Analysis on Nylon 6/6 Camshaft Gear Temperature Simulation In A 1.1 Kva Elepaq Generator Using Inventor and ANSYS

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Camshaft gear temperature simulations are presently crucial as they offer a distinctive visual account of the temperature profile within the generator, they permit superior manufacturing assessment and the design of heat-resistant camshaft gear with high performance and low cost. However, available information to designers is inadequate as they omit the approximate global maximum temperature, particularly for the nylon 6/6 camshaft gear in a 1.1 kVA elepaq generator. In this article, the idea is to simulate and account for the global minimum and maximum temperature using the Inventor and ANSYS software. The stress-induced on the generator was considered. The results of the simulation revealed an approximate global maximum temperature of the nylon 6/6 camshaft gear as 37°C max with 22°C min. Furthermore, the global minimum at 35°C max with 21°C min was considered. Besides, the structural steel global maximum of 38°C max, 25°C min and global minimum 35°C max, 24°C min. The stress values did not exceed 0.1419 MPa on ANSYS but the ANSYS revealed that the camshaft gear strain was within safe limits. The simulation approach predicts the minimum and maximum temperature of the nylon 6/6 camshaft gear and the stress and strain values. The utility of this attempt is to help designers to implement effective decisions on material choice and design parameters for optimisation, performance and low-cost design.

Keywords : Nylon 6/6, Camshaft, Generator, Simulation, Inventor, ANSYS

1. INTRODUCTION

In Nigeria, the energy supply crisis is deepening and the failure of the country's power sector to offer a sufficient supply of electricity to households and industries. To solve this problem, individuals and small scale enterprises have adopted the use of generators to power homes and offices but at monitored costs. The 1.1KVA generator set is one of the most commonly used power sources and several brands are available: Lutian, Elepaq, Firman, Elemex and Honda, among others. In generators, timing gears permits the camshaft as well as crankshaft to rotate the timing chain. While the turning of the crankshaft positions the pistons in up and down movements within the cylinder, the motion of the camshaft often permits the opening and closing of the intake and exhaust valves attached to cylinders. Thus, these components serve an important purpose in appropriate engine timing.

But the camshaft gear temperature needs to be monitored and inadequate information exists on this in the literature. In recent times, the materials for camshafts are changing. In a generator, nylon 6/6 is used. Thus we require a clear approach to understanding the behaviour of the nylon 6/6 camshaft and establish the approximate global temperature coupled with the maximum stress values. The insight is essential so that the generator can work effectively and offer good power output to customers. A proposal is made to replace the current nylon 6/6 camshaft with another composite that is expected to be economical. However, there is no approach of easily testing this alternative and this will make development and sustainable manufacturing difficult to attain in the nearest future.

The principal area where this study is located is on gears and the review of literature is embarked upon

with this in focus, to determine the possible research gap in the literature. Li *et al.* [1] worked on lyrical gears with a concern for the heat transfer problem. The author initiated by heat coupled with machining and installation error. They analysed the thermal influence developed by deploying the finite element method as well as the APDL program. It was concluded that with elevated machining error, there is a possibility for a higher temperature change. Hoskins *et al.* [2] established a simulation procedure on gear applications via the wear associated with the PEEK desk where contact involving rolling and sliding exists. The discussion also analysed the pitch area of gear teeth in polymer it was concluded that surface failure of gears has a strong association with the morphology of the contact surface regarding the gear tooth. While these articles established the thermal influence on gears and in the rolling and sliding process, the information provided is of little help to understand the temperature behaviour of the nylon 6/6 camshaft gear in a 1.1 KVA elepaq generator.

Roda-Casanova and Sanchez- Marin [3] proposed a numerical method to predict the temperature of a polymer spur gear using a 2-dimensional finite element method. The heat generated was perceived as a thermal load thermal analysis was conducted using the finite element model. The article reported concurrence of the experimental readings with the similar Fernandez *et al.* [4], deployed the finite element approach on heat transfer to understand the characteristics of the flash and bulk temperature of gears of various material makes with the model constrained by energy loss, assumptions were made on the values of temperature used and the thermal flow path for the gear tooth. While the first article takes a divergent approach from the present work, the article by Fernandes *et al.* [4] is closely linked to the present work. However, the peculiar behaviour of the nylon616 camshaft gear was not studied and may offer differing outcomes. Furthermore, some works also studied the misalignment of polymer gears [7-9]. They concluded that the wear of acetal gear is independent of the radial and axial misalignment but affected by the yaw and pitch misalignment while misalignment is an important phenomenon in gears, the issue of camshaft gear in the context of temperature analysis for the nylon 616 material for the 1.1 kVA generator was not analyzed.

In the present study, an analysis of a 1.1 kVA elepaq generator camshaft gear by simulating the temperature behaviour of the nylon 6/6 camshaft using Investor and ANSYS software is conducted. A prime aim was to obtain the approximate global maximum/minimum temperatures of the nylon 6/6 camshaft that is presently installed in the generator and understand the stress induced in the generator. This was achieved by adjusting the design parameters in the present product brand of 1.1 kVA elepaq generator camshaft gear. Consequently, this study applies the concept of temperature to assess and update the present knowledge on camshaft gear temperature behaviour. The idea of temperature is hinged on the establishment of the mean speed of the camshaft gear's molecules. Temperature is a heat phenomenon that evaluates the quantity of heat energy occurring in the camshaft's gear. This research is significant since it provides a platform to determine an essential deficiency of an approximate minimum and maximum temperatures of the nylon 6/6 camshaft gear in performance evaluations of generators. Besides, it provides designers information to implement effective decisions on material choices and design parameters for optimisation, performance and low-cost design. Furthermore, by tackling and establishing the problem yet to be focused upon and the gap in the material behaviour of nylon 6/6 camshaft gear subjected to temperature, future research is stimulated.

2. MATERIALS AND METHODS

Procedure followed for the design and simulation of the Elepaq SV2200 camshaft gear

The steps for the design and simulation of the cam and crankshaft gear discussed in this article are as follows:

- Step 1: The crankshaft and camshaft were purchased from a local Elepaq distributor.
- Step 2: Accessible dimensions of the gear geometry were measured with vernier caliper by a machinist and recorded. i.e. root diameter, tip diameter, tooth depth, face width, shaft diameter.
- Step 3: Other internal patterns and design features were measured and recorded.
- Step 4: The power transmitted by the crankshaft engine is estimated neglecting losses as provided by manufacturer.
- Step 5: The gears were designed and assembled on Autodesk Inventor while specifying some input and gear material type and properties.
- Step 6: The speed transmitted by the crankshaft is suggested by inventor design accelerator calculator at 1.1 kVA power output.
- Step 7: The crankshaft and camshaft gear assembly was saved in step format and exported to ANSYS 2018.
- Step 8: Static structural simulator was used to suggest stress and strain induced on both gears with information from inventor.
- Step 9: Transient thermal was used to predict the temperature distribution on the camshaft gear in static air.

- Step 10: The material of the camshaft gear was replaced with structural steel and results generated were compared for steel-steel contact and steel- nylon contact.

The basis for selecting nylon 6/6 as the material for the camshaft gear

The choice of materials for understanding the temperature behaviour of the camshaft gear during operation should be considered to guide the choice of the research model. The reason is that if the wrong material is chosen, the wrong inferences may be given from the experimental results. Consequently, the central problems faced in this article are (i) why the nylon 6/6 camshaft gear is selected for the research? (ii) why not use other camshaft gear materials? In the activity concerning choosing the material for the study of the temperature behaviour in a generator while analysing the camshaft gear changes in physical properties, there is scope to include the nylon 6/6. As generator manufacturers exhibit extensive alternatives to choose materials for the non-metallic camshaft gear parts, nylon has become a preferred choice due to adaptability. Of particular interest in the manufacture of camshaft gear is nylon 6/6, which comprises of two monomers, namely the hexanedioic acid and the 1, 6-diaminohexane. The first monomer comprises of a 6 carbon acid having a -COOH group at the ends while the second monomer contains a 6 carbon chain having an amino group, written as -NH_2 at the ends. There are several bases for choosing nylon 6/6 as the material for the camshaft gear, including the following:

Tensile strength of the camshaft gear

First, the tensile strength of the camshaft gear is a major issue that should be considered while choosing a camshaft gear. The tensile strength reflects the capacity of the material to resist tensile load lacking failure. A high tensile strength which the nylon 6/6 exhibits is desirable. But if a material deforms easily due to tensile stresses, then it is ductile with the possibility to rupture during usage. Such material is undesirable for the camshaft gear as it threatens the lifespan and functionality of the generator. Consequently, on noticing that nylon 6/6 exhibits high tensile strength, it was chosen as the material for the camshaft gear used in this article. However, strongly linked to tensile strength is stiffness and nylon 6/6 also demonstrates resistance to deformation while responding to an applied load during operation; this has further made nylon 6/6 a preferred choice for camshaft gear development.

Heat resistance

Being heat resistant, the nylon 6/6 can safeguard the camshaft gear from the heat generated during the operation of the generator due to high-temperature activities. They attempt to minimize the possibility of unsafe off-gassing exposures. The competence of the design engineer in designing a high-performing generator is partly measured by the ability of the designer to select heat resistant material for the camshaft gear. This parameter ought to be used as a benchmark during design analysis to choose material for the camshaft gear. As nylon 6/6 possess this attribute of heat resistance, it qualifies as a material for choice in the making of the camshaft gear for a generator.

High melting point

In materials with high melting points, strong intermolecular forces are said to occur between atoms. However, energy is required to surmount the forces of attraction among the non-confined electrons in the nylon 6/6 and the ions. Since constant heat is generated in the camshaft gear, the high melting point of nylon 6/6 is favourable to withstand the heat generated in the generator without failure. However, on noticing this advantage of nylon 6/6, its choice was made as to the material for the camshaft gear used in this article.

Dimensional stability

Dimensional stability is an essential issue that should be considered while contemplating the choice of camshaft gear in a generator. The component designer is eager to know the proportion of change in the linear dimension of the camshaft gear when it is exposed to intensive temperature. This parameter is a good indicator of the internal stress added to the system during operation. However, on noticing that nylon 6/6 has a good dimensional ability, it was chosen as the camshaft gear material of choice in this article.

High lubricity and resistance to hydrocarbons

High lubricity is the function of the nylon 6/6 that plays a principal role in the longevity and functioning of the generator, aiding the minimization of wear between the camshaft gear and other parts while minimizing friction between the fixed parts and those rotating. Lubricity promotes resistance to hydrocarbon. The generator needs to be operated in a risk-free situation and wear introduces risks in equipment as there could be a sudden failure. However, on noticing that nylon 6/6 has high lubricity and can resist hydrocarbons, it becomes a choice for the camshaft gear used in the present article.

Exceptional balanced strength

In the vast majority of design activities for the generator, a good balance of strength is essential. High tensile strength materials, heat resistant material, resistance to hydrocarbon and more are the necessary components of a good balance. This helps the camshaft gear to enhance stability and avoid failure. However, on noticing that nylon 6/6 exhibits outstanding balanced strength, it is chosen as the right candidate for the material of the camshaft gear.

3. RESULTS AND DISCUSSION

Firstly, the power rating of the elepaq generating set and other parameters such as number of teeth, face width, tooth thickness, tip and root diameters are measured and manufacturers specification. The figures show the predicted maximum and minimum temperature and stress induced on the injection moulded cam and steel gear (crankshaft) designed on inventor and tested on ANSYS and Inventor for performance parameters. The maximum and minimum stress induced in 1 sec at driver speed value of 2500rpm and 4Nm torque and power of 1.1kw with a driven value of 1250 rpm and 8Nm torque and 98% power transmission efficiency was suggested through ANSYS (static structural) solution. Also, the transient thermal problem solver was used to investigate the maximum and minimum surface temperature encountered under 83seconds. Nylon 6/6 dry as moulded, heat stabilized material was used with corresponding density of 0.23 g/cm³ poisson ratio of 0.4, tensile modulus of 3.3GPa at 25°C. This is in agreement with Nozawa *et al.* [10-11]. **Figures 1 to 12** show the sample and the results associated with this work.

Figure 1. Elepaq injection moulded camshaft gear

Figure 2. Maximum and minimum contact temperature of nylon reached against time

Figure 3. Interface of the ANSYS program for maximum and minimum temperature values under 83seconds

Figure 4. Maximum temperature reached by structural steel gear cam under 83seconds of thermal load

Figure 5. Minimum and maximum temperature reached under 83seconds

Figure 6. Contact stress induced on contact surface (flank radius)

Figure 7. Maximum and minimum stress induced in both nylon and steel spur gears

Figure 8. Steel and nylon gear in contact (ANSYS Multiphysics)

Figure 9. Steel gear design accelerator

Figure 10. Inventor gear design accelerator for alloy steel and nylon gear material

Figure 11. Gear parameters in mesh

Figure 12. Drawing file of the gears on inventor

From the results generated on ANSYS and Inventor, the approximate global maximum temperatures of the nylon 6/6 camshaft gear was found at 37°C max, 22°C min. Similarly, its global minimum is at 35°C max, 21°C min. Also, structural steel global maximum of 38°C max, 25°C min and global minimum 35°C max, 24°C min. The stress values did not exceed 0.1419 MPa on ANSYS. The ANSYS depicts the cam gear strain was within safe limit.

4. CONCLUSIONS

Camshaft gear temperature simulations are critical in the development of high performance and low-cost generators. In this study, a simulation approach is adopted to understand the material behaviour on nylon 6/6 camshaft gear under temperature influence, using inventor and ANSYS. From the analysis of results, it was found that the global temperature values are in closes range for the initial 83 seconds. Nonetheless, the difference suggests that the program should be run for a longer time to ascertain the lifespan as well as damage that may occur during the source life of the camshaft material. The values suggested by the program shows some levels of a substitution effect between metal gears and nylon gear materials.

The contributions of this article to the power generation literature by establishing a simulation approach to camshaft gear temperature behaviour for nylon 6/6 camshaft gear in a 1.1KVA elepaq generator. This is unclear in previous camshaft gear research and this knowledge adds to our comprehension of research and assessment parameters in the area. In addition, this work is also highlighting research flaws on camshaft gear behaviour under temperature to adequately establish new research aims.

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