Research of thermal deformation of a kinematic wave reducerwith a modified tooth profile during the work in low temperature conditions

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Abstract. In the conditions of the Extreme North working resource of mechanicaltools and machineelements is reduced because of bad weather conditions in this region.At a low temperature materials are exposed to deformation which is capable to break operability of the mechanism.In connection with the high requirements to the accuracy of a kinematic wave reducer, it is necessary to conduct a research for the purpose of comparison of value of thermal deformation and the appointed admission on a reducer detail.If value of thermal deformation is more admission, then it can lead to jamming of the mechanism.The research was conducted for a collected reducer and separately for not loaded driver gear.

1. Introduction

A simplified diagram of a modified gear tooth profile is illustrated in Figure 1. This profile of teeth driven gear provides a possibility to create the transmission, which has a difference between the driver and the driven gear in one tooth. It is a feature of a reducer with the modified shape of the tooth. The use of a similar profile and a difference of teeth of a driver and driven gear provide the big area of contact, in comparison with evolvent gearing. Such difference allows several teeth to perceive a high value of ability of loading.
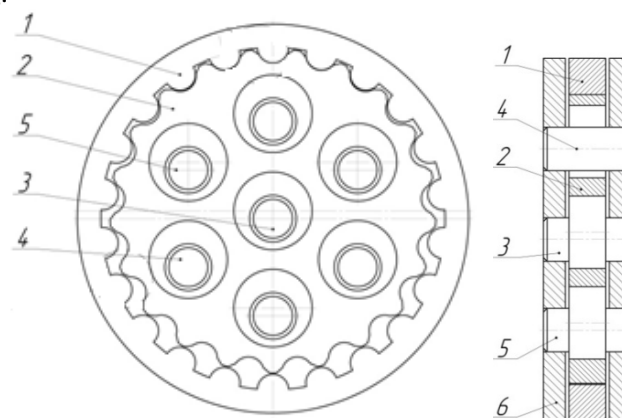

Figure 1. The simplified scheme of a reducer with the modified profile of tooth: 1 – Driven gear; 2 – Driver gear; 3 – Eccentric shaft; 4 – Hub; 5 – Fingers; 6 – Mobile wheel.

Analysis of the details of a reducer revealed thatthe mostdeformable detail is the drivergear.Deformation of thedrivergear can lead to jamming of a reducer. Therefore, we will conduct a research of values of possible deformation for driver gear with the purpose to exclude a possibility of jamming of a reducer under the influence of temperature changes.

2. Materials and methods of a research.

Driver gear made of steel 40X [11]. Let's define deformations of a gear wheel as separate detail. The driver gear is established on 4 bearings according to the kinematic scheme of a reducer. The research was conducted of using the SolidWorks Simulation program at a temperature of driver gear of –50 °C.

Results of thermal deformation are visible in figure 2. The figure shows that the maximum deformation occurs at places with the smallest amount of material. In these points, the value of resultant movement makes 0.02 mm (figure 2 a), and value of equivalent deformation makes 0.0014 N/m^2 (figure 2 b).

a   b
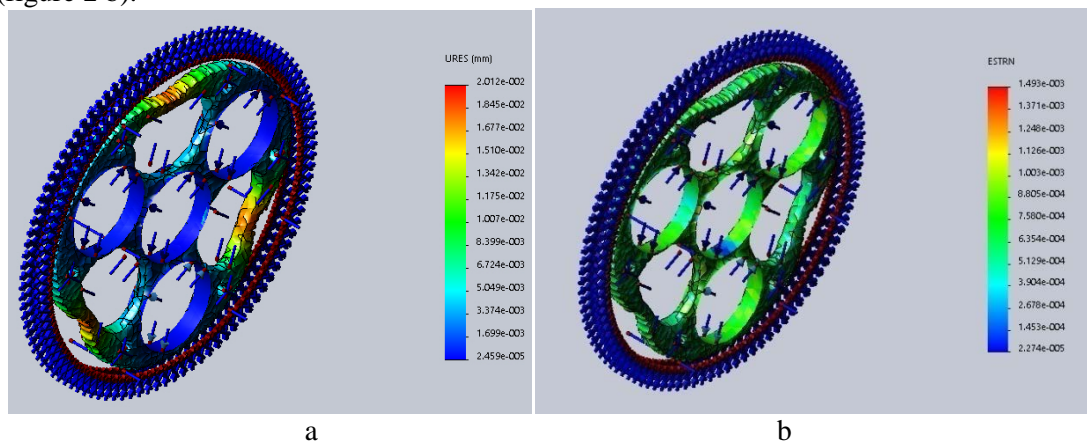
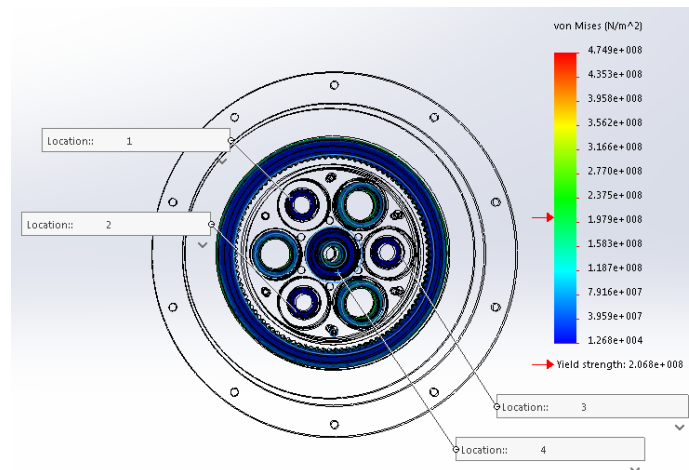**Figure 2.** Results of thermal deformation: a – value of resultant movement; b – value of tension.

3. Thermal deformation on assembly of a reducer with temperature in a zone contact of teeth of a driver and driven gear +90°C and on all parts of a reducer at a temperature of -50 °C.

All parts of a reducer are made from steel 40X [11]. As a result of the analysis diagrams of resultant movements and tension are received.
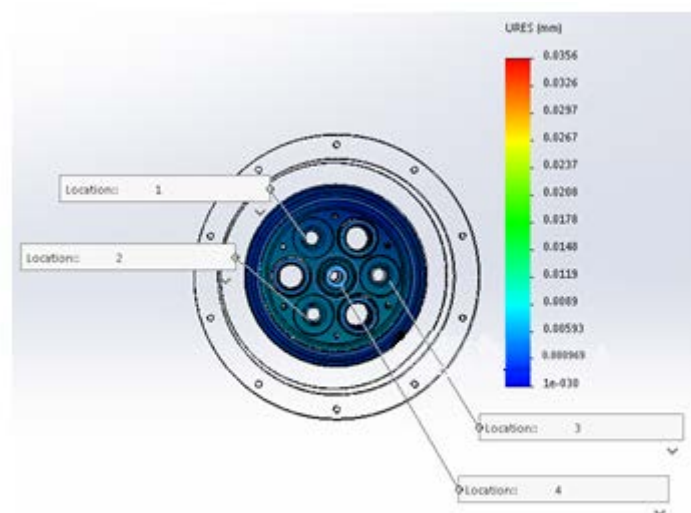
Figure 3. Resultant movement on eccentric and input shaft: Location 1 – 0.00694 mm; Location 2 – 0.00829 mm; Location 3 – 0.00677 mm; Location 4 – 0.00855 mm.
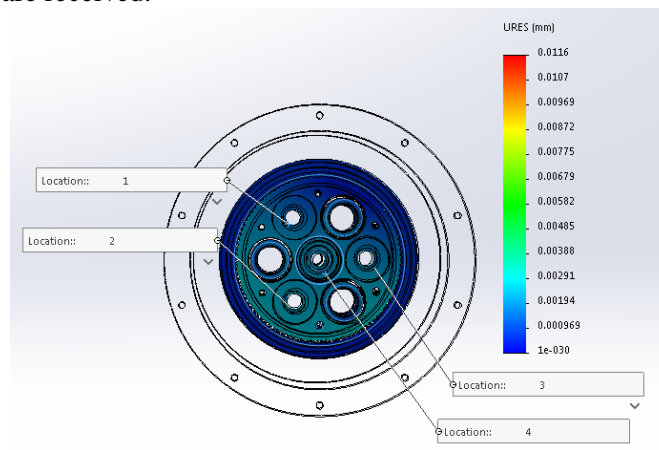
The greatest value of resultant movement on eccentric makes 0.00855mm (figure 3). This value is less than value of a gap in bearings. The greatest value of tension makes $4.966 \cdot 10^7$ N/m^2 (figure 4), this value of tension doesn't exceed the yield strength of steel 40X $\sigma_t = 2.068 \cdot 10^8$ N/m^2, it follows from this that durability of a design is provided.

Figure 4. Value of tension in eccentric: Location 1 – $4.506 \cdot 10^5$ N/m^2; Location 2 – $2.024 \cdot 10^5$ N/m^2; Location 3 – $6.232 \cdot 10^5$ N/m^2; Location 4 – $4.966 \cdot 10^7$ N/m^2.

4. Thermal deformation on assembly of a reducer with temperature in a zone contact of teeth of a gear wheel and a wheel + 90°C and on all parts of a reducer at a temperature of +50 °C.
All parts of a reducer are made from steel 40X [11]. As a result of the analysis diagrams of resultant movements and tension are received.

Figure 5. Resultant movement on eccentric and input shaft: Location 1 – 0.00219 mm; Location 2 – 0.00293 mm; Location 3 – 0.0024 mm; Location 4 – 0.00298 mm.

The greatest value of resultant movement on eccentric makes 0.00298mm (figure 5). This value is less than value of a gap in bearings. The greatest value of tension makes $1.865 \cdot 10^7$ N/m^2 (figure 6), this value of tension doesn't exceed the yield strength of steel 40X $\sigma_t = 2.068 \cdot 10^8$ N/m^2, it follows from this that durability of a design is provided.
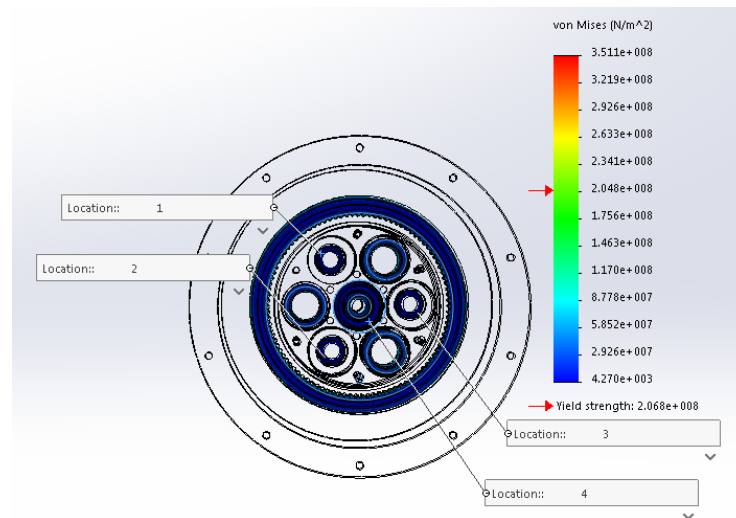
Figure 6. Value of tension in eccentric: Location 1 – $2.001\cdot10^5$ N/m^2; Location 2 – $1.004\cdot10^5$ N/m^2; Location 3 – $2.517\cdot10^5$ N/m^2; Location 4 – $1.865\cdot10^7$ N/m^2.

5. Conclusion

The mechanism has difficult geometry and great demands are placed on production accuracy. The thermal analysis has revealed that, the maximum resultant movement makes, at a temperature of influence of –50 °C on all details and +90 °C in a gearing zone of driver and driven gear makes 0.0225 mm. This value is less than value of the lower limit admission which makes 0,025 mm therefore this influence won't bring to get jammed a reducer.

References

[1]   Marisova A F 2010 *Epicyclic gearing. Calculation and design* (Rostov-on-Don, Don State Thechnical University)
[2]   Dunaev P F, Lelikov O P 2008 *Construction components and machine parts* (Publishing center Academy)
[3]   Fishenko V N 2016 *Handbook for constructor. Book 2. Design mechanism and parts.* (Publishing center Infra-Engineering)
[4]   Kudravchev I V, Halimanovich I V, Lekanov A V, Masanov A G, Silchenko P N, Novikov E S 2013 *The 14 Russian Conf. Young Sci. on Math.Modeling and Information Techn.* **1** 132-134
[5]   Semenov Y A Semenova N S, 2015 *Theory of Mechanisms and Machines* (Saint Petersburg, Polytechnic University)
[6]   Stepanova D L 2014 *Modern Thechnics and Thecnonogy* **1** 201-202
[7]   Stepanova D L 2014 *Modern Thechnics and Thecnonogy* **1** 283-284
[8]   Luminarskiy I E 2014 *Bullatin of University. Mechanical engineering* **3(648)** 8-15
[9]   Timofeev G, Egorova O, Samailova M 2015 *The 14 IFoMM World Congress*
[10]   Tarabarin V B, Tarabarina Z I *Bull. of Bauman Moscow State Techn. Univ. Mech. Eng.* **5** 117
[11]   GOST RF 7370-98, Railway arrow of the types P75, P65 and P50, Moscow, 1999