MATHEMATICAL DESCRIPTION OF A PROCESS OF MELON SKIN PIERCING BY CYLINDRICAL PIN

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Mathematical model of melon skin piercing by cylindrical pin was developed using mathematical and statistical methods; optimal parameters of pin were identified. The acquired model is used for calculation of melon slice transportation joint in the pilot unit for separation of skin from flesh.

The main task of our research is to optimize the parameters of melon skin piercing process: where x_1 is the pin sharpening angle (α, degrees) and x_2 is pin diameter (d, mm), at which the force of melon skin piercing F (N) has the best (optimum) value.

The solving of the set task was obtained by the methods of multifactor experiment planning, statistical processing of test data and search for optimization. The optimization parameters and most significant data affecting the melon skin piercing process were selected for this process; plan for conduction of experimental study was developed along with mathematical model made on the basis of obtained test data that was used for the study of influence of controlled factors on the output parameters of a process in a stationary factor space.

Laboratory research of melon skin piercing process was conducted by the full three-factor planning of experiments.

According to the experiment data the following was assessed for each index mean M and the mean error of m, median (med) and thickest value (mod), standard (mean-square) deviation s and variance s^2, the least (min – minimum) and the biggest (max – maximum) value, span R, asymmetry parameters A and kurtosis parameter E, variation ratio V.

Standard errors of resulting indices are less than 15% of the corresponding mean values. There is an approximate parity of the mean and median. The thickest value for Y is missing and the values of kurtosis are negative; minimum and maximum values are approximately equidistant from the average. It speaks about the closeness of empiric to normal or generalised-normal distributions.

The next stage of our research was the building of non-linear regression of melon skin piercing process. Using the estimates of b-factors it is possible to record the following quadratic regression equations for two parameters of melon skin piercing: Y – force of melon skin piercing F,N.

$$Y=10.07333 + 1.22767x_1 - 0.093000\,x_1^2 +$$
$$+ 5.17933x_2 + 0.41800\,x_2^2 + 0.73200x_1x_2.$$

The analysis of obtained values of Student's t-criterion and corresponding significance levels p confirms the significant influence on the resulting melon skin piercing forces indices: x_1 – pin sharpening angle, deg; x_2 – pin diameter, mm. Thus the most significant impact is from x_1 and x_2 parameters and from x_2, where y is $p<0.05$. The significance of x_1^2 and x_2^2 is not significantly impacts on the resulting criteria Y.

Thus, based on the data acquired during experiments and least-square methods, the quadratic regression equations were calculated.

Isolines or contour charts represent the projections onto the horizontal plane of horizontal sections of response surface resulting from the approximation of experimental data by quadratic regression.

Right of the graphs there are color marks, which make it possible to determine the range of values of controlled parameters, where the response function Y = F has the optimal value.

To determine the optimal value of Y, the obtained regression equations were used as target functions, and the lower and upper levels of variation of independent variables were taken as bilateral limits on the parameters studied. Optimization tasks were solved by relaxation. In this case the steps were selected based on heuristic assumptions on the type of response function.

Optimization criterion in the starting point $Yopt_1 = 18.63$ N.

Subsequent transformations showed that $x_1=39.9$. The coordinates of new point: $V_0=(39.9; 3.78)$. The amount of optimization criterion Yopt = 16.77 N since the further change of factors x_1 and x_2 does not lead to the significant change in the optimization parameter.

Optimality criteria values will be as follows: Y = F – the force of melon skin piercing, N. Y = 16.77 N.

Reliable and adequate regression equations of technological parameters were acquired that most fully characterize the studied technological process of melon skin piercing. Mathematical model was developed that will optimize the parameters of melon skin piercing process. Optimal value (Y) of melon skin piercing force and pin parameters were defined.