AN EXPERT YARN ENGINEERING SYSTEM

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ABSTRACT

This paper develops the concept and structure of an expert system for yarn engineering. It describes the process of yarn engineering, in addition to the structure, components and functional features of a yarn engineering expert system. To reduce the complexity of the expert system it needs to be broken down into a number of sub-expert systems that enable the determination of fibre specifications, yarn type, yarn specification, twist, draft sizing and yarn performance under various spinning systems. These sub-expert systems interact and exchange information to produce a seemingly whole functionality.

Key Words: Expert system concept, Yarn engineering, Spinning

1. INTRODUCTION

Expert systems have been adopted to provide substantial support in the textile industry. These systems are computer models of human expertise in a specific domain of work. They are capable of offering advice and decision-support related to specific problem-solving in a well-defined knowledge domain. An expert system acts like an expert consultant, asking for information, applying this information to the rules it has learned, and drawing conclusions [3], [7].

The typical expert system receives inputs describing a problem in its field of operation, and then uses its inferencing technique to extract appropriate information from its knowledge base to produce an answer, diagnosis or description of a solution. Such systems have been used to interpret medical test results, diagnose car problems and determine the causes of telephone line failures [3], [7].

This paper describes the concept and structure of an expert system that enables the process of engineering a yarn. The four areas where an expert system can provide support to the various experts involved in yarn engineering process are; (1) in yarn design, where the expert system can recommend choices of composition, structure, manufacturing parameters and manufacturing procedures for the intended yarn; (2) prediction of yarn properties and performance; (3) interpretation of testing results where the performance of sample yarns can be analysed and compared; and (4) modification of yarn design and processing parameters, where the expert system can diagnose the most likely causes of any discrepancies between the designed and the required yarn, and provide advice on how to modify the design and manufacturing parameters. The architecture of the yarn engineering system takes these into consideration. The system envisaged would consist of a small number of sub-expert systems to provide guidelines for determining the yarn type, fibre specifications, yarn twist, etc, and enabling the yarn performance characteristics under various spinning machines to be compared.

The remainder of this paper is structured in the following manner:

Section 2 introduces a general overview of an expert system. Section 3 looks at related work. Section 4 describes the yarn engineering process. Section 5 describes the components of an expert systems architecture for yarn engineering, looking at each of the sub-expert systems separately. Section 6 summarises the benefits of this architecture.

2. COMPONENTS OF AN EXPERT SYSTEM

The components of an expert system include the knowledge base, inference engine, knowledge acquisition component, and explanation system as illustrated in Figure 1.

Knowledge base. The permanent knowledge of an expert system is stored in a knowledge base. It contains the information that the expert system uses to make decisions. This information presents expertise gained from top experts in the field. This knowledge comes in the form of facts and rules. Facts are minimal elements of the knowledge which must be identified before anything else. For example, "Hairiness is a characteristic of yarns" is a fact. Rules consist of if….then statements, where a given set of conditions will lead to a specified set of results. If a condition is true then an action takes place. For example, "if the yarn linear density is 40 then the hairiness level for an USTER specification of 95% is 9.5" [13]. A frame is another approach to capture and store knowledge in a knowledge base. It relates an object to v values s rames knowledge are also calle based expert systems. Semantic nets, neural networks and fuzzy logic are other methods of rep knowledge in the exper knowledge base.

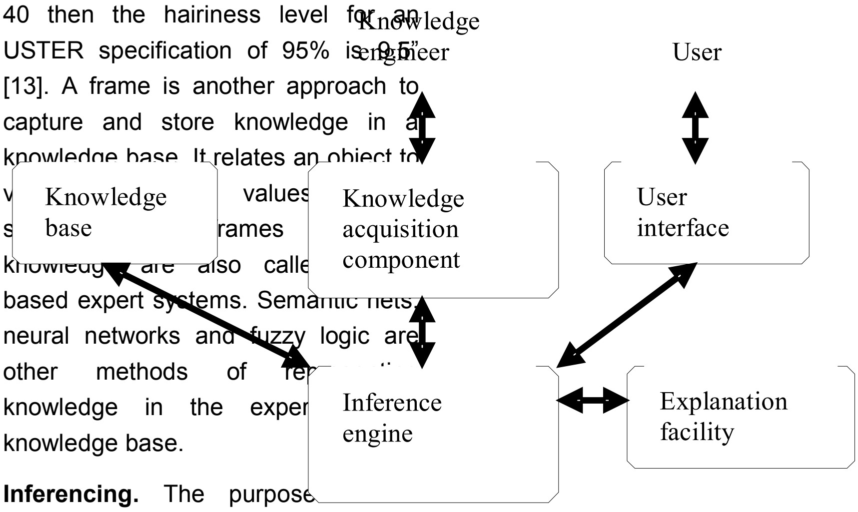

Figure 1. General structure of an expert system

Inferencing. The purpose inference engine is to seek information and form relationships from the knowledge base and provide answers. It determines which rules will be applied to a given question, and in what order, by using information in the knowledge base. The inference engine drives the system by drawing an inference from relating user-supplied facts to a knowledge-base rule and then proceeding to the next fact and rule combination [16].

Two types of inference methods typically implemented in expert systems are backward and forward chaining. Backward chaining is an approach that starts with the goal, e.g., "What is the hairiness level of the yarn for a 5% USTER specification?" and works through a potential thesis until it reaches the fact that supports the thesis. A forward chaining inference engine is goal-oriented in the sense that it tries to prove a goal or rule conclusion by confirming the truth of all its premises. These premises may themselves be conclusions of other rules. It is a method that begins with a set of known fact or attributes values and applies these values to rules that use them in their premise.

Knowledge acquisition. Most expert systems continue to evolve over time. New rules can be added to the knowledge base by using the knowledge acquisition subsystem.

Explanation subsystem. Another unique feature of an expert system is its ability to explain its advice or recommendations and even to justify why a certain action was recommended. The explanation and justification are done in a sub-system known as the explanation subsystem. It enables the subsystem to examine its own reasoning and also explain its operations. The ability to trace responsibility for conclusions to their sources is crucial both in the transfer of expertise and in problem solving.

3. RELATED WORK

This section discusses literature that is related to yarn engineering. [2] identifies four critical aspects of yarn engineering, namely yarn type, fibre type, yarn structure and the contribution of yarn structure to fabric performance characteristics from a broad perspective. The idea of post spinning yarn has also been discussed in [11]. [5 and 6] also studied the possibilities and limits of yarn engineering for ring yarns and open-end rotor yarns based on the simulation of knitted fabrics and from the point of view of the innovative changes for the engineering of blended yarns. Neural networks have been applied in the prediction of the yarn characteristics in the false-twist process [14]. A computer-based mathematical simulation model of the interaction of yarn count, fibre fineness, fibre tenacity, fibre friction and fibre length for engineering air-jet spun yarns was also studied in [15].

4. THE YARN ENGINEERING PROCESS

The end use of the yarn determines the type of fibre and the fibre characteristics required and the standard yarn performance characteristics, such as the twist factor, and spinning system. The yarn performance characteristics are in turn determined by the spinning machine that is used. Figure 1 shows the flow of processes in yarn engineering.

From an analysis of the end use of the product the engineer comes up with the specifications of the fibre/yarn. The fibre/yarn specification looks at the linear density (tex) of the yarn, the blend of fibres used, the twist, hairiness, evenness and tensile strength of the yarn, etc. The specification of the yarn identified is then matched to an USTER specification. For example, to produce a yarn that falls within the 5% range of an USTER specification means that

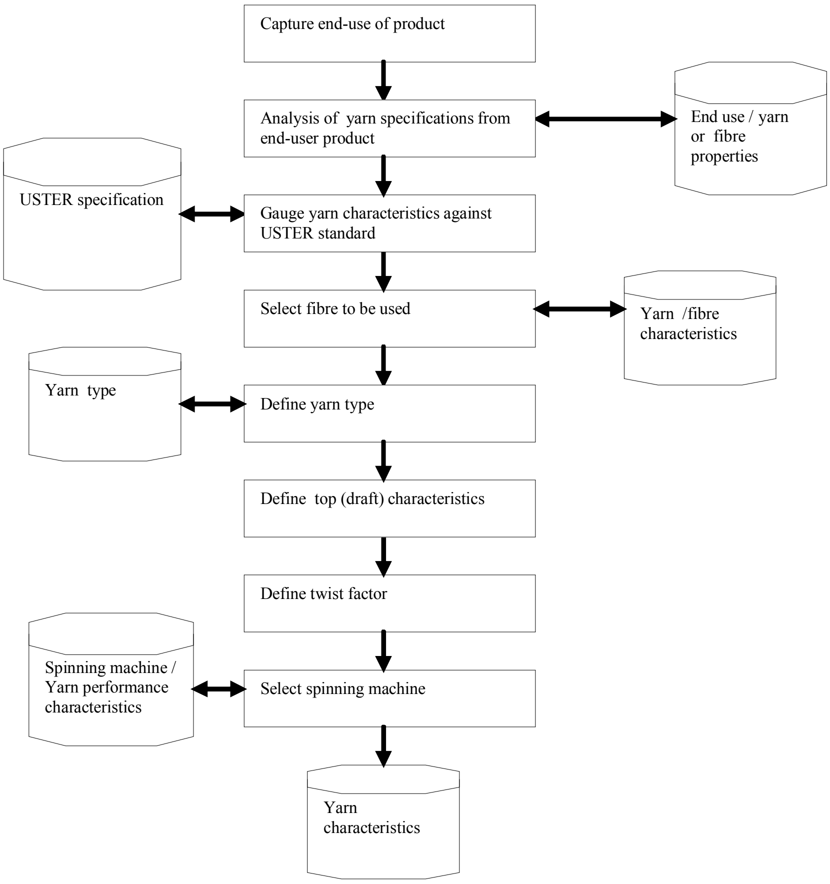

Figure 2. System flow for yarn engineering

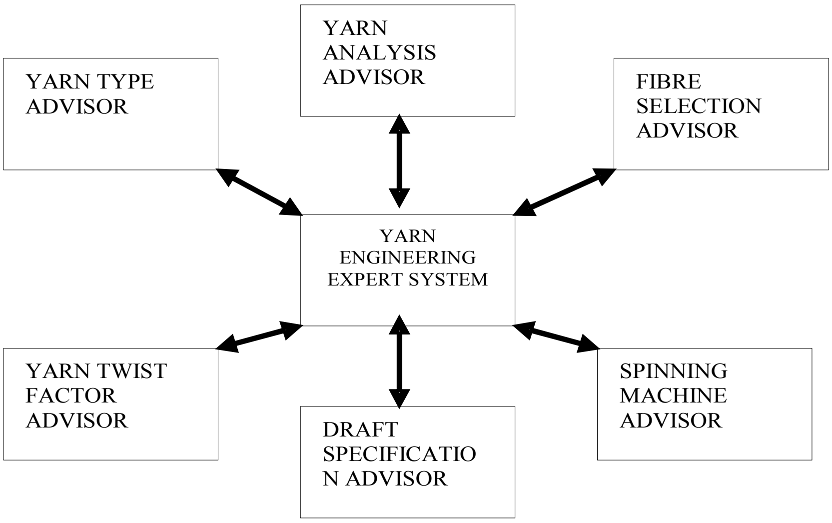

Figure 2. Architecture of yarn engineering expert system

only 5% of the world yarn manufacturer have been able to produce a yarn of a similar quality. The USTER specification determines the fibre blend type and yarn type required from the selected fibres. The yarn type which can be ring-spun, rotor-spun, staple, filament, single, plied, twisted or non-twisted or a combination of some, as required by the manufacturer is identified [13].

In the case of the worsted system, from the combination of the fibre and yarn type used the linear of the top and draft that is required for spinning are determined. When calculating the size of the top to be processed into a yarn waste is compensated for. For example, if a spinning system suffers a loss of 5% of its fibres during processing then this has to be compensated for within the draft or in the linear density of the input sliver or roving.

The twist factor is normally defined by the user or end use. If the yarn is to be bulky and/or soft it means the twist factor is to be reduced. Generally the yarn twist related is inversely proportional to the square root of the yarn or linear density.

Different types of spinning machines produce yarns of different structural qualities. For example, for minimum hairiness, an open-end spun yarn will be preferable to a ring spun yarn. Nevertheless, different spinning systems cannot always handle all the diversity of fibres available. For example, rotor spinning machines are predominantly used for short staple fibres such as cotton, but are rarely used for long-staple fibres, such as wool.

5. ARCHITECTURE OF THE YARN ENGINEERING EXPERT SYSTEM

The architecture of the yarn engineering system is shown in Figure 2. It shows the various sub expert systems that make up the whole yarn engineering expert. This includes the yarn type advisor, the fibre selection advisor, the yarn twist advisor, yarn analysis advisor, draft specification advisor and the spinning machine advisor. Each of these adopts the structure of an expert system as described in section 2.

5.1 Fibre selection advisor

Fibre selection is based on the relationship between two sets of data, that is, the fibre/yarn to be used versus the properties of the end product. For example, if summer apparel is needed to retain coolness, be strong and have dimensional stability, a blend of cotton and polyester would suffice. Polyester would bring coolness and dimensional stability, while cotton retains warmth and moisture. The required quality and processes of the yarn are also critical. For example, if a high quality fibre weaving yarn is required the fabric would out of necessity have to be long and fine.

Fibres can be broadly classified into four groups, namely, animal, vegetable, mineral and synthetic fibres. Examples of animal fibres are wool, mohair, silk and angora hair. Vegetable fibres include cotton, linen, hemp, jute and sisal. Mineral fibres on the other hand include asbestos, carbon, glass filament and ceramic. Synthetic fibres cover nylon, polyester, acrylic and polypropylene.

The end uses of fibres are varied. These can be classified as apparel, domestic, industrial and technical. In apparel fibres are used in underwear (vests, underpants, etc), outwear (shirts, suits, socks, dresses, cardigans) and the like. Domestic end uses fibres include bedding, kitchen towels and cloths, drapes such as curtaining and linings, floor covering such as carpets and mats, and upholstery and cushions.

5.2 Yarn specifications advisor

This component determines the yarn specifications given the end use of the product. The USTER standards define yarn specifications. USTER statistics [13] represent a comprehensive survey of the quality of textile materials produced in major textile regions around the world, and they constitute the mainstay of global market intelligence related to textile quality. USTER statistics are there for quality benchmarking. The statistics covers yarn quality for carded and combed fibres. The fibres can be fibre blends or pure fibres such as 100% cotton, 100% polyester, 100% rayon, 65% polyester/35% cotton, 65% polyester/35% rayon, 50% polyester/50% cotton, 100% wool, etc. The yarns can be ring spun, rotor spun, airjet spun, etc.

Table 1. USTER yarn specifications for hairiness in 100% combed cotton on ring spinning

	95%	75%	50%	25%	
40	9.5	9	8	7.5	7
30	8.5	8	7.5	7	6.5
25	7.5	7	6.5	6	5.5
20	7.25	6.5	6	5.5	5
15	6.5	6	5.5	5	4.5
10	4.75	4.25	4	3.75	3.5
5	3.5	3.25	3	2.75	2.7

An example of the USTER standard values for yarn hairiness on 100% combed cotton on ring spinning is as shown in Table 1. The percentages indicate the numbers of textile manufacturers that produce yarns with the particular characteristics, e.g., in this case, the particular hairiness characteristics. The same approach is applied for yarn neps, breaking tenacity, elongation, coefficient of variation, thin and thick places, and all related yarn characteristics.

5.3 Yarn type advisor

This component assists in the identification of the yarn type during yarn engineering. A yarn is a constructed assembly of textile fibres to produce a coherent entity or yarn type. A range of yarns can be produced in terms of staple, filament, single, plied, twisted, and cabled as shown in Figure 2.

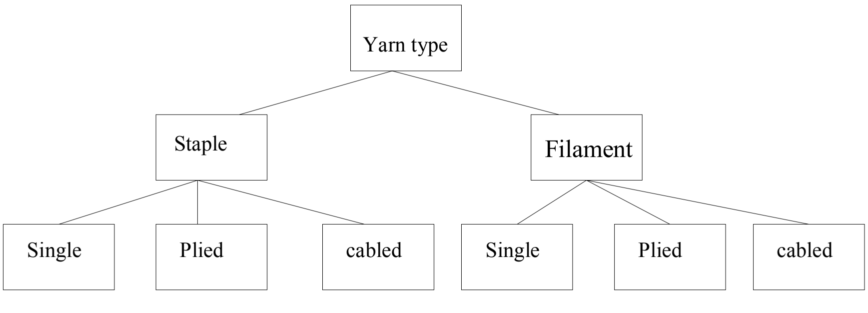

Figure 2. Classification of yarn types

However, to be more general, yarns can either be spun staple yarns or continuous filament yarns. Staple fibres are twisted together. Filament yarns fibres are laid side by side and virtually running straight the whole length of the yarn. Yarns spun from filaments are generally smooth and shiny. This is because filaments are continuous strands of fibre that can be many kilometres long. The only natural filament is silk. Shorter lengths are referred to as staple. Staple lengths vary in length from fibres which are a centimetre long such as rabbit fibres to fibres that are several centimetres long as in merino wool. Longer staple will spin into smooth lustrous yarn. Longer staple also lends strength and resilience to a yarn. Yarns made of a short staple will tend to have a fuzzy appearance.

There is a vast range of staple fibre yarns. Ring spun yarns remain the most popular and are produced on the ring and traveller system from a wide range of fibres of different types, fineness and length. Rotor spun yarns are produced mainly from short staple fibres on rotor spinning machines. Twistless yarns are produced from staple fibres where the consolidation of fibres is by means of some form of adhesive.

Wrap spun yarns consist of a parallel bundle of staple fibres bound into a compact structure by another yarn, usually continuous filament. Core spun yarns are characterised by having a central core wrapped with staple fibres. Self twist yarns are two ply yarns produced in a single operation. During manufacture, each component is twisted in alternating directions in short segments. The two components are subsequently put together in such a way that they twist together to form the final yarn. Friction spun yarns are produced on spinning systems which use two rotating rollers to collect and twist individual fibres into a staple yarn structure. Air-jet yarns are produced by air-jet (vortex) where fibres in the yarn are intermingled and wrapped around.

In most cases, except for self-twist, for example, the yarn is first spun into a single yarn. These single yarns are often “plied” together to form 2-ply, 3-ply and 4-ply yarns. Plying makes the yarns stronger, more uniform and more abrasion resistant. Each ply is a single yarn which is generally plied together using a twist that is opposite to the one that is used in the initial spinning of the yarns. That is, a plied yarn having a Z-twist comprises single yarns that were spun with an S twist. The linear density of the resulting yarn depends not only on the number of plies in the yarn but also on the linear density of the single yarn. A yarn in which two or more folded (plied) yarns are twisted together in one or more operations is called a cabled yarn.

Continuous filament yarns may be produced in either monofilament or multifilament form. Standard filament yarns are known as “flat” filament yarns in contrast to textured yarns. Textured filament yarns are man-made continuous filament yarns that have been modified by subsequent processing to introduce durable crimps, coils, loops or other distortions into the filaments, so as to improve its bulk and related properties.

In terms of wool, depending on the length of the fibres and the way they are handled before spinning we have “worsted” and “woollen” yarn. Worsted yarns are spun from longer combed fibres, so resulting in yarn that is smooth and firm. Woollen yarns are spun from uncombed wool and are fuzzier and not as strong, much shorter fibres being used for woollen spinning.

5.4 Draft specification advisor

Different end-uses require yarns of different thicknesses. The accepted way to indicate the thickness of yarn or material from other stages of processing is to state its linear density. The linear density can be expressed either directly as mass/unit length, or indirectly as length/unit mass. The main direct system in use is the Tex system. Tex is the weight in grams of 1000 metres. The coarser the yarn the higher the linear density.

Drafting is the processing of fibres prior to spinning. By passing fibres between relatively slow rotating back rollers and a pair of front rollers running at a higher surface speed in a spinning machine, the fibres are caused to slide over each other so that the fibre assembly becomes longer and thinner (i.e. fewer fibres in the cross-section) and fibre parallelisation is improved. The draft imposed is usually expressed as the ratio of the input mass per unit length to the output mass per unit length. Drafting can take place in two stages, viz. initial or break draft and final draft. Therefore to produce a yarn of a specific linear density, the total draft, from the above ratio is equal to the Initial Draft multiplied by the Actual Draft.

In drafting and spinning, a factor of great importance in determining processing performance is the number of fibres required in the yarn cross section. In terms of fibre diameter the formula relating the number (n) of fibres in the yarn cross-section to fibre diametre and other variables for fibres of reasonably circular cross-section is:

$$n = \frac{1{,}000tex}{\frac{\pi d^2}{4}} \frac{}{(1+v^2)} \frac{}{\rho}$$

Where,

n=number of fibres in the cross-section

tex = yarn count (linear density of yarn)

d = average fibre diametre (microns)

v = coefficient of variation of fibre diametre expressed as a fraction

p = density of fibre

5.5 Yarn twist advisor

Yarn twist is the spiral disposition of the components of a yarn, which is usually the result of the relative rotation of the extremities of the yarn [10]. The twist lends strength to the yarn. A twist advisory component recommends a suitable range of yarn twist by taking into account the end use requirements, yarn count (linear density of yarn) and tarn type.

A recommended range of yarn twist is calculated using the equation

$$T = \sqrt{\frac{1000}{tex} M}$$

T is turns per metre

Tex is the single yarn linear density in tex

M is the metric twisting factor as shown in Table 2

In filament yarns either Z or S twist is used. However, the twist direction of the majority of spun yarns is Z twist and the twist direction of their folding or final twist is S twist. Twist can be classified from several view points [9]:

Table 2. Yarn twist factor ranges

Yarn Twist Factor Ranges

Wool Blend	**Twist Factor (Metric Count) Ranges**
Pure new wool – 2 fold yarn for flannel (semi-melton)	70-80
Pure new wool – normal 2 fold yarns	80-85
Pure new wool – single weft yarns	65-70
55/45 polyester/wool (normal polyester)	100-110
55/45 polyester/wool (anti-pilling)	85-95
70/30 wool/regenerated cellulosic fibres	75-85

- Twist direction. The twist can be "Z twist", which runs upwards and to the right, formed by spinning the yarn in a clockwise direction. "S twist" is formed by twisting the yarn counterclockwise, the resulting twist runs upwards and to the left. The twist in the yarn for S and Z runs in the same direction as the diagonal used to form these letters.
- The amount of twist, e.g., <300 t.p.m. for a low twist, <1000 t.p.m for an ordinary twist, and <3000 t p m for a hard twist (depending upon the yarn linear density)
- Single or ply twist. Twisted single or multiple yarns into one direction, i.e., S or Z twist….single twisted, Twisted two or several single twist yarns, first twist into the opposite direction….ply twist

5.6 Spinning machine advisor

Yarn performance characteristics are largely determined by the spinning machine used. Once the fibre has been selected according to the ultimate output, the question is, "is the equipment to process these fibres available. Ring-, rotor-, air-jet-, friction-, composite-, self-twist, vortex-, and centrifugal-spinning machines will each produce a yarn of different characteristics from the same set of fibres. Ring spinning, for example will produce more hairiness than open-end spinning. The yarn characteristics include the linear density (yarn count), yarn twist, yarn breaking strength (tenacity), extension at break, irregularity (CV%), thick and thin places / 1000m, neps, hairiness and end breaks. Please note that open-end spinning variants include rotor, friction and vortex (air-jet) systems (Nissan, 1959) and [4].

Through the spinning machine advisor it is made possible to compare the resultant yarn characteristics from the various spinning machines. The following section looks at the characteristics of ring and open-end spinning to show how each would affect the quality of the yarn.

Ring spinning. Spinning is continuous in its action and uses roller combined with apron drafting entirely. The purpose of drafting is to reduce the sliver or roving to yarn proportions. The resulting attenuation by fibre slippage causes an improvement in the alignment of the fibres which is necessary for spinning. The simplest method of drafting is by passing the sliver through two successive pairs of rollers, the second pair rotating at a faster speed than the first pair. The ratio of their peripheral speeds is known as the draft.

The bottom rollers are each mechanically driven. Each top roller is pressed down upon its lower roller, using either dead-weighted or spring pressure, so that the fibre strand is sandwiched between them at what is called the nip. In a system such as this there is always a possibility of roller slippage taking place, thus this possibility is reduced by using fluted bottom rollers working in conjunction with top rollers covered with resilient material such as synthetic rubber, cork, or leather on cloth, and by weighting these sufficiently to give and adequate pressure at the roller nip. To better control the fibres within the drafting zone aprons, from leather or other material, are used between which the fibres are sandwiched and transported or carried.

The roller setting, i.e. the distance between the nips of the 2 pairs of rollers, is of importance – if too narrow a setting is used the long fibres will be gripped by both pairs of rollers and may be broken, whilst too wide a setting would afford very little control to the fibres, particularly the shorter fibres. The actual setting used depends upon the staple length of the fibre sample, although other factors which can affect it are the draft applied, the inter-fibre friction and the extent of the roller nip, which itself depends upon the diameters and degrees of hardness of the rollers.

Twist is inserted into yarns to increase inter-fibre friction to the extent of preventing slipping. Twisting is performed by one of two methods – spindle or flyer. Spindle twisting is basically only used on hand spinning wheels. In flyer twisting the flyer frame (which, in the processing sequence, precedes the spinning frame) for making of rovings, twisting and winding are performed at the same time. Twist is inserted by the constant rotation of the flyer and winding is performed by the rotation of the spindle relative to the flyer.

Ring spinning is an extreme example of flyer spinning, in which the flyer, in order to enable it to be pulled round at high speed by the yarn process, is reduced in size to the dimensions of a small wire clip, viz. the traveller, giving bobbin-lead winding.

Open-end spinning. While in ring spinning a drafting action is applied to the sliver or roving to create a yarn, in open-end spinning the sliver is dismantled at a point and the fibres are transferred to a collecting point at which they are assembled in sequence to form a yarn. As the fibres arrive at the point of break, they are withdrawn at the rate necessary to form a yarn of the required count, thus for example, a finer yarn would require a faster rate of withdrawal. The yarn is then wound onto a take-up package. Thus, unlike the conventional drafting system, there is a break in the continuity of the sliver and an open end of yarn appears. This open-end must be rotated to impart the necessary twist on the yarn formed. This is achieved by means of a rotor which rotates at a very high speed of up to 180 000 r/min

Fibres in an open-end spinning yarn have a more open structure and are not as well orientated as in ring-spun yarns. However, open-end yarns are more uniform than ring-spun yarns made of the same material; they also contain fewer thin places, thick places and neps and are less hairy, but are much weaker and needs a higher twist.

The yarns produced by such a system are defined having so-called fascinated yarns, having outside binding fibres wrapped around a core of parallel fibres.

Because of the striking increase in speeds of preparatory processes for spinning and consequently the actual spinning process became a bottleneck, which impeded automating beyond the drawn sliver stage. Rotor spinning was one of the first improvements and then came air-jet spinning, especially in the short staple spinning side. The major difference between air-jet spinning and rotor spinning is that the former method is a false twist process and does not involve open-end technology.

Air-jet spinning. Air-jet spinning uses a high-speed spinning frame, with no high-speed rotating mechanism, which twists and spins yarn by means of compressed-air jet [1]. This system consists of a stretch breaking unit to break the filament supplied, an air-operated collecting aspirator, an air-jet false twister and a cheese type winding unit. The process involves drafting strands of fibres which are forwarded by an aspirating jet to a torque jet, whereby the fibres are consolidated into a fascinated yarn assembly by fluid twisting. The drafting fibres are presented in a flat, ribbon-shaped bundle to the aspirating jet, and advanced to the torque jet which introduces true twist or wrappings to the surface by a phenomenon referred to as “twist transference”.

After drafting, the supplier sliver emerges from the front roller as a uniform, ribbon-shaped fleece. The drafting fibre band is separated by a fleece separator and, as a result, one part becomes free fibres. These fibres having one end in the open-end state are twisted around the remaining assembly of fibres. The twisted fibre strand and the untwisted free fibres are subsequently consolidated and after they pass through the nozzle, the free fibres wrap around the non-twisted core. The Toray is composed of a 4 line drafting system, a yarn-forming section that includes a single air-jet nozzle and a fleece separator, and a winding section that includes a delivery roller, a slub catcher and a cheese winder. Many man-made fibres, cotton and blends can be spun by this system, compared to the first one.

In air-jet spinning there are several parameters that can affect the yarn properties, such as air-pressure in the nozzles – influences tenacity, evenness, thin and thick places and neps. Draft-influences breaking load, elongation and hairiness. Delivery speed and take-up ratio influences tenacity, evenness, hairiness, fibre extend, twist and thin and thick places and neps. The condenser width influences yarn strength due to fibres wrapped around the parallel core fibres

6. CONTRIBUTION AND CONCLUSION

In the textile industry there is a need to maintain adequate skills levels among workers. But the problem is a shortage of experts to impart such skills to the populace. Expert systems are therefore an appropriate solution to substitute the expert. The advantages of expert systems are:

- They act as consultants once the knowledge of experts has been captured.
- Since human experts are in short supply, expert systems provide the means to use knowledge in a wide number of locations without actually having the human expert on site.
- They provide advice that is more consistent
- They can be put to work in a hostile environment

In this paper an architecture of an expert system for automating the process of yarn engineering has been looked at. The architecture is made up of component expert systems to offer advice on the selection of fibre, yarn type, yarn specification, draft sizing, yarn twist and spinning machine. The advantage of this architecture is that it reduces the complexity of the yarn engineering process by breaking down the processes into modules of smaller, less complex expert systems. Each of these is autonomous and specialised, but they all interact to create a whole functionality.

The added advantage is that this is an interdisciplinary architecture. It marries textile technology and Information Technology (IT).

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Bu yenilikçi eser, tekstil terbiyecileri ve terbiye makinesi imalatçılarının yanında; öğrenciler, eğitim-öğretim ve Ar-Ge çalışanları; iplikçi, dokumacı ve örmeciler; kimyasal madde üretici ve satıcıları; tüketiciyi koruma organizasyonları ve özellikle de konfeksiyoncular, tekstil ticaretiyle uğraşanlar ve küresel satın almacılar için tekstil ürünlerinin terbiyesi hakkında vazgeçilmez bir başvuru kaynağı oluşturmaktadır. Bu insanlar için küreselleşen pazarda daha geniş bir bakış açısına sahip olmak önemlidir.

Prof. Dr. Hans-Karl Rouette, Hochschule Niederrhein’in Tekstil ve Konfeksiyon Tekniği Bölümü’nde tekstil terbiyesi ve ekoloji dersleri vermektedir. Rouette, tekstil terbiyesi ve terbiye makineleri konularında uluslararası görev yapan yeminli hakem olup, tekstil terbiyesi, ekoloji ve tekstil tarihi hakkında çok sayıda kitabın yazarıdır.