ENGINEERING OF KNITTED FABRICS USING STARFISH

by

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INTRODUCTION

Two of the important new concepts of recent years are those of "Quick Response" and "Total Quality Management". These are both large and complex subjects which, for practical implementation in a knitting factory, require the adoption of many new technical and organisational procedures and, perhaps more importantly, some fundamental changes in attitudes. Among these new procedures and attitudes are:

- The ability to develop new products, or improve the performance of existing products very rapidly and according to the specific requirements of the customer (rather than according to what we have always made before).

- The ability to predetermine product quality and reliability through the identification and continuous positive control of key raw material and process parameters (rather than by trial and error processing) so that product quality is guaranteed by making it "right first time and every time".

A feature of modern quality assurance systems is that they rely to a large extent on more or less exact numerical solutions to development and control problems, rather than trial and error solutions based on past experience plus manual tuning. In modern production situations, trial and error development and control systems are simply too expensive and too unreliable. In other words, when we want to develop a new product, we have to be able to calculate in advance exactly what are the raw materials which must be used and the control settings of the key machines which must be maintained.

Probably the most obvious and widespread example of this approach is computer-based dye recipe selection combined with automated dyebath preparation and metering (together with strict quality control of water and chemicals) to allow one-shot dyeing for the majority of dyelots with no need for shading additions. Although the cost of such equipment is high, it can easily be justified in terms of savings in time, reductions in reprocessing, and improvements in quality and reliability.
A further example, in the field of circular knitted cotton fabrics, is the need to guarantee that the weight per unit area and especially the shrinkage of the fabric shall conform to particular customer requirements reliably and consistently. In this case, the computer software which models the fabric manufacturing, dyeing, and finishing processes is the STARFISH system and the raw material which has to be closely controlled is the yarn. The main yarn quality parameters which affect the weight and shrinkage of knitted fabrics are the yarn type (ring, rotor, carded, combed), the yarn count (yarn weight and diameter), the yarn twist, and the basic fibre quality (especially fibre fineness and maturity). Other yarn properties are of course important for manufacturing efficiency and fabric appearance but they do not affect the weight and shrinkage.

In the STARFISH software, the separate effects of these four different aspects of yarn quality are modelled by only two parameters, namely the yarn type and the yarn count. This is partly because of the enormous time and expense which would be required to develop a comprehensive data base to take account of variations in twist and fibre quality. However, it is also the case that, in practice, only a narrow range of twist factors is actually used for knitting yarns and, moreover, the quality of fibre used tends to be related to the yarn type and the yarn count. Therefore, the practical range of influence of twist and fibre quality is much less than the potential range.

In spite of this reasoning, it is important for the knitter to monitor the twist of his yarns and to ensure that the fibre quality stays more or less the same from lot to lot if he wants to guarantee a consistent product. As a matter of fact, we would like eventually to be able to include the yarn twist as a separate input parameter in the STARFISH computer software because twist is important in determining the spirality of plain jersey fabrics. Spirality is a fabric performance property that we have studied extensively and that we would like to be able to predict in a future version of the STARFISH software.

In the remainder of this paper, it is taken for granted that a vital part of knitted fabric engineering is that the yarn to be used must be carefully chosen, properly specified, and rigourously controlled.
FABRIC ENGINEERING

For the purposes of this discussion, we define the "Engineering of Knitted Fabrics" as follows.

- Specification of the appropriate raw material, knitting conditions, and finishing targets in such a way that the performance requirements of the final finished fabric shall be ensured.

Furthermore we define "performance requirements", to include only the weight, width, and shrinkage values that are demanded by the customer in the finished fabric. This is not to deny the importance of other aspects of performance, such as fabric appearance, or colour consistency, etc. but these are outside the scope of today's presentation.

When faced with specific customer demands for weight, width and shrinkage, we want to be able to calculate how the cloth should be knitted and how the cloth should be finished in order to guarantee that level of performance.

How do we calculate weight, width and shrinkage?

- Weight = Yarn count x Course length x Courses per inch
- Width = No. of Needles / Wales per inch
- Length shrinkage = (CpiA - Cpi) / CpiA
- Width shrinkage = (WpiA - Wpi) / WpiA

Where Cpi and Wpi are the courses and wales per inch in the finished fabric, as delivered to the customer, whereas CpiA and WpiA are the corresponding courses and wales after the shrinkage test has been carried out.

There is no escape from the discipline of these four basic equations. They immediately show us what are the main knitting and finishing variables that have to be predetermined, and closely controlled, in order that we can engineer our fabrics to give the required performance in terms of weight, width, and shrinkage.
They are:

- Yarn count
- Course length
- Number of needles
- Courses per inch, as delivered
- Wales per inch, as delivered
- Courses per inch, after shrinkage
- Wales per inch, after shrinkage

These variables can be classified into three basic types.

The first three are the independent knitting variables, Yarn count, Course length, and Number of needles. They form the key part of the specification for the knitting operation. We are at liberty to select any values for them that are consistent with practical limitations but, once they have been selected, they must be maintained essentially constant. Note that the Course length is the product of average Stitch length and Number of Needles; the key control parameter is the average Stitch length.

The second group comprises the Courses and Wales per inch in the delivered fabric. They represent the length and width of the fabric, as delivered to the customer, and they therefore form the essential part of the finished fabric specification. In fact they are the finishing targets. It is important to note that, when the independent knitting variables have been fixed, then selection of these finishing targets also selects the delivered weight and width. In practice, of course, the weight and width are the finishing targets rather than the courses and wales per inch, but the essence of the argument is unchanged. Once we have fixed the basic knitting variables, then fixing the weight and width of the delivered fabric automatically fixes the number of courses and wales.

This fact has an important consequence for finishers.

*It means that any finisher who is doing a good job of delivering the exact weight and width required by the customer has virtually no control over the shrinkage.*

The last two variables in our four basic equations, namely Courses and Wales after shrinking, are dependent variables. This means that the values we get for them depend primarily on the values that we choose
for the independent knitting variables. In fact, they are influenced also by a few other independent variables, such as the quality of the yarn that we choose, (e.g. ring versus rotor) and the type of wet processing route that we use to dye and finish the fabrics (e.g. continuous prepare versus jet).

Because they are dependent variables, we can not control them directly. But we do need to ensure that they are under control because, once we have fixed our independent knitting variables, and we have chosen our finishing targets according to the weight and width demands of the customer, then

*the two dependent variables (courses and wales after shrinking) determine the levels of shrinkage that we will get.*

This means that we must exert very strict control over the knitting variables (yarn quality, yarn count, and average stitch length) if we want to have any hope of controlling levels of shrinkage in the finished fabrics.

In other words, successful engineering of knitted fabrics means that we have to discover exactly how to adjust (and control) the knitting conditions so that, when we achieve the right weight and width in the finished fabric, then the right shrinkage values follow automatically. The problem is that the courses and wales that will be found in the finished fabric, after the shrinkage test has been done, can not be discovered until after the fabric has already been made and finished. This is the reason why many knitted fabric development managers (and finishers) spend a large proportion of their time chasing their tails.

By the way, notice that, at no time have we mentioned the performance specifications of the greige fabric. Some knitters pay great attention to the weight per unit area and width of the greige fabric. Some even measure courses, wales and shrinkage. They are probably wasting time and money. What has to be specified, and controlled are the independent knitting variables and these have to be chosen in regard to the finished fabric, not the greige. Provided that the knitting conditions are correctly chosen, and accurately maintained (and the wet processing is consistent), then the weight of the greige fabric is guaranteed to be appropriate for the final product. It does not change merely by being measured!

Many companies will keep detailed records of all of the fabrics that they have ever made and the corresponding performance data. Whenever they have to develop a new product, then they consult these data and
make a guess as to the knitting conditions that will be required. Anyone who has tried to use this system of fabric development will know its many limitations, even when good records have been kept.

The modern alternative is to use the STARFISH computer prediction program. With the STARFISH program, it is as though every fabric that ever could have been knitted and processed (within a certain range) is stored ready for recall and scrutiny, filed according to the fabric type, the yarn used, the course length knitted, and the wet processing. In a matter of a few minutes, it is possible to scrutinise a wide range of knitting and finishing conditions to see what are the practical options for producing a given set of performance values in the finished fabrics. If it is actually physically possible to fulfil the customer’s demands with the available yarns and equipment, then STARFISH will usually be able to demonstrate how.

EXAMPLES

When first we were asked to make this presentation, we requested examples of typical fabric specifications that were common in the USA. Amongst others, we received the following.

1. Interlock - 30" cylinder
   
<table>
<thead>
<tr>
<th>Cut</th>
<th>Yarn</th>
<th>Weight</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>30/1 Ne</td>
<td>8.5 - 9.0 oz./lin.yd.</td>
<td>60-62&quot; wide</td>
</tr>
<tr>
<td>24</td>
<td>40/1 Ne</td>
<td>9.5 - 9.8 oz./lin.yd.</td>
<td>60-62&quot; wide</td>
</tr>
</tbody>
</table>

2. Jersey - 30" cylinder
   
<table>
<thead>
<tr>
<th>Cut</th>
<th>Yarn</th>
<th>Weight</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>18/1 Ne</td>
<td>8.5 - 9.0 oz./lin.yd.</td>
<td>60-62&quot; wide</td>
</tr>
<tr>
<td>22</td>
<td>20/1 Ne</td>
<td>10.0 oz./lin.yd.</td>
<td>62-64&quot; wide</td>
</tr>
</tbody>
</table>

3. Single knit piqué - 26" cylinder
   
<table>
<thead>
<tr>
<th>Cut</th>
<th>Yarn</th>
<th>Weight</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>20/1 Ne</td>
<td>10.5 - 11.0 oz./lin.yd.</td>
<td>29-30&quot; wide</td>
</tr>
<tr>
<td></td>
<td>18/1 Ne</td>
<td>11.5 - 12.0 oz./lin.yd.</td>
<td>32-33&quot; wide</td>
</tr>
</tbody>
</table>

It was said that the objective of the industry is that all fabrics should have shrinkages of not more than 5 x 5%.