

## Dyfl.0 Software Code: Prediction and Processing data for Design of Yarns

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**Abstract:** The paper presents DYF1.0 software code for prediction and processing data for design of yarns. The design of the yarn is an important part of the whole yarns' production process, starting with the purchase of the raw materials and ending with the dispatch of winding yarns. The need for software codes for design of yarns is generated by the high demands on the quality of the yarns, combined with low prices. The stages in the yarn's design are presented. The main features of the DYF1.0 software code are also discussed in details. The application of the software code in designing and education is presented at the end.

**Keywords:** DYF1.0 software code, design of yarns, design of fabrics, yarns properties, blends

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### I. Introduction

As any other production, the production of textiles aims at the optimization of time, expenses and materials. This is particularly important in the production of yarns as they are rarely the final product that reaches the customers but most often are used as an input product in the manufacture of fabrics – knitted or woven. Therefore, the lower the cost of production, the more profitable the yarns are for the fabrics' manufacturers. The design of the yarn is an important part of the whole yarns' production process, starting with the purchase of the raw materials and ending with the dispatch of winding yarns [1]. The yarns' design is in the background of the manufacturing of quality textile products with low cost and this process is also a subject of several requirements: to be performed quickly and without errors, allowing multi-versions that provide quick "simulation" of options for finding the optimal for the particular type of fibers and yarns with a specific application [2]. The need for software codes for design of yarns is generated by the high demands on the quality of the yarns, irrespective of their application. Depending on their use, the yarns are subjects of demands that are related to their mechanical properties, chemical properties, consumer performance, etc. The most important indicators are uniformity of the cross-section, strength, and elongation at break and the variation coefficient of their average value resistance to abrasion, hairiness, volume, defects in appearance, resistance to weathering and chemicals, dyeing ability and others.

The factors that determine the quality of the yarns are divided into two groups [3]:

- Arising from the raw materials used for the yarn spinning. Raw materials are crucial as their indicators affect directly the yarn properties.
- Arising from the used technology, equipment status, and the qualification of the staff. They can influence the quality of yarns in both directions, to improve or deteriorate some of their properties, obtained as a consequence of the fiber properties.

There is a relationship among these indicators: for example, the unevenness in the cross-section of the yarn affects its strength and strength's regularity.

Before proceeding to the design of a yarn a technical assignment is necessary, which should contain the following information in a brief or an extensive form:

- Name of the item.
- Area of application.
- Technical requirements such as composition, structure, linear density, basic physical and mechanical properties of the yarn.
- Production technology, which will provide the desired performance.
- Economic requirements, including cost, the ex-factory price, and profit.

The software codes that today are created and used for designing of yarns are related in most cases to more complex software packages [4], which purpose is to simulate the structure and properties of the yarns as part of the complex structure of woven or knitted fabrics, or composite materials. A very good example in this direction is the software package WiseTex, which provides geometrical and mechanical models of yarns and textile macrostructures. It can simulate the internal geometry of woven, knitted, two- and three-axial braided fabrics, etc [5]. In the real manufacturing, however, the engineers in the design stage need fast and reliable products that enable the calculation of structural, geometric and mass characteristics of the staple fiber yarns. One possibility is to use excel spreadsheets, which was proposed in our previous works [6, 7]. Such an approach

is very useful also for the training of students. In the presented here DYF1.0 software code however, there are many more options for the consumer, while his participation in comparison to working with spreadsheets is less, as the worksheets require choosing the appropriate selection of data, coefficients, parameters and methods. The DYF1.0 software code is much more "black box" for the user, but in contrast, is more reliable and minimizes the human errors from incorrect choice. In the design of yarn in actual production, however, engineers need fast and reliable products that enable the calculation of structural, geometric and mass characteristics of staple yarns. One possibility is to use excel spreadsheets, which was made in a previous ours [6, 7]. Such an approach is very comfortable and the training of students. In the developed here software code, there are much more options for the consumer, while his participation in taking decisions is much less in comparison to working with spreadsheets that require choosing the appropriate table selection factors, parameters, and methods. The developed software code is much more a "black box" for the user, but in contrast, it is more reliable and minimizes the errors from an incorrect choice.

## **II. Yarns Design**

The design of the yarns includes the development of a technical project based on the assignment of the customer. The technical project, which is a basic document, includes:

- Selection of a raw material or raw materials, which is most often done on the basis of two indicators – linear density of the fibers and length of the fibers.
- Prediction of the spinning ability of the selected fibrous material; in some cases it is not possible to reach the required linear density with the selected fibers and then a correction is necessary or use of higher-quality raw materials.
- Theoretical determination of the strength of the yarns, which by any means has to be higher than the strength, indicated in the assignment or the standard value. If this requirement is not fulfilled, the composition of the fibers blend has to be revised.
- Selection of appropriate twist multiplier and /or second twist multiplier depending on the type of raw material and the final application of the yarns.
- Optimization of the fibers' composition, which will be used for spinning the yarn. This is necessitated by the fact that often the linear density and desired performance of yarns can be reached by raw materials of different quality. The aim is to find out the fibers composition that is the cheapest one but can ensure the necessary characteristics of the yarn. As the cost of the raw material has a substantial impact on the cost of the yarn, namely it is the objective function of the optimization process and its value has to be minimal. Restrictions in the objective function have to be introduced to guarantee the desired characteristics of the yarns.
- Selection of a spinning system, which is typically determined by the assignment, i.e. the linear density of the yarn and the required characteristics. If the spinning system is not specified, the designer needs to determine it, taking in mind the mentioned factors.
- Development of a spinning plan.

In some cases a separate technology project that includes complete characterization of the processing conditions for the production of the yarn is made. This project also involves the climatic conditions during processing and the quality control of the semi-finished and finished product.

The developed DYF1.0 software calculates the different characteristics of the yarns and for the substantial part of them the average value is calculated together with the dispersion and the variation coefficient is a measure for the irregularity of the particular characteristic.

The most important characteristics of the yarns that DYF1.0 software can predict are:

- *The average length of the fibers in the blend.* It is necessary the quota of the fibers from each component of the blend, and the average length of the fibers of each component to be known.
- *The linear density of the fibers in the blend.* The input parameters are the quota of the fibers of each component in the blend and the mean linear density of the fibers of each component separately.
- *The strength of the fibers in the blend.* The input parameters are the quota of the fibers of each component in the blend and the average strength of the fibers of each component separately.
- *The number of fibers in the cross section of the yarn.* This characteristic is important, so as to ensure the minimum number of fibers in the cross section of the yarn according to the system of spinning (a rotor spun yarn requires a larger number of fibers in the cross section than a ring spun yarn).
- *Twist.* Depending on the application of the yarn the necessary twists are defined. The metric and the critical twist multipliers are predicted.
- *Using the strength of the fibers.* The coefficient of utilization of the strength of the fibers in the strength of the yarn is calculated as a function of the fibers number and length, their irregularity, and the status of the equipment.

- *Theoretical strength of the yarn.* It is predicted on the basis of the strength of the fibers in the blend, taking into account the effect of the least stretchable component.
  - *Spinning ability.* It is calculated as a function of the linear density and length of the fibers in the blend, the average strength of the fibers in the blend and the theoretical strength of the yarn.
  - *Elongation at twisting.* It can be evaluated knowing the end-use of the yarns, its linear density and twist multiplier.
  - *Second twist multiplier.* It is determined according to the number of single yarns, their linear density and twist.
  - *Nominal and actual linear density* of the double folded yarn.
- These basic characteristics, together with the methods for their predictions are discussed in detail in [3].

### III. Using The DYF1.0 Software Code

The DYF1.0 (Design of Yarns and Fabrics) works in the frame of Microsoft DotNet Frameworks 4.0. The programming language C# was used for its development - Fig. 1. Two main modules are included – \*design of yarns and \*fabrics design (the fabric design will be presented in a separate paper).

```

double.TryParse(textBox13.Text, out Vlp);
alf1 = alf1 / 100;
alf2 = alf2 / 100;
textBox21.Text = Math.Round((((Lp * alf1) * ((Vlp * Vlp) + (10 * 10 * 10 * 10)) +
Math.Sqrt(((Vlp * Vlp) - (Vlpe * Vlpe)) * alf1 * ((Vlp * Vlp) + (10 * 10 * 10 * 10)))) / (alf1 *
((Vlp * Vlp) + (10 * 10 * 10 * 10)) - ((Vlp * Vlp) - (Vlpe * Vlpe))), 2).ToString();
for (int i = 0; i < lines.Length; i++)
{
    if (string.IsNullOrEmpty(lines[i]))
    {
        lines[i] = "V,ne = " + textBox18.Text + "[%]";
        break;
    }
}
for (int i = 0; i < lines.Length; i++)
{
    if (string.IsNullOrEmpty(lines[i]))
    {
        lines[i] = "e,ne = " + textBox19.Text + "[%]";
        break;
    }
}

```

Fig. 1. Part of the DYF1.0 code

In the main "File" menu the following sub-menus are set:

- "New" – clears the fields for a new calculation.
- "Save" – writes the data to a text file "Results"; with each new recording of the results from the predictions, the name of the file "Results.txt" has to be changed to avoid overwriting.
- "Exit" – closes the application.

The module "Design of yarns" enables the user to define a series of characteristics to be calculated; their choice may be individual and opens to individual screens.

Figure 2 shows the screen for fibers selection and a composition of a short fibers blend (cotton and cotton type man-made fibers). Each of the characteristics can be calculated and displayed automatically by the wish of the user. The boxes in white color require data entry, and the boxes in green bring out the predicted values. In addition, the symbol of the variable is written to the left of each box, and its dimension is written the right side of the box. The click on the button "Yes" makes the program to calculate the corresponding variable and to display the result in the box on the right side of its symbol. The software is very suitable for training as opportunities for familiarization with the basic formula for calculating or database (in tabular form), which is used to select certain parameters, are introduced. Figure 3 visualizes the same screen from Fig. 2, but the button "Table" is pressed and a window with the database is automatically opened. The window with the table (or formula) appears on the same basic screen, but clicking on the basic screen the table screen disappears; remaining open, but inactive, it can be called quickly and consulted further in the process of calculation. Similarly, the user can be informed of each formula by pressing the appropriate button. An additional window is shown in Fig. 4, which is opened to inform the user about the formula for calculating the coefficient of variation of the fiber's length.

Figure 5 illustrates the menu, which predicts the characteristics of a blend of fibers. Figure 6 shows the screen of the menu, which calculates the theoretical strength of the yarn, and Fig. 7 – the menu for calculating the spinning ability of the fibers in the blend.

The relationship between the individual menus is by default: although the user may need only a part of the output data, she/he is obliged to introduce the necessary data inputs - if any of the input data is missing, the program provides information about an error in an input parameter.

**1.Подбор на памучните влакна**

1.1.Дължина

L1 33 [mm] Lл 34.2 [mm]

L2 35 [mm]

α1 40 [%] Таблица

α2 60 [%] \*Съдържание на влакната

Да Формула-1

1.2.Линейна Плътност

Тт1 1.5 [dtex] Ттл 1.56 [dtex]

Тт2 1.6 [dtex]

Да Формула-2

1.3.Здравина

R1 34 [cN/tex] Rл 33.4 [cN/tex]

R2 33 [cN/tex]

Да Таблица

Rл 5.21 [cN]

Да Формула-3

Fig. 2 Menu “Fibers selection”

**1.Подбор на памучните влакна** 1.4.Вариационен Коэффициент

1.1.Дължина

L1 33 [mm] Lл 34.2 [mm]

L2 35 [mm]

α1 40 [%] Таблица

α2 60 [%] \*Съдържание на влакната

Да Формула-1

1.2.Линейна Плътност

Тт1 1.5 [dtex] Ттл 1.56 [dtex]

Тт2 1.6 [dtex]

Ттл [dtex]

Формула

Показател	Качество	Тип влакна						
		1	2	3	4	5	6	7
Щапелна дължина, mm	O, I-во,II-ро	38-39	37-38	35-36	33-34	31-32	30-31	29-30
	III-то	36-37	36-37	35-36	33-34	31-32	30-31	29-30
	IV-то	35-36	35-36	35-36	33-34	31-32	30-31	29-30
Специфична здравина, cN/tex	O, I-во	33,3	31,4	29,4	25,5	24	23,5	23
	II-ро	32,3	30,4	28,4	25	23,5	23	22,5

Fig. 3 Display screen with additional database

1.4.Вариационен Коэффициент

V1 [%] Vсм 1.56 [%]

V2 [%]

Да Формула-4

εл [%] \*Разтегливост на памучните влакна

Формула

Дисперсия

$$V^2 = \sum_1^k \alpha_j \cdot V_j^2 \cdot \left(\frac{x_i}{x}\right)^2 + 10^4 \cdot \sum_1^k \alpha_j \cdot \left(\frac{x_i}{x} - 1\right)^2$$

Вариационен коефициент

$$V_{Lсм} = \sqrt{V_L^2}$$

Vле [%] - Вариационен коефициент на химичните влакна

εле [%] - Разтегливост на химичните влакна

Rле [cN/tex] - Здравина на химичните влакна

Lле [mm]

Да Формула-5

Fig. 4 Display screen with additional equations

Вид на преждата	Суков коефициент
1. Мокропредена от дълги влакна	90..110
2. Сухопредена от дълги ленени влакна	75..100
3. Мокро и сухо предена от хехелован дреб	90..115
4. Мокро и сухо предена от швингован дреб	100..120
5. От дълги конопени влакна	90..110
6. От къси конопени влакна	100..110
7. От юта	75..85
8. От кенаф	80..90

Fig. 5 Menu “Prediction of the characteristics of the blend”

Fig. 6 Menu „Theoretical determination of the fibers’ strength in the blend”

Fig. 7 Menu „Prediction of the spinning ability”

#### **IV. Conclusions**

One of the main advantages of the developed DYF1.0 software code is that the user has continuous contact with the methodology for prediction of the yarn's properties during the design process. The program also provides a feedback that indicates errors in the input data. Thus the user can iteratively explore different options with varying efficiency of the decision before the yarns are actually spun. This gives rise to alternative designs that correspond to the same technical assignment, but without the physical need to produce samples of real yarns. So through "simulation" of various design decisions during the design phase, the total cost of design as part of the cost of the final product is significantly reduced. Another advantage of the DYF1.0 software code can be found in its application in the learning process of students or engineers, as they can explore the design of yarns at different levels of abstraction. The better prepared the user, the faster she /he can predict the effect of the change of some of the input parameters of the fibers and blends on the geometric, structural and mass characteristics of the yarns or their properties, which are subject to prediction.

On the third place, the DYF1.0 software code is an effective means of demonstrating concepts in the teaching process. Although this version of the software does not have a postprocessor such as graphical or animation output, such processing can be easily be done in the frame of other software packages of Microsoft, including that of MS Office. Indicating the possible decisions taken by the input parameters as properties of the fibers, desired parameters of the yarns and their further application, the student can track what would happen in the process of the production chain and be with a better understanding of the dynamics of the spinning processes. In conclusion, the development of computer code in the frame of Microsoft DotNet Frameworks 4.0 allows an easy increment of users, as many of them work with Microsoft Windows, and .NET Framework software framework runs primarily on it.

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