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METHODS AND TOOLS OF CONCURRENT ENGINEERING

Abstract. *Content of the term concurrent engineering. Information technology and concurrent engineering. Necessity of variant generation in a primary product proposal phase. New approaches: mathematical logic; technology classification; generation of semi-product conceptional variants, machines and tools, fixtures. Phenomenon of change of industrial culture. Product design from the life cycle point of view.*

1. Sequentional and concurrent organisation of product development

Product development and its production planning are stages, those are traditional means proceeding one by one. First it creates product concept and its components and then their production draws. From the production draws are worked out technologies for production procedure. There are calculated production capacities and are proposed manufacturing systems. After the complition of manufacturing system production can be started.

Up to now the process is sequential. Trucker and Leonard [1] stated a sequential engineering process scheme (fig. 1). In the activity chain there exist reverse paths. These are iniciated by the subjects, those arise to polish the original proposal by changing the material component, production technology etc. Requirements (claims) to change the original proposal can arise at any stage of process: while ordering or buying components, material, during manufacturing, assembly, expedition or sale, even repair or liquidation of product.

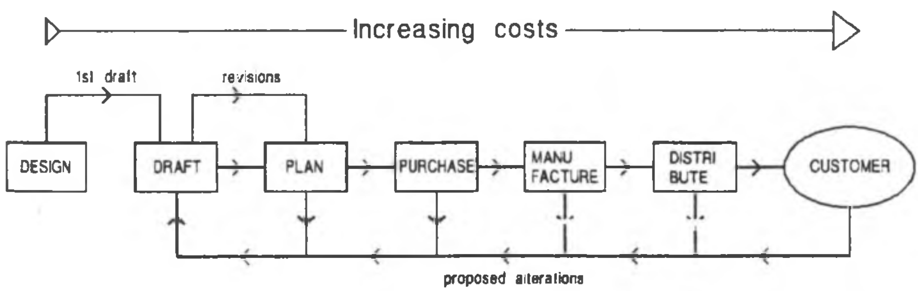


Fig. 1. The sequential engineering process [1]

Changes in production documentations or technologies demand time and expenses. Late the change is practised, expensive will be its realization and longer will be the time to market. It decreases competitionability of the manufacture.

Present trend in manufacturing can be characterised by shortening time to market. It is possible by current labour organisation in every single stage of the process and by rooting out the lateral changes.

Such a labour organization is named as parallel one. We talk about simultaneous or concurrent engineering. Effect of the concurrent product development can be seen in fig. 2. Figure is symbolic, assumes that every stage can start and finish simultaneously. But really, it is impossible.

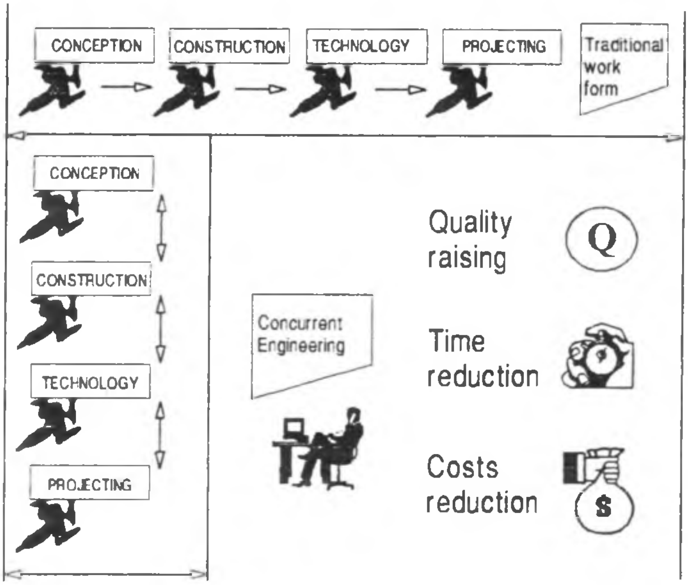


Fig. 2.Scheme of Sequentional and Concurrent Engineering

It is evident that concurrent work organization shortens the full process time for product design and manufacture, resp. for the given time there is more available time for every single stage as during sequentional one. It is the result of a team work of specialists.

2. Information technology and concurrent engineering

There exist an opinion that the information technology (IT) is capable to solve the problem of team work and companies those are intrested to use concurrent engineering (CE) have to invest into the IT systems for their ability to offer information for strategic aims: to shorten the time to market. It is being asserted that CAD, CAPP, CAM, MRP (Material Requirements Planning), MRP II (Manufacturing Resource planning) are able, under the umbrella of CIM, to create concurrent engineering (fig. 3). It is not, however, such simple. If it could be, there is nothing about what to discuss.

Computers offer expressive aid while applying CE strategy, however, it is necessary to realize that computer implementation to the design of products, production technology and production devices does not mean automatic implementation of concurrent engineering.

Fig. 3. Main methods and tools of the CE

But fact is that without computer means we cannot overcome over time, costs and product quality.

Traditional CAD systems have no means to aid the search phase of solution principles. Systems creating production procedures specialize in operation technology. Part similarity, group technology and selection of technological method is very often escaping.

The emphasize on computer means have to play a role in primary phase of proposing a product and its production, while redeciding and selecting different conceptional variants.

May be, formal accesses are overvalued and real scientific appoach is missing its main point. Hereby, are given a few examples.

3. Conceptional semi-product variants

This part could be named, as well basic classification of shape creation or classification of mechanical technologies.

Part is being made by changing the charecteristics of the semi-product. We constrate on the changings in (solid) volume by separating, transforming or addition of material. Volume, being separated, transformed or added per unit time may be perceived as relatively small or big.

By this logical construction we get six principal means of material transformations - six basic technological methods.

Tab.1 Basic technological methods

Volume relation	Essence	Relative volume	Examples
$d_0 > d_K$	separation	small big	machining shearing, breaking
$d_0 = d_K$	transformation	small big	forming, forging bending
$d_0 < d_K$	addition	small big	casting, sintering, coating welding, soldering, gluing, assembly

d_0 - semi-product or its element volume d_K - workpiece volume

Classification of shape creation (tab. 1) represents all technologies, by which are produced semi-products and parts. Material shape transfer procedure from d_0 to d_K is technological process. Procedure in reverse direction is being used while proposing semi-product shape and size. During the process are obeyed technological laws.

Essence of semi-product proposing in detailed steps is the proposing of technological process. In recent publications [2] material shapes in detailed steps were named as intershapes.

While proposing semi-product shape and size, it is necessary to know:

1. material and technologies used to produce semi-product.

2. technologies used to produce part from semi-product.

4.Conceptional variants of machines and tools for machining

It was created so-called insit algebra of logical model (LM), using symbols

$$ROTi, TRSi, NIL: i \in (X, Y, Z, XY, XZ, YZ, XYZ) \quad (1)$$

expressing rotational or translational course of something along the respective axis. That something may be motion, line, tool edge, arrangements etc. along the vector direction of the Carthesian coordinate system. NIL means absent.

The logical surface model (LSM) arises as a set of two symbols, lines (1) those cover the surface with enough density, e.g. the LSM of taper mantle or its part is

$$LSM = \{ TRSXY, ROTX \} \quad (2)$$

The logical machining model (LMM) arises from LSM by substituting their elements and completing the missing one to the expression

$$LMM = [1PR, 2PR, 3PR, NPR] \quad (3)$$

where 1PR is the main motion, 2PR - first feed, 3PR - infeed, NPR - the second feed.

The substitution depends upon the value of NPR, if it exists or absents. The element 3PR misses always. It must have a perpendicular component and must stop on the surface or its extension. When the element 1PR is missing, then the created motion must have a tangental component to the surface.
These are the rules those allow to use mathematical procedures with symbols (1).

The Conceptional Logical Machining Model (CLMM) arises from LMM by putting indexes *j*

$$j \in \{O, N, ON, K\} \quad (4)$$

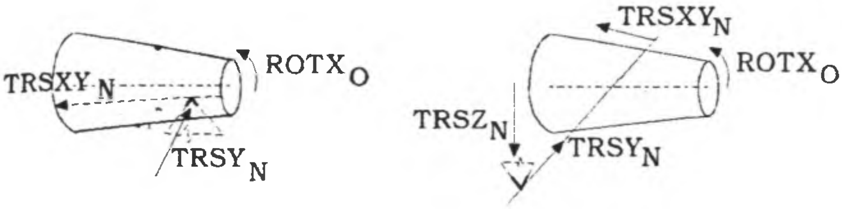
The meaning is the bearer of real motion (workpiece, tool or both), resp. K - a realisation form by concrete thing, with a tool edge(s) or their arrangement.

The choise depends upon criterion and customer's wishes. We obtain for the LSM (2) e.g. this model:

$$CLMM1 = [ROTX_O, TRSXY_N, TRSY_N, NIL]$$

$$CLMM2 = [TRSY_N, TRSXY_N, TRSZ_N, ROTX_O]$$

The first one is a usual turning, where second is shaping of a taper mantle (fig. 4).



a b

Fig. 4.Scheme of taper mantle machining: a - usual (single point) turning, b - shaping

Procedure creates all conceptional motion variants of the machine and shape of the cutting edge for given surface. So, it solves the basic task while proposing technological process: allocation of machine and tool to the part surface.

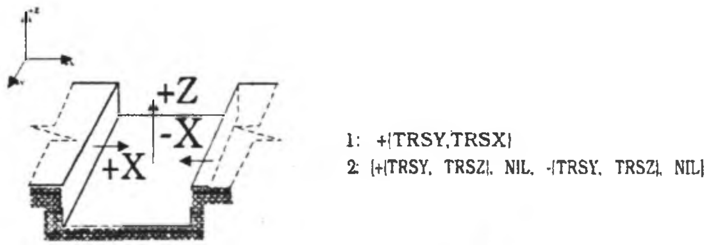
5. Conceptional variants of fixtures

Surface surrounding

Workpiece fixation variants are created on the base of logical part (workpiece) model. Logical part model is a set of *n* members. The members (elements) are logical surface models. Sequence of elements answers for their arrangement in space.

Elements have their signs and indexes. Signs (plus / minus) show presence of material inside or outside the surface. Indexes show distance of plane surface or the center line of the rotational surface from basic co-ordinate system.

Code system is under development. Figure 5 shows an expression of a plane surface and its surrounding. Symbol NIL shows that closing surface absents. Figure 6 shows a logical model of a simple part.



a b

Fig. 5. Plane surface (1), and its adjoining surfaces (2), a - layout, b - logical models

Clamping

Clamping has two functions: accurate locating and gripping (fixing). One or both of them may be absent,(e.g. barell or vibratory finishing, centerless grinding etc.).

Accurate locating of a prism needs 3+2+1 or 2+2+2 touch points on three adjoined planes of a Carthesian coordinate system (fig. 6). A cylinder may have 2+2+1 or 3+1+1 touch points, a sphere only 1+1+1=3. Superflouos are not minded.

In practice 3 points are realized by planes, 2 points by strips, 1 by little land. Statics of touch points is very important, therefore these may be far from each other.

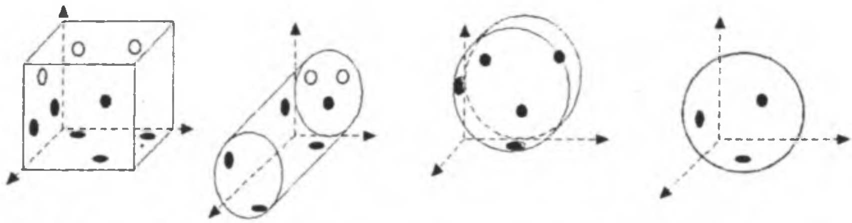


Fig. 6. The needed touch points for accurate locating on three adjoining surfaces of the envelop prism

The full number of touch points is determined by using envelop prism. When the workpiece is stepped, then for the steps internal theoretical envelop prism is used.

Fixing is an effect of push - compression forces applied against the location points. The holding force has to be centered. It may act concentratively or distributively.

It is possible to clamp and fix the workpiece, tool or both of them. The laws of nature (gravitation, friction, deformation) work in a hidden form.

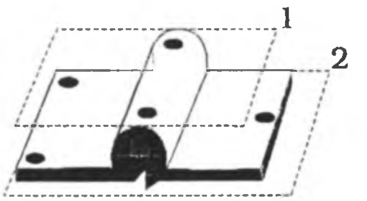


Fig.7. The top side of envelop prism: 1 - external, 2 - internal prism

6. Change phenomenon of industrial culture

There works in nature basic law of material flow. Every thing taken by the man from the nature returns back to nature. Survival damands that return has to be in such a form, that is in accordance with the nature (environment friendly).

Many assume that manufacturing will change dramatically in the next decade.

Alting L. [3] characterizes the present industrial culture by a continuous development of high performance materials (often composite types), improved and new processing technologies and increasing applications of information technology. The consequences of this culture are becoming very visible in environmental problems (waste and pollution of all kinds), occupational health problems (diseases, accidents, allergy etc.) and a large consumption of non-renewable resources.

New industrial culture will be characterized by life cycle design of industrial products.

Then the CE has to solve the task to shorten time to market under restrictions given by the life cycle concept where a product is developed for sustainable production, distribution, usage and disposal. Number of experts concerned in the design and manufacture of product will increase.

7. Conclusions

In conclusions it is necessary to respond two questions: which are the methods and tools of the CE and what is the relation between the CE and CIM.

It is widely accepted that CE is a teamwork of many experts as constructers, designers, technologists, materialistics, environmentalists, experts for logistics, occupational health etc. with a common aid: to reduce the time to market.

Software products as CAD, CAPP, CAM, MRP, MRP II, DFM (Design For Manufacture), DFA (Design For Assembly), various methods as JIT (Just In Time), Kanban, databases, knowledge based and expert systems established for specific topic of design are very useful.

It would be a mistake to overvalue the role of computers in the CE, however their speed and memory is significant for the strategic purpose of reducing time to market. But these are not capable to replace the human creativity.

Evidently many of new tools and methods are waiting for invention yet, maybe one of them is the logical model and modelling shortly showed in this paper as a novel powerful tool for concurrent engineering.

8. References

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