Classic or unconventional cotton yarns?

A Bucevschi¹, M S Fogorasi¹, C Nicolaescu² and I Barbu¹

¹“Aurel Vlaicu” University of Arad, Faculty of Engineering, Department of Automation, Industrial Engineering, Textile and Transportation, Revolutiei Avenue, 77, Arad, Romania
²“Aurel Vlaicu” University of Arad, Faculty of Economics, Department of Economic Disciplines, Revolutiei Avenue, 77, Arad, Romania

E-mail: ionelbarbu@yahoo.com

Abstract. In this paper we compared a classic and an unconventional system for the manufacturing of cotton yarns 100%. For this comparison we analyzed the complexity of classical and unconventional technological lines, the differences between the yarn structures, the fields of use of the yarns, as well as a cost-benefit analysis.

From the point of view of the complexity of the technological lines and implicitly of all the necessary adjustments we can say that the technological line for the unconventional system is much easier and shorter. Considering the complexity of technological lines, we can say that the human resources requirement is much lower for unconventional technological lines. For this we realized a comparative calculation of costs for workers and for taxes that an employer has to pay. Starting from the complexity of the technological lines, the unconventional technological line being shorter with two machines, we made a comparative calculation of the energy consumption. The calculations were made for a spinning mill with a production of 4000 t/year, a typical production for a medium size. From the point of view of the production costs and investment effort, we can say that the unconventional system is better, but considering the structure of the yarns we can say that the destinations are different, so the unconventional yarns are better suited to certain products, such as the jeans clothing.

1. Introduction

Patented in 1937 by Berthelsen, the unconventional open-end spinning system was introduced in industrial practice in 1965, when the first OE spinning machine was made by the Elitex company from Czechoslovakia. The structure and characteristics of yarn alter according to the production phase and the spinning system applied for manufacturing. Besides, the technology used for yarn formation relies upon the fibers involved, expected properties of manufactured yarn and certainly on economic significance,[1].

The spinning systems comprise conventional and unconventional approaches. Based on this classification, the ring spinning system is considered as conventional system while open-end, OE, wrap, air-jet and self-twist spinning technologies are unconventional systems. Regardless of the embraced system, the major target of the spinning technology is to attain enhanced production with acceptable yarn quality, [2].

This paper deals with a comparative study traced between a classic and an unconventional system for the manufacturing of cotton yarns 100%. For this comparison we analyzed the complexity of
classical and unconventional technological lines, the differences between the yarn structures, the fields of use of the yarns, as well as a cost-benefit analysis, [3].

Accordingly, the first part of the paper comprises an evaluation of the two technological lines including all technological phases, the semi-finished product and the obtained yarns.

Further, the structure analysis of the two types of yarns occurs, according to the arrangement of the fibers in the yarn construction.

The economic component of the analysis covers several areas, namely: Cost with raw material; Amortization costs as a result of the investment effort; Costs due to human resource, wages and social tasks and costs caused by energy consumption.

2. Analysis of technological flows
Aim of the study lies in the comparison of the classic flow, carded system, and unconventional flow [4]. The technological line for the classic flow is represented in figure 1.

![Figure 1. Classic technological flow (line).](image1)

Used abbreviations: B – blow rooms; C – cards; DF I – draw frames, the first passage; DF II – draw frames, the second passage; RF – roving frames; RSF – ring spinning frames; WM – winding machines.

The bands obtained at the last passage of drawing frame are fed directly to the spinning machine OE with the rotor where the yarns are made as the final spinning product. In the classical system, the bands obtained at the last passage of the drawing frame are fed to the roving frame, which produces the roving, then this semi-finished product is fed to the classic spinning machine with rings. The yarns will be further processed in the weaving and knitwear industries. In both cases the yarns are processed from the coils. The unconventional machine produces yarns deposited on coils, and the classical machine makes yarns deposited on a cops with a weight up to 100 g. The yarns from the cops have to be passed on big formats with a mass of 1.5-1.7 kg, which is done on winding machines. So also from this point of view the unconventional system is shorter.

![Figure 2. Unconventional technological flow (line).](image2)

Further figure 2 presents the technological line for the unconventional flow [4, 5] where OESF represent the unconventional spinning machines open-end with rotor.

The unconventional technological line is much shorter than the classic one. As it obvious from the flow, this line does not contain neither roving frame, RF, ring spinning frame, RSF, not winding machines, WM, it comprises only open-end spinning frame, OESF. Nevertheless, for both technological lines, the second passage draw frames, DF II, is mandatory component of the technological flow.

![Figure 3. Classic technological line. Semi-finished and finished product.](image3)
The differences between the two lines along with the obtained semi-finished product are highlighted in figures 3 and 4.

![Figure 4. Unconventional technological line. Finished product.](image)

The investigation of the two procedures indicates an increased investment effort for the classical technological line since this line contains additional several types of machines compared to the unconventional line, namely roving frames and winding machines. From the point of view of manufacturing technology, it can be considered that the classical technology line is much more expensive due to the enhanced number of semi-finished products. Consequently, this leads to more interruptions of the technological flow, numerous several inter-phase control qualities along the line, after several machines.

### 3. Analysis of the yarn structure and destination

The figures 5 and 6 present the structures of the classic or unconventional yarns, [4]. A significant difference between the two structures is visible without a laborious analysis.

Classical spinning machines with rings can produce yarns up to the fineness of Nm 270, by drafts between 8 and 130. From the technological point of view, it is recommended that the draft value should not exceed 80, otherwise the yarns exhibit a higher irregularity and breaking frequency.

From performance standpoint, the ring-spinning frame can create yarns up to Nm 500, a value with which Rieter entered the record book. These extremely fine yarns were produced from Egyptian cotton fibers characterized by a length of over 40 mm and very high fineness, with Nm > 10000. Actually, from practical viewpoint this achievement is not considered a performance because it is really difficult to use such fine yarns of Nm 500. Commonly, yarns with fineness up to Nm 140 are used.

In the structure of the classic yarn, the fibers have a random position. Besides, the number of fibers in the cross-section and their radial positions is also variable. Moreover, for a mathematical analysis, we can approximate that fibers describe helical trajectories, after a right cylindrical screw.

Taking into account the fiber positioning in the yarn structure, it is obvious that most fibers contribute with their own breaking load to the yarn breaking load.

Unconventional OE rotor spinning machine can produce fine yarns up to 100-120Nm, but basically fine yarns up to 100Nm are used. Above these values the yarns are uneven.

![Figure 5. Structure of classic yarn, [4.](image)

The presence of short fibers, with different lengths in the range of 10-40mm, with a rather large non-uniformity of the length of the fibers, exert an influence upon the irregularity of the yarn fineness. Thus, this fineness irregularity generates irregularity of the burst load along the yarn.

![Figure 6. Structure of unconventional yarn, [4]](image)
Furthermore, the structure of the unconventional differs from that of the classic yarn. It is easily observable that on the outside of the yarn the fibers have a variable torsion angle. Thus, few fibers present a helical arrangement while other fibers coat as a ring the fibers from the middle layers of the yarn. Accordingly, this structure resembles to a core yarn.

The fact that the yarns are not so compacted as the classic yarns, cause to a high degree of swell. These yarns are bulkier, so they suit better for thicker clothing such as jeans.

4. Analysis/ Evaluation of production costs

For the production costs evaluation, the two technological lines, classical and unconventional, were taken into consideration. These lines, designed for 100% cotton fibers processing, produce yarns with average fineness 27Nm and a total production of 4000 tons/year.

The types of yarns included in the study are comprised in table 1.

Table 1. Types of yarns.

| Yarn number | Fineness, Nm | Destination | Weight in production, % |
|-------------|--------------|-------------|-------------------------|
| 1           | 24           | Weft        | 49                      |
| 2           | 27           | Warp        | 30                      |
| 3           | 34           | Warp        | 21                      |

The comparative analysis of production costs encompasses: raw material costs; amortization costs as a result of the investment effort; costs due to human resource, wages and social tasks; costs caused by energy consumption.

Prior the evaluation, we calculated the parameters of the preliminary spinning plan aiming to establish the kinematic and technological parameters required to obtain yarns with a quality according to the standards.

Table 2. Components of final spinning plan.

| Technological phase                  | Number of machines classic technology | Number of machines unconventional technology |
|--------------------------------------|---------------------------------------|---------------------------------------------|
| Blowroom                             | 1                                     | 1                                           |
| Cards                                | 30                                    | 30                                          |
| Draw frames, I and II                | 14                                    | 16                                          |
| Roving frames                        | 8                                     | -                                           |
| Ring spinning frames                 | 59                                    | -                                           |
| Spinning machines open-end with rotor| -                                     | 26                                          |
| Winding machines                     | 6                                     | -                                           |

Further, the calculation part envisages the theoretical production for each equipment contained in the technological flow along with the performance of the machines and the practical production.

Based on the of technological losses, the need of semi-finished products was calculated for each technological phase, followed by calculus of machine number in order to establish a correlation of production capacities, table 2.

All these are constituents of the final spinning plan that provide us with data about the quantities of raw materials and semi-finished products and the number of machines for each technological phase.

4.1. Raw material costs

Considering the normative technological losses, for both classical and unconventional technological flow, the value calculated for the yield of raw materials utilization is 94.5%
Technological lines run 254 days/year, 24 hours/day, 3 shifts of 8 hours excluding holidays and holidays as non-working days. From the calculations of the final spinning plans resulted a requirement of 694.4 kg/h raw material for both technologies.

So, in terms of production costs for raw material, based on the specific consumption norms, no differences could be noticed between the classic and unconventional technological flows.

4.2. Amortization costs as a result of the investment effort
Starting from the FOB prices of the machines, an investment effort of 121.914 million RON for the classic line and 49.999 million RON for the unconventional technology were necessary, for an average course of 1 USD = 4.1988 RON. This value encompasses the transport costs and customs duties too.

In the study, we did not take into account the costs for purchasing beating aggregates and cards because the two analyzed technological lines implies the same number of these machines.

According to the government decision HG 2139/30.11.2004 [6], given the working regime, 24 h/day, for these equipment, an amortization period of 8 years was adopted.

Under this circumstance, the amortization for the classic and unconventional technology is 15.239 mil. RON/year, and respectively 6.249 mil. RON/year, table 3.

| Equipments | Classic technology | Unconventional technology | Purchase price, USD (without VAT) |
|------------|--------------------|---------------------------|----------------------------------|
| DF         | 14                 | 16                        | 85000                            |
| RF         | 8                  | -                         | 240000                           |
| RSF        | 59                 | -                         | 275000                           |
| OESF       | -                  | 26                        | 300000                           |
| WM         | 6                  | -                         | 500000                           |
| Total      | 93780198           | 38461008                  |                                   |
| Total transportation costs, RON | 121914257 | 49999310                  |                                   |
| Annual amortization, RON | 15239282 | 6249914                   |                                   |

The results reveal a difference 8.989 mil. RON/year, which related to the total production of 4000 tone/year, result a cost of 2.25 RON/kg of finished product.

Thus, in the classic technology, costs will be higher by 2.25 RON/kg due to the higher investment effort by approximately 144%.

4.3. Costs due to human resource, wages and social tasks
For this purpose, the calculation of the needed human resource was accomplished according to the number of machines and their service standards.

The number of employees for each technological phase, men, M, and women, W, required for the three production shifts is noted in the table 4, for classic technology, and table 5, for unconventional technology. These values include also personnel reserves for medical leave, situation and vacation.

Accordingly, the classic approach requires 310 workers whilst the unconventional one only 243 workers.

In Romania, the salary of basic workers in the textile industry has the lowest in the economy compared to other industries.
According to HG 937/2018, the minimum gross salary from 1st January 2019 is 2080 lei per month [7]. To these wage costs are added also costs regarding social contribution allowances. Therefore, for the companies this implies a minimum labor cost of 2127 RON/month for each worker.

| Profession name                  | Shift I |  | Shift II |  | Shift III |  | Total | Reserve | Total |
|----------------------------------|---------|---|----------|---|-----------|---|-------|---------|-------|
| Blow room                        | W       | 1 | M        | 8 | -         | 5 | -     | 5       | 19    | 1     | 20    |
| Cards                            | W       | 7 | M        | 6 | 7         | 2 | 7     | 2       | 31    | 1     | 32    |
| Draw Frame I and II              | W       | 6 | M        | 2 | 6         | 1 | 6     | 1       | 22    | 1     | 23    |
| Roving Frame                     | W       | 8 | M        | 2 | 8         | 1 | 8     | 1       | 28    | 1     | 29    |
| Ring spinning                    | W       | 30| M        | 8 | 30        | 7 | 30    | 7       | 112   | 7     | 119   |
| Quality control                  | W       | 4 | M        | - | 4         | - | 4     | -       | 12    | -     | 12    |
| Windind                          | W       | 2 | M        | 1 | 2         | 1 | 2     | 1       | 9     | -     | 9     |
| Warehouse raw materials          | W       | 1 | M        | 1 | -         | - | -     | -       | 2     | -     | 2     |
| Yarn deposit                     | W       | 1 | M        | 4 | 1         | 2 | 1     | 2       | 11    | -     | 11    |
| Diverse personnel                | W       | 2 | M        | 17| 2         | 15| 2     | 15      | 53    | -     | 53    |
| Total staff                      |         | 60| M        | 48| 58        | 33| 58    | 33      | 290   | 11    | 310   |

| Profession name                  | Shift I |  | Shift II |  | Shift III |  | Total | Reserve | Total |
|----------------------------------|---------|---|----------|---|-----------|---|-------|---------|-------|
| Blow room                        | W       | 1 | M        | 8 | -         | 5 | -     | 5       | 19    | 1     | 20    |
| Cards                            | W       | 7 | M        | 6 | 7         | 2 | 7     | 2       | 31    | 1     | 32    |
| Draw Frame I and II              | W       | 6 | M        | 2 | 6         | 1 | 6     | 1       | 22    | 1     | 23    |
| OE Spinning Frame                | W       | 25| M        | 4 | 24        | 3 | 24    | 3       | 83    | 5     | 88    |
| Quality control                  | W       | 4 | M        | - | 4         | - | 4     | -       | 12    | -     | 12    |
| Warehouse raw materials          | W       | 1 | M        | 1 | -         | - | -     | -       | 2     | -     | 2     |
| Yarn deposit                     | W       | 1 | M        | 4 | 1         | 2 | 1     | 2       | 11    | -     | 11    |
| Diverse personnel                | W       | 2 | M        | 17| 2         | 15| 2     | 15      | 53    | -     | 53    |
| Total staff                      |         | 47| M        | 42| 44        | 28| 44    | 28      | 235   | 8     | 243   |

This amount includes both staff remuneration and social tasks incurred by the employee and the company. Due to the difference of 67 workers, for the classic technology the financial effort of the company exceeds with 1.710 mil. RON/month that needed for the unconventional line. Reported to the total annual production, this means a higher production cost with 0.44275 RON/kg.

4.4. Costs caused by energy consumption

The accomplishment of this analysis requires the installed power for each type of machine and the total yields, CUM.

The total yield, CUM, was calculated with the equation (1):

\[ CUM = CTU \cdot CUF \] (1)

where:
- CTU - the coefficient of useful time, the partial yield, which is dependent on the pauses imposed by equipment service and accidental repairs;
- CUF - machine efficiency in operation, the partial yield, which depends on pauses imposed by planned repairs: current repairs 1, RC1, current repairs 2, RC2, and capital repairs, RK.

The table 5 comprises the values for the installed power, according to the machine's technical books, and for the total yields CUM.
Table 6. The installed power and total yields of the machines.

| Equipment                     | Installed power [kW] | Total yield [%] | Total consumption [kW/year] |
|-------------------------------|----------------------|-----------------|-----------------------------|
| Draw frames I and II          | 5                    | 87              | 26517.60                    |
| Roving frames                 | 10.45                | 87.3            | 55612.89                    |
| Ring spinning frames          | 16.5                 | 94              | 94548.96                    |
| Spinning machines open-end    | 13.7                 | 94              | 78504.29                    |
| Winding machines              | 10                   | 85              | 51816.00                    |

The beating unit and the cards are not included in table 6 because we have the same number of machines in the analyzed lines.

Based on the number of machines, table 2, and working 254 days in a year, the calculus reveals an energy consumption of 6.705 million kWh for the classic version and a consumption 2.465 million kWh for the unconventional process, which means a reduction in energy consumption of 4.240 mil. kWh.

Taking into account the medium voltage energy price of 450 RON/MWh for the region covered by Enel Vest, [8], actually 0.45 RON/kWh, a difference 1.908 mil RON could be registered. Related to the total annual production, we get a higher cost of 0.477 RON / kg for the classic technological line.

Corroborating the results, the classic variant involves a higher production cost of 3.1545 RON/kg of finished product compared to the unconventional technology.

5. Conclusions

From the point of view of the complexity of the technological lines and implicitly of all the necessary adjustments, we can state that the technological line for the unconventional system is simpler and shorter. The bands obtained at the last passage of drawing frame are fed directly to the spinning machine OE with the rotor where the yarns are made as the final spinning product. In the classical system, the bands obtained at the last passage of the drawing frame are fed to the roving frame, which produces the roving, then this semi-finished product is fed to the classic spinning machine with rings.

Additional, the analysis of the structure of the two types of yarn reveals that the classic yarn is stable, more compact and suit for finer clothes. Contrariwise, the unconventional yarn can be likened to a core yarn.

The fibers situated inside the yarn are straightened and parallelized, but on the outside the fibers are disposed like rings, dressing and wrapping the core. Therefore, these yarns are more bulky and uniform, but present inferior resistance indices.

Economic analysis discloses diminished production costs for the unconventional yarns, compared to the classic ones. Indeed, all parameters involved in the study compete to the decrease in costs (amortization due to investment effort, financial effort for human resource, wages and social charges, costs generated by energy consumption).

6. References

[1] Koc E and Kaplan E 2007 An Investigation on Energy Consumption in Yarn Production with Special Reference to Ring Spinning Fibres & Textiles in Eastern Europe 15(4) 63
[2] Khurshid M F, Nadeem K, Asad M, Chaudhry M A and Amanullah M 2013 Comparative Analysis of Cotton Yarn Properties Spun on Pneumatic Compact Spinning Systems Fibres & Textiles in Eastern Europe 21(5) 30-34
[3] Sava C and Ichim M 2005 Filatura de bumbac – Tehnologii si utilaje in preparatie (Iasi, Romania: Performantica Publishing House) pp 117-126
[4] www.rieter.com, accessed at 15.02.2019
[5] www.truetzschler.de, accessed at 15.02.2019
[6] HG 2139/30.11.2004 – Government decision for the approval of the classification catalogue and the standard operating times of the fixed assets
[7] HG 937/2018 – Government decision for the minimum gross salary in Romania
[8] www.electricafurnizare.ro, accessed at 15.02.2019