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The mould as the central part of production unit. Part I

Summary — The paper presented at a Regional Meeting of the Polymer Processing Society [1], now reported in two Parts, describes selected historical and contemporary considerations concerned with tool making. These considerations can be regarded as the beginning of the tool-making philosophy, because tool-making fulfills all the top criteria required for the production. Tool-making has been and still is the foundation of product manufacturing and has experienced deep changes in the history. By developing the technical, especially manufacturing sciences, tool-making has introduced experience into scientific knowledge, which makes it possible to solve tasks that are becoming increasingly difficult. The position of tools in the culture and the term production are discussed. The philosophy of links between the design and production is approached and an explanation is given why tools constitute the central element of production lines.

Key words: tool-making, natural and artificial tools, moulds, philosophy of tool-making, production, design, making.

Our intention is to discuss in the second text the re-engineering in the mould design and mould manufacturing. Re-engineering proves the old thesis that the mould is the central part of the line for production of polymeric parts [2]. At the same time, tool-making is the oldest profession and it is at least 2.5 million years old, starting with the manufacturing of the first artificial tool, the stone edge, found at Gona, Ethiopia [3]. This profession has always been the basis not only for the making of products, but also for the culture as a whole, and in the human history it has lived through substantial changes. By the development of production sciences, tool-making has combined experience with scientific knowledge that enable the increasingly difficult tasks to be solved and also to be provided with its own philosophy, as a part of the philosophy of technics*) [4].

TOOL-MAKING AS THE OLDEST PROFESSION

In the next century tool-making will be the basic profession for material culture. The introduction of computers, not only as computer-aided design or manufacturing, but also in a lot of simulations, rapid prototyping and rapid tool-making, has completely changed the traditional tool design and manufacturing, including draconian shortening of the manufacturing time. This paper sets out to discuss the development not only of moulds for processing plastics and rubber, but also of tools in general.

But it is of interest to *"go back to the very beginning"* of the starting point of natural tools. The first tool was a natural one, a human hand with his special part, the fist. This happened when the human being stood upright and started to walk on two feet sometime 4 or 4.5 million years ago [5].

Natural and artificial tools

According to German philosopher Oswald Spengler, the formation of human being is strongly connected with the development of the hand [6]. Today, the hand continues to be an excellent natural tool serving not only for the procedures of making. At the same time, the hand perceives the presence and feels the shape, the weight and the place of resistance, and carries natural objects and things in space. In some aspects, the hand as a natural means of action and transport as well as a sensor of touch is even today unique and surpasses any

*) Word technics is an old English word for German word Technik. Unfortunately, this word is too rarely used in modern practice, because it is mostly replaced by the word technology, which is necessary for other purposes.

artificial tool. Some of these unique characteristics of the hand will be discussed later.

Many philosophers like Nietsche or Montaigne assumed that the human being could be regarded as a rapacious beast. The eye of this rapacious beast can be regarded as the theoretical governor of the World. And then, the hand is practically the queen [6].

But the hand is short, and the making can be done only within a certain range of shear viscosity. In his famous lecture "The man and the technics" back in 1931, Spengler called attention to the following fact. The hand alone is not sufficient, so it needs extensions. Freud would have said, the hand needed artificial organs. And Spengler assumed that, at the same time, with the formation of human hand, also the carriage of walk must be formed a tool. The question arises, which kind of tool? Now, this is our contribution to this subject. This can be only natural tools—objects (German: Dinge) like a piece of stone, a wooden branch or a gnawing bone. And then we have for 2 million years the empire of natural hands and natural objects. And then the Man made his first artificial tool, a stone cutting edge. With this explanation we introduce two categories of tools, natural and artificial tools.

Ambivalence of technics

In the same text Spengler wrote *"technics is primeval"*. Technics is not something specifically historical, but something infinitely general, because it reaches beyond the Man far back into the life of animals, and that of all animals [6].

We have to stress, from the very beginning, the hand was and is at the same time a good tool and a bad one, a weapon. And this ambivalence of hand is the basic problem of the whole technics up to these days. The same problem arises with the first artifical tool—stone cutting edge, which can be used as a helping means of action (*"good tool"*) or as a weapon. This dilemma of the nature of tools is even today of greatest possible importance, not only in tool-making, but also in the technics as a whole.

In the history, tools have also been changing significantly. In spite of this experience-based fact about the significance of tools for the overall development, tools, also the production ones, receive insufficient attention at all levels. Therefore, tool-making needs its own philosophy, which leads to the basic conclusion that the tool is the central element of every production unit. All the rest, design materials and equipment, have a merely potential value, if the necessary tool does not provide the manufacture of the needed part.

Tool-making really is the oldest profession and Jobst Gellert reminded of that fact in this article: "Why we must promote the oldest profession" back in 1996 [7].

Tool-making as the basic profession for 21st century

Profession is occupation and craft. Tool-making, which is now a vocation (craft) and occupation (*e.g.* trade), as we explain, existed since the beginning of the mankind. One should only think of the first inventions of the mankind such as clothes and footwear for protection against the elements of nature, weapons for acquiring food, *etc.* People needed tools to make them [7]. Therefore, tool-making is indeed the oldest profession. But the question is, whether J. Gellert was aware during the preparation of this text that tool-making is about 2.5 million years old. Namely, the tool-making and the culture as a whole started in the area of *homo* or *homo habilis* [8].

But the time has changed. Over the time, the chain from tool designer (product designer) to the tool user (now consumer) has been extended. So now, there is a tool designer, a tool maker and a tool user. But who is the tool maker now? The craftsman who is only able to turn mill? Or the man responsible for assemblying the tool parts and rendering soul to the tool. This means that it is not sufficient just to put together parts of a tool. The tool, as the means of action, must make the product. And this is a difficult task.

Though Gellert speaks of American experiences, these are very much world experiences as well. Therefore, more of Gellert's ideas need to be quoted. "Tool-making is more than the art of cutting and fitting — it's the science of creating something useful. It's understanding a need and manufacturing a solution. It's been said that good tool makers have fingers of gold. They create value-added products" [7]. J. Čatić would add: "These gentlemen with bowler hats are not clerks, they are Tool-makers" [3].

"What makes a tool-maker good?" asks Gellert. A good tool-maker has to have the sense for intangibles: the ability to see a workable solution for position processing which can be like a nightmare, he must take part and suggest innovations in design, to know what will work and what will not. It is not a question of intelligence, but of having the knowledge that comes from experience. That is the essence of tool-making, and why apprenticeships are vital. But the fact that nobody wants to be a tool-maker in USA (and not only in that country), is entirely true.

THE POSITION OF TOOLS IN THE CULTURE

Particle separation machining is the oldest culturological activity

(I. Č. 1997.) [9]

The role of tools in the culture

If tool-making as a profession has always been the basis for culture as a whole, it is worth the effort to find the place for tools in general culture.

The first mankind product was a stone axe. This product was the starting point in the development of general culture. At one place in the present Germany a spear, about 400 000 years old and balanced to provide better flying, as well as the tools necessary to manufacture this item, were found. So, the fact that the description of the human culture starts with the culture of tool, as it is presented in the World Book Encyclopaedia [10], should not surprise anybody. For a better understanding of the term culture, it is necessary to define it. The simplest explanation is that the term culture is the opposite of the term nature. Culture is all that is the result of man's will and effort. For this text the most appropriate definition is the one given by British anthropologist Sir Edward Burnett Tylor in his book "Primitive culture"

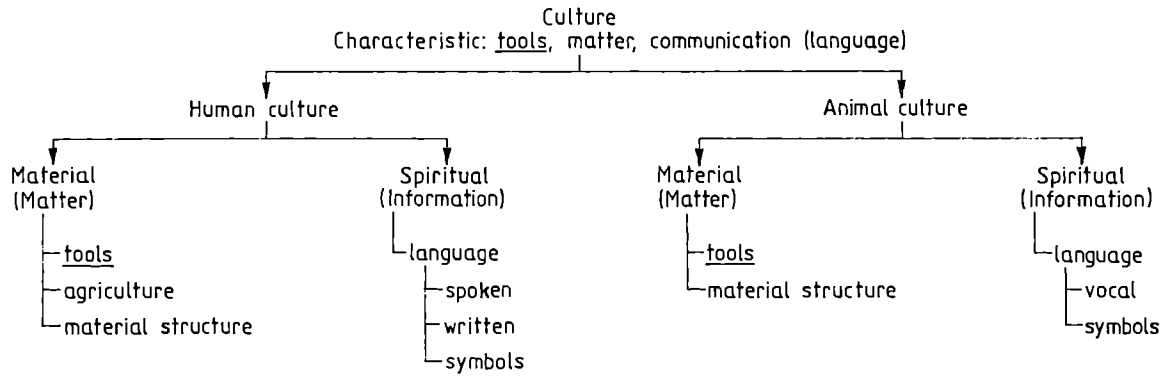

Fig. 1. Culture trail

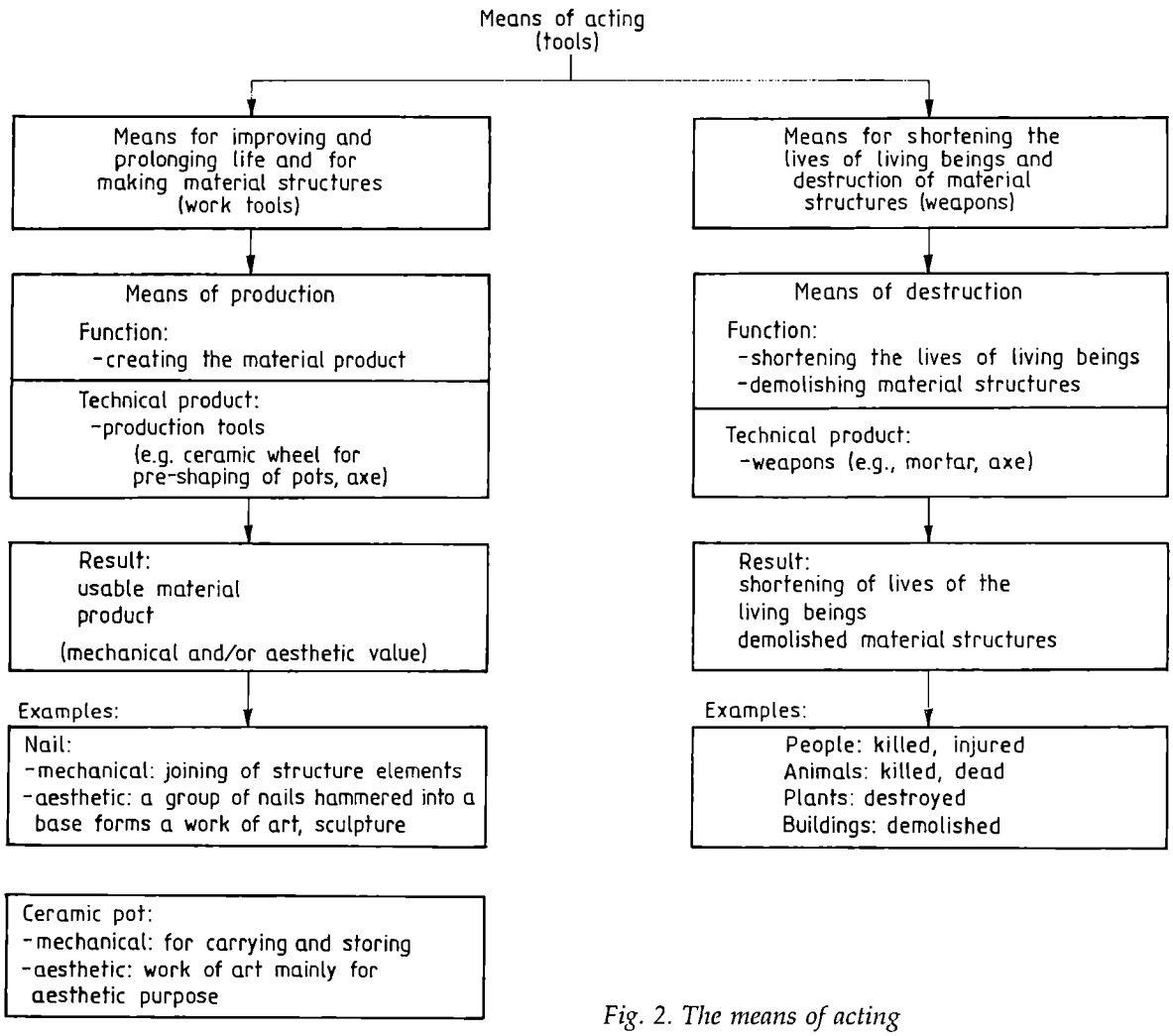

Fig. 2. The means of acting

(1971) [10]. Tylor has defined culture as "that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society" [10]. The art means, among others: artistry, as opposed to nature, craft, craftsmanship, knowledge, method, skill [11, 12]. Some of the meanings of the word art give us the right to express the opinion that the technics is the integral part of culture. Culture can be human and animal one [10]. Based on this idea, we have developed Figure 1 for describing the culture and its characteristics [4].

There is at least one example of a common tool in the human and animal culture: the back scratcher. The event is itching and the function of eliminating itching is rubbing [10].

In this paper we discuss the tools and tooling in general the tools as the means of acting (Fig. 2) [4].

We intend to pay attention to the means of prolonging life and making material structures (work tools). Strictly, if we take, as an example, the mould for injection moulding act commonly as a work tool, in some case, however, it can act as a weapon. The work of such a tool injures a lot of people. Before concluding this part of the text, there is yet another argument for overlapping between tools and culture. In the first layer, the word culture is traced from Latin word *culter tri* = (butcher's) knife = tool [13].

Three conclusions follow from this description. First, the tool is the first culturological product and the culture starts with manufacturing the tool, a stone edge. The tools give opportunity to every man's action to be preserved in material and spiritual culture. And finally, as the means of action, the tools alone are responsible for the macrogeometrical shape and properties of the part. This issue will be discussed later.

If we take into account that tools are the basis for every permanent cultural activity, the question is asked what kind of apprenticeship will be needed by the tool makers working on manufacturing the work tools in the 21st century. One of the possible answers is also one of the aims of this paper.

Professionals of the 21st century

"Industry in the 1950s could well afford to have an excess of personnel on staff. In many cases these people, some of whom bore the title of *"executive"*, had *"specialised"* duties, *i.e.* their areas of responsibility were rather narrow — and image was the key to success. Was this corporate necessity, corporate luxury, or corporate fat" [12]. The philosophical basics for such a division will be considered later.

At the end of the second millennium the importance of a person and his/her affiliation in the company may be expected to be a thing of the past. Globally, business is calling for flexible and mobile executors: people who can function on the "battlefield" of everyday life, rather than glide through the "corridors" (performing tasks); *i.e.* people whose contributions can be realised in the board room and on the shop floor. The day of the skilled generalist (author's remark), the 21st century renaissance man may well be upon us [14].

On a global scale, industry needs people who are able to provide versatile contributions on all levels of manufacturing and organisation. For too long the objectives have been set to their specific executives. We have become a society of specialists who perform but one function, and whatever is found on either side of the specific area of expertise loses significance and this may have been heard before. But those who have worked for relatively small companies know the positive effect an employee can have when s/he has knowledge of more then one job function and of the company's corporate plan, and exercises his/her skill/knowledge level in making day-to-day decisions [14].

The mandate for industry in the 21st century is for a renaissance in materials, products, processes, possibilities, and personnel. In order to meet this mandate, industry professionals must become versatile contributors whose objective is the growth of personal and organisational excellence [14].

Ferris is not the first author to emphasise the renewed significance of the generalists. In as early as 1983 at the Rector's Conference of German Universities it was, among other things, stressed that: "generalists precede specialists". The overall concept of the fractal entrepreneur culture is based on the generalists as company managers [14]. And tool-making in small companies have been always such generalists.

The special intention of this paper is to discuss the bond between the mould design and mould making. For this reason the term production must be discussed.

THE TERM PRODUCTION

The starting point for this description of the term production (Figures 3—5) is a paper published in 1986 [15] and its latest version will be discussed now [16]. The production starts always with the idea. But it is not so long ago that we realised that the end of production

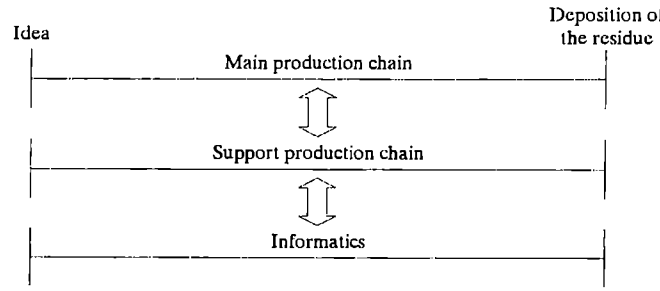

Fig. 3. General model of production [16]

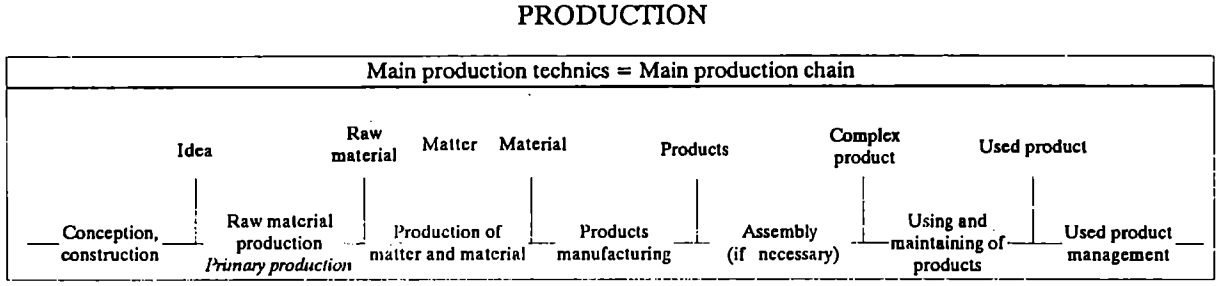

Fig. 4. Main production chain

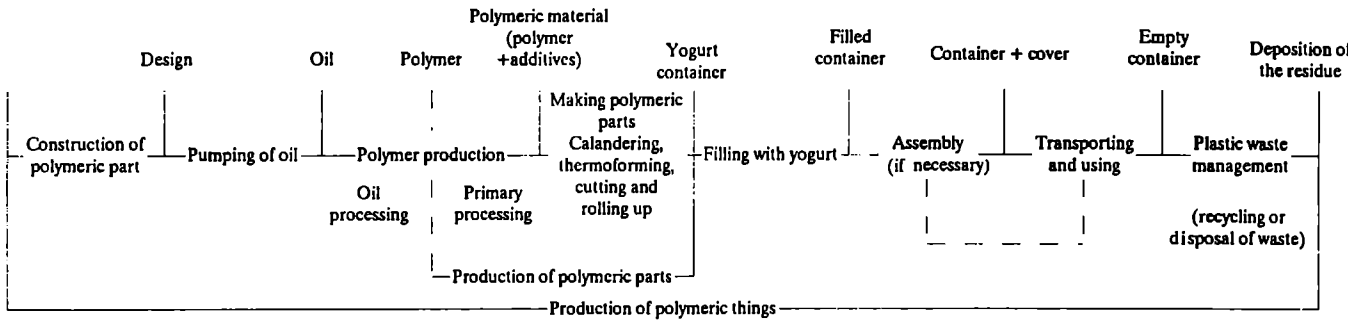

Fig. 5. Main production chain for making polymeric parts

is deposition of the residue of the exhausted parts (Figure 3) [16].

For transforming the idea into the final product, thing*), and then to deposit the used rest of exhausted product, we need a lot of operations. The concretisation of main production chain is given in Figure 4 [16]**).

For developing the main production chain, an idea from the Bible has been used. It was Eekels who called attention to the following text [17]: "One of the oldest accounts of making action is the story of the creation of the world (Gen. 1:1): "Dixitque Deus: Fiat lux. Et facta est lux. Et vidit Deus lucem quod esset bona". ("And God said: Let there be light. And there was light. And God saw light, that is was good").

Here we have the famous triplet: "fiat, fecit et facta est". The religious writer stressed the terms: "fiat lux" the "setting the purpose". "Et facta est lux" means, "performing the act". But it is also important to stress: "Et vidit Deus lucem quod esset bona", "evaluating the result". And the result is the use of product. We often neglect the results of the designers' and producer's work. And this is damaging, particularly for the designer. Based on this and some other fine ideas from Eekels, we have developed the philosophy of tool-making, as a part of philosophy of technics [4, 9, 18].

Successful tool-making is based on the optimisation of interrelations of the two activities, designing and making. We must first translate the word making in the modern sense of the meaning. The terms production or fabrication, are probably two of the possible translations of the word making. The main production chain for making of polymeric parts (*e.g.* yogurt container) is given in Figure 5 [16].

REMARKS ON PHILOSOPHY OF BOND BETWEEN DESIGN AND PRODUCTION

Technicians, and hence tool-makers, are one of the latest creative vocations and occupations. At the same time, one of the basic shortcomings of technicians, and therefore technics as well, is that they consider themselves self-sufficient. They very rarely cross the borders of technics. And this could be extremely useful. One such especially interesting field is the philosophy of technics. And on following ideas we developed the philosophy of tool-making, and thus the philosophy of mould making [4].

"The philosophy of technics is a rather young discipline. Most of the treatises focus on the position of technics in society as a whole, on its effects and counter effects, and its ethical implications", wrote Eekels [4], for example, the environment protection. In this treatise Eekels emphasised the aspects of the inner structure of technics, *i.e.* he discussed making and design. Special incentive is given by the idea that design certainly is very important, but cannot be considered without the production process. Design and production make a whole, so that Eekels' remarks on design refer to this activity within production, *i.e.* as a part of the whole [4].

*) Under the term thing we understand any material object made by people, so called gripped body.

**) Based on this model we are developing also models for production of food, warm-blooded animals and even for production of human beings [16].

Why is this fact stressed ? For a long time these activities, even in tool-making, have been separated. Analysing production in his capital work "Das Fraktale Unternehmen" (Fractal Entrepreneur Culture) over the past hundred years, Warnecke has come up with the conclusion that this actual need for entanglement has been recognised only in the last quarter of the century [4]. In his novel "Disclosure", American writer M. Crichton thus described the need for this entanglement: "The main reason why we need production is the following. We are primarily a scientific development company and we design new products, but we need production as well. If there is anything that we have learned over the last twenty years, is that the product development and its production are a joint process. Should you separate designers from part makers, you will get a poorly developed product. You will end up like General Motors" [19]. In order to avoid the implications of a long-term separation of development and production of parts, there are tendencies to bring them together again, which has been included in the phrase of simultaneous engineering.

It is far from the intention, and anyway it would prove impossible, to include in this paper all of the very stimulating Eekels' ideas, but let us repeat at least a few [17].

The term making

"Man is often defined as "homo faber", "man — the maker". "Making", in an engineering sense, can be defined as "the exercise of the creative with respect to more or less durable creations". In all forms of creativity (art, technics, science) we can distinguish between reproducing creativity that concretely realises itself in material reality. And conceiving creativity that is enacted on the mental stage, and that produces design for the reproducing creativity. Therefore, design (*e.g.* of moulds) is inseparably connected with the concept of making (*e.g.* mould making). In discussing the one, the other is automatically considered, too. In the philosophy of technics, the philosophy of creation forms its important part. "In his work Eekels quoted philosophers like Plato, Aristotle, St. Bonaventura, St. Augustine, Locke, Kant, Dessauer, and van Riessen considering the bond between design and making.

Combining philosophy and tool-making it should be noted that Plato (427-347 BC) in his learning about ideas used the concept of mould, pre-figure in a certain way [4]. Explaining Plato's teaching to the hero in this work "Sophia's World", Gaarder asks "how to make 50 pepper-cakes" [20]. The hero answers, using a mould. It does not matter that these pepper-cakes are not equal in all the details, but are alike. Plato's standpoint is interesting, since the actual process is based on the eternal ideas, by which creation is directed towards efficient result [17]. Dessauer, who assumed a kingdom of technical ideas in the Platonian real sense of ideas, can find a similar standpoint also in the 20th century [17]. Eekels considers creation based on Plato's eternal ideas narrows the space for the designer's creativity (excluding, of course, God himself), and that many designers will not be really enthusiastic about such a standpoint [17]. However, the conclusion is far-reaching for the production. If ideal mould does exist, then the products merely look alike in practice, and their real distinction requires measuring and application of a certain apparatus of stochastic mathematics [4]. We will have to return to Plato later.

Two thoughts of one of the greatest philosophers in history, Aristotle (384-322 BAD) are of importance for these reflections. He demonstrated a deep insight in the essence of technics when he wrote: "At the outset of making stands a design of the object to be made, a technical drawing for instance this means the form not connected with matter. And at the end the material object itself of a prescribed macrogeometric form and properties" [17]. Aristotle discussed, among other things, the relation between form and matter or form and structure. "Everything that we observe in the world is formed matter. Matter is thus, not only a reality but also possibility, "potential", it exists only by means of forms" [17].

We now make a large jump through the history and go to the 17th century, where we meet John Locke (1632—1704) [17]. Some of his ideas are very important not only for engineer-designers, but also for engineering as a whole (all citations, which follow, are taken from [16]). The transformational aspect of making is pointed out well by this English philosopher, where he says, "The mind finds no greater difficulty to distinguish the several originals of things into two sorts. First when the thing is wholly made new, so that no part therefore did ever exist before: as when a new particle of matter doth begin to exist in rerum natura, which had before no being, and this we call creation. Secondly, when a thing is made up of particles, which did all of them before exist, but that very thing, constituted of pre-existing particles, which considered all together, make up such a collection of simple ideas, had not any existence before, as this man, these eggs, cherry, *etc.* And this when referred to a substance, produced in the ordinary course of nature by internal principle, but set on work by, and received from an external agent, or cause, and working by insensible ways we perceive not, we call generation. When the cause is extrinsical, and the effect produced by a sensible separation or juxtaposition of discernible parts, we call it making. When any simple idea is produced, which was not in the subject before, we call it alteration. Thus a man is generated, a picture made, and either of them altered, when any new sensible quality or simple idea is produced in either of them, which was not there before; and the things thus made to exist, which were not there before, are effects; and those things which operated to the existence, causes". We understand here under the term causes, Beckman's means of action, tools.

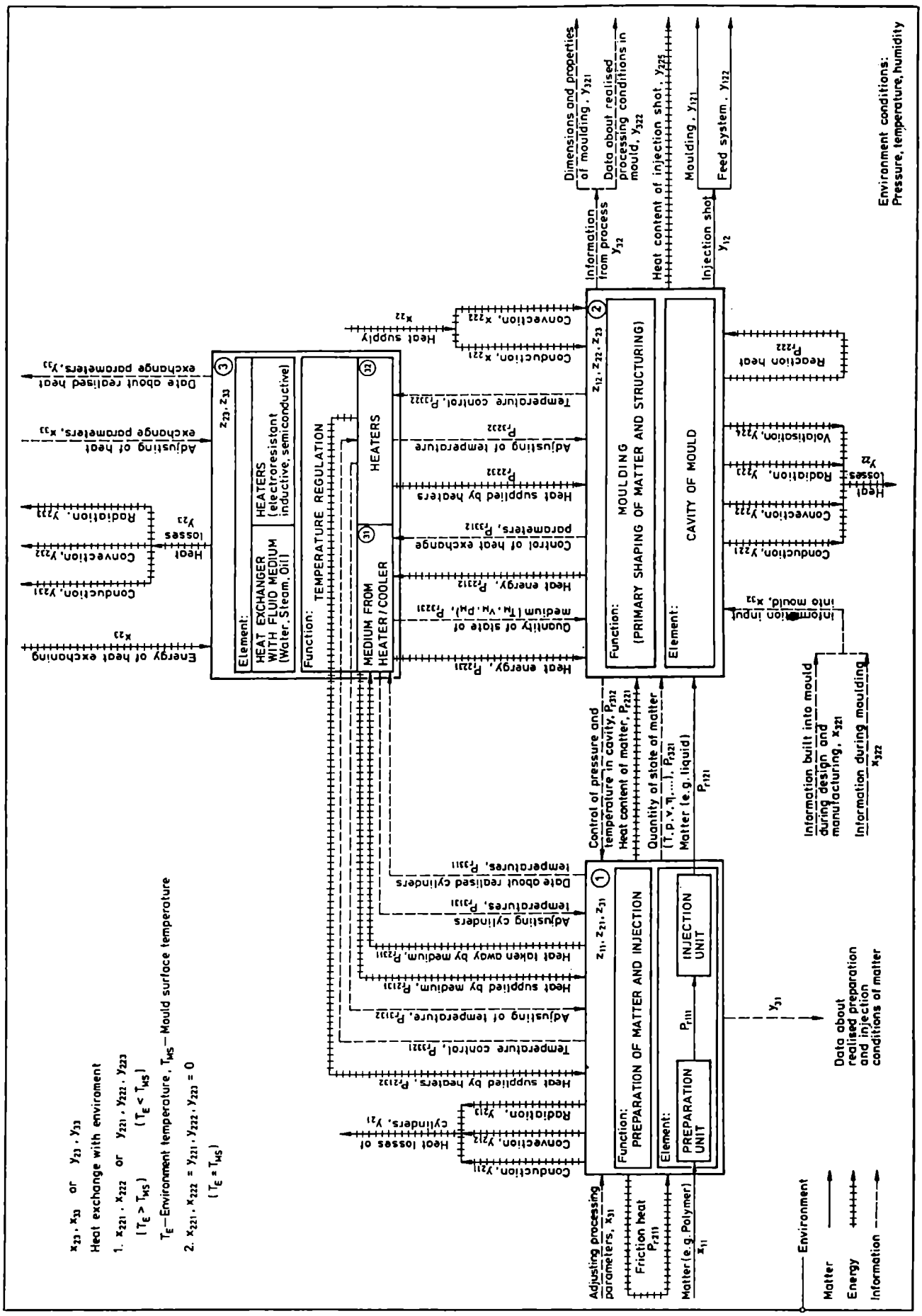

Fig. 6. Reactive injection moulding system for processing of polymeric matter

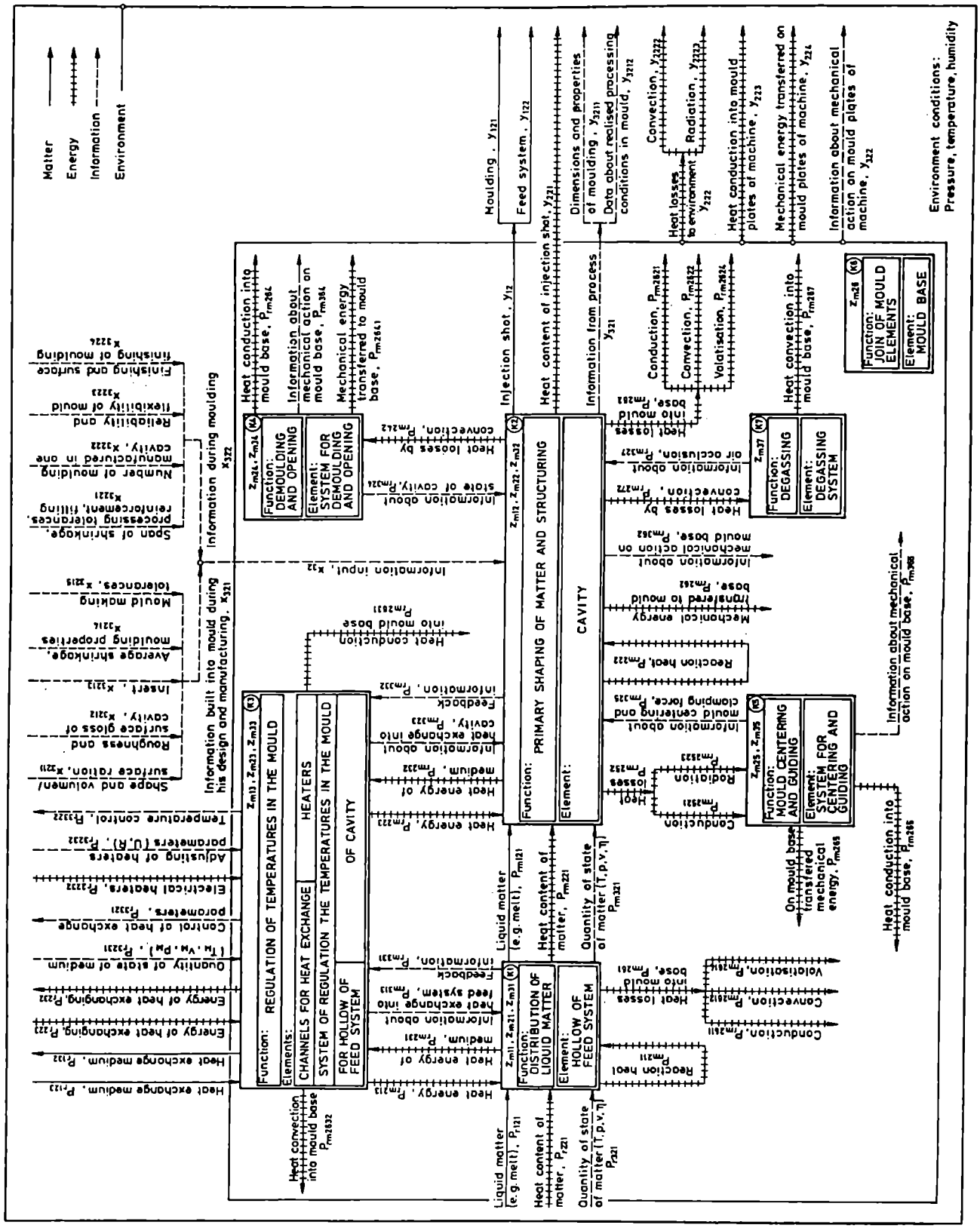

Fig. 7. Mould for injection moulding as a system

"Nowadays we would say that Locke occupies a purely cybernetic standpoint: he looks at the real system and its behaviour only. The dualism 'mental stage —real manufacture' is not present in his considerations", wrote Eekels in this analysis of Locke. "Locke's definition of making illustrates his practical standpoint. His distinction between (divine creation), generation, making and change in general are valuable up to this day" [17].

In this respect, it is interesting to return to Plato and to see what his definition of making is: "We find it in the Symposium", wrote Eekels [17]. "For of anything whatever that passes from not-being into being the whole cause is making action". This sounds as if Plato restricts the meaning of τε'χνη to Locke's concept of creation. But this is not the case. Plato does not restrict making to matter, but includes all aspects that can be distinguished in being, such geometrical forms, properties *etc.* Thus, if a form comes into being that did not exist before (although the matter bearing the new form existed before in other form), then Plato calls this 'making', too. This becomes clear from what follows in the text, quoted: 'so that the production of all crafts are kinds of making action and their craftsmen are makers'. The agreement between Plato and Locke is obvious, the difference too. On the one hand, Plato includes coming into being by natural causes (lowering of a plant for instance) is also making, on the other hand, Locke's treatment of the problem is, because of the finer distinctions he makes, clearer and more useful to us", wrote Eekels [17].

Difference between production and manufacturing

We call attention to two important facts in this Eekel's discussion about making. First, in making of polymeric parts we can distinguish production of polymeric parts manufacturing of polymeric parts (Figure 5). If we are making at the same time a part with defined macrogeometrical shape (physical action) and prescribed properties by means of chemical reactions, which is the case during the reactive primary shaping, we can use the word production or fabrication. If we produce a part, *e.g.* from thermoplastics melt (only physical action), we must use the word manufacturing. We also understand the word making in two senses. First, the action of elaboration of mental things, which is the duty of a designer (*e.g.* tool designer), and material thing (gripped body) which is the result of work of marker (*e.g.* tool-marker).

Previous ideas would be used in the second text [21], describing the scientifically based mould designing with the examples of design using morphological matrix, types primary shaping, and the application of the general assembly theory in tool-making. This discussion about this entanglement is very important for re-engineering of mould as the central part of the production line.

WHY ARE THE TOOLS THE CENTRAL ELEMENT OF PRODUCTION LINES ?

In his proposal "General Technology" Johann Beckmann wrote in 1806: "The totality of the procedures that are found in the variety of trades should be taxonomically classified in terms of their identical or similar purposes, with each group of a similar working tool, while the kind of material that is subjected to working is of secondary importance" [22].

The key idea for those considerations is the existence of the required means of action, tools, and the mould in this case. As a confirmation, the following saying by A. Griffits is true: "... because it is the mould which forms the vital link between product design and ultimate moulded components" [23]. In injection moulding of polymers there are three basic functions: preparation and injection of the matter, primary shaping of matter and structuring, as well as achieving the required temperature field in the mould (Figure 6) [24—26].

This is released by means of the elements of the injection moulding system, machine, mould and the heat exchange device. For the injection moulding process the most important is the partial function: primary shaping of matter and structuring. This is achieved in the means of action (operation), the mould (Figure 7) [26].

The mould cavity dimensions depend on the information sub-input into injection moulding system, shape and thickness of the mould wall. This sub-input determines the type of moulding material, characteristics of the injection moulding machine and other equipment, including the heat exchange device. At the same time it determines also the dimensions and the shape of the mould, the distribution of the heat exchange channels, type of feed system, *etc.* So, this must be sufficient to understand that the mould is the central part of each production line.

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