Veneer Lathe Settings by Computer Response-Surface Analysis

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Abstract

Veneer peeling machines have become increasingly sophisticated during the last few years: with the full computer control of the speed, nosebar compression, feed, or horizontal nosebar opening. But vertical nosebar opening has to be adjusted according to veneer thickness on certain levels, usually between 0.5 and 1 mm. In spite of very high degree of electronic and computer control, it is not possible to measure complex veneer quality indicators during the peeling process, and to obtain automatic veneer quality control. Measuring of veneer thickness standard deviation, veneer roughness, lathe check depth is possible only after peeling, and during the peeling we can compensate only predicted, and expected irregularities. Because of that it is important to have reliable method for veneer quality estimation and prediction.

Incomplete 3^3 Box-Behnken factorial design has been made with three levels of nosebar compression: 5%, 10%, 15%; three levels of knife clearance angle : 0.5°, 1 °, 1.5°; and three levels of nosebar vertical opening : 0.5 mm, 0.7 mm and 0.9 mm. According to the above design matrix, 15 poplar bolts 1.3 m long have been peeled into 3.5 mm thick veneer, with double-surfaced fixed nosebar. Three veneer quality indicators : veneer thickness deviation, veneer roughness and lathe check depth have been measured for each run. Response-surface analysis was applied to the averages for veneer quality for 15 sets of peeled blocks. The 3-D response-surface plots, polynomial equations and ANOVA tables have been obtained for each veneer quality parameter.

Key words: response surface methodology, veneer peeling, veneer quality prediction

Introduction

Veneer peeling lathe is a very complex dynamic machine system that works in circumstances of numerous stochastic influences, caused by openings in machine system, irregularities in the structure of wood, irregularities in nosebar compression, heat distortion, bending of the bolt at small diameters, vibrations, and so on. All of these irregularities have to be kept under control if we want to produce high-quality veneer.

In spite of very high degree of electronic and computer control, it is not possible to measure complex veneer quality indicators during the peeling process, and to obtain automatic veneer quality control. Measuring of veneer thickness standard deviation, veneer roughness, lathe check depth, or veneer tensile strength is possible only after peeling, and during the peeling we can compensate only predicted, and expected irregularities. Veneer peeling lathe requires very precise adjustment (with accuracy of 1/100 mm). Veneer peeling thickness computer control by means of hydraulic servo-cylinders, control of peeling speed, knife angle, nosebar compression, back up roll, by means of precision electronics, does not mean necessarily high quality veneer. Veneer quality is defined by nature of wood failures ahead of the cutting edge, and these failures are a function of wood mechanical properties and cutting geometry (Mc Millin 1958). It becomes obvious if we want to work with less known wood species or if we want to change knife or nosebar shape, or their relationships.

Producers of veneer lathes usually recommend veneer peeling schedules, with fixed vertical opening between 0.5 and 0.7 mm.depending on veneer thickness, and nosebar compression has to be adjusted by horizontal opening, often by means of computer control. Operator still needs to know which vertical opening, nosebar compression and knife angle are optimal in the particular case.

Very suitable method of solving this problem is Response-Surface Methodology (Warren 1980), which is used to estimate how veneer quality indicators respond to changes in nosebar compression, vertical opening and knife clearance angle. Due to development of PC computers, this analysis becomes fast, cheap, and reliable.

Experimental Design

In this paper, the objective is to find the combination of nosebar compression, vertical opening, and knife clearance angle, that results in the minimum of veneer quality indicators: thickness standard deviation, veneer roughness, and lathe check depth. As the functions of veneer quality parameters are different, it becomes a matter of joint optimization.

We introduced a highly efficient 3^3 incomplete experimental design known as Box-Behnken, with only 15 runs, while full factorial would require 3^3 -- 27 points (Warren, 1980). It is a central composite design in three dimensional factor space, with three replicates at the central point. The responses from these replicates were used to provide the mean response and an estimate of pure experimental uncertainty.

The values of three experimental variables were chosen carefully to cover the feasible range of each variable, as follows

1. 5%, 10% and 15% for nosebar compression
2. 0.5 mm, 0.7 mm and 0.9 mm for vertical opening
3. 0.5°, 1° and 1.5° for knife clearance angle.

After computer analysis, the form of the second order polynomial equation is obtained.

Material and Methods

There are many commercial computer software packages available, which can calculate the statistics required for this analysis. With one of these packages we obtained randomized design matrix, with 15 runs. According to this design matrix, 15 poplar bolts 1.35 m long, approximately of the same diameter, have been peeled into 3.5 mm thick veneer, with double-surfaced fixed nosebar. It was proved earlier that double-surfaced nosebar enabled better veneer thickness control and smoother veneer (Leney, 1960, Voskresenjskii, 1967). We also proved that veneer peeled by double-surfaced nosebar was 33% smoother than veneer peeled by conventional nosebar (Zdravkovic, 1991, 1992).

The bolts were peeled on the computer controlled veneer lathe, under constant speed of 100 m/min, with electronically controlled change. of knife clearance angle, and nose bar compression (with preset of horizontal nosebar opening). Vertical and horizontal openings were manually controlled and adjusted by comparater accuracy of 0.001 mm.

Veneer ribbon was scanned and clipped by the computer controlled rotary veneer clipper, and stacked on the vacuum stacker.

The green veneer samples, peeled from the same range of bolt diameter, were taken from the vacuum stacker, for each of 15 bolts (runs).

The veneer samples, 1.3 x 1 m, were dried at the Thermojet veneer dryer, to final moisture content of 8-12 %.

After conditioning for a few weeks, veneer thickness standard deviation (aprox. 70 measurements per each run), veneer roughness $R_{ma,}$ criteria (aprox. 100 measurements per each run), and lathe check depth, relative to veneer thickness, (aprox. 300 measurements per each run) were measured by usual methods (Zdravkovic, 1991, 1992).

Results

The complete uncoded design matrix together with all results has been shown in Table 1.

After computer analysis, the ANOVA tables, polynomial equations, and 3-D Response Surface Graphs have been obtained.

Table 1

Deign matrix with lathe settings and veneer quality for 3.5 mm poplar dry veneer						
Run	Nosebar compression (%)	Vertical opening (mm)	Knife clearance angle (°)	Thickness standard deviation (mm)	Veneer roughness (µm)	Lathe check depth (%)
1	15	0.5	1.0	0.119	110.36	62.71
2	10	0.5	0.5	0.110	106.80	62.46
3	5	0.5	1.0	0.091	105.02	64.30
4	5	0.7	1.5	0.064	120.15	62.89
5	10	0.9	0.5	0.122	138.84	61.54
6	10	0.5	1.5	0.086	113.92	62.00
7	15	0.9	1.0	0.067	95.23	65.40
8	10	0.7	1.0	0.065	117.48	65.65
9	10	0.7	1.0	0.076	105.91	61.26
10	15	0.7	0.5	0.064	105.02	59.33
11	10	0.9	1.5	0.122	110.81	60.95
12	15	0.7	1.5	0.119	107.25	51.98
13	5	0.7	0.5	0.112	105.02	66.13
14	5	0.9	1.0	0.096	113.92	65.27
15	10	0.7	1.0	0.066	112.14	63.75

Table 2

ANOVA table for Veneer thickness standard deviation and polynomial equation				
Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio
Total (corrected)	14	0,008487		
Regression	9	0,007409	0,000823	3,817
Residual error	5	0,001078	0,000215	
Lack of fit	3	0,00065	0,0003168	4,970
Pure error	2	0,000127	0,0000638	

$$y = 0.477 - 0.0029 * X_1 - 0.68 * X_2 - 0.3 * X_3 + 0.00014 * X_1^2 - 0.014 * X_1 * X_2 + 0.01 * X_1 * X_3 + 0.518 * X_2^2 + 0.09 * X_2 * X_3 + 0.069 * X_3^2$$

Coefficient of multiple determination $R^2 = 0,873$

Table 3

ANOVA table for Veneer roughness R_{max} and polynomial equation				
Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio
Total (corrected)	14	5419,469		
Regression	9	3700,134	411,126	1,19
Residual error	5	1719,335	343,867	
Lack of fit	3	1652,271	550,757	16,42
Pure error	2	67,064	33,532	

$$y = -79.403 + 17.91 * X_1 + 305.5 * X_2 + 7.62 * X_3 - 0.428 * X_1^2 - 13.5 * X_1 * X_2 - 1.29 * X_1 * X_3 - 62.229 * X_2^2 - 87.87 * X_2 * X_3 + 32.95 * X_3^2$$

Coefficient of multiple determination $R^2 = 0,683$

Table 4

ANOVA table for Lathe check depth and polynomial equation				
Source of variation	Degrees of freedom	Sum of squares	Mean square	Variance ratio
Total (corrected)	14	169,808		
Regression	9	111,826	12,425	1,071
Residual error	5	57,982	11,596	
Lack of fit	3	48,300	16,100	3,330
Pure error	2	9,682	4,870	

$$y=70.76 - 0.055 * X_1 - 47.06 * X_2 + 26.05 * X_3 - 0.015 * X_1^2 + 0.43 * X_1 * X_2 - 0.41 * X_1 * X_3 + 31.53 * X_2^2 - 0.332 * X_2 * X_3 - 12.3 * X_3^2$$

Coefficient of multiple determination R^2=0,658

Discussion

The veneer thickness standard deviation was in six lathe setting combinations greater than 0.105 mm allowed by standard for veneer thickness of 3.5 mm. ANOVA analysis shows that fitted model explains 87.3% of the variability in veneer thickness standard deviation. But R^2 should not be used by itself to indicate the effectiveness of factors. The F ratio of 4.97 is not significant, as tabulated value is 19.16 at p=0.05 probability level, thus confirming that the model is adequate. As shown in Fig. l, it is most effective to keep vertical opening above 0.7 mm, and the decrease of the opening causes over compression and unstable veneer thickness. Knife clearance angle must be kept at lower values of about 0.5°.

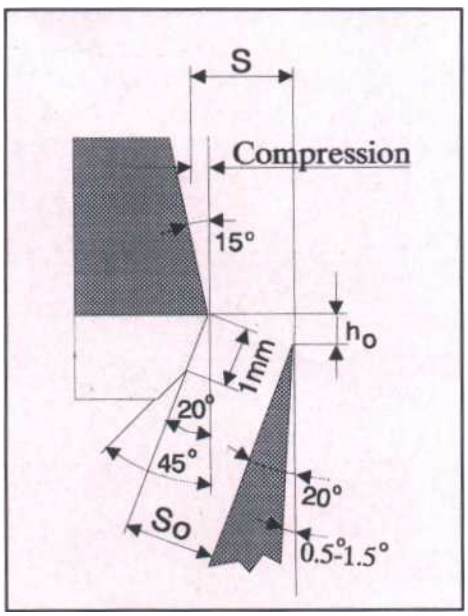

Fig. I: Double-surfaced nosebar (Zdravkovic 1991)

Effectiveness of double-surfaced nosebar was proved by low values of veneer surface roughness, with the highest value of 138.85μm that corresponds to VI class of veneer roughness, while GOST 7016-75 allows V class of veneer roughness (up to 320μm).

ANOVA analysis shows that the model explained 68.3% of the variability in veneer roughness. Calculated var-

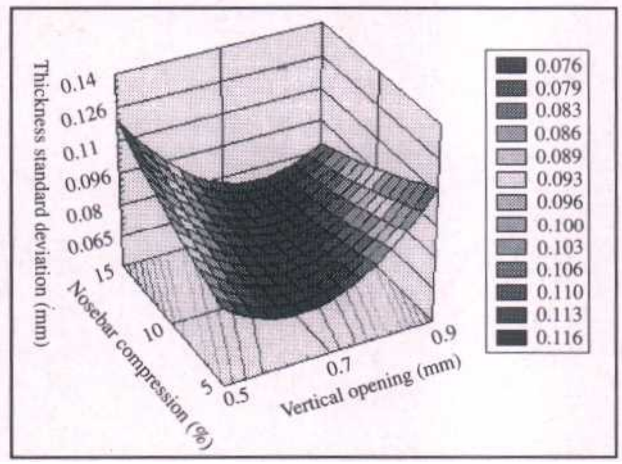

Fig. 2: Veneer thickness standard deviation response surface graph in the function of nosebar compression and vertical opening with clearance angle fixed at 1°

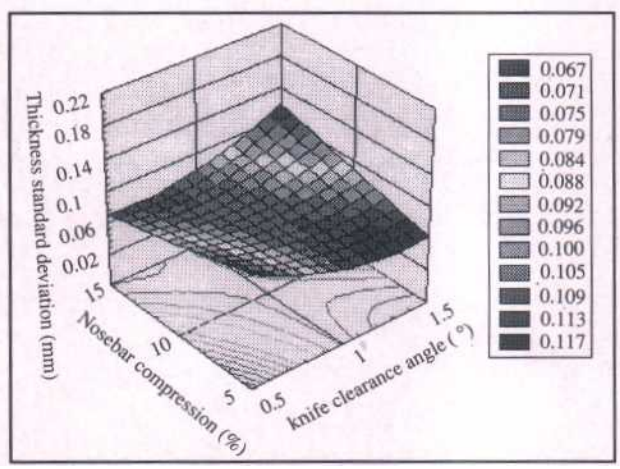

Fig. 3: Veneer thickness standard deviation response surface graph in the function of nosebar compression and clearance angle with vertical opening fixed at 0.7mm

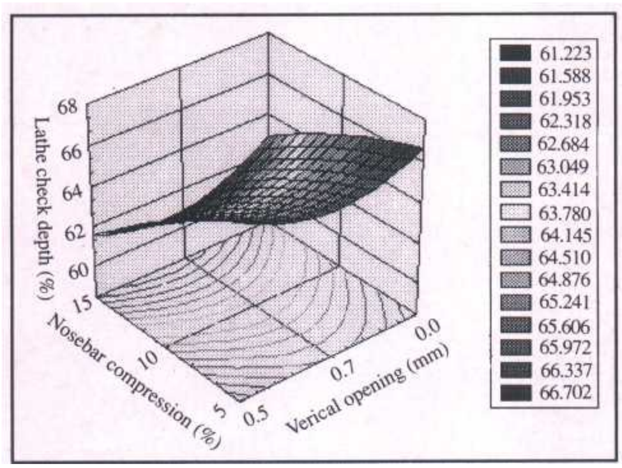

Fig. 4: Lathe-check depth response surface graph in the function of nosebar compression and vertical opening with knife clearance angle fixed at 1°

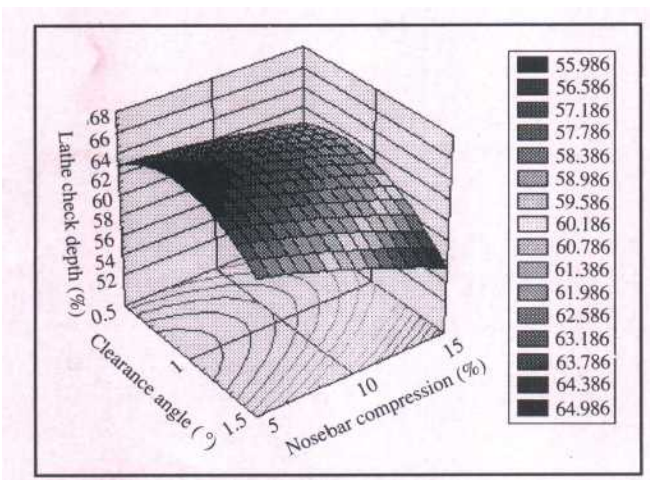

Fig. 5: Lathe-check depth response surface graph in the function of nosebar compression and knife clearance angle with vertical opening fixed at 0.7mm

iance ratio of 16.42 was still less than tabulated value at p=0.05 probability level, which indicates that the model is adequate. In the whole design region veneer roughness is less than it is allowed by standards, so this factor should be excluded in the joint analysis. Lathe check depths were more than 50% of veneer thickness, which could be expected because of veneer thickness of 3.5 mm. General trend is that lathe check depth *decreases* as nosebar compression increases, specially at higher vertical opening. The smallest values were at higher nosebar compressions about 15.% and vertical opening of 0.7 mm, with knife clearance angle of 1.5%.

If we carry out joint analysis of influence of lathe settings on veneer thickness standard deviation and lathe check depth, by simple examination of all the above graphs, the following trends are obvious: Both veneer thickness standard deviation and lathe check depth decrease as nosebar compression increases. It can be seen that veneer quality parameters reach the optimum at different lathe settings, so finding the optimum is the matter of joint optimization. There are many commercial software packages available, which can calculate the stastistics required for response surface analysis. It is not our intention to promote any of them so we would not mention their names. Most of them can give 3-D response surface plots, or contour plots, or both of them, as we presented in this paper. Three-dimensional plot is unpractical because we need to overlap responses for veneer thickness standard deviation, veneer roughness and veneer lathe check depth, and simultaneously find the optimum. Instead of that we used two-dimensional plot that traces the contours of the estimated dependent variable as a function of the other variables.

Each contour line represents combinations of the independent variables, which have a selected value for the estimated dependent variable. One can predict the next value for the dependent variable by following the ridge of the contour. If we obtain the contour plots for upper limits for veneer thickness standard deviation (6S), veneer roughness (R._) and veneer lathe check depth (LCD), the area where graph overlap is the optimum (Figure 6-7). For more detailed calculations, an optimization method such as the canonical analysis, should be carried out.

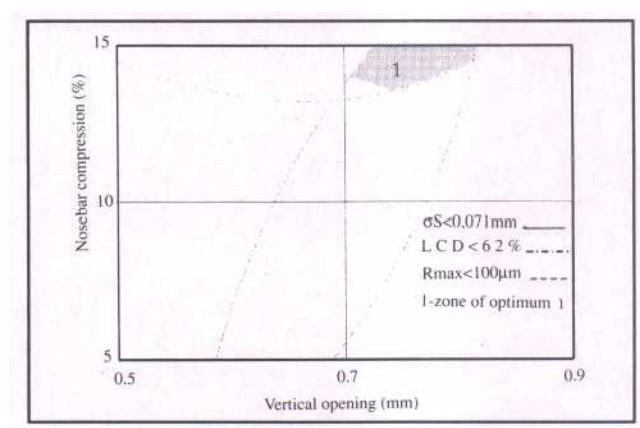

Fig. 6: Superimposed response contours of veneer thickness standard deviation, veneer roughness and lathe check depth, in function of nosebar compression and vertical opening

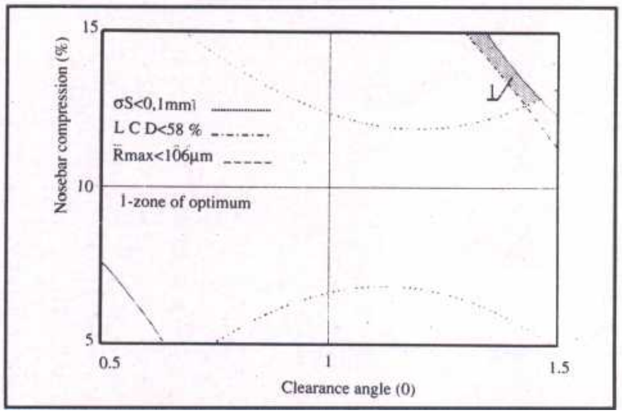

Fig. 7: Superimposed response contours of veneer thickness standard deviation, veneer roughness and lathe check depth, in function of nosebar compression and knife clearance angle

Conclusions

Although Response Surface Methodology is well known in the industrial experimentation, its implementation in plywood industry would be faster with the development of PC computers and suitable software. With the change of the nosebar geometry we carried out the whole experiment only on 15 bolts, researching the influence of this change, together with change of nosebar compression, vertical opening and knife clearance angle, on veneer quality.

In spite of relatively small number of experimental runs, and great variability of poplar wood properties, all models were adequate and reliable. Optimal area of lathe setting parameters is at nosebar compression of 14% - 15%, vertical opening of 0.72 mm - 0.82 mm and knife clearance angle of 1.3" - 1.4". One can predict the next value for the dependent variable by following the ridge of the contour.

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