Planning of Wastes Generation and Development of Life Cycle Technology in Preproduction of a New Product

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Abstract. Management concept of all types of products generated in the production is proposed on the basis of detailed planning of their life cycles during preproduction of a new commercial product. A technique has been developed that allows, at the stage of preparing the production of a new product, to calculate adequately the generation volumes of all wastes in each technological operation. The systematization of wastes types is given. A set of works on the design of wastes life cycle was defined. Documents circulation has been developed. An example of calculation is given.

1. Introduction

The era of primitive technologies lasted for tens thousands years of mankind development. Their capabilities scarcely allowed them to get the right volumes of products to meet people's vital needs. And all other production results (including wastes) were considered only as an inevitable supplement to the planned result. Since then, the technological power of mankind has multiplied. However, specialists continue to develop life cycle technologies only for a commercial product [1]. Meanwhile, the amount of wastes in a number of industries has become a significant factor in changing the natural environment. Today more people are often interested in reducing the influence of production enterprises on the natural environment, than in their commercial products, and while exhaustion of natural resources they become almost the entire population of the planet. Therefore, it is obvious that an assessment of the effectiveness and efficiency of production activities should include consequences of all processes.

The quality of commercial products is laid while preparing their production. In order to be able to adequately predict and evaluate the significance of any kinds of products generated in production, the planning and detailed preparation of a new commercial product manufacturing must be supplemented with equally careful development of their life cycle processes. This requires the creation of a universal methodology for simulating any technology, which consists of the material product life cycle, as well as the processes of activity on the workplace.

2. Theoretical part

Each natural process (high water of the river, wavering of a leaf on a tree by the wind, burning of a dry grass blade under a sun ray, focused by a drop of dew) is basically a sequence of instant acts of interaction with each other from a number of separate pairs of entities due to external conditions. In these processes, we do not see a purposeful impact. They are uncontrollable.
In order to obtain on the industrial scale the right quantity of a product with the required quality and productivity under the targeted standard of resource consumption, it is necessary to create an artificial process technology.

Creating a technology for manufacturing a product, a person uses the most appropriate sets of natural ways of interaction for the necessary entities (mechanical, chemical, thermal and others) through their systematized flow in technological systems (artificial worlds). It arranges them by creating technological equipment and outfit and prepares suitable raw materials. At the same time, it neglects side interactions of the structural elements of these modules, considering them insignificant. However, they also generate a lot of new products, the characteristics of which are determined by the conditions created to obtain a commercial product. To ensure the desired degree of controllability, it is worth remembering that any existing object (technological module, food product and others) has a hierarchical structure, so that in analyzing the interaction, for example, of two solid bodies, one should analyze all their structural elements, up to atoms.

In this paper, the production technology of material objects is viewed as a planned, artificially created controllable process with a hierarchical structure, in each element, along with the product, many by-products are generated, which may be of interest to certain groups of people.

For example, the widely used technology for shaping the surface of a future machine part by cutting is based on the mechanical action of one solid body (tool) to the other (work material) as they move relatively to each other along specified paths. The essence of the technology is that it is necessary to remove a layer of excess metal (allowance) from the workpiece and obtain the required dimensions and surface quality.

The technological machine (machine tool) provides working movements with due accuracy. The forming tool element creates a surface profile of the workpiece. The future surface of the workpiece is formed by incrementing its elementary areas and the allowance turn into microvolumes of chips or material wastes. Another by-product is the wear particles of the contact areas in the cutting edge of the tool. On grinding operations, these tool scraps (abrasive dust) have to be forcibly collected. Due to the high degree of deformation of the metal being removed, 90% of shaping turns into heat. Its main volume remains in the cutting zone where temperatures reach hundreds degrees Celsius. This by-product should be referred to lubricoolants. When interacting with a hot metal, the liquid particles evaporate, forming aerosols. Under high temperature the atoms of the basic sections of the chip surfaces and the wedge in the contact zone are intensely oxidized. Strength of oxides is small; their microvolumes are easily erased from the tool surface and are carried away with chips or dispersed in the air. A set of generated products is shown in Fig. 1.

![Figure 1](image_url)

Figure 1. By-products of shaping machine parts process.
So, even a single workflow is accompanied by a multitude co-interactions that generate a variety of by-products. In the considered example, the vast majority of them do not have a noticeable effect on the environment, so they should not be ignored. In this unified controlled scheme, each of them must find its own place.

Maintaining the required workflow conditions in the operating technological system requires a lot of necessary interactions. For example, feed and main motion drive, positioning mechanisms are functioning in the machine tool. Each interacting pair of co-parts, (for example, gears) when performing the transfer of torque, it generates products for wear and oxidation of the material. Before changing waste oil, they are inside the case and it seemed it is not interesting for us. But when it comes, we get a visible output volume of complex wastes i.e. used lubricating fluid. It is necessary to plan in advance the subsequent technological routes and operations of its life cycle for this volume.

It is worth preparing in advance a number of necessary conditions for shaping the surface by setting up the technological system and positioning the workpiece with the required accuracy. These processes generate their own by-products. Finally, all modules of technological system are subjected to maintenance procedures. An example of wastes generation in them is contaminated wiping rag after rubbing the surfaces of the machine tool. The main types of by-products are given in Table 1.

### Table 1. Output of significant by-products in the cycles of activity at the machine tool workplace.

| Cycle content                  | Wastes of the processed material | Product groups                      |
|-------------------------------|---------------------------------|-------------------------------------|
|                               | Solid                           | Liquid                              | Gaseous | Emissions |
| 1. Equipment maintenance      | Waste lubricants:               |                                     |         |
|                               | - lubricoolants;                |                                     |         |
|                               | - washing liquids;              |                                     |         |
|                               | - hydraulic fluids              |                                     |         |
| 2. Performing the production task | Solid contaminations            | Liquid contaminations                |         |
|                               | Contaminated wiping rags        | Contaminated cleaning liquids.       |         |
|                               | Lubricoolant spray              | Lubricoolant spray                   |         |
|                               | Aerosol (evaporation of         |                                     |         |
|                               | lubricoolants)                  |                                     |         |
| 3. Performing the operation   |                                 |                                     |         |
| 4. Working procedure          | Chips                            | Abrasive dust                        | Heat, electromagnetic emission |

For the gross calculation of the wastes volumes or emissions during the registration of the company's environmental passport, and for calculating the excess of emissions relatively to the maximum permissible level at the enterprise as a whole, methods and developed databases have now been developed [3-6]. They can be used to plan the generation volumes, output volumes, and also to plan the life cycle technologies of all significant by-products.

### 3. Practical implementation

In order to plan the life-cycle processes of the whole gamut of generated significant products, the content of the technology is complemented by the following characteristics:
- Generation volume (appearance) of a by-product (including waste of one type) in the process of manufacturing a commercial product;
- Output volume of the by-product - its volume accumulated at the workplace, which further appropriately processes;
- Life cycle of the by-product volume - technology flow from its generation and accumulation to utilization;
The basic rules for identifying these processes are developed and processes are streamlined for the stages of preproduction that allow fulfilling direct and inverse management tasks.

For this some additions to standardized activities of preproduction project for a new commercial product have been developed [12]. They are presented in Table 2.

**Table 2.** The main work on preparing the production of passing products at the stages of the APQP project.

| Stage                    | Types of work on life cycle:                                                                 |
|--------------------------|-------------------------------------------------------------------------------------------|
|                          | of commercial product                                                                    | of planned wastes                                  |
| 1. Concept development   | Generating demands:                                                                      | Generating the basis of legislative requirements to the quality of potential wastes |
|                          | - legislative;                                                                            |                                                                                               |
|                          | - customers;                                                                             |                                                                                               |
|                          | - evaluation of competitors capabilities;                                                 |                                                                                               |
|                          | - evaluation of own capabilities.                                                        |                                                                                               |
| 2. Designing self-component| Development of technical requirements for quality. Confirmation of compliance with requirements by testing a prototype. | Development of life cycle technology flow maps by types of by-product s.                        |
| 3. Process development   | Technology development:                                                                  | Planning of generation volumes.                                                                |
|                          | - Life cycle of the self-component.                                                      | Planning of periodicity and output volumes.                                                    |
|                          | - Providing jobs with resources.                                                         | Development and documentation of life cycle technologies.                                      |
|                          | - Control and management.                                                                | Development of tasks for the purchase of equipment and instrumentation.                        |
| 4. Final preproduction   | Verification of preproduction results.                                                   | Registration of waste quality indicator values at the output of setting lot. Development of management plans. |
|                          | Registration of factor values affecting quality.                                          |                                                                                               |
|                          | Development of management plans.                                                        |                                                                                               |
| 5. Output, delivery, improvement | Monitoring of product quality and the stability of production processes.                    | Monitoring of accumulation and concentration of wastes that affect the personnel health.        |

At stage 1 for each product type, legislative requirements for their quality and accumulation process should be defined. Thus, for the lathe operation of processing the aluminum filter housing (total duration of 6.1 minutes, 7 process steps), the most significant wastes are emissions of emulsol in the form of aerosol (maximum permissible concentration is not more than 5 mg / m³), the presence of aluminum dust in the air (MPC is not more than 2 mg / m³), as well as noise is not more than 85 dB.

At stage 2 a technology flow map is developed for each type of waste. Table 3 presents a flow map of a potentially dangerous substance - emulsol in the form of aerosol, which appears when the lubricating-cooling liquid evaporates. The flow map includes the basic operations of the aerosol life cycle, up to the filter utilization on the landfill for solid domestic wastes. It indicates the basic characteristic of the aerosol - the maximum permissible concentration of the substance and also the basic characteristic of the process - the tightness of the container for storing the spent filter.

At stage 3 a technique for calculating the wastes volume during the production technology design of a commercial product for the main groups of by-products has been developed. The calculation is based on a hierarchical model of technology content. Elements of the model are setup cycles, operations, processing in working positions, process steps, working procedures. The duration of their performance by construction of time chains is normalized [13].
Volume calculation of each product consists in sequential summation of product volumes generated in the elements of the production task. Thus, for the above operation, the total weight of chips produced in all machining steps of 3300 workpieces is 267 kg and the bulk volume is 1.74 m$^3$.

Emission rate of lubricant in the form of an aerosol is $0.041 \times 10^{-5}$ g / kW engine power of the main motion in one second [7].

### Table 3. Technology flow map for life cycle of emulsol emissions in the form of aerosol.

| No. | Procedure       | Type | Basic characteristics of a waste or a product | Basic characteristics of the process |
|-----|-----------------|------|--------------------------------------------|-----------------------------------|
|     |                 |      | Production | Displacement | Storage | Control |
| 050 | Lathe work      | x    | not more than 5 mg / m$^3$ |                  |
| 060 | Ventilation     | x    |                          |                  |
| 070 | Filtering       | x    |                          |                  |
| 080 | Controlling     | x    |                          |                  |
| 090 | Cleaning        | x    |                          |                  |
| 100 | Storage of spent filter | x |                          | Tank storage tightness t $20^\circ$C $\pm$ 5 $^\circ$C |
| 110 | Transportation  | x    |                          |                  |
| 120 | Utilization     | x    |                          |                  |

According to [8], the maximum permissible concentration is 5 mg / m$^3$. During the procedure, 2 mg of emulsol is emitted. Since the operating area of the machine is approximately 2 m$^3$, the concentration of aerosol in it will not exceed 1 mg / m$^3$. To ensure removing aerosol, the ventilation interchange power must be at least 20 m$^3$ / h. Depending on the performance and design of the ventilation system, a switch on-switch off periodicity can be scheduled for assured removal of harmful contaminants.

Another potentially dangerous product is aluminum dust formed during processing. According to the specifications for the processing of aluminum alloys [7, 8], 0.0025 g / s of dust is formed, so in this case 0.925 g of dust will be discharged. However, the use of lubricant almost completely prevents the spread of dust on the workplace.

In addition, a specialist also plans the use of resources - need for tools [14], the work of operator and service technician [15], the consumed electrical power [16-21]. The results of calculations are reflected in a complex of application forms to the technological procedure map.

### 4. Conclusion

So, the total management of production activities requires planning and monitoring the life cycles of all types of production products. The availability of such information allows:

- Analyze a sufficiently wide range of the effects of production activities at the stage of product design and technology choices.
- In the shortest possible time to determine the cause of volume exceeding or MPC of each by-product and promptly reduce it to the normative values.
- Plan the implementation of processes for the life cycle stages of wastes and by-products.
- In the final analysis, create a management system with all types of manufactured products, instead of local systems certified for example in accordance with [14, 15].

Here shown the possibility of transition to total management of all types of products through step-by-step additions of preproduction processes of a commercial product by procedures for developing technology flows along the life cycle of by-products, starting with the most significant ones.

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