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Working position with recomposed production systems

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Abstract. High productivity and flexibility with a different range of production type can be achieved by using the recomposed production systems. These systems combine the advantages of aggregate machines and turning centres due to the design features described in this article. The types of nodes and system elements in the compiled and decompiled state are given. Algorithms and schemes for the functioning of recomposed work stand (RWS) in comparison with the working stand of automatic lines (WSAL) were developed. Equation for determining the average time between failures of the RWS is presented. The visualization of the system element and the scheme of the system element - the intermodular element of locating (IEB) was performed. In the conditions of the actual machine-building production, the accuracy of estimating the economic effect requires the use of robust design models implemented not only in the form of algorithms, but also in programs. In the future, it is planned to develop a special software allowing to determine the reliability of the RWS relative to the stand with a rigid interaggregate relation.

1. Introduction

Nowadays, one of the solutions of the problem of creating production systems which combine a high level of productivity and flexibility in multiproduct production is the creation of recomposed production systems (RPS), combining the advantages of aggregate machines and machining centers, due to constructive and functional innovations in comparison with the work stand of automatic line (WSAL), which allows to provide a high level of technical, operational and reliability factors.

2. Structure of RWS

The recomposed work stand (RWS) as well as WSAL, consists of k sets containing j tiers. In accordance to figure 3.1, the tier j-3 of sets 1 and 3 is the tier of processing; tier j-2 of sets 1 and 3, is the tier of displacement; tier j-2 of set 2 is a tier of fastening. Interaggregate relation in contrast to WSAL (rigid interaggregate relation) is flexible, which allows implementing an automatic recompose process based on the RWS [1, 2]. Flexible interaggregate relation is possible by the use of intermodular element of locating and fixing (IELF), which automatically fasten and unfasten the automatically exchangeable unit on the RWS. Using the example of an aggregate unit, the automatic exchangeable unit of the RWS under investigation consists of two parts:

- the executive part - repeating the construction of the aggregate unit of the work stand with a rigid interaggregate relation has four eyelets necessary to remove, install and transfer the automatically replaced unit;
- the intermodular element of locating and fixing (IELF) consists of a housing in the form of a plate with the lower and upper base surfaces for connection to automatically replaced units. Housings are located in parallel. The upper base surface of the IELF is rigidly attached to the upper exchangeable unit. On the lower base surface, there are executive elements of the fastening and locating mechanisms, for connection to the downstream automatically exchangeable unit. The mechanisms of locating and fixing the IELF are unified [3, 4].

Analyzing the design features of the RWS in comparison with the WSAL, lets consider the functioning features of the RWS in comparison with the WSAL.

The main difference in the functioning of the RWS in comparison with the WSAL include the ability of RWS to process of different products types in a wide range of product designs and technological processes on the basis of the application of automatically replaceable units and recomposing processes of work stands continuously during the functioning cycle of the recomposed production system [5, 6].

Another difference is that operability restoration of the RWS in case of failure of one of the units is carried out without intervention of machine setup men and traditional repair of WSAL. It is carried out on the basis of the replacement of the faulty unit by the replaced unit, after which the RWS continues to operate.

On changing the processing technology and machined parts due to the change of automatically replaceable units, the work stand has a variable nature of the arranging and structural transformation [7, 8]. The recomposed work stand is exposed to automatic recompose and automatic change of units based on the use of automatic devices of control computer of the industrial robot for automatic change of work stand units. In this regard, control computer with a CNC or an industrial robot is used when changing the workpiece and changing the processing technology on the RWS in the recomposed cycle. According to the CNC program, computer recompose the sets of exchangeable units, if necessary, of all three sets and all tiers.

In the process of recomposing, the work stand from the automatically replaceable units of three sets of multi-tiered layout is transferred from the assembled state to decomposed, changing replacement units, tool, and equipment. Then, changing the layout, transfer the state of the units from the decomposed state of the work stand to the assembled with the possibility of replacing the units and the new layout formation of the work stand with new properties, technical and operational parameters [9, 10].

3. Efficiency indicators of RWS

The recomposed work stand (RWS) is a new class production system that allows to produce products in volumes comparable with mass production and flexibility of machining centers. To achieve such high technical and operational characteristics, RWS must have higher performance indicators [11, 12].

Operability is the state of a recomposed production system (RPS) which is able to perform specified processes of functioning and recomposing in accordance with the parameters established in the technical documentation.

The average operating time to failure for the work stands of production systems with rigid interaggregate relation is defined as the ratio of the total operating time to the number of failures during the operation period under consideration [13, 14].

In accordance with the definition, the average time to failure of the WSAL consists of aggregate units, according to the formula:

$$t_{avWSAL} = \frac{\sum_{1}^{N} t_{Hi}}{N} = \frac{\sum_{1}^{k}\left(\sum_{A}^{D} t_{yi}\right)}{\sum_{1}^{k}\left(\sum_{A}^{D} N_{yj}\right)} \quad (1)$$

where:

t_{Hi} – i-th operating time to failure of WSAL;
$\sum_{1}^{N} t_{Hi}$ - the total duration of the WSAL operation for the period in consideration;
N – the number of failures for the period in consideration;
i – serial number of the operating time before the failure of the WSAL;
k – number of sets of WSAL aggregate units;
A, B, C, D – designation of the WSAL tiers;
N_{yj} - number of failures of the i-th aggregate unit of the j-th tier of WSAL;
t_{yj} - i-th operating time of the aggregate unit operating on the j-th tier of the WSAL.

In recomposed work stands in contrast to rigid work stands, the failure of one of the nodes is characterized by the RWS transition from the operable state of processing the products to the operable state of the layout change, during which the failing unit automatically changes to operability unit, and after that the RWS continues products processing [15, 16, 17].

Considering that the failure of an automatically exchangeable unit does not disrupt the performance of the entire RWS [18, 19, 20], the indicator that determines the operating time of the recomposed work stand before the failure of one of the automatically exchangeable units is the average time to failure ($t_{stopRWS}$).

The property of recomposition is the main distinguishing feature of the RWS from the WSAL. It characterizes a flexible interaggregate relation. Flexible interaggregate relation can be automatically carried out with the possibility of locating and refixing the units in the process of unit change and recomposing the RWS. For the implementation of flexible interaggregate relation the RWS is equipped with IELF (figure 1).

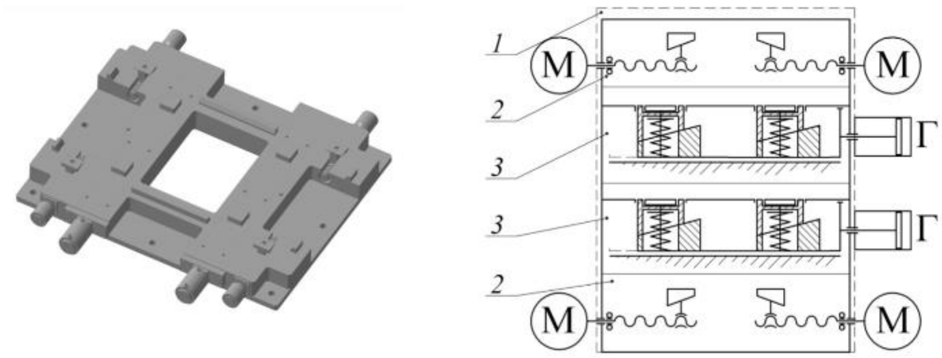

Figure 1. The IELF scheme; the numbers indicate: 1 - the intermodular device for locating and fastening; 2 - mechanism for fixing the IELF; 3 - mechanism for locating the IELF.

The IELF is located between each two interfaced neighboring exchangeable units with the possibility of locating, fastening and re-fastening. Conjugation of units occurs automatically by the mechanisms of locating and fastening, located in the IELF. In accordance with the functions performed, the IELF actuators have 2 states:

1. The state in which the IELF's actuators support interaggregate relation with the conjugate unit and do not require the operation of the executive mechanisms (the IELF actuators do not move).

2. The state in which the actuators of the IELF perform the locating, fastening or unfastening and dilution of the conjugate units (the actuators of the IELF move).

In the vertical arrangement, the exchangeable units form a multi-tiered work stand with vertically arranged sets of automatically exchangeable units. An automatically exchangeable unit operate on the RWS tier, consisting of aggregate unit and rigidly fixed IELF (figure 1) on the lower plane of the executive aggregate unit.

Therefore, to determine the value of the average operating time before failure the RWS ($t_{stopRWS}$) it is necessary to take into account the performance indicators of the IELF.

The design of the IELF consists of a housing with built-in fastening and locating devices. The number of mechanisms of fastening and locating in the IELF depends on the tier of its location, the dimensions of the conjugate unit and the required rigidity of the resulting relation. Consequently, the average time to failure of one IELF (t_{avIEBF}) taking into account its design can be calculated by the formula:

$$t_{avIEBFi} = \frac{\sum t_{IEBFi}}{N_{IEBFi}} = \frac{n \cdot \sum t_{Ki} + m \cdot \sum t_{Fi}}{N_{Ki} + N_{Fi}} \quad (2)$$

where

$\sum t_{IEBFi}$ – the operating time until the failure of the i-th IELF;

$\sum t_{Ki}$ – the operating time until the failure of fastening mechanism of the i-th IELF;

$\sum t_{Fi}$ – the operating time until the failure of locating mechanism of the i-th IELF;

N_{IEBFi} – the number of failures of the i-th IELF;

N_{Ki} – the number of failures of the fastening mechanism of the i-th IELF;

N_{Fi}– the number of failures of the i-th IELF locating mechanism;

n – the number of fastening devices of the i-th IELF;

m – the number of locating devices of i-th IELF.

4. Results and discussion

The developed methods make it possible to calculate the reliability of work stands with a rigid and flexible interaggregate relations. However, in a real production environment, when the issues of implementing a new technology are being solved, it is necessary to accurately realize the advantages of the proposed option relatively existing one.

To solve this issue, it is proposed to develop a software application based on existing software that will allow to determine the reliability indicators of the recomposed work stand relative to the applied work stand with rigid interaggregate relation. The future of WSAL in industry 4.0 is promising, including those using additive technologies [21].

5. Conclusions

Basing on the operational reliability values of the WSAL, a methodology has been developed for determining reliability indexes, taking into account the structural and functional features of the RWS in the conditions of multiproduct production.

Basing on the values of the operational reliability of the WSAL, a methodology for determining the maintainability indicators was developed, taking into account the constructive and functional features of the RWS in the conditions of multiproduct production.

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