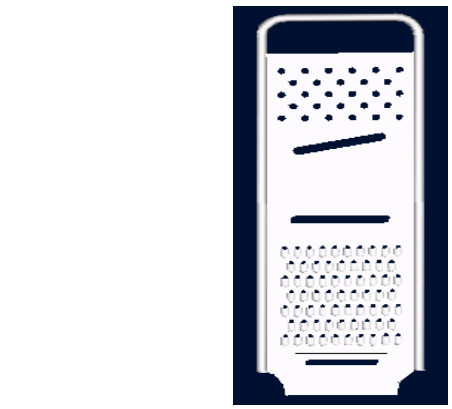
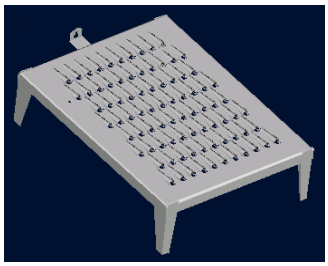
The house is the physical setting for family living. Women spend more time in the home than any other member and devote more time in meal preparation than any other duty. Kitchen tools *i.e.* knives, graters, tongs, peelers and others which aid in this activity are very vital. As the women spend most of their time in cooking, they find cooking arduous, time consuming and a drudgery.

Although in recent years, the use of modern gadgets and appliances has apparently simplified the methods of performing household activities. It has on the other hand brought in several ergonomic issues towards the health and safe working performance of users. To avoid work hazards, which occur due to various tools used and work environment, ergonomic evaluation of tools is needed (Balges and Krieger, 2000). Amongst different kitchen tools, grater is one of the important tools which is injury prone but essential in day to day life. In the light of the above, the ergonomic evaluation of identified models of graters was carried out. In the present study, Taguchi technique was used for analyzing the performance of the graters (Fig. 1) used at various households, selected based on the household and market survey at twin cities of Hyderabad and Secunderabad, The ergonomic evaluation of the graters was carried out on a multiparametric approach considering the two major aspects of subject and object (Lewis and Narayanan, 1993). To enhance the quality of process of evaluation, the present study was conducted with an objective of using Taguchi technique for the analysis.

Taguchi technique is a standardized form of experimental design technique used to enhance the quality of products and process. Design of experiments (DOE) using Taguchi approach attempts to improve quality, which is defined as the consistency of performance (Hsiang *et al*., 1997) Consistency is attained when variation is reduced which can be achieved by moving the mean



**Greater 1 (Level 1)**



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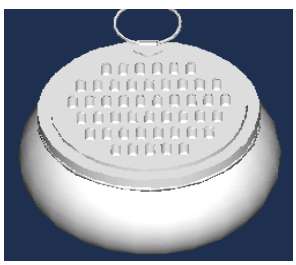

**Greater 3 (Level 3)**

**Fig. 1 : Graters used for the ergonomic evaluation**

performance to the target as well as by reducing variations around the target. Taguchi approach involves use of standard orthogonal arrays which are fractional factorial experimental models giving the pattern of combinations of levels of factors in each trial.

**Evaluation criteria:**

Experimental bearing samples were tested and performance was evaluated by observing comfort (weighed at 30%), efficiency (weighed at 40%) and safety (weighed at 30%). These three criteria were combined to produce an overall evaluation criteria (OEC). The OEC allows evaluation of multiple objectives using a single numerical index which is formed by combining the different criteria for evaluation when there are multiple criteria such as 'bigger is better' or 'smaller is better' where in interpretation is difficult, an average of these criteria was taken for average influences and easy interpretation, through which only one 'Quality Characteristic' (QC) can be considered (Roy, 2003). The QC in the present study is 'Bigger is better' where comfort, efficiency and safety are desired at higher levels.

## METHODOLOGY

Function of a product or a process can be viewed in terms of a 'system' that requires an INPUT to produce OUT PUT making use of many "factors". Such schematics representing the functions of a system is popularly known as process diagram. The analysis of ergonomic evaluation of graters using TAGUCHI technique is depicted in the Fig. 2.

For the ergonomic evaluation of grater, which is a process function, was given an input of three graters to produce an output of user's comfort, efficiency and safety utilizing the factors. The factors, which are not considered in the study, are termed as noise factors. Noise factors in this study were environmental factors *i.e.*, temperature, lighting, noise etc. For the analysis of ergonomic evaluation of grater, L-9 array was used. Experiments with Four 3-level factors were designed using L-9 arrays. An L-9 array has four3-level columns. The factors A, B, C, D could be assigned arbitrarily to the four columns. Table 1 shows the factors and levels considered for the study.

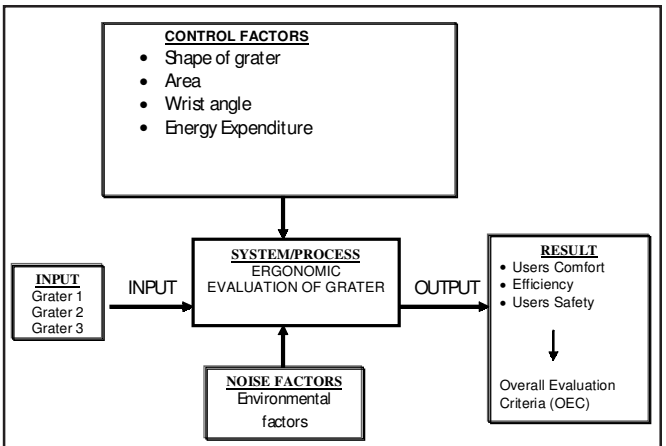


**Fig. 2 : Ergonomic evaluation of grater - process diagram**

**Table 1: Factors and levels considered for the study**

| Attributes | Factors | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| A | Shape of the grater | Rectangular-small | Rectangular-big | Round-box type |
| B | Area of the grater ($cm^2$) | 14 | 26 | 16 |
| C | Wrist angle (Degrees) | 53 | 86 | 84 |
| D | Energy expenditure (KJ) | 18.71 | 8.62 | 13.07 |

Instead of conducting $3^4$ trials, the experiment was conducted only with 9 trials and the product was optimized. The output factors considered to come out with overall evaluation criteria were comfort, efficiency and safety. The overall evaluation criteria (OEC) was constructed with the following formula:

**OEC= (X1/X1ref) W1+(X2/X2ref) W2+(X3/X3ref) W3**

where, X = Evaluation under a criterion

Xref = A reference (maximum) value of reading

W = Weighing factor of the criterion (in %)

Overall evaluation criteria was used as it offers an objective method of determining the optimum condition based on overall performance.

## FINDINGS AND DISCUSSION

Table 2 shows the results of overall evaluation of graters using L-9 array .The average factor influences showed trend of influence of various factors, which help to determine the desirable condition for the quality characteristic (QC). It also helps to determine the levels of the interacting factors most suitable for the desired performance (Table 3). 56.94 was the derived average performance value. The average performance at Level 1 ($A_1$') was 24.16; Level 2 ($A_2$') was 83.33 and Level 3 ($A_3$') of Factor A (shape of the grater). As the QC is "Bigger was better" the best performance was seen at Level 2 for Factor A.

For Factor B (area of the grater), the average performance at Level 1 ($B_1$') was 60.83, Level 2 ($B_2$')

**Table 2: Overall evaluation of graters using L-9 Array**

| Trial No. | Input-factors/ levels | | | | Output-response | | | |
|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | Comfort | Efficiency | Safety | OEC |
| 1. | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 20 |
| 2 | 1 | 1 | 1 | 2 | 4 | 2 | 2 | 52 |
| 3 | 1 | 2 | 2 | 1 | 4 | 2 | 1 | 46 |
| 4 | 1 | 2 | 2 | 2 | 5 | 5 | 5 | 100 |
| 5 | 2 | 2 | 3 | 1 | 5 | 4 | 5 | 92 |
| 6 | 2 | 3 | 1 | 2 | 3 | 4 | 3 | 68 |
| 7 | 3 | 1 | 3 | 2 | 4 | 4 | 5 | 86 |
| 8 | 3 | 2 | 1 | 3 | 2 | 3 | 4 | 60 |
| 9 | 3 | 3 | 2 | 1 | 4 | 3 | 3 | 66 |

The three levels taken were:
Level 1 - Grater 1
Level 2 - Grater 2
Level 3 - Grater 3

**Table 3 : Main Effects (Average Performance)**

| Sr. no. | Factors | Level 1 | Level 2 | Level 3 | L2-L1 |
|---|---|---|---|---|---|
| 1. | A | 24.16 | 83.33 | 63.33 | 59.16 |
| 2. | B | 60.83 | 60 | 50 | -8.33 |
| 3. | C | 36.66 | 65.83 | 68.33 | 29.17 |
| 4. | D | 49.16 | 60.83 | 60.83 | 11.67 |

was 60 and Level 3 ($B_3$') was 50, the best performance was seen at Level 1, the difference between average performances of Level 1 and Level 2 was minute, which indicates either level can be considered. The average performance at Level 1 ($C_1$') was 36.66, at Level 2 ($C_2$') it was 61 and at Level 3 ($C_3$') it was 68.33 for Factor C (Wrist angle), the best performance was seen at Level 3. The average performance at Level 1($D_1$') for Factor D (Energy expenditure) was 49.16, at Level 2 ($D_2$') it was 60.83 and at Level 3 ($D_3$') it was 60.83. As the QC was bigger is better the best performance was seen at both Level 2 and Level 3.

## Conclusion:

The optimum condition derived from the analysis was the shape of the grater at Level 2, area of the grater at Level 1/Level 2, wrist angle at Level 2 and Energy expenditure at level 2/level 3. The best combination identified was $A_2B_{1/}$ $B_2C_2$ $D_{1/}$ $D_2$. The most significant factor identified was shape of the grater followed by wrist angle. The most significant interaction in relative deceasing order was between area of the grater and wrist angle; wrist angle and energy expenditure; shape of the grater and energy expenditure and shape of the grater and area of the grater.

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