CONCURRENT DESIGN

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ABSTRACT

In recent years the performance of many engineering companies has greatly improved through the introduction of concurrent engineering: design by a multi-disciplinary design team considering all aspects of the product simultaneously throughout the design process. Most companies in the textile industry still have the classical three stage division between design, sampling and production.

Early design decisions are made by the designers based on their fashion research, the target customers, and the available resources. The designers specify the garments as best as they can and hand them over to technicians to turn into samples. Designers often design without regard to technical constraints; technicians often have to do a lot of detail design, and make changes to the designs without understanding the designers’ objectives. In many cases the samples have little to do with the designers’ initial ideas.

These problems can be overcome by integrating technical and production consideration into a concurrent engineering design process. Designers can not be expected to have enough technical knowledge to create producable designs on their own. They need to be supported by technical staff who advise designers when they design garments; this requires technicians who are informed about fashion and understanding the working methods of designers. In an integrated process technicians can act proactively by anticipating the designers’ needs, for example by working on specific knitted structures; this can help overcome the rush towards the end of a design season.

1. INTRODUCTION

Concurrent engineering is the involvement of specialists in all the different aspects of design, manufacturing and marketing from the beginning of the design process to ensure that the concerns and requirements of all aspects of the design are taken into account throughout the design process. Concurrent engineering has become increasingly widespread in the engineering industries, to improve the efficiency of the design process and reduce the time to market. In this paper we compare their design and production processes and use of computer technology to that in the textile industries.

Our work results from empirical research in a large number of different types of textile companies in the European Union, and the assessment of different CAD/CAM/CIM systems on the market or in the research arena. We report on the nature of the design processes in the knitwear industry and how the uneven pattern of work through the year causes severe problems in the interaction between designers and their technical colleagues.

We argue that significant gains can be made by moving towards a more integrated approach to design, the technical realisation of designs, and production planning in the textile industries. We propose some guidelines and practical recommendations based on
2. EXPERIENCES IN ENGINEERING

experiences in engineering, for a textile industry to use as a starting point for assessing the degree of integration required between the different functions of design, technical development and production planning for maximum benefit.

2. CHALLENGES FOR THE TEXTILE INDUSTRY

In the late 20th century the world-wide textile industry confronts a number of significant challenges, some are as old as the industry and others that have only become prominent in recent years.

The time to market of all textile products is the industries’ most critical challenge. Designs need to match the fashion of the time of sale: the longer the design and sampling time the greater is the scope for error. Companies must have the capability to respond to unpredictable fashion fads such as special colours or franchised motifs at the last moment. Products need to be delivered on time for the beginning of the season or customers might look to other suppliers. The first garments to arrive in the shops are used to decorate the show windows and attract the attention of the end customers. So, companies that produce locally and are agile in their response to the market are argued to have an advantage over companies whose products are imported over large distances.

The merits and demerits of such arguments are best seen in the light of issues concerning global branding and niche markets.

Manufacturers in western countries are under constant threat from countries offering cheap labour. Environmental legislation, especially in Germany, increases the cost of production processes involving the use of chemicals for, say, dying or tanning. Also, social legislation increases labour costs. Some textile companies in Europe (for example C&A in Germany) have already moved much of their production to the Far East or Eastern Europe. Coats Viyella in the UK lags behind this trend and has published targets for production outside the UK by the year 2000. UK lace companies are building factories in Mexico. In Germany many companies, e.g. Mondi, have moved sampling to the place of production, while design and administration remain at headquarters. In Britain companies have problems finding skilled labour at current wage levels in traditional textile centres such as Leicester or Hawick.

Technology is changing rapidly requiring large scale capital investment and increased training over the last decade. The new technologies not only make production more efficient but also increase the scope of designs that can be mass produced. For example, knitting companies replacing a large proportion of their production machines are spending at the rate of £50,000 to £100,000 per station including technical and CAD training, to cover almost the complete capabilities of hand knitting.

The demand for specific products and machines fluctuate enormously with fashion, for example lace fabrics are currently in vogue whereas a few years ago many knitted garments were embroidered and companies invested heavily in embroidery machines. Such changes in technology also require different skills in the work force.

A large number of samples are often produced for each garment that goes into sales. The situation is probably the most extreme for suppliers to Marks & Spencer who produce
hundreds of designs and dozens of samples to sell four or five garments in a season. The sampling costs covering wages for designers, technicians, support staff, equipment etc. can be about 5% of the cost of a garment in the knitwear industry. A thousand pounds is a realistic estimate for the price of one knitted sample. In some companies and industries samples need to be produced on production machines by production personnel; the most extreme example is probably the footwear industry.

The design process is often inefficient. In the knitwear industry many designs cannot be produced to the target price even though designers think in terms of “a twenty pounds sweater”: designers specify impossible designs, technicians do not implement the design specified by designers and materials are not available when required. Knitwear designers comment that they only spend about 10% of their time designing, the rest being dedicated to administration and making technical improvements to garments.

To stay competitive textile companies need to be able to produce quickly and cheaply the garments required by the market. This can only be achieved when design and production collaborate without design being stifled by production requirements.

3. COMPARISON BETWEEN ENGINEERING AND THE TEXTILE INDUSTRY

Concurrent Engineering was promoted strongly across all industrial sectors through the agency of the dti (Department of Trade and Industry) in the UK. Its driving force was efficiency gains possible from the involvement of all relevant participants in the early stages of the design-to-production process.

The natural successor to Concurrent Engineering is the Computer Integrated Manufacturing & Engineering Systems movement that promises the linking together of product data management with business process execution in clusters of collaborating and competing companies. The logical end point for such modelling and simulation activities is the Virtual Enterprise. For further reading in this area see CiME (Computer Integrated Manufacture & Engineering), vol. 1, No. 2. In essence the architectural descriptions of Computer Integrated Manufacturing systems are providing the language with which interactions within an organisation are described, whether or not a computer is involved.

Of interest here are the types of issues in system developments in general engineering that have attracted significant investment and have the potential to influence the design and production of textiles. Issues such as:

- the possibility of a ‘once per design’ system

In complex systems, such as aircraft, that contain many intersecting technologies the number of times that design issues are revisited is very large. Significant effort goes in to minimising modifications; for example wooden mock-ups of Airbus wings are used for detailed routings of services and to resolve inspection problems at an initial design stage.

Although even the most complex textile products are far less complex then many engineering products, the possibility of reducing the number of initial designs, based on computer representations rather than on samples, is of significant interest.
The possibilities for revisiting earlier decisions in the design process are legion. Often, the reasons that a designer’s ideas are not achieved are due to a technical specialism’s imperatives that occur later in the timeline of the design to production process.

- **the reduction of time to market.**

  By way of contrast the time to market, a very strong textile industries imperative, also occurs in, say, the toy industry. For example, plastic concept toys prepared for the Christmas market and its aftermarket (what do I spend my Christmas money on?) that are produced in the UK depend critically on understanding the local market and being quick to respond from design to delivery on demand. Typically, the large retailers are not holding stocks of toys, simply demanding supply at their convenience. Such movement of stockholding down the supply chain is well known in the UK textile supply industries.

- **heavy investment required in tooling for mass production.**

  Typically, for small plastic items or metal components, tooling is an order of magnitude greater in cost than the design process. Design for concept toys starts with choices between sketches and progresses to working mock-ups that are used for catalogue pictures before commissioned mass-production tooling is completed. Prototypes can be made in similar materials to those that will be used for the final product, but the drive for simple tooling is very strong, hence the movement towards rapid prototyping. The final, expensive, mass-production tooling can only be modified in small details and such modifications are not cheap so the once-per-design or right-first-time imperatives are very strong. “I just hope that some trace of my original concept remains at the end of the day” reports Martin Richards, a toy designer.

So, how does this global perspective compare with design to production and sale in the textile industries and are there lessons that can be learned from how other industries operate and respond to initiatives such as that of concurrent engineering?

The first clear message is that investment in the use of computers in the design loop for storage of designs, communication between different specialists and driving production machines is common to both textile industries and industries with dedicated mass-production tooling. Certainly, both types of industries have the problem of producing prototypes for evaluation, by themselves and by potential customers.

**4. A SIMPLE MODEL OF THE DESIGN PROCESS IN THE TEXTILE INDUSTRY**

The exact details of the design processes vary from domain to domain, however the same basic stages recur.

Designers begin their work on a new season’s offerings by researching the fashion trends for the coming year. Designers identify important themes and styles, they collect features that are going to be influential and can be used in their designs, and they make a broad
selection of the materials that they will use. They attend fashion shows and study how their product has been employed by catwalk designers. The process is described in more detail in [1].

Designers plan their garments to be produced to a target price based on research and on input from customers; and work out a framework for all the types of designs that are required. This provide the basis for the selection of materials for specific garments, for example fabric for a dress or yarn for a sweater. Often a design is a combination of different parts which have been designed and sampled separately. Sometimes individual designs are worked out completely from scratch.

In some textile domains designers work out all of the details for a particular design. In other domains the detailed work is left to technicians. For example, carpet designers work out the grid pattern of a carpet (a technical stage), aware that different carpets can be created from the same water-colour image. Knitwear designers, however, often leave all the technical details entirely to technicians, such as the creation of grid patterns from sketches.

Sampling during the idea generation stage is concerned with the technical realisation of a design. In many textile domains it is not possible to create a representation of the product that a customer can be confident about without producing the design in some form. For example, it is impossible to create a knitted sample without knitting the fabric, whereas a garment can be made from toile fabric in order to try out a style or style change. Changes to a design are often required for technical and financial reasons.

Once sample garments are presented to customers, who select styles from the available samples, it is possible to predict production requirements from information about the quantities of materials needed, and so on.

The timespan between beginning research for a new season and the time when the garment reaches the shops can be as long as to two years. Figure 2 shows the overlap of design phases for a company with a relatively short design to production time. It indicates that most of the sampling occurs while its designers are already working on research for the next season. Their designers are in a different mindset when the technicians approach them with questions about the current season’s problems.

5. CONCURRENT DESIGN: PARALLELISATION OF STAGES IN THE DESIGN PROCESS

5.1 The Design Process and its Problems

The following analysis describes possible improvements to the knitwear design process. Knitwear is a complicated product in which fabric is created at the same time as the intended shape so both aspects have to be incorporated at the time of design. The range of tasks in the knitwear design process mirrors tasks and skills from several other textile domains:
• fashion design: the creation of the shape of the garment, consideration of drape and flow;

• lace design: the inclusion of stretch and contour;

• textile design: the creation of fabric, often based on artwork as sources of inspiration [1];

• carpet design: the translation of a drawing into a grid pattern.

As Figure 2 shows there is a considerable overlap between the different seasons. While fashions for the new season are researched and designed the sampling for the previous season is in full swing. These overlaps are well known in other industries where computer systems are used to smooth flow through the system. For example, Sony in South Wales produces TV sets at the rate of one every two seconds. The company is processing about a hundred and fifty designs a year with an expected production life of 1.25 years. Two hundred suppliers to Sony have access to their plans a year ahead, some with direct, online computer access.

In most textile companies the knitwear design process goes through the same stages in a fairly linear order (a full description can be found in [2]). The process is as follows:

• **Research: fashion overview.** Designers study the general context of fashion in a coming season by visiting yarn shows, trade fairs, and going on shopping trips, so enabling them to develop a feeling for what will be fashionable in the new season and which candidate designs will be most suitable.

• **Research: selection of topics for the company.** Designers select topics suitable for their own company’s style, their target customers and general fashion themes. Some companies use themes predicted by fashion forecasters, others have themes given by their customers, such as Mark & Spencer (often in a very primitive form), others develop their own themes from a general understanding of the fashion context. A common theme is a very powerful way to tie co-ordinated ranges from different manufacturers together.

• **Creation of theme boards.** The results of research processes are encapsulated in a theme board that can include photographs of garments from fashion magazines, sketches, yarn samples and swatches. Although sketches might show one particular garment they stand for a whole class of possible designs.

• **Selection of yarns.** Knitwear designers trawl catalogues from spinners and discuss yarn qualities with sales people. Many companies maintain a fairly stable range of yarns and only introduce a few completely new yarns every season. Testing a new yarn involves creating swatches in different structures to evaluate the knitting properties and conducting finishing tests. New yarn swatches also give designers an idea of how yarns look, feel and handle when knitted.

• **Design of pattern elements and development of new features.** The development of swatches is a gradual process that starts during research when designers generate new ideas. Once the new yarns for a season are selected designers begin to develop key
structures and features. Having identified a certain neckline or pocket as very important they begin to develop it as a main feature. In many companies a collection or a topic are tied together by some key structure or motif which is designed and sampled at this stage. Cross-cultural issues become important in a global marketplace:

“The Japanese idea of the UK is The Stag at Bay and tartan.”

Knitwear Designer

- **Design of garments.** Garments are either designed specifically or constructed by combining already tested swatches. The aim in many companies is to achieve a novel appearance while reusing the greatest number of stitch structures. Designers require swatches to develop their ideas and evaluate their designs, so the design of a garment is normally expressed by a sketch in combination with a swatch.

- **Creation of technical representations.** Once sketches are selected by the designers, customers, or a suitable panel, a formal description of the garments can be created. This representation usually consists of a short verbal description, a set of measurements and a two dimensional outline drawing of a garment. Only at this stage a garment enters the system and has a reference number.

- **Sampling of fabric.** Formal sampling by technicians begins with the sampling of fabric panels for garments. More than a swatch, a panel includes all the structures and motifs in a garment piece. These need to be synchronised in order to minimise knitting time and reduce strain in the yarn.

- **Creation of cutting patterns or inclusion of shaping instructions.** For cut & sew knitwear the cutting pattern is created in the meantime. In shaped or fully fashioned knitwear technicians include shaping instructions into the fabric program.

- **Pattern placing.** The fabric and the shape need to be brought together at the end of the design and development process. Technical modifications are made to avoid conflict between shaping instructions and fabric or to avoid cutting through structurally critical parts of a design, such as a cable cross over. In an ideal world all pattern elements are rearranged to reach on optional solution. In reality many compromises need to be made.

5.2 Inefficiency of the Process

This design process is fundamentally inefficient. A large percentage, in some cases over 30%, of garments specified by designers are impossible to produce. Most designs are compromises in the end, simply because time has run out. Designers often have to settle for the suggestions presented by technicians, even if they do not correspond to their original ideas. Many designers are unsatisfied because their designs are not realised and their artistic aspirations are frustrated.

The inefficiency of the design process can be attributed to a variety of reasons:

- **A breakdown in communication** between designers and technicians [2]. Designers and technicians don’t discuss design issues in sufficient detail in most companies, rather
they depend on interpreting assertions and specifications which they don’t entirely trust. Knitwear is extremely difficult to communicate because most representation are intrinsically ambiguous and incomplete, resulting in major changes from the original intentions of designers.

- **Lack of technical knowledge** by designers and misunderstanding of design by technicians. Designers don’t always know what is technically feasible and the technicians cannot interpret design ideas correctly because they are not aware of specific design contexts.

- Even though many designs are created by modification from previous designs (stitch structures and entire garments are often an evolution of designs from previous seasons), **design ideas and garments are not usually recorded**. Most companies keep sample garments a few seasons old, but do not keep swatches and sketches. The industry depends on the memory of designers and technicians. In knitwear companies technicians are in stable employment but designers change their jobs fairly frequently.

5.3 **Improvements**

Designs need to be produced under time pressure whilst incorporating an ever changing and ever increasing range of skills, so more efficient design processes are needed.

To change the current situation a better integration of the tasks of designers and technicians is required. Such an integration can be achieved in a variety of ways:

- **Time pressure can be relieved through continuous development and sampling of design ideas**, garment features and materials by designers and technicians. In knitwear design development of new ideas occurs at the busiest time of the year for technicians: when they have to finish sampling garments for the previous collection to a deadline. Even though designers concentrate on designing at the beginning of work for a new season they never stop thinking about new designs. These ideas could be utilised better, if they were sampled immediately. Over the seasons the range of designs changes very little. In knitwear a few new yarns are used in every season, some strong and novel structures, such as a complex Arran pattern or some new intarsias, are developed. These features could be developed continuously through the year, when designers and technicians have time to work together, because they are fairly independent of fashion.

- **Technicians could develop features on their own initiative**, when time is available. Technicians are the most knowledge people about the technical realisation of a design. Knitwear technicians, who enjoy the challenge of pushing a machine to its limits, are the only people who understand the full capability of the machine. Technicians often do the detail design of garments, for example they might develop a fabric based on a vague description such as “crochet effect”. In some companies technicians are designing complete garments without input from designers, in others technicians work independently for months between the employment of freelance designers. These technicians are highly motivated and successful. The same approach could be taken and supported in larger manufacturers; by recognising the creative potential of technicians their status within the company is increased and they become more equal partners with designers.
• To enable technicians to design successfully they should be integrated into the research process. By visiting shows and shops, reading magazines and talking to their colleagues, designers discover the space of possible designs for a season. If technicians are excluded from this research they do detailed design without knowing the context, beyond other designs they have produced in-house. In consequence technicians often fall back on old solutions from previous years. Through research technicians can be motivated to develop design features on their own. In the few companies that have integrated technicians into the research process this has led to a true dialogue between designers and technicians; both suggesting and evaluating ideas.

• Technicians should be included in the design idea selection process, which is hardly ever the case. This is partially due to the status of technicians in a company hierarchy. It is often argued that technicians don’t understand design considerations. The decision as to which designs to pursue are, however, made in many companies by managers with a background in business. Technicians can provide feedback on costly technical problems that might occur in production, they can also suggest modifications leading to more effective, and therefore cheaper, production.

• Designers and Technicians should work near to each other, to encourage a quick exchange of ideas and quick feedback. Currently technicians are often located close the production machinery; and designers in a quite corner of the factory.

• Designers often have little technical knowledge of their product, for example knitwear designers cannot program knitting machines, fashion designers cannot grade garments and leisurewear designers do not understand dyeing. If a designer specifies different materials for a waistband than the main body of a garment a textile technologist has to spend days approaching different suppliers to get a suitable colour match. Designers’ technical training often depends on picking up snippets of information from technicians rather than a planned program of learning. Companies should invest in appropriate technical training courses for designers. For example, designers who have attended knitting machine programming courses specify garments that are more likely to be technically realisable from a technician’s perspective. There is, however, a widespread hostility to technical training for designers by both designers and senior management. It is feared that the designers’ creativity will be reduced by knowledge of technical limitations. There is evidence that experienced designers are less creative when they design according to what they know can be realised, rather then innocently pushing the limitations of a machine. See [3] for a more detailed discussion. In most companies, however, the practical advantages of realisable designs are likely to outweigh any possible restrictions on design creativity. In the carpet industry it is recognised that designing on a computer imposes its own creative limitations on designers, so managers deliberately plan design time using traditional methods. So, sensible management can be used to offset any tendencies towards contextual rigidity of design.

• Some companies are successful by using an intermediary to liase between designers and technicians. Such a person needs to combine technical and design knowledge in order to organise the interactions between designers and technicians. This process can work on different levels, ranging from an assistant who helps with legwork, collects and passes on feedback, persuades and soothes (in knitwear design this rôle is sometimes
taken by the person who creates the visual representation of the design in the CAD systems) to a competent manager who understands both design and technology so can provide feedback to both parties without agitating either side. Both models are successfully employed by large German garment manufacturers where designers have less technical training than their British colleagues. In lace design the technical rôle has a strong interpretative element so there is a natural aesthetic bridge between technician and designer.

- **An intelligent computer support system** can take an intermediary rôle by making technical knowledge accessible to designers. For example in fashion design, the Gerber system enables designers to specify an initial design by modifying a previous design and receive an initial costing feedback. The initial source of the design — a photograph or a drawing — can be referred to by the pattern cutters. The Stoll and Shima knitwear CAD systems are now marketed directly to designers as the end users. Theoretically, designers can create the machine program automatically from their designs. In practice this still requires considerable technical skills, so the traditional division of labour has changed very little. [2] and [4] propose an intelligent CAD system that uses the customary incomplete and tentative description of designs to generate suggested solutions automatically.

Individual companies have to look at their own design processes and contexts to find which of these suggestions are applicable. It would be useful for most companies to step back and critically assess their design processes independently of personalities and the company tradition. There are, however, two practical points that are helpful in many companies:

- It is useful to create a **detailed timetable** for the design and sampling process. By analysing when compromises need to be made by overtired, overworked individuals because of time pressures the processes can be rearranged so that some of the pressures are alleviated. A timetable helps all participants to assess how their work is progressing and to plan their time.

- A large number of designs are created by modifications to, or evolutions from, existing designs. However, textile companies are poor at **keeping records** of their previous designs and design ideas. This problem has been identified by [5] and [6]. For example, many knitwear companies keep all records for a year, some keep the finished sample garments, others depend on brochures. In many companies the archive is in the heads of designers and technicians and is lost with them. Some companies that have been good at keeping record samples are losing their discipline as new CAD technology is introduced. This, despite the potential archiving advantages of the new technology.

6. **CONCURRENT PRODUCTION: CO-ORDINATION OF DESIGN AND PRODUCTION**

Production machinery in the textile industry requires significant capital investment in looms, spinning machines or knitting machines. For example one modern knitting machine costs in the order of £100,000; a medium-sized, western manufacturing company needs to operate dozens of these machines to compete internationally.
Historically looms and knitting machines were driven through punched cards, which led to an obvious application of computer programming by representing designs through colours or symbols. These machines are reconfigurable so, once set up, can be used to produce batch runs of any economical number. The carpet industry uses small, rapid-prototyping machines that are also reconfigurable for swatch evaluation.

The gulf between the technology and skills required to produce both a prototype and a tool for mass production is very much larger in industries with dedicated tooling than in the textile industries. It is most unusual for a toy designer to be able to cut metal, whereas designers in the textile industry tend to have a basic understanding of how the product is made. It follows that mass-production industries are ahead of the textile industries in considering how to bring key design and production decisions together. We argue that even greater technical understanding and input at an early stage in the design process is desirable in the textile industry.

Designers’ lack of technical knowledge and the exclusion of technicians from the decision making process also leads to sub-optimal use of companies’ production capabilities. To maximise profit, production machines need to be running maximally during the customary working hours. Many British companies run two or three shifts a day and weekends. In Germany this is usually not economical because of bonus payments. Knitwear designers rarely know about the production capabilities of their companies and are not involved in production planning. Production managers give the designers broad indications of how they would like the machines to be used, regardless of fashion.

Many companies lose significant amounts of money by overcommitting their production resources and selling based on samples that cannot be produced in-house. This problem can be avoided by the early integration of production planning and design, following the lead of the mass-production industries that use dedicated tooling.

7. COMPUTER IN THE TEXTILE INDUSTRY IN THEIR ROLE IN CONCURRENT ENGINEERING

The formalisms demanded by the common use of computers at different stages from design to production imposes a division of labour into specialist tasks. Communication between the sub-tasks opens up the possibility of moving traditional technical skills up to the designer's desktop, or at least to provide a framework within which discussion between specialists can take place.

So, the technical function and the degree to which a designer can, with the appropriate tools or automation, take over, or contribute to, the function is an interesting issue for all industrial sectors. The degree to which technology can provide such services is increasing rapidly. Computers have rendered the capability of engineers to integrate mathematical expressions obsolete and the structural analyst is under threat from developments in computer technologies that offer the promise of stress analysis at the touch of a designer's button. Such trends are ignored at one's peril. The other side of this coin is to identify those areas of technical specialism that are not now at the stage of automation required by a ‘lights out’ factory, or are not amenable to solution by algorithm. Such areas of activity
require the designer to learn the skills of the specialism (as, perhaps, they diminish) or to co-operate with the specialist whose skills are not under threat. This puts us firmly in the ballpark of concurrent engineering.

There are a wealth of issues in different areas of the textile industry that are relevant to this line of reasoning. Given the, often confusing, claims of the computing industry and its prophets it is illuminating to look at some aspects of the textile industry and how relationships between design and technical functions are developing.

Companies such as Brintons (carpet manufacturers in Kidderminster, UK) recognised the potential for designing on a computer screen, together with the ability to automatically generate instructions for driving looms, very early in the history of the use of computers in the textile industry. Brintons have moved from mainframes driving character based graphical output onto paper, to PCs with colour bit-mapped screens. It is the carpet designer who performs the first technical stage, which is to turn a water-colour into a series of coloured squares: different representations of the same design intent. At this stage the main concern is that of colour matching and the designers have little interest in the technical features of the looms. The main technical driving force at the level of the loom is for ever more rapid setting up of new designs to minimise the downtime of the machines.

Carpet designs can be easily input directly onto the screen of a PC but the company’s designers regularly move back to using water-colours in order to ‘refresh their creativity’. Explanations for this range from ‘the size of the screen’ or ‘it needs to be horizontal’ to ‘it just doesn’t feel right’. The new generation of designers hold the same view as the established designers and the chief designer is a relatively young man, so the generation gap does not provide us with an explanation, and Brinton’s designers are convinced that the traditional methods will always be used in some form.

It is salutary to note that two experienced designers will produce technical representations (coloured squares) from the same water-colour that result in carpets that are recognisably different when woven. An issue that is not recognised in the knitwear industry where sketches for intarsia patterns are given to technicians to convert into stitches.

In the carpet industry, perhaps the simplest of the textile design and production processes, we observe that the designer owns the primary technical function but that the computer has, as yet, not rendered the technical function obsolete. This, despite the capability of drawing on the screen directly and producing the appropriate size of coloured squares automatically.

In the knitwear industry the technical function has a strong presence despite the advanced state of development of CAD systems with a direct connection to flexible knitting machines and the ability to simulate the knitting process and show the knitted fabric on the screen. Designers at Shima Seiki recognise the technical functionality as a separate process. As we have argued in section 6, a better integration of those two processes is essential for a more efficient design and sampling process.

There are two aspects of knitwear design-to-production that militate against the totally automatic delivery of instruction sets from a design representation to a production machine:
The first is uncertainty associated with the anisotropic effect of materials properties in
heat-set artificial fibres that it is not possible to emulate with the conventional tension
square. The behaviour of yarns and fabrics is only poorly understood: a predictive
type, for example, would need to account for effects that make some yarns knit
differently according to ambient conditions.

The second is exemplified by intarsia knitting designs produced on modern knitting
machines. The detail of the way in which a complex intarsia design is created and
effect has a significant influence on the productivity of an automatic machine. Badly
effect designs lead to more machine problems. Designers in the knitwear industry
recognise this and do not usually attempt to usurp the technical process. The analogy
with concurrent design imperatives that urge early involvement between different
specialists is strong.

In the lace industry designers are very much more aware of the capabilities of different
machines and play a rôle in communicating to potential customers the advantages of, say,
Levers lace. Customers of lace producers Guy Birken report an improved ‘strike rate’
from designs produced as computer print-outs rather than traditionally, as sketches. The
technical stage that follows a computer generated design representation is a reformulation
of the design, as yarn paths, that takes into account the anisotropy of a particular design.
This process is strongly skill oriented and, when completed, produces a more elegant
portrayal than the original, conceptual design representation. The overhead in this process
is large and so there is a strong, natural inclination for the person creating the technical
representation that drives the machines to be involved in the early stages of a design.
Production of lace samples for customer evaluation is very expensive as production
machines are used to produce samples from full-width production.

8. CONCLUSIONS

The textile industry differs from mass production engineering in the importance given to
two main considerations

- in engineering it is often necessary to revisit the same design aspect many times due to
different technical issues; however in the textile industries, such as knitwear there is a
strong, but subtle interaction between the way a design is produced and its appearance.

- in engineering special tooling machines need to be built for each design. This is not
necessary in the textile industries, but they also invest heavily in the technical realisation
of each design.

Both industries are under the same pressure: to bring a product to the market as quickly as
possible. Concurrent engineering principles from the general engineering domain and their
use of CAD systems can be applied to the textile industries by integrating the functions of
design, sampling and production much more than is current practice.

We argue that a close involvement of technicians in the design process, designers with
greater technical knowledge, and a well-structured process that leaves time for continuous
development can ease the pressures on designing and sampling. Designers should also
work more closely with production managers to make optimal use of resources.
Computer technology has significantly contributed to the integration of design and manufacture. At the same time automatic technical capability has increased significantly in many parts of the textile industry. However the scope for automating technical design is limited by the unpredictability of yarns and fabrics, and conditions influencing the manufacturing processes.

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Figure 1 A Simple Model of the Design Process in the Textile Industry (for more complex representations see Eckert ...)
Figure 2 Overlap between Seasons