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System Approach to the Research Process in Problems of Textile Engineering and Technology

Abstract
This paper presents a method of system approach to the realisation of the research process in textile engineering. A system of research actions based on the division of a textile manufacturing process has been devised in order to develop the manufacturing process for a given textile product. The two independent system types are singled out:
- *First: the autonomous anticipatory research cycles concerned with scientific examination of the problem for future use;*
- *Second: the design/construction research cycles leading to a practical solution of the problem.*

The method presented enables the realisation of research processes in all areas of textile engineering.

Key words: *system approach; transforming operator; R&D process; decomposition process; textile manufacturing system.*

Introduction

To ensure his survival in his national economy, the textile manufacturer must continuously adapt his production to the changing requirements of the market in which the predominant tendency is to expect new textile products of higher and higher quality. The function of research in textile engineering is to supply the textile industry with technical and technological innovation so as to enable the manufacture of such products.

To generate innovations and new technical and technological solutions in the textile industry, it is necessary to rationalise the research process in order to better understand and learn the 'art' of quick implementation of new developments in industry.

One of the methods that lay the foundations for improving the operational and methodological efficiency of the research process is to approach it as a system. In this method, the properties of a textile manufacturing system (operating technical system) can be analysed or synthesised using the essential property of the system as its identification.

In the system approach[1] (according to Dietrych [1], when applied to the designing of technical objects (TO), or Wrocławska [6] in an another application) the basic idea is the operator OP which transforms the inputs IN into corresponding outputs OUT (Figure 1), every input or output being classified as mass M, energy E, or information I. In the model of technical objects in the system approach, the inputs are marked as IN_M, IN_E, or IN_I, while OUT_M, OUT_E, and OUT_I denote the respective desired outputs (material, energy, information).

Depending on the complexity of the technical system, Dietrych identifies:
- an elementary operator, consisting of a single indivisible element;
- a complex operator, consisting of many elements, and which is divisible into relatively self-contained elementary operators;
- a megaoperator - a system of high complexity consisting of many complex operators.

In textile engineering, operators represent the production means (i.e. individual machines, production lines, etc., each of which is conventionally described as a textile manufacturing system), and a megaoperator represents a production department of a manufacturing enterprise, or even the whole enterprise itself.

This method of system approach to concrete material objects is currently in use, and at the same time is being developed further [2,3,4]. The method of system approach was introduced to the textile manufacturing systems and improved by Wrocławski [7]. Reference is made here to the relevant designs (unpublished) developed at the Polmatex-Cenaro R&D Centre of Textile Machinery, Łódź, and the Institute for Terotechnology, Radom. The method as applied to the textile technological processes, i.e. a series of

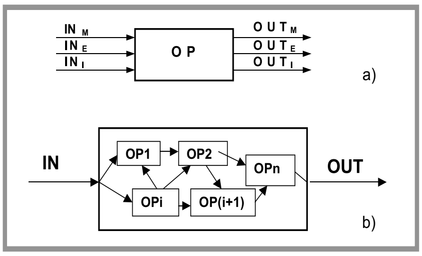

***Figure 1.** Model of a technical object in system approach: a) general, b) complex; IN - inputs, OUT - outputs, - technical objects.*

events realised by *textile manufacturing systems*, is described in the author's DSc thesis [8]. The application of the method can (as shown underneath) be expanded to include research activities, where it is an efficient stimulant of the process.

Realisation of Research Process in Textile Engineering

To carry out a given research task in textile engineering, it is necessary to design a rational plan of action whose scope of realisation must be both complex and substantially complete. It is worth noting here that the 'four jinns' criteria (quality, economy, aesthetics, modernity) formulated by Kazimierz Szpotański in the inter-war period have retained their validity.

The research process, as a basis for action in the area of fundamental and utilitarian research activities, has an essential effect on both the quality and efficiency of the development of technological science and on the creation of technological progress in the industry. Improvement of this process may significantly shorten the period 'from idea to industry'. In analysing these problems, modelling the process by the set theory provides a useful and efficient instrument.

In set-theory modelling, the research process in textile engineering θ is an ordered triple of the following elements: the new-product manufacturing technology T; the manufacturing process P realised on a textile manufacturing system; and the research R, which verifies both the manufacturing process and its technology.

$$\theta = \langle T, P, R \rangle$$

Between these elements of the set, there are relations which in the research process are analysed, verified, described and implemented in accordance with the needs as defined earlier. Figure 2 represents the idea of research process realisation in which are marked the successive, increasingly more detailed 'identifications of need' in the area of the abstract, and increasingly perfect solutions of the technical system in the area of the concrete.

The more rationalised are the creative activities in the area of the abstract and the research activities in the area of the concrete, the shorter is the time of arriving at the expected final result.

Decomposition of Research Process into Component Operations

In the adopted thesis, the **transforming operator** (complex) is the method, technology, etc. of the realisation of a technological textile process on a textile manufacturing system to obtain a textile product meeting a definite social need, of which the **input** is broadly understood information (based on market research etc.) about the need and the **output** is the product satisfying the need.

In the system approach, the process of creative activities leading to satisfaction of the social need for the given textile product P was divided into the following component operations, as was done by Migdalski [5].
- Identification of the need (NI),
- Design of the manufacturing process of the textile product (DT),
- Design of the manufacturing system for realising the manufacturing process (DM),
- Construction of the manufacturing system (machine, production line, etc.) (CM),
- Production of the textile product (TMS),
- Distribution/sale of the product (DP).

Figure 3 shows a sequential arrangement of the component operations mentioned, or a sequence of events (without design & construction operations) in which the inputs of the respective 'followers' are outputs of the respective 'preceders' as was described in reference [8] regarding a non-woven textile product.

The components of a research process in textile engineering are:
- the process of continuous market research to identify the need (anticipatory research);
- the design/construction process for the new product and/or manufacturing system (applied research).

The process of continuous market research to identify the needs

The essence of this research is a continuous reconnoitring of the public needs or expectations in the given area, and the readiness to create new artefacts to meet the public need. Figure 4 presents a model of the scientific identification of a need, based on the system approach.

Depending on the task assigned, the continuous identification of the need *rp* may require the following activities:
- *Expertise and consulting* (E&C), usually in the form of determination of the manufacturing process parameters (*sp*) for the designing (or modification) of the manufacturing system.

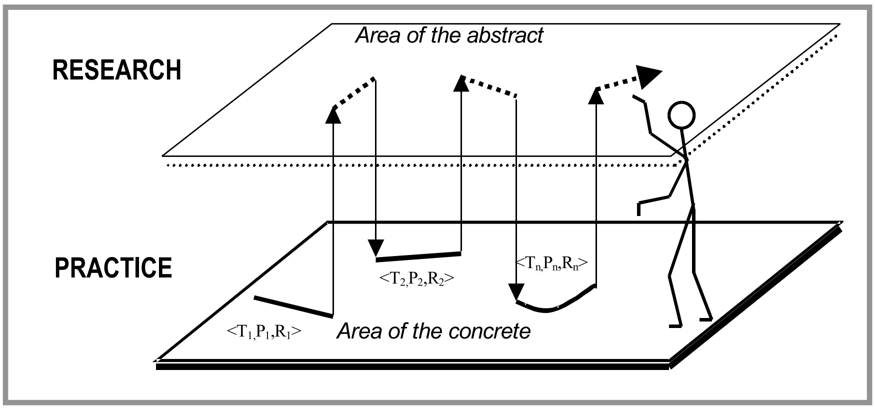

***Figure 2.** Idea of research process realisation; T - manufacturing technology, P - manufacturing process, R - research.*

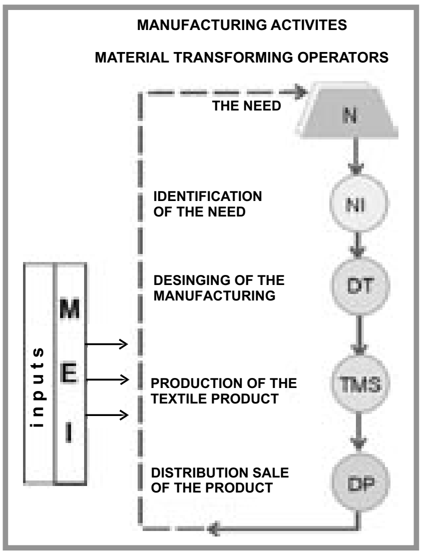

Figure 3. *Model of the process of meeting the need for a textile product until the need is satisfied by textile enterprises; M - mass, E - energy, I - information, N - need.*

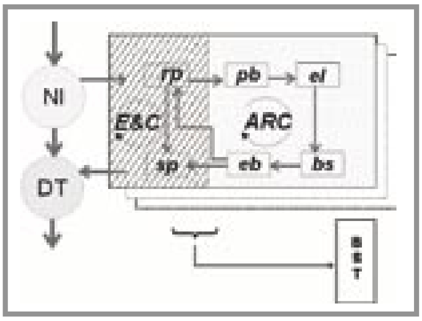

Figure 4. *Model of the scientific identification of need in system approach, NI - need identification, DT - textile designing according Figure 3, BST - Science & Technology Data Basis, E&C - expertise and consulting, ARC - autonomous research cycles, rp - continuous identification of the need, sp - manufacturing process parameters, pb - research programme, el - laboratory experiments, bs - test stations, eb - research effects.*

The description of the need may be made use of by the future buyer;

- *Autonomous research cycles* (ARC) leading to the development of appropriate research programmes *pb* realised via laboratory experiments *el* and construction of suitable test stations *bs*. This leads to the obtaining of research effects *eb* that imply their further utilisation, for instance for the purposes of scientific or technological progress. The results of this research may also be regarded as an offer for the industry, suggesting a potential technological innovation. In the case of transfer of a technology so developed, the parametrically determined technological process *sp* is, in the system approach, an input to the subsequent material transforming operator DT. In this way, the creative activity realised in a routine research cycle is transferred to the realisation of the concrete (a concrete thing).

The above-mentioned activities supply new knowledge for the given discipline and create research databases for the database of Science and Technology BST. The results of this research cycle are developments that are ahead of the state-of-the-art textile manufacturing technology. Should a concrete need occur, they provide a good foundation for new utilitarian solutions.

The research process described is realised by the **intellectual operators of transformation** (workers in research and technological science) which transform the respective information by using their own research data and data from the database of science and technology and various research instruments (computers, measuring devices, test stations, etc.).

If it becomes necessary to realise a further research process, the design of the manufacturing technology (in the form of output of the transforming operator DT) can be verified on an existing textile manufacturing system TMS, or it may be used as a basis for the designing and construction[2] of a new TMS.

The design/construction process for a new or modernised textile manufacturing system

This process (Figure 5) must also be preceded by appropriate market research *rt*, establishment of the guidelines *sz*, development of a programme of research work and procedures *hb*, and the construction of a model of the manufacturing system *mu* to test its end-use functions *be* before developing the relevant technical documentation *dt*. This documentation will enable the future buyer/user of the textile manufacturing system TMS to start preparation for constructing a prototype *bp*, or modernisation or modification of an existing textile manufacturing system. During the testing-in-use of the prototype *tp*, it may become necessary to verify the documentation *wd* and introduce any necessary corrections, changes or improvements *po* to it. Thus, the design/construction of a prototype supplies or supplements the user with a new technical means, of which the assigned manufacturing possibilities are a result of the description of a concrete need.

This research process has a utilitarian character and it is implemented, in direct co-operation with the industry, as a design/construction cycle DCC. The design/research cycle is realised, as are the autonomous research cycles ARC, by the **intellectual operators** who transform the relevant type of information into a real model, whereupon the information is verified by the technological process.

In the realisation of a DCC, the participation is necessary of **material transforming operators** of which the inputs are **materials** (raw materials), **energy**, and **information.** As mentioned before, the result of the realisation of a research process is the satisfaction of a concrete need. However, as needs change with time and saturation of the market occurs (logistic curve S), anticipatory research is needed for a new, more perfect product with better end-use properties, or a qualitatively new manufacturing system. Therefore, the presented model of the process has a cyclic character, and its rate of realisation reflects the efficiency of the technical and technological development. The quality and value of the actions that are part of the presented cycle are verified by the number of implementations to industry,

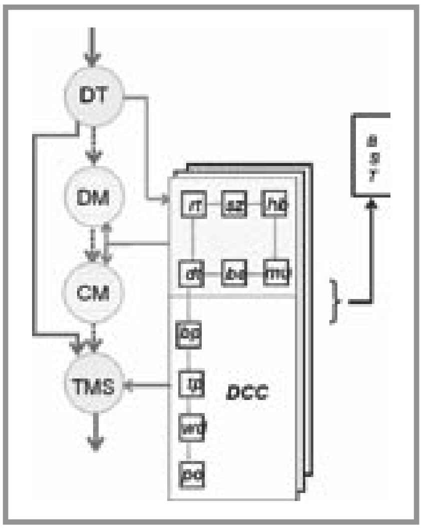

Figure 5. *The research/design/construction cycle; DM - design of the manufacturing system, CM - construction of the manufacturing system, DCC - design/construction cycle, rt - market research, sz - guidelines, hb - programme of research, mu - model of the manufacturing system, be - end-use functions, dt - technical documentation, bp - construction of prototype, tp - testing-in-use of prototype, wd - documentation verification, po - changes and improvements.*

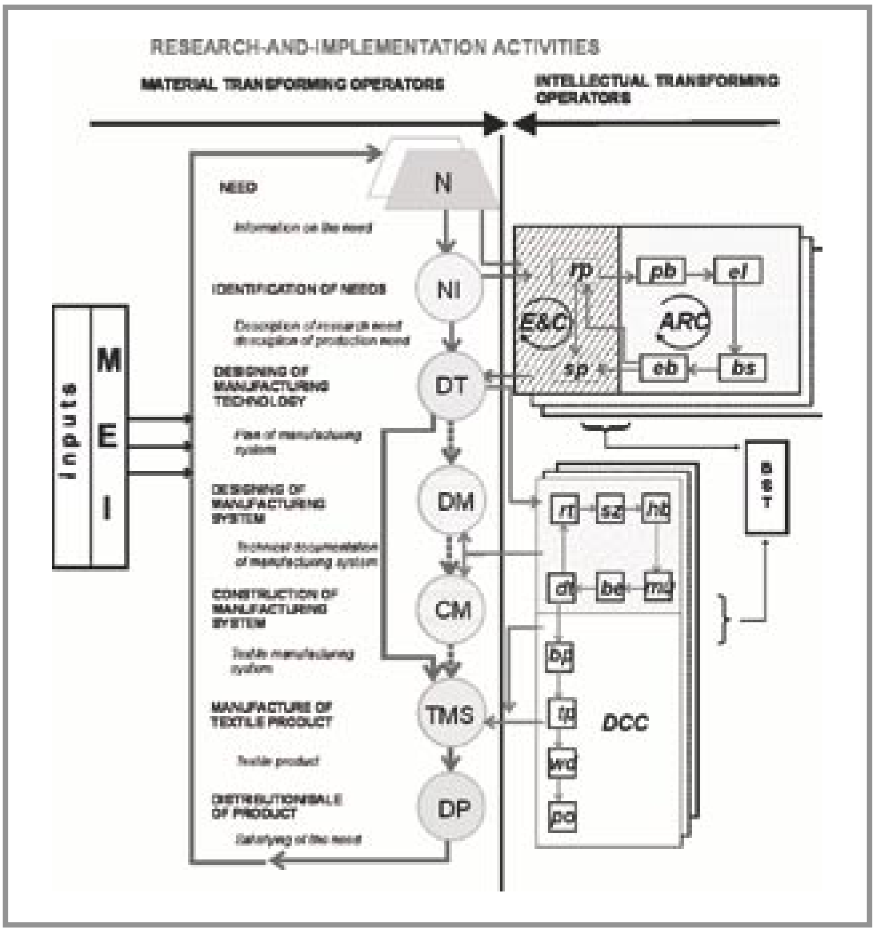

Figure 6. *Model of need satisfaction process in textile production (textile market). All designations as in Figures 3, 4 and 5.*

licences granted to manufacturers, economic and extra-economic effects, etc.

To sum up, it is possible to say that the research process in the system approach is represented unambiguously and in an ordered manner, and that it also improves and unifies the research methods, in this case the methods belonging in textile engineering and technology. Figure 6 presents a complete model of the process of creating innovation and development in the textile industry.

The question arises of how to organise the research process and manage the research personnel to ensure the possibility of continuously expanding creative work. The answer is as follows:

- First, continuously adapt the intellectual and experimental possibilities to the solving of inter-disciplinary problems under changing market and manufacturing conditions;
- Second, create an efficient and flexible policy of co-operation with the industry;
- Third, remember that the implemented research projects, both basic and practical, usually generate new challenges which contribute to progress and further development. Hence, the research process should be open to new problems leading to new developments in technology.

Organising research means improving the work of the teams of research workers by appropriate co-ordination and stimulation to release their intellectual energy towards more efficient creative activity.

The research organisation which creates a strong basis and rationally utilises the specialised qualifications of its staff has a better chance of developing under the hard conditions of the market economy.

Conclusion

It follows from the analyses presented that:

- The autonomous research cycles ARC increase research resources, contribute to the resources of science and technology, and provide a basis of knowledge that can be utilised in the future.
- The design/construction research cycles DCC well serve the implementation and utilisation of concrete technical and technological solutions and promote the technological progress.

Acknowledgement

The paper is dedicated to Professor Zbigniew Wrocławski on his 80th birthday, with thanks for the time he devoted to our discussion of the problems of system analysis of 'the concrete and the abstract.'

Editorial notes:

1. *Earlier, Ludwig von Bertalanffy published his concept of an open biological system in which there is 'import and export of substance' (von Bertalanffy, L., 1950, General System Theory: A New Approach to Unity of Science [in] Human Biology No 23, 1951, pp. 302-311 and 356-361.*
2. *This can also be the modernisation or adaptation of a manufacturing system, or the selection and arrangement of machines into a production line.*

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