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Design analysis and fabrication of a 24 - teeth spur gear from HT250 gray cast iron

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Abstract

Spur gears are types of gears used for transmitting motion between two parallel shafts. This machine often encounters failure and downtime as a result of failure of the gear component. These failures include; pitting, scoring, fracture, wear, and so on. This study focused on the use of Gray Cast Iron (HT250) to develop a spur gear having 24 teeth and a protruding connecting shaft to link it to a machine using keys or other means. The fabrication process that was used to obtain gear was Casting which was done in the Foundry Workshop of the Mechanical Engineering Department in Covenant University. The failure indicated on the gear was a cyclic failure due to fracture. The stress analysis was carried out on this element using this software. A cyclic force of 10 N was subjected

to the gear and the following values were obtained: the maximum Von-mises stress was 3.548 x 10^{5}N/m^2 and the minimum was 5.629 x 10^{-1}N/m^2, The maximum displacement or deflection gotten was 6.306 x 10^{-5} mm and minimum is 1 X 10^{-30} mm, The maximum strain gotten was 2.599 x 10^-6 and the minimum was 9.825 x 10^-12. Various parameters were used to obtain the nature of failure on the material such as the force on 10 N on a single tooth and on all 24 teeth, a torque of 10 N/m, temperature of 50-degree, pressure of 20 Pa and centrifugal force of 5 rad/s. These results to variation in the von mises stress.

Introduction

Gears can be referred to as mechanical components with toothed wheel shaped which when fused with another toothed wheel with similar design convert motion, torque and power from a shaft to another for the purpose of the smooth running of appliances such as machine, equipment and so on that are used to perform various tasks for diverse applications of everyday life [1]. Depending on the industry, such as the energy, aviation, automotive, and manufacturing sectors, they are made or produced using various materials. Similar devices that transmit power other than gear include pulleys, belts, and ropes and so on. According to Puneeth and Mallesh, [2], various design gear parameters must be considered when designing a gear. They include gear module, gear ratio, number of teeth, pressure angle, profile shifting factor addendum factor and damping ratio. Gears involve characteristics such as a gear train, gear shaft, gear drive, gear pumps, etc. Gear trains are widely used in automotive, industrial and aerospace applications. Nowadays, with the increasing demand of high speed, heavy transmission, quiet operations and light weight which are present in the gear systems, vibrations and noise reduction has become very relevant. The purpose of the gear train is to minimize the error occurrence between the obtained gear ratio (that is the gear ratio measured or determined from an analysis) and the required ratio (also called the standard or given ratio value) [3]. According to Lynwander, [4] gear drives are a critical component of the mechanical system which is used in diverse industries such as turbomachinery, refinery and so on, it also increases the reliability and improves the technology in mechanical components. The gear drives assist in the transmission of motion and power through mesh interaction.(See Table 1, Table 2, Table 3, Table 4, Table 5 Table 7, Table 8, Table 9, Table 10, Table 11, Table 12, Table 13, Table 14, Table 15, Table 16, Table 17, Table 18).

An important moving part in gears which transfer torque, power and rotary motion in an automobile or machine with a fatigue design failure is known as “gear shaft”. Its safety has become a very essential aspect in the manufacturing and servicing of gears. There are many forms of gear failure such as surface fatigue, wear, pitting e.t.c[4]. Gears can take on many different shapes and forms, but the four main varieties are spur gears, bevel gears, helical gears, and worm gears. Power transmission in spur gears occur between two parallel shafts [5]. In the case of bevel gear's, gear teeth should be straight and error-free for effective transmission and longer service life. Helical gears are gears with high bearing strength, smooth transmission, little impact, and low noise, according to [6]. In comparison to spur gear, internal helical gear teeth are superior. In contrast, worm gears were described by [7]as gears with the potential to enable a compact gear design and high-power density based on a high gear ratio that occurs on a single stage.

They frequently resist high thermal loads and frictional heat while slowing high sliding speeds within its tooth contact. Spur gears will be the main area of focus for the various types of gears. Spur gears, also known as the simplest type of gear, are used to transmit torque, power, and rotary motion between parallel shafts. They are also the simplest sort of gear to produce. It can be used for positioning systems improvement, speed reduction, resolution, accuracy, and torque multiplication [8]. According to a study, involute spur gears are one type of spur gear [9]. Two types of involute spur gears are distinguished: symmetric and asymmetric involute spur gears. It is apparent that symmetric involute spur gears are widely used in modern technology, may be produced in small diameters or with high torques, and can transmit power with the same dimensions. Also, new designs of this kind of spur gear are created to fulfill high-performance demands, including the ability to boost load transfer capability, extended life, cheap cost, and the ability to reduce vibration and noise. However, the asymmetry is created by utilizing an involute profile with various tooth pressure angles. These angles impact the prices and drive of the teeth. The study's asymmetrical design is intended to reduce size, mass, vibration, and noise while increasing load carrying capability. High power transmission efficiency, compact design, high power transmission, dependability, ease of maintenance, and suitable and flexible components are a few of spur gears' benefits [10]. Various profile modifications and loading conditions are the basis for the investigation of gear failure. The gear mesh stiffness is significantly influenced by the gear tooth inaccuracy [11]. Spur gears typically fail due to a number of failure mechanisms, such as fatigue, fracture, wear, and stress rupture, depending on specific circumstances. The teeth on the spur gear are damaged by pitting at the spur gear surface and tooth breaking near the tooth area [12]. This tooth breaking gives the tooth's surface a destructible appearance. Additional causes of spur gear failures due to particular circumstances and factors include inadequate gear set design, inaccurate gear geometry, misaligned gears, overloading of weight on the gear, internal cracks caused by operation on the gear that are found in critical regions, improper material and tool selection, and heat treatment process [13]. These are serious issues that affect spur gear functioning, machinability, and tool life. According to Wasim et al. [14] cast iron is referred to as an iron carbon alloy that contains essential elements such as manganese, silicon, Sulphur, and phosphorus. Cast iron can be majorly divided into two which are white cast iron and gray cast iron [15]. Studies have shown that corrosion occurs in cast iron especially cast-iron pipes causing failures. These pipes are not only affected by P^H and moisture content but also by the thickness loss of buried cast iron pipes causing leakages [16]. In another sense white cast iron is formed when on solidification, carbon in the solution cannot form graphite. Also, it was established that its properties include hardness, brittleness, cannot be easily machined, light appearance due to absence of graphite, high compressive strength, and retains strength at high temperature. Grey cast iron is softer, easier to manufacture, and less brittle than white cast iron since most carbon is found in graphite flakes. The casting compositions contain 25% - 4% of carbon, 1% - 3% silicon and additions of manganese which covers a range of 0.1% - 1.2% [17]. Cast iron also comes in ductile and malleable varieties, but these are less typical. Because of its unique qualities, gray cast iron is used for cylinder heads, car brakes, piston rings, bottling machines, gears, and other

things. These characteristics include affordability, superior casting qualities, outstanding machinability, and effective shock absorption [18].
This study is mainly about spur gears with the use of a type of gray cast iron in coating the gears and this type of gray cast iron is HT250 gray cast iron. HT250 gray cast iron is a type of cast iron with distinguished properties such as high strength, wear resistance, heat resistance and tensile strength of 250 MPa and these properties will help in the sustainability of the gear life during machining [19]. Studies have shown that the traditional gray cast iron performance no longer meet the required operations, it is therefore advised that a variety of ways needs to be implemented such as cladding, carburization, nitriding, an electroplating [20]. In recent development, studies have shown that corrosion of spur gears in ethanol environment can be reduced by heat treatment. However, there are limited books and theories of spur gear applications in ethanol environment. [21] defined ethanol environment as a solvent that contains the presence of hydroxyl group among the hydrocarbons family with the ability to dissolve ionic compounds.
However, the main goal of this study is to design and fabricate a 24 teeth spur ear using HT250 gray cast iron by using SolidWorks for the design and stress simulation.

Section snippets

Material selection

In this study, the material of focus for the manufacture of the spur gear is grey cast iron. The material is tested and characterised to aid in the development of an appropriate material that would not fail under the required conditions, this being for use in a rinser machine. Due to its excellent wear qualities, it is used in the manufacture of gears. Casting process makes it simple to create complex shapes. When a smooth operation is not required, this method is used. Grade HT250 of cast iron

For standard material

This result indicates a minimum induced stress of $5.629\times10^{-1}N/m^2$ and a maximum induced stress of $3.548\times10^{5}N/m^2$. Also, the maximum possible displacement of the tooth is of a magnitude of 6.306×10^{-5} mm.
Fig. 5, Fig. 6, Fig. 7 shows the induced stress, surface displacement behavior and strain analysis of the material when subjected to a force. At the tip of the tooth, a maximum displacement was observed, displacing the tooth from its original position. This displacement causes a bending fatigue on

Conclusion

The constant problem facing design and machine designers is gear failure due to material degradation. Machine components often function differently from theoretical and designed behavior due to the different conditions present in the application environment. These factors pose a severe problem to the industry as they experience downtime. It is due to component failure, low product quality, and low yield because of faults in components before their lifespan. This research focused on studying the

CRediT authorship contribution statement

Enesi Y. Salawu: Conceptualization. **Okoye-Nnaeze Chinaecherem:** . **Oluseyi O. Ajayi:** Writing – review & editing. **Samson O. Ongbali:** Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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