Method of creating reasonable roughness of functional surfaces for details in friction couple

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Abstract. Upgrading operational characteristics at the late stages of designing in the course of development of the modern multi-component instruments and systems is the extremely crucial task. Possibility of increasing the gyrostabilizer stabilizing moment via usage of the processing method, which does not cause the substantial changes of mass and dimensions parameters of the whole instrument and may be applied at the late stage of the development work, was studied in this investigation.

1. Introduction
Currently gyrostabilizers are widely used in different fields of aircraft building, shipbuilding and rocketry.

The majority of modern gyrostabilizers are designed for the following two operation modes within the carrier:
- stabilizing and control;
- axis elements caging in absence of electric power supply.

Extensive investigations are devoted to the analysis of gyrostabilizers operability providing methods in a stabilizing and control mode; for instance, works [1 – 2], in which the methods of providing principal parameters of different gyrostabilizers (stabilizing errors, targeting errors, platform travel velocity and others) at different stages of their designing, manufacturing and testing, are considered. At the same time, providing gyrostabilizers' parameters in the caging mode (particularly, stabilizing moment and uncaging time) is limited by considering design methods only, which makes it practically impossible to increase these parameters at the late stage of the development work without substantial changing the instrument's design, which often leads to disparity of the whole system.

2. Materials
The authors of this work investigated possibility of increasing the stabilizing moment of a gyrostabilizer in the caging mode via usage of the processing method of creating reasonable roughness of the functional surfaces for details in the friction couple.

In this investigation, the authors made measurements of the stabilizing moments at the axis of a biaxial controlled gyrostabilizer (hereinafter referred to as DUGS), which has been developed within the development project.

Stabilizing axis elements of the DUGS instrument in absence of electric power supply is realized owing to usage of COMBISTOP frictional clutch as a part of the axis' drivers (Figure 1).
The detail "Disk" is manufactured from retinax by die stamping and is included into the delivery set of COMBISTOP frictional clutch.

The detail "Bracket" is manufactured from the steel AISI 121 at the plant, where DUGS is manufactured.

The value of stabilizing moment at the axis of the DUGS device is determined by the stabilizing moment of clutch ($\bar{M}_{cl}$) which may be calculated from the formula:

$$\bar{M}_{cl} = F_s \cdot f \cdot r,$$

where $\bar{M}_{cl}$ – average value of stabilizing moment of the clutch, N·m; $F_s$ – spring force, N; $f$ – friction coefficient, $r$ – average friction radius, m, which may be calculated from the formula:

$$r = \frac{D_1 + D_2}{2},$$

where $D_1$, $D_2$ – outside and inside diameters of the friction surfaces, m.

The equation analysis (1) shows that the stabilizing moment of the frictional clutch may be increased via increasing the friction coefficient in the investigated friction couple.

3. Method and experiment

The authors of this work investigated possibility of increasing the friction coefficient via usage of processing method of creating reasonable roughness of the functional surfaces for the detail "Bracket" in friction couple. For this purpose, the following technique was developed:

1. Apply different cutting modes, make several samples of materials constituting the friction couple of the frictional clutch characterized by different roughness of the functional surfaces.
2. Determine the graphical criteria of the samples’ functional surface roughness (profile ordinates density distribution and profile slope ratio density distribution).
3. Using the manufactured samples, determine the stabilizing moment of the frictional clutch to spot for each of these samples (both regular instrument units as well as bench test equipment may be used).
4. Determine the graphical criteria of the samples’ functional surface roughness [3 – 5], which are providing the maximum value of the stabilizing moment of the gyrostabilizer to spot as reference values and fix treatment parameters of such surface treatment (cutting modes and the tool) for their substantial usage in the serial manufacturing.

The following experiment was performed for checking correctness of the above-mentioned technique.
Ten sets of samples were manufactured from the steel AISI 121 and from retinax, while the steel samples were characterized by different roughness of the functional surfaces. Taking into account the greatest effect of the feed (as compared with other cutting modes) on the surface quality created during the lathe work, different roughness were created via changing the feed (s) in the range from 0.02 to 0.2 mm/rev, in increments of 0.02 mm/rev.

The determined graphical criteria of the samples' functional surface roughness (profile ordinates density distribution and profile slope ratio density distribution) are presented in Figure 2.

![Figure 2. Profile ordinates density distribution and profile slope ratio density distribution for the functional surface of samples 1, 2, 3, 4, 5, 6, 7, 8, 9, 10](image2)

Analysis of the graphical criteria presented in Figure 2 evidences on existence of substantial difference in the functional surfaces roughness of the manufactured samples. Thus, the peaks of plots pertinent to profile ordinates density distribution for the samples 1, 4, 7 and 9 practically are not shifted relative the central point, which evidences on uniform distribution of protrusions and bays. At the same time, shifting the peaks of plots pertinent to profile ordinates density distribution for the samples 2, 3, 5, 6, 8 to the left and of the peak for the sample 10 to the right evidences on prevalence of bays and protrusions, respectively.

Measurements of the friction coefficient for the "steel AISI 121 – retinax" friction couple were performed using the bench test equipment (friction test machine).

Plot of friction coefficient vs time for the "steel AISI 121 – retinax" friction couple represented by the set "sample 1 – disk" is presented in Figure 3.

![Figure 3. Plot illustrating dependence $f(t)$](image3)

Measurements of the friction coefficient were performed in increments of 100 s during the period of 600 s. Parameters of the experiment (duration 600 s, spindle speed of the friction test machine 40 rev/min) were determined with due account of both instant operating mode of COMBISTOP frictional clutch within the DUGS driver, as well as the requirement towards providing life cycle of the gyrostabilizer unit of not less than 10 years (not less than 600 revolutions).

Based on the data of the plot the average value of friction coefficient for the pair "sample 1 – disk" was calculated from the formula:
\[
\bar{f}_1 = \frac{1}{n} \sum_{i=1}^{n} f_i \\
\bar{f}_1 = 0.31
\]  

Average values of the friction coefficient for the rest 9 sets of samples were determined similarly.

4. Conclusion

The results of the experiment performed for determining the friction coefficient between the samples are presented in Table 1. The required value of stabilizing moment for COMBISTOP frictional clutch is provided via usage of sample 1.

Table 1. The results of experiment performed for determining the maximum friction coefficient

| Sample No. | S, mm/rev | \( f \) (100 s) | \( f \) (200 s) | \( f \) (300 s) | \( f \) (400 s) | \( f \) (500 s) | \( f \) (600 s) | \( \bar{f} \) |
|------------|-----------|----------------|----------------|----------------|----------------|----------------|----------------|---------|
| 1          | 0.02      | 0.286          | 0.320          | 0.326          | 0.310          | 0.309          | 0.308          | 0.310   |
| 2          | 0.04      | 0.258          | 0.244          | 0.252          | 0.268          | 0.264          | 0.257          | 0.257   |
| 3          | 0.06      | 0.258          | 0.241          | 0.238          | 0.247          | 0.261          | 0.266          | 0.252   |
| 4          | 0.08      | 0.275          | 0.265          | 0.267          | 0.276          | 0.272          | 0.264          | 0.270   |
| 5          | 0.10      | 0.265          | 0.254          | 0.247          | 0.247          | 0.248          | 0.263          | 0.254   |
| 6          | 0.12      | 0.247          | 0.232          | 0.231          | 0.244          | 0.255          | 0.254          | 0.244   |
| 7          | 0.14      | 0.236          | 0.238          | 0.240          | 0.246          | 0.244          | 0.245          | 0.242   |
| 8          | 0.16      | 0.236          | 0.232          | 0.232          | 0.246          | 0.244          | 0.246          | 0.239   |
| 9          | 0.18      | 0.229          | 0.225          | 0.228          | 0.238          | 0.236          | 0.233          | 0.231   |
| 10         | 0.20      | 0.224          | 0.211          | 0.214          | 0.222          | 0.227          | 0.230          | 0.221   |

Analysis of data presented in Table 1 evidences on existence of effect of the functional surface roughness of the detail "Bracket" on the stabilizing moment for COMBISTOP frictional clutch.

The graphical criteria of the functional surface roughness for the sample 1, which are shown in Figure 4, were designated as the reference ones, and the process used for its creation was selected for the serial manufacturing.

![Figure 4. Profile ordinates density distribution and profile slope ratio density distribution for the functional surface of the reference sample.](image)

The results of the performed experiment confirmed the possibility of increasing the stabilizing moment at the axis of DUGS device in the caging mode via usage of the processing method of creating reasonable roughness of the functional surfaces for the detail "Bracket". Therewith, for its description it is necessary to use more informative graphical criteria that allow one to find the dependence between the functional surface roughness of the detail and the stabilizing moment of the gyrostabilizer in the caging mode.
5. Results
The performed investigation allowed obtaining the following results:

1. The technique bringing to increasing stabilizing moment of gyrostabilizer in the caging mode via usage of the processing method has been developed and implemented.

2. The plots characterizing the time behavior of the friction coefficient for the "steel AISI 121 – retinax" friction couple at different parameters of functional surface roughness of the steel samples have been obtained.

3. The graphical criteria (profile ordinates density distribution and profile slope ratio density distribution) of the reasonable functional surface roughness for the detail "Bracket" providing the required value of the stabilizing moment for COMBISTOP electromagnetic frictional clutch have been obtained.

4. Treatment parameters (cutting modes and tools) providing creation of the reasonable functional surface roughness for the detail "Bracket" have been determined.

References
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