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AN ALGORITHM FOR COMPUTER-AIDED DESIGN OF A TECHNOLOGICAL PROCESS WITH PRESET MANUFACTURABILITY PARAMETERS*

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Abstract

The article describes an algorithm for computer-aided design of a technological process with preset manufacturability parameters. The method of developing the machining route and selecting technological operations was suggested. Manufacturability criteria for evaluating the technological process were identified. The algorithm is analyzed on the example of the frame which is an aircraft construction product.

Keywords: design, design automation, technological operations, manufacturability, design manufacturability.

1. Introduction

Automation and digitalization of production are the main directions of technological development. Modern industries use digital and computer technologies in all areas. Almost all the operations (direct control, process control, technological design, etc.) are performed using digital

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data and digital infrastructure. Design of the machining process is a very time-consuming task. The technologist should take into account manufacturability parameters. Therefore, in order to produce parts with the lowest labor intensity and minimum material consumption volume, it is necessary to develop several options of the technological process (TP), and choose the most effective one. This approach increases intensity of labor required for the technological preparation. Moreover, the TP development is one of the least automated stages of the manufacturing process (Filonov et al., 2003; Izraev et al., 2015; Timiryazev et al., 2016).

Some research groups devoted their research to the cutting method which can ensure optimal technical and economic indicators based on the technical and economic modeling (Ishenin, 2020; Kuznetsov et al., 2012). The works of Sokolova (2013), Nepomiluev and Sokolova (2013) deal with the method used to justify engineering solutions. Other researchers deal with the automated system for designing technological processes (Govorkov and Chien, 2015; Zhukov et al., 2020). However, despite the large number of works devoted to the automated TP design system, this issue is relevant, since there is no final solution to this problem.

2. Methods

2.1. Algorithm and frame

The technological design process taking into account manufacturability parameters is the process of searching for the most economical TP options. To solve this problem, it is necessary to develop an algorithm for the automated design of a technological process using manufacturability parameters (Fig. 1). For a deeper study of the automated TP design method, it is necessary to consider the technological process for producing a real part, for example, a frame.

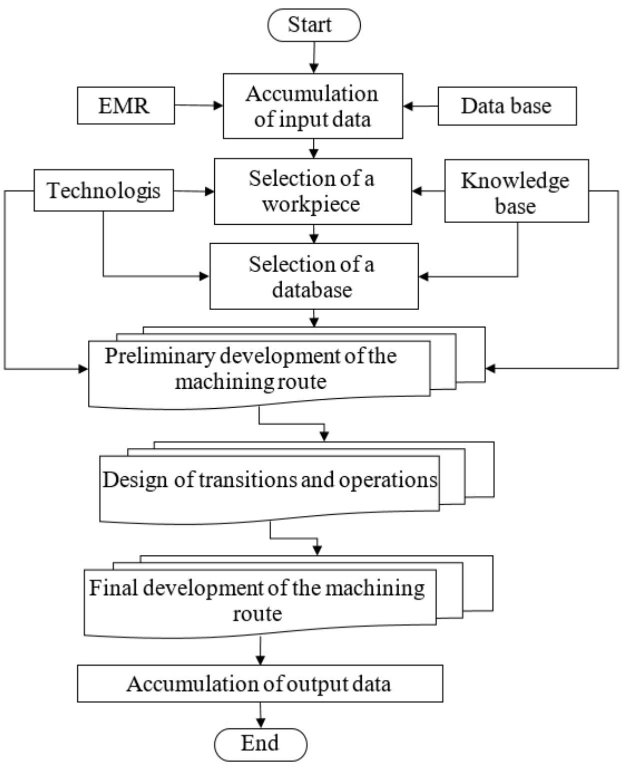

Fig. 1. The general scheme of the process design algorithm.

The algorithm is developed on the example of a technological process of manufacturing the "frame" (Fig. 2). The "frame" is a part of the transverse force set of the aircraft which can be referred to stiffeners. This part is fully milled, made from an aluminum plate using a CNC machine. The frame has medium overall dimensions, it is flat and symmetrical in relation to both axes. The location of the structural elements is one-sided. The rear wall lacks machined structural elements.

It is the base surface. Machining along three coordinate axes is required. The main machined structural elements are wells. The area of the base is small. The height of well walls is small. The radii of conjugation of the walls and the bottom are small. The workpiece is fixed on a vacuum table.

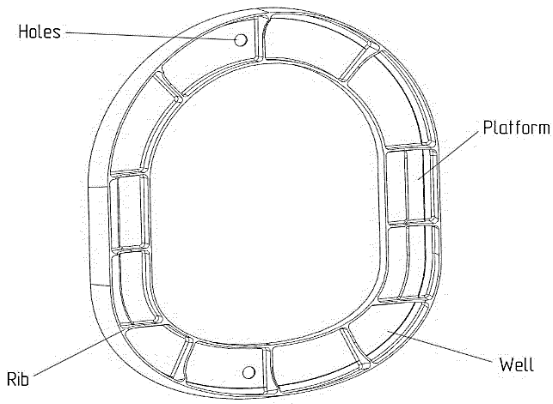

Fig. 2. The frame of the study

2.2. Steps of analysis

1. Accumulation of input data

The design process begins with the accumulation of input data. For the design process and each of its stages, certain sets of input data are required. Some data are taken from the database. Other data (e.g., geometry data) are taken from the electronic model of the product.

2. Selection of a workpiece

The input data are geometric data on the product obtained with EMR. The material and method are assigned by the technologist using a special knowledge base.

Upon completion of this stage, the technologist should have various options of workpieces presented as: Z (m, GI, s);

where: m – workpiece material;
GI – geometrical data;
s – production method.

The "frame" is a critical part of the aircraft; the type of its workpiece is specified in the design documents, and cannot be changed.

3. Selection of databases

At this stage, the technologist should select the base according to the rules of the knowledge base. The input data are data on the geometry and structural elements of the product obtained with EMR. For the "frame", the rear wall is the base (a surface with no information).

4. Preliminary development of the machining route

The machining route is developed by highly qualified technologists using various directories and regulatory documents. At the stage of designing machining routes, the technologist creates a sequence of technical operations. It is impossible to formulate each technological operation, but it is necessary to choose its type. The input data are information on the geometry and structural elements of the product.

The machining route can be presented as an ordered sequence of operations:

M (O_1, O_2, …O_i);

where: O_i – technological operation.

Each operation should transfer the workpiece from "state n" to "state n + 1" (Fig. 3). The real route for the "frame" is as follows:

M (O_{p1}, O_{m1}, O_{p2}, O_{c1}, O_{f1}, O_{f2}, etc.),

where: O_p– preparation;
O_m – marking;
O_c – control;
O_f – forming.

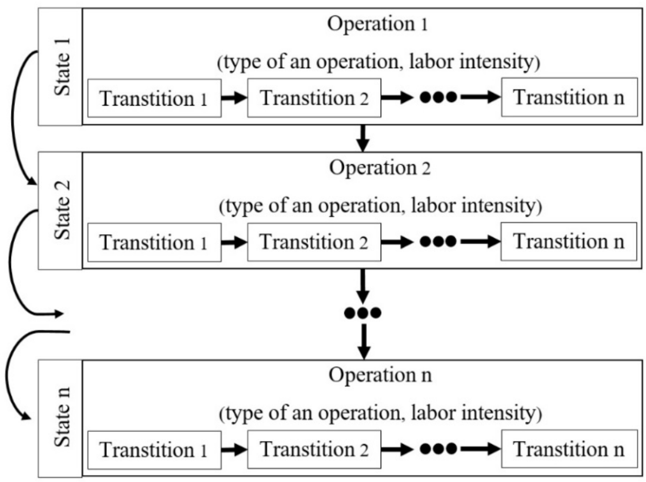

Fig. 3. The machining route

3. Results

3.1. General description

1. Initial development of technological operations is carried out when designing transitions and operations.

The system selects operations based on the preliminary machining route. The input data are information on the geometry, structural elements of the product, workpiece materials, and manufacturing accuracy

The technological operation can be presented as O (v, n, t),

where: v – type of the operation
n – state of the product
t_0 –v cutting time.

However, it will be more accurate to present the operation as a sequence of transitions:

O (P_1, P_2, … P_n).

The transition can be presented as P (v, t_0),

where: v – type of the operation

t_0 – cutting time.

The parameter of a product state describes the current type of a workpiece at each stage of the machining route. Each state of the workpiece is characterized by geometric and technological parameters. The operation is based on the criterion of least labor intensity. At this stage, equipment is selected based on the machining route. The equipment database is selected using knowledge base rules.

2. Final development of machining routes

Based on the results of the previous stage, the system forms several options for the machining route, selecting technological operations based on the criteria of manufacturability. The task of optimizing the route is to find the shortest routes with the subsequent selection of the least time-consuming ones. The input data are data obtained at the previous stages.

3. Accumulation of output data

The technologist has several TP options which are ranked by their labor intensity. The algorithm scheme is presented in Fig. 4.

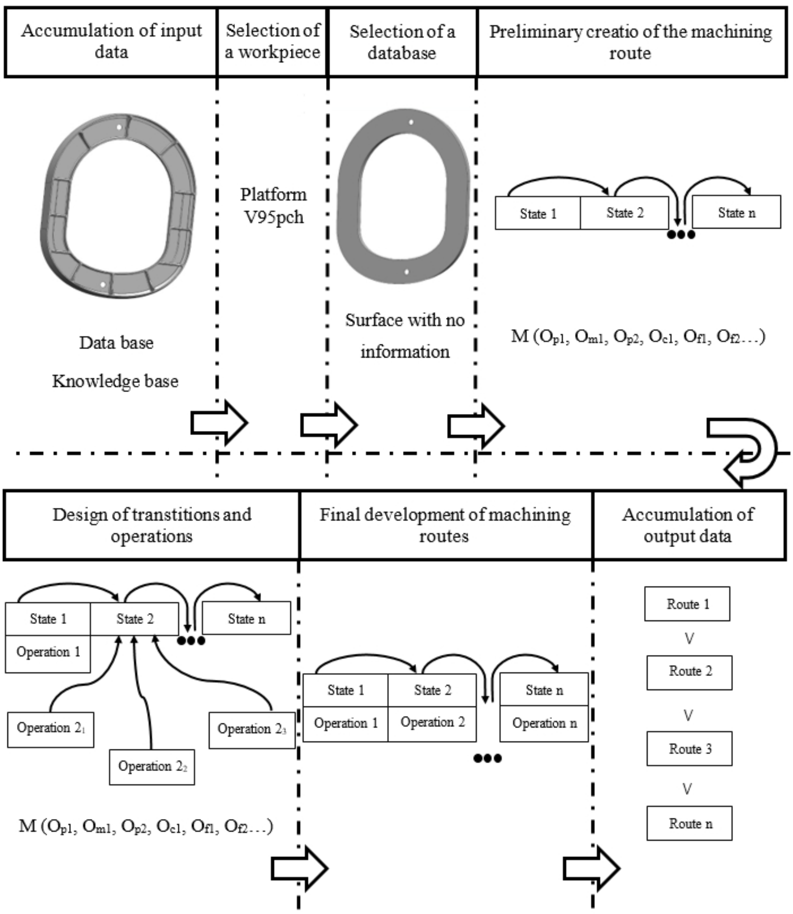

Fig. 4. The scheme of the design algorithm for the "frame"

4. Conclusions

This approach to the design of the technological process can

- improve quality of the technological process due to the formalization of the design process, and reduce the number of errors made by the technologists;
- reduce labor costs and time for developing the technological process.

Thus, this algorithm used for designing the technological process using manufacturability parameters will allow enterprises to improve quality of their products and reduce production time. It is required for enterprises of the machine-building and aircraft industries working in conditions of fierce competition. A competitively oriented environment requires technological flexibility by implementing automation and digitalization technologies.

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