Formation of technical requirements for flexible rotary machine nodes

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Abstract. The method of parameters determining for the flexible rotary machines and lines and its individual components is described in this article. The method is based on the analysis of the fail safe performance probability. It allows determining the fail safe performance probability for tools, transportation and tool changing device nodes, elements of flexible rotary machine and is based on the analysis of flexible rotor line structure. The relationships between rational flexible rotary line structure and parameters of the individual nodes are shown on the flexible rotor line for the screws processing.

1. Problem
Processing of screws during continuous transportation on flexible rotary lines is the most efficient way to produce them [1-5]. Known design methods for flexible rotor lines allow developing rational structures and schemas for these lines [1, 4], but transitioning from theoretical studies to identify the specific parameters of machines during parametric synthesis is insufficiently studied. It is therefore necessary to improve the process of parametric synthesis for flexible rotary lines.

The purpose of performing this work is to study the relationship between the fail safe performance probability of flexible rotary line and machines for determining their individual parameters that are used as initial data in parametric synthesis.

To achieve this goal it is necessary to investigate the fail safe performance probability of the flexible rotary line and the fail safe performance probability of rotary machines to choose the most rational structure of the flexible rotary machine.

2. Method
Structural analysis is used to figure out the logic scheme of the rotary line. Probability theory is used to determine the fail safe performance probability for the various elements of the line.

3. The method of parameters determining for the flexible rotary machines and lines
Figure 1 shows the constructive-technological scheme of flexible rotary line for the manufacture of rod fasteners - screws. The scheme shows the flexible rotary machine for cutting and alignment end faces TP1, technological rotary machines TP2 and TP3 for preliminary and final shaping of end faces respectively. TP4 is a technological rotary machine for the threaded rod extraction and TP5 is a technological rotary machine for thread rolling. Transportation rotary machines TrR1-TrR5 carry out interrotary transfer of details. Wire on input stream V is supplied to the technological rotary machine TP1. Here the wire cut into individual blanks. There is an alignment of end faces and disembarkation...
of a facet on one of the ends of a core in the same rotary machine. Next, the workpiece moves to the next technological rotary machines, where a preliminary and final shaping of a head, reducing threaded rod and thread roll forming are performed. A replacement of tool occurs during idling in multinomenclature working positions for processing of other nomenclature products by turning the tool drum. Thereafter parts are discharged from the line by output stream W.

![Figure 1. The constructive-technological scheme of flexible rotary line.](image)

Let's look at the fail safe performance probability of flexible rotary line. This line corresponds to the logic scheme (figure 2), which is a mathematical model of the line.

![Figure 2. The logic scheme of flexible rotary line.](image)

We must consider that refusal in branched system will lead to loss of parts of the same size. The probability of the release of all types and sizes of products should be assessed during the line design, rather than the probability of sustaining performance above a predetermined value. The fail safe performance probability of flexible rotary line is evaluated under the following conditions.

1. The line stops either at refusal in unbranched system, or in case of failure more than one group in branched system.
2. Features of tools and tool selection devices are the same, i.e. they each have the same performance and have the same fail safe performance probability. Gripping bodies of transport rotary machines also have the adequate characteristics.

Thus, the line can be in one of states:
1. Preservation of full productivity $P_1$
2. Failure of one tool $P_2$
3. Failure of one of the gripping body $P_3$
4. Failure of the control unit in one multinomenclature tool module $P_4$
5. Refusal in unbranched system or refusal more than two elements in the branched system $P_5$.

Since all considered states form full group, the sum of probabilities of these states is equal to unit

$$P_1 + P_2 + P_3 + P_4 + P_5 = 1.$$  

(1)

Then fail safe performance probability of flexible rotary line can be determined by the following formula:

$$P = 1 - P_5 = P_1 + P_2 + P_3 + P_4$$  

(2)

$$P = P_{n}^{15} \times P_{t}^{20} \times P_{u}^{46} \times P_{i}^{120} + P_{n}^{15} \times P_{t}^{20} \times P_{u}^{46} \times \left( \sum_{5} C_{23}^{3} \right) \times (1-P_{i}) \times P_{i}^{19} +$$

$$+ P_{n}^{15} \times P_{u}^{46} \times P_{i}^{120} \times \left( \sum_{6} C_{3}^{1} \right) \times (1-P_{t}) \times P_{t}^{19} +$$

$$+ P_{n}^{15} \times P_{t}^{20} \times P_{i}^{120} \times (1-P_{u}) \times P_{u}^{45} \times \left( C_{24}^{23} + 2 \times C_{4}^{3} + C_{6}^{5} + C_{8}^{7} \right).$$  

(3)

where $P_{n}$ - fail safe performance probability of elements in unbranched system, $P_{t}$ - fail safe performance probability of transport devices, $P_{u}$ - fail safe performance probability of control units of the group tool module, $P_{i}$ - fail safe performance probability of the tool.

The dependence of fail safe performance probability of the flexible rotary line on fail safe performance probability of the tool and probability of transfer of the product was determined for $P_{n} = 1$ and $P_{u} = 0.995$ (see figure 3).

![Figure 3](image)

**Figure 3.** The dependence of fail safe performance probability of the flexible rotary line on fail safe performance probability of the tool and probability of transfer of the product.

Figure 3 shows that fail safe performance probability of the flexible rotary line most affected by fail safe performance probability of the tool. The probability of transfer of products between the rotaries significantly does not influence, since the number of gripping bodies in line considerably smaller than the number of tools.

Let's consider two variants of flexible rotary machine structures (figures 4 and 5). Flexible rotary machine shown in figure 4 is performed on the "classic" scheme. Within this scheme on elements of the rotary housing (RM) are installed a fully self-contained power heads (PH), which contains all the
necessary elements to carry out their functions. The logical scheme representing mathematical model of flexible rotary machine will include elements of not branching part, - RM, and also elements of the branching subsystem, - PH.

![Figure 4](image)

**Figure 4.** Flexible rotary machine is performed on the "classic" scheme.

Figure 5 shows the structure of flexible rotary machine, formed on the block diagram of new flexible rotary machine [1]. Such rotor machine has the configuration, classical for technological rotors, and includes power system (PS), general for all group tool modules. Group tool module have units for switching characteristics of the power system and stores of tools and devices [1]. Not branching part in the logical scheme of such machine will include the RM and PS elements. Branching part will include group tool modules.

![Figure 5](image)

**Figure 5.** Flexible rotary machine, formed on the block diagram of new flexible rotary machine.

Let's consider fail safe performance probability of flexible rotary machine which scheme is shown in figure 4. The fail safe performance probability of the flexible rotary machine can be defined as the sum of fail safe performance probabilities in all possible states.

We estimate the fail safe performance probability of the flexible rotary machine under following conditions.

1. Flexible rotary machine stops either at refusal in unbranched system, or in case of failure more than one power head or group tool module.
2. Characteristics of power heads and group tool modules are identical, i.e. they have respectively identical productivity and have identical probability of no-failure operation.

According to the first condition flexible rotary machine 1 can be in one of states.

1. Preservation of full productivity P1:
where $P_a$ - fail safe performance probability of a power head, Rrt - fail safe performance probability of flexible rotary machine elements.

2. Refusal of one power head $P_2$:

$$P_2 = P_{pm} \cdot \left( \sum_{i=6} \binom{C_i}{2} \cdot (1 - P_a) \cdot P_a^{11} \right)$$

where $C_{ij}$ - quantity of combinations from $i$ on $j$.

3. Refusal of elements of the flexible rotary machine or refusal more than one group tool module $P_3$.

Since all considered states form full group, the sum of probabilities of these states is equal to unit:

$$P_1 + P_2 + P_3 = 1$$

Then fail safe performance probability of TP1 can be determined by the following formula:

$$P = 1 - P_3 = P_1 + P_2$$

Dependence of fail safe performance probability of flexible rotary machine 1 on fail safe performance probability of power heads was determined for Rrt = 1 and $P_a$ = 0.980 ... 1 (figure 6).

![Figure 6. Dependence of fail safe performance probability of flexible rotary machine 1 on fail safe performance probability of power heads.](image)

We estimate the appropriateness of the proposed flexible rotary machine. To do this, compare it fail safe performance probability with the fail safe performance probability of flexible rotary machine 2, formed accordingly to scheme in figure 5 (where the flexible rotary machine has an overall power system and products processed in group tool modules).

According to the given above conditions flexible rotary machine 2 can be in one of 3 states.

1. Preservation of full productivity:

$$P_1 = P_{pm} \cdot P_{pr} \cdot P_a^6$$

where $P_{pr}$ - fail safe performance probability of elements of power system.

2. Failure of one group tool module:

$$P_2 = P_{pm} \cdot (C_6^3 \cdot (1 - P_a) \cdot P_a^5$$

3. Refusal of elements of the rotor machine, elements of power system or refusal more than one group tool module.

Since all considered states form full group, the sum of probabilities of these states is equal to unit:

$$P_1 + P_2 + P_3 = 1$$
Then the fail safe performance probability of flexible rotary machine 2 can be determined by such formula:

\[ P = 1 - P_3 = P_1 + P_2 \]  

\[ P = P_{pm} \cdot P_{pr} \cdot P_{a_1} + P_{pm} \cdot (C_{a_1}^5) \cdot (1 - P_{a_5}) \cdot P_{a_5} \]  

In figure 7 dependence of fail safe performance probability of flexible rotary machines 1 and 2 on fail safe performance probabilities of elements of power system and group tool module is presented. It is obvious that both of these indicators influence on fail safe performance probability of flexible rotary machine 2, however reliability of power system will render in this case crucial importance.

4. Results

This work is dedicated to the development of design methods for flexible rotor lines that will combine several large-scale productions of products of different sizes in the mass diversified flow of goods by processing several sizes of goods in each group tool module. The developed method allows to conduct the structural analysis of flexible rotor lines and to determine the requirements on the fail safe performance probability for the line individually. These requirements can be used as input parameters at the parametric synthesis stage during design of flexible rotor machines for screws processing. The developed method can be used to establish connection between the machine structure and the parameters of their individual components and mechanisms.

References

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