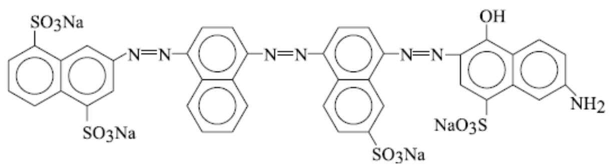
RESEARCH REGARDING THE INFLUENCE OF DYEING PROCESS CONDITIONS ON STRUCTURAL PARAMETERS OF COTTON KNITTED FABRICS

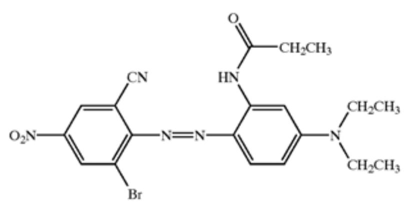
Mihaela MACSIM, Romen BUTNARU, Mihai PENCIUC
Gheorghe Asachi Technical University, Faculty of Textile-Leather and Industrial Management, Department of Chemical Engineering, Iasi, Romania
E-mail: mmacsim@tex.tuiasi.ro

Abstract
To obtain from the design phase of knits knitted textile surfaces with predetermined characteristics it is very important to know the influence of finishing process conditions on structural parameters of knitted fabrics. This paper presents changes in structural characteristics of plain-weft knitted fabrics from 50% Cotton and 50% Polyester blended yarns performed on CMS 530 E 6.2 weft flat knitting machine, Stoll, Germany, after finishing operations. For this purpose has been used multiple regression method with three independent variables. It was concluded that dyeing conditions have a decisive influence on structural parameters of plain-weft knitted fabrics and according to this textile materials destination may establish the dyeing process conditions leading to optimal values of structural parameters and appropriate knitted fabrics appearance according to destination.
Key words: plain-weft knitted fabrics, dyeing process, multiple regression method, structural parameters

1. Introduction
The knitted fabric is considered one of textile materials that largely meet the requirements of comfort due to specific properties. These properties such us elasticity, air permeability, water permeability, heat insulation, etc., are determined by three basic elements: raw material, knitted fabric geometry and structural parameters and finishing conditions.
Finishing process must maintain the dimensional stability of raw knitted fabric geometry, relaxed and improve it by removing the latent tensions existing inherent in the knit. Finishing process can influence by its parameters the dimensional changes and dimensional stability of the knits.
The purpose of this work is to establish the influence of dyeing conditions on structural parameters of plain-weft-knitted fabrics performed from 50% Cotton and 50% Polyester blended yarns.
The experiments were performed using a multiple regression method [1], taking as independent variables dyeing time process (minutes)-X_1, dyeing temperature (°C)-X_2 and pH dyeing bath noted with X_3 and as dependent variables following structural parameters: wale density, row density, the loop length and mass per unit area noted with Y_1, Y_2, Y_3 and Y_4 [2, 3].

2. Experimental part
For this study raw knitted samples made from 50% Cotton and 50% Polyester blended yarns performed on CMS 530 E 6.2 weft flat knitting machine, Stoll, Germany were used and subjected to dyeing operations using a direct dye (C. I. Direct Blue 71) and a disperse dye (C. I. Disperse Blue 183) [4, 5, 6].
The chemical structures of direct and disperse dyes are presented in Figure 1:





(C.I. Direct Blue 71) (C.I. Disperse Blue 183)

Fig. 1. Chemical structures of C.I. Direct Blue 71 and C.I. Disperse Blue 183

The dyeing bath composition:

- 1.5% direct dye
- 1.5% disperse dye
- 10% sodium chloride
- 2g/l wetting agent
- bath ratio 1:20
- pH alkaline performed with Na_2CO_3 (sodium carbonate) and pH acid performed with CH_3COOH (acetic acid).

Dyeing operations were performed using an installation type POLYCOLOR Mathis, according to the following diagram (Figure 2):

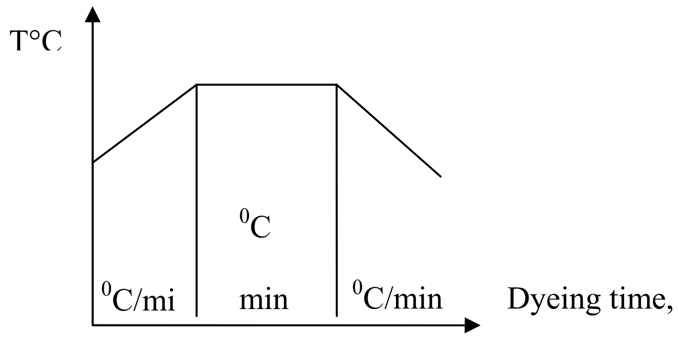


Fig. 2. Dyeing diagram of cotton knitted fabrics with direct and disperse dyes

Table 1 presents the values of independent variables and Table 2 presents the experimental plan and structural parameters values of knitted fabrics.

Table.1. The values of independent variables

Variable	Code	Coding value				
		-1.682	**-1**	**0**	**+1**	**+1.682**
	Real value					
Dyeing time, minute	X1	30	36	45	54	60
Dyeing temperature, °C	X2	80	88	100	112	120
pH-dyeing bath	X3	5.5	6	6.5	7	7.5

Table.2. Dyeing experimental plan and structural parameters values of knitted fabrics

Nr. exp	X_1	X_2	X_3	Y_1 **Wale density,** [wale/50mm]	Y_2 **Row density,** [row/50mm]	Y_3 **Loop length,** [mm]	Y_4 **Mass per unit area** [g/m^2]
1	-1	-1	-1	37	40	13.52	236.8
2	+1	-1	-1	35	41	13.42	234.4
3	-1	+1	-1	36	41	13.22	242.0
4	+1	+1	-1	36	42	13.32	259.0
5	-1	-1	+1	37	41	13.48	222.0
6	+1	-1	+1	35	40	13.36	234.4
7	-1	+1	+1	35	41	13.24	241.0
8	+1	+1	+1	37	41	13.26	231.0
9	-1.682	0	0	36	41	13.36	236.0
10	+1.682	0	0	37	42	13.42	236.0
11	0	-1.682	0	36	40	13.50	242.4
12	0	+1.682	0	35	42	13.20	241.6
13	0	0	-1.682	36	41	13.36	231.2
14	0	0	+1.682	36	41	13.48	237.0
15	0	0	0	36	41	13.36	235.0
16	0	0	0	37	42	13.38	236.0
17	0	0	0	37	42	13.36	236.8
18	0	0	0	37	42	13.36	236.8
19	0	0	0	37	42	13.36	236.8
20	0	0	0	37	42	13.36	236.8

Based on these data, using a factorial rotatable central program of order II, the following regression equations was achieved to determine correlations between the knitted fabrics structural parameters noted by Y_1, Y_2, Y_3 and Y_4 and those three variables considered for the study [7].

3. Results and discussions

3.1. Knitted fabric wale density, [wale/50mm]

Regression equation 1 describing the relation between this structural parameter and studied variables is of the form:

$$Y_1 = 36.837X_1 - 0.0233X_1 - 0.1257X_2 + 0.0026X_3 + 0.75X_1X_2 + 0.25X_1X_3 - 0.1105X_1^2 - 0.464X_2^2 - 0.2872X_3^2 \quad (1)$$

Thus, Figure 3 presents the variation of knitted fabrics wale density depending on dyeing time, temperature and pH dyeing bath.

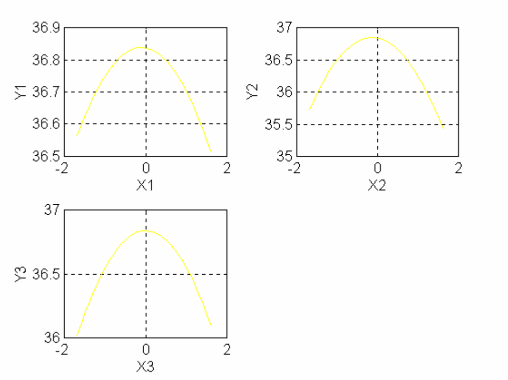


Figure. 3. The variation of knitted fabrics wale density depending on dyeing time, temperature and pH

It can be noted that the knitted fabrics wale density increases with increasing time up to value of 37 (wale/50mm), followed by a decrease of this structural parameter. The same thing it can be noted in case of knitted fabrics wale density variation depending on dyeing temperature and pH dyeing bath. From the regression equation it can be noted the interaction between dyeing time and temperature X_1X_2, while the interaction X_1X_3 (dyeing time and pH) and X_2X_3 (dyeing temperature and pH) are not confirmed.

Figures 4 and 5 presents in plane and space variation of knitted fabrics wale density depending on dyeing time and temperature, where it can be seen that the knitted fabrics maximum contraction is achieved at higher time values and temperature values located in the centre of experimental field. Regarding the knitted fabrics minimum contraction is achieved either at low time values and elevated temperatures or at higher time values and low temperatures.

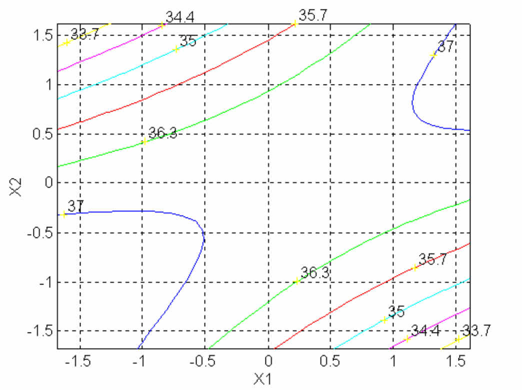


Fig. 4. In plane variation of wale density depending on dyeing time and temperature

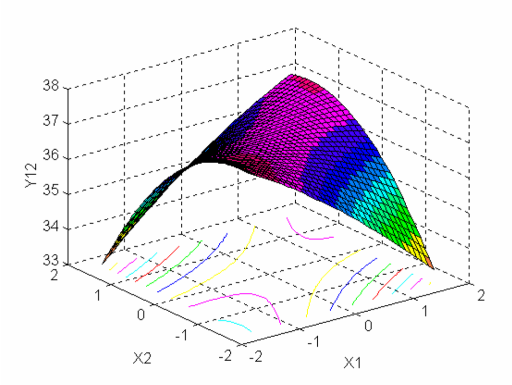


Fig.5. In space variation of wale density depending on dyeing time and temperature

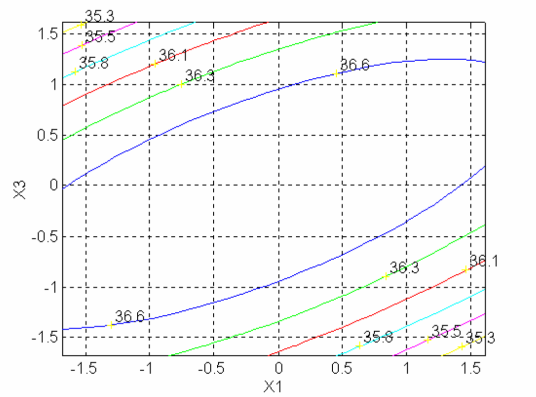


Fig.6. In plane variation of wale density

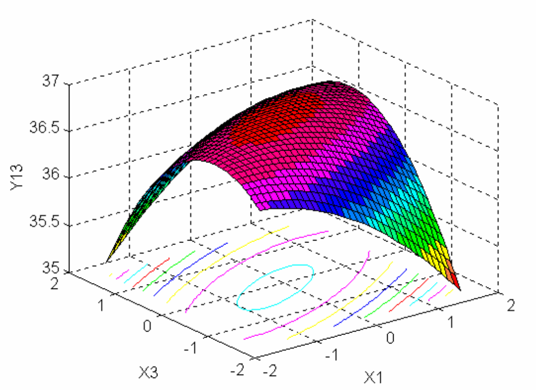


Fig.7. In space variation of wale density

depending on dyeing time and pH

depending on dyeing time and pH

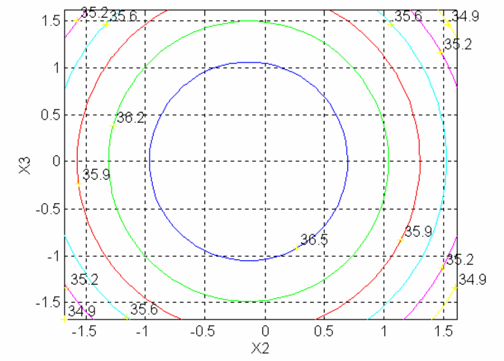


Fig. 8. In plane variation of wale density depending on dyeing temperature and pH

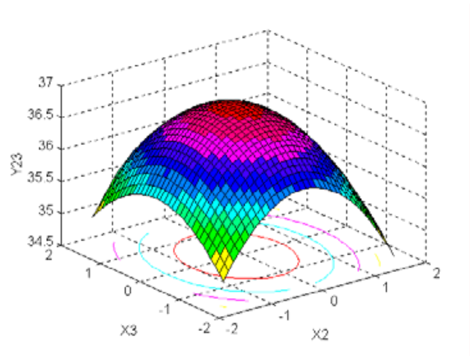


Fig. 9. In space variation of wale density depending on dyeing temperature and pH

Figures 6-9 presents in plane and space variation of knitted fabrics wale density depending on dyeing time and pH, dyeing temperature and pH, where it can be noted that the best results are achieved in the central area of the dyeing time, temperature values and in the maximum pH-values area.

3.2. Knitted fabric row density, [row/50mm]

Regression equation 2 which describe the relation between this structural parameter and the variables considered for this study is of the form:

$$Y_2 = 41.8475 + 0.1964X_1 + 0.4629X_2 - 0.0702X_3 + 0.125X_1X_2 - 0.375X_1X_3 - 0.125X_2X_3 - 0.1746X_1^2 - 0.3514X_2^2 - 0.3514X_3^2 \quad (2)$$

Figure 10 shows the variation of knitted fabrics row density depending on dyeing time (X_1), temperature (X_2) and pH (X_3).

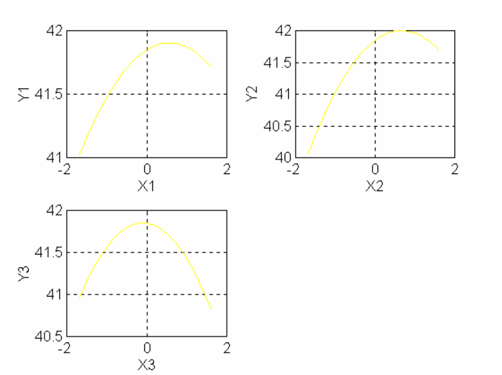


Fig. 10. The variation of knitted fabrics row density depending on dyeing time, temperature and pH

It can be noted that the row density increases with increasing time up to value of 42 (row/50mm), followed by a slow decrease of this structural parameter. The same behavior has also been reported in case of knitted fabrics row density variation depending on dyeing temperature and pH dyeing bath, except the fact that after an increase o knitted density which occurs with increasing of pH, follows a continuous decrease of this parameter.

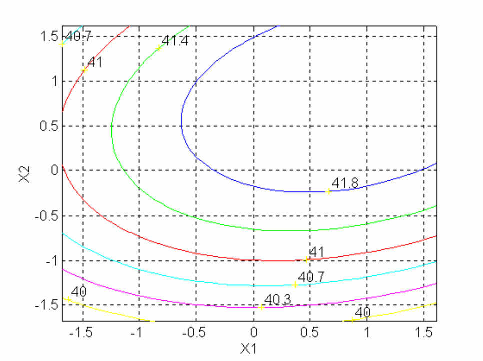


Fig. 11. In plane variation of row density depending on dyeing time and temperature

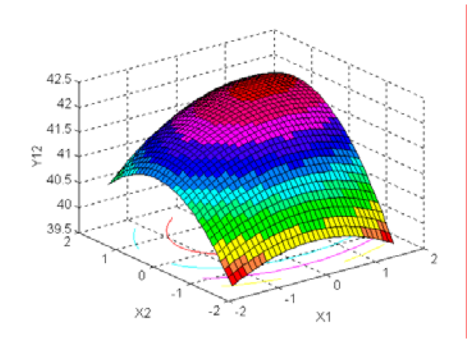


Fig. 12. In space variation of density depending on dyeing time and temperature

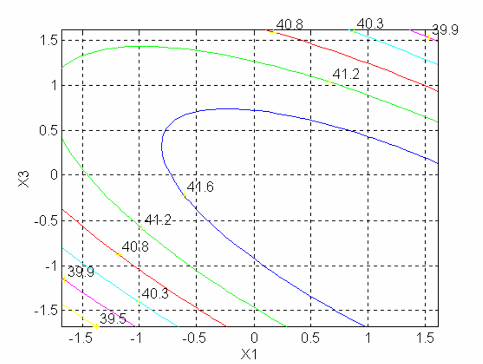


Fig.13. In plane variation of row density depending on dyeing time and pH

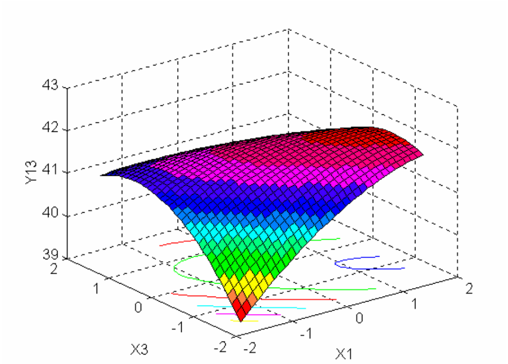


Fig.14. In space variation of row density depending on dyeing time and pH

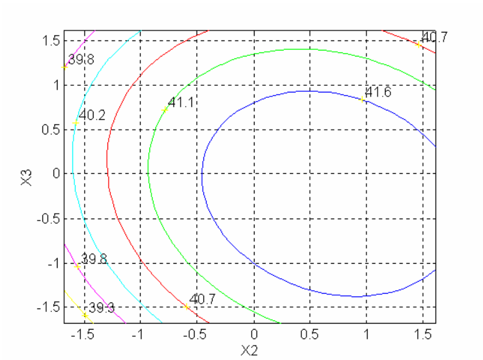


Fig. 15. In plane variation of row density depending on dyeing temperature and pH

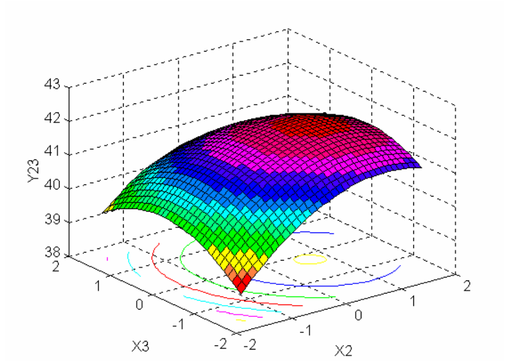


Fig. 16. In space variation of row density depending on dyeing temperature and pH

Figures 11-16 presents in plane and space variation of knitted fabrics row density depending on dyeing time and pH, dyeing temperature and pH, where it can be noted that the best results are achieved in the central area of the dyeing time, temperature values and in the maximum pH-values area.

In conclusion, it can be noted that both wale and row knitting densities, after finishing process changes, the knitted fabrics showing a tendency to shrink. But, depending on their destination one can establish the finishing process technological parameters leading to optimal values of wale and row knitting densities and appropriate look according to destination.

3.3. Knitted fabric loop length, [mm]

Regression equations 3 describing the relation between the knitted fabrics loop length and variables considered for this study is of the form:

$$Y_3=13.3664+0.0001X_1-0.0921X_2+0.0055X_3+0.0425X_1X_2-0.0125X_1X_3+0.0075X_2X_3+0.0007X_1^2-0.01234X_2^2+0.0113X_3^2 \qquad (3)$$

The regression equation describing the influence of three variables (dyeing time, temperature and pH) on the knitted fabrics loop length is plotted in Figures 17-23.

Thus, in Figure 17 it can be noted that the loop length decreases with increasing time up to value of 13.36 mm, followed by an increase of the structural parameter. The same behavior has also been reported in case of knitted fabrics loop length variation depending on pH dyeing bath, while the variation of this structural parameter depending on dyeing temperature, the loop length decreases with increasing temperature.

From the regression equation it can be seen the interactions X_1X_2 (time-temperature) and X_2X_3 (temperature-pH) and X_1X_3 (time-pH).

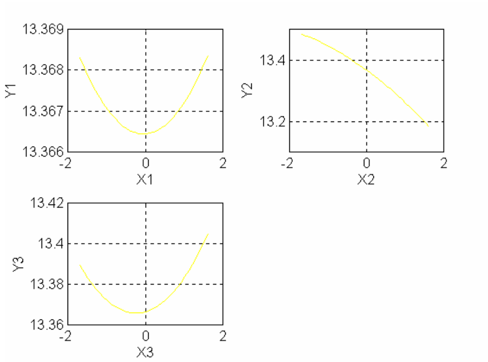


Fig. 17. The variation of knitted fabrics loop length depending on dyeing time, temperature and pH

Figures 18 and 19 presents the influence of interaction between dyeing time and temperature on the knitted fabrics loop length, where it can be seen that the maximum values of this structural parameter are achieved after dyeing operations of knits at low time and temperature values and the minimum values are achieved after dyeing operations of knits either at low time values and elevated temperatures or at higher time values and elevated temperatures.

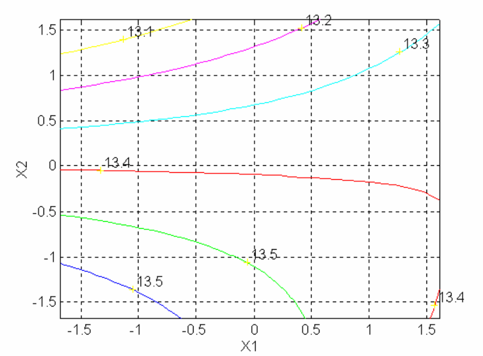


Fig.18. In plane variation of loop length depending on dyeing time and temperature

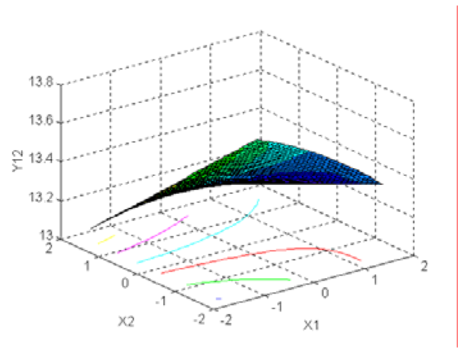


Fig.19. In space variation of loop length depending on dyeing time and temperature

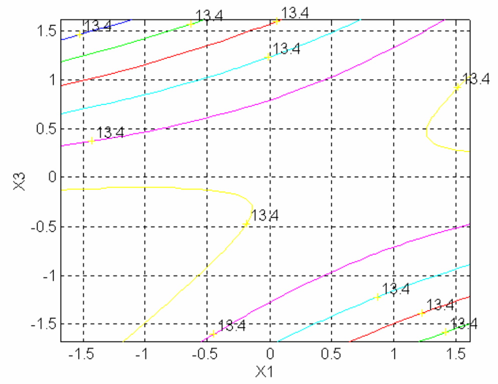


Fig. 20. In plane variation of loop length depending on dyeing time and pH

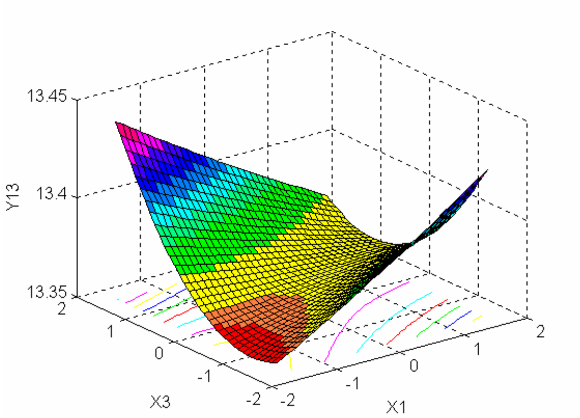


Fig. 21. In space variation of loop length depending on dyeing time and pH

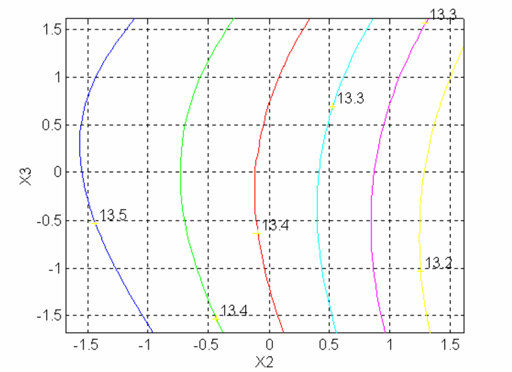


Fig.22. In plane variation of loop length depending on dyeing temperature and pH

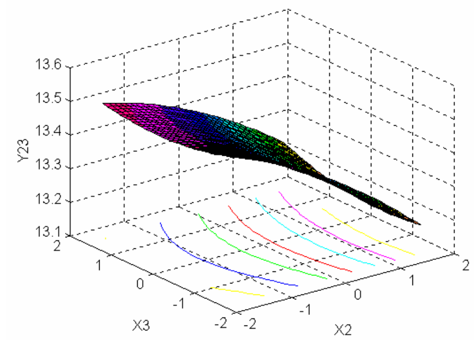


Fig. 23. In space variation of loop length depending on dyeing temperature and pH

Of interaction between dyeing time and pH plotted in Figures 20 and 21 it can be seen that this interaction does not significantly influence the knitted fabrics loop length.
Figures 22 and 23 presents in plane and space variation of knitted fabrics loop length depending on dyeing temperature and pH dyeing bath. It can be noted that the loop length maximum values are achieved after dyeing operations of knits at low temperature and pH-values and the loop length minimum values are achieved after dyeing operations of knits at low or high pH-values but at elevated temperatures.
From the results it can also be noted that no similar correlation between the influence of independent variables and structural parameters: the loop length and knitted fabrics densities and the increase of the loop length is not related to changes of knitted fabrics densities.

3.4. Knitted fabric mass per unit area, [mm]

Regression equation 4 describing the relation between this structural parameter and variables considered for the study is of the form:

$$Y_4=236.3966+1.2448X_1+3.2081X_2-2.4759X_3-0.375X_1X_2-1.525X_1X_3-1.775X_2X_3-0.1201X_1^2+2.0009X_2^2-0.7918X_3^2 \quad (4)$$

The influences of three variables (dyeing time, temperature and pH) on the knitted fabrics mass per unit area are plotted in Figures 24-30.

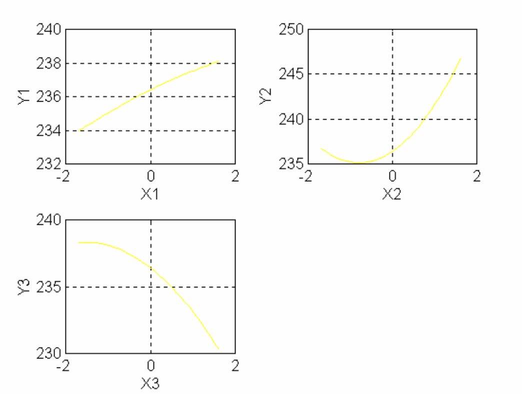


Fig. 24. The variation of knitted fabrics mass per unit area depending on dyeing time, temperature and pH

Thus, in Figure 24 it can be seen that the mass per unit area increases with increasing time, while the variation of this structural parameter depending on dyeing temperature, the mass per unit area decreases with increasing of variables up to value of 235 g/m^2, followed by a increase of the structural parameter. In case of knitted fabrics mass per unit area variation depending on pH dyeing bath, it can be noted a continuous decrease of this parameter which occurs with increasing pH-values.
From the regression equation it can be seen the interactions of those three variables X_1X_2 (time-temperature), X_1X_3 (time- pH) and X_2X_3 (temperature- pH).

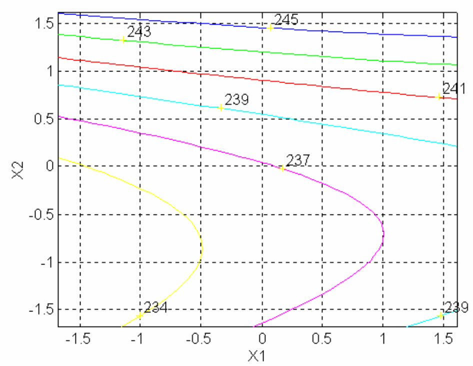


Fig.25. In plane variation of mass per unit area depending on dyeing time and temperature

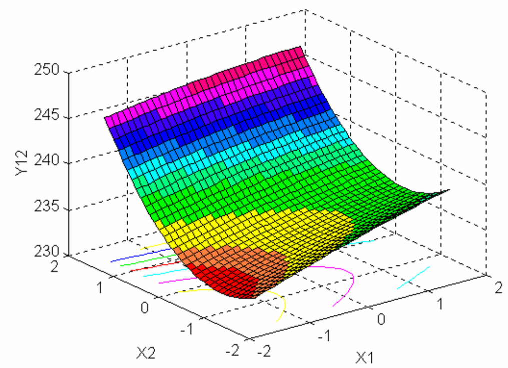


Fig. 26. In space variation of mass per unit area depending on dyeing time and temperature

From the interaction between dyeing time and temperature plotted in Figures 25 and 26, it can be noted that the knitted fabrics mass per unit area maximum values are achieved after dyeing operations of knitted fabrics at higher time values and elevated temperatures and the minimum values are achieved after dyeing operations at low time and temperature values.
Figure 27 and 28 presents in plane and space variation of knitted fabrics mass per unit area depending on dyeing time and pH, where it can be seen that the knitted fabrics mass per unit area maximum values are achieved after dyeing operations of knitted fabrics higher time values and low pH-values and the minimum values are achieved after dyeing operations at low time and higher pH-values.

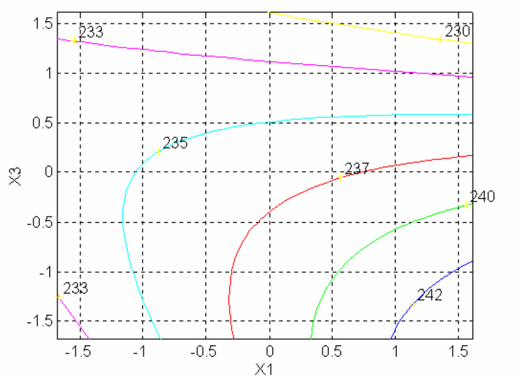


Fig.27. In plane variation of mass per unit area depending on dyeing time and pH

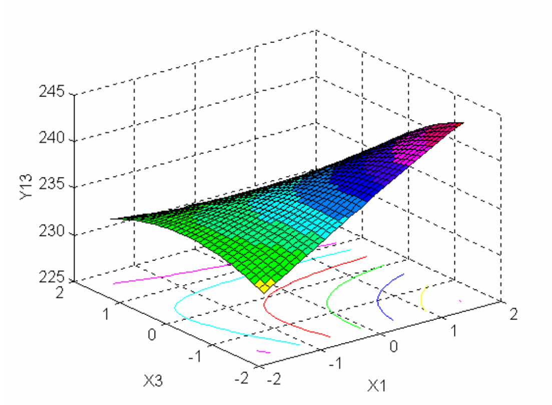


Fig. 28. In space variation of mass per unit area depending on dyeing time and pH

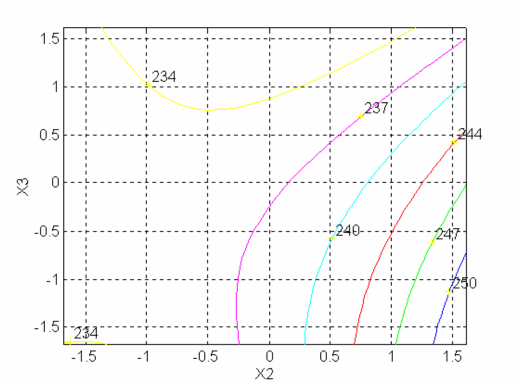


Fig. 29. In plane variation of mass per unit area depending on dyeing temperature and pH

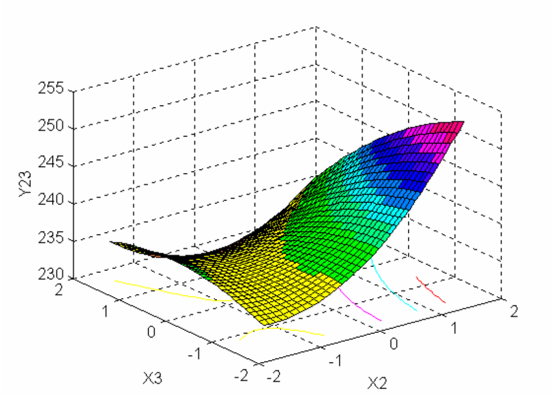


Fig. 30. In space variation of mass per unit area depending on dyeing temperature and pH

Figures 29 and 30 presents in plane and space variation of knitted fabrics mass per unit area depending on dyeing temperature and pH dyeing bath. It can be noted that the mass per unit area maximum values are achieved after dyeing at elevated temperatures and low pH-values and the mass per unit area minimum values are achieved after dyeing at low temperature values and higher pH-values.

Data analysis proves that the increase of knitted fabrics mass per unit area is strictly related to knitting densities change, the increase of densities causing the proper increase of the mass.

4. Conclusion

The objective of this work was to study the influence of dyeing conditions on structural parameters of plain-weft-knitted fabrics performed from 50% Cotton and 50% Polyester blended yarns. It was concluded that dyeing conditions have a decisive influence on of knitted fabrics and depending on the destination of knits one can establish technological parameters of finishing process (dyeing process) leading to optimal values of structural parameters and appropriate look of knits according to destination.

Moreover, in order to obtain knitted textile surfaces with predetermined characteristics from the design stage of knits it is very important to know the influence of finishing process conditions on structural parameters of knitted fabrics.

5. References

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