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Design optimization and new product development of hub idler gear

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Abstract - *In business and engineering, new product development (NPD) covers the complete process of bringing a new product to market, renewing an existing product or introducing a product in a new market. A central aspect of NPD is product design, along with various business considerations. New product development is described broadly as the transformation of a market opportunity into a product available for sale. The products developed by an organization provide the means for it to generate income. For many technology-intensive firms their approach is based on exploiting technological innovation in a rapidly changing market.*

Market share by a regular development of new products. There are many uncertainties and challenges which companies must face throughout the process. The use of best practices and the elimination of barriers to communication are the main concerns for the management of the NPD.

Importance of introducing new products can be summarized in these "Seven reasons why new product development is necessary

Key Words: NPD, HUB IDLER GEAR, FEA

1. INTRODUCTION

The most effective way to transmit power between two shafts is through gears. They are utilised more frequently in power transmission than belts and chains. The teeth on the gears might be straight, spiral/helical, or bevelled. Bevel gears are used to transfer power between perpendicular shafts, while straight toothed gears are used to transfer power between horizontal shafts. Since helical gears can rotate at higher speeds without wearing out, they are now preferred over straight tooth gears in many applications. Machines for spinning and weaving frequently use gears. They are utilized for take up and let off motions in weaving machines. Both sizing machines and the movements of the speed frame constructor use bevel gears. Gears are thought of as positive drives.

The idle gear rattle phenomenon is associated with the characteristic noise that unselected impacting gears radiate to the environment. The phenomenon occurs at low impact forces, qualitatively similar to the noise produced, when a marble hits a tin can. The problem is induced by engine order vibrations in the presence of backlash in meshing pairs, and is particularly troublesome in vehicles with diesel engines, because of higher output torques [1]). Rattle has a distinct sound quality that differentiates it from noises produced by other sources in the vehicle [2], while the attenuation of engine noise during the past decades has brought it to the forefront of noise and vibration issues, as a major concern for the automotive industry [3]. Vehicle owners are usually annoyed by this noise and often attribute it to some form of malfunction. In addition to possible warranty claims, a low-quality image accompanies the manufacturers' products.

2. LITERATURE REVIEW

Most previous studies of such phenomena propose analytical models for the vibroacoustic behavior of the entire mechanical system (gears, transmission chain). In [1], Singh et al. retain a Lumped Model, non-linear, and find analytical solutions, derived piecewise, section after section, from a linear analysis. In this particular case, the stiffness is described with functions which have non-continuous derivatives.

In [2], the authors improved the latter model by the introduction of friction. Moreover the authors derive analytical solutions based on the Harmonic Balance Method. Many investigations have been performed to define contact characteristics of simple or multi-mesh gear trains, taking into account friction phenomena and the influence of backlash.

The first experiments focused on the detection and the analysis of non-linear phenomena [3]. The instantaneous characteristics in the signals can be obtained from the ridges and skeletons of the Wavelet Transform [4]. Such non-linear systems can also be described with a Volterra Functional Series, which generalizes the Superposition Principle and allows impulse Responses and Transfer Functions of various orders to be obtained [5].

Other detection methods are based on the speed variations [6]; in this paper, the authors show that a low-cost conventional tachometer is sufficient for measuring the induced speed variations due to backlash. They can also be predicted via simulation. For example, Tjahjowidodo et al. [4], uses a detailed multi-body simulation to develop and test the effectiveness of the proposed detection approach. The idle gear noise is chaotic [7].

The chaotic behavior gets stronger with increasing backlash, see [8]. In [9], Tjahjowidodo et al., quantify the chaotic responses and correlate them to the parameters of the non-linear system, in particular the magnitude of the backlash.

Al shyyabetal.

[11] And Ajmietal. [10] Proposed models to introduce non-linearity in the contact elasticity. They also take into account the structural elasticity of gears. Ajmietal. [10] Considers a continuous non-linear model concentrated on contact lines in gears with a finite element global description.

3. MANUFACTURING OF HUB IDLE GEAR

3.1) Turning

Turning is a type of machining where the work piece rotates while a cutting tool, usually a non-rotary tool bit, moves more or less linearly to describe a helical tool path. Turning can be done manually, on a traditional type of lathe, which frequently necessitates constant operator supervision, or on an automated lathe, which necessitates none. Computer numerical control, or CNC, is the current most used method of automation.

3.2) Milling

By moving a cutter into a work piece, milling is the method of machining that uses rotating cutters to remove material [1]. This can be accomplished by adjusting cutter head speed, pressure, and direction [2] on one or more axes.[3] Small individual pieces to massive, heavy-duty gang milling processes are all included in the broad category of milling activities. One of the most popular methods for producing custom parts with exact tolerances is this one.

3.3) Grinding

The grinding machine consists of a bed with a fixture to guide and hold the workpiece, and a power-driven grinding wheel spinning at the required speed. The speed is determined by the wheel’s diameter and manufacturer’s rating. The grinding head can travel across a fixed work piece, or the work piece can be moved while the grind head stays in a fixed position. Fine control of the grinding head or table position is possible using a vernier calibrated hand wheel, or using the features of numerical controls.

3.4) Marking

The process of utilising lasers to carve an object is known as laser engraving. Contrarily, laser marking is a broader group of techniques that can include charring, foaming, melting, ablation, and other processes in addition to changing the colour of an object owing to chemical or molecular changes.[1] The method has an advantage over other engraving or marking technologies since it doesn't require the use of inks or tool bits with worn-out bit heads that come into contact with the engraving surface.

For specially created "laserable" materials and some paints, the effects of laser marking have been more noticeable. These include new metal alloys and polymers that are sensitive to lasers. [2

Fig -1: Turning

Fig -2: Milling

Fig -3: CNC grinding machine

4.) RESULTS AND DISCUSSSIONS

$$f(x_1, x_2, x_3, x_4, x_5) = x_1x_2x_3 + \frac{x_1}{x_2x_3} + \frac{3x_2}{x_1x_2}$$

$$\text{Posynomial} = x_1x_2x_3 + x_1{x_2}^{-1}{x_3}^{-1} + 3x_2{x_1}^{-1}{x_2}^{-1}$$

$$U_j = C_j{x_1}^{a_{1j}}, {x_2}^{a_{2j}}, {x_3}^{a_{3j}} \dots \dots \dots \dots . {x_n}^{a_{nj}}$$

$$f(x) = U_1 + U_2 + U_3 + U_4 + U_5 \dots \dots \dots U_N$$

$$f(x) = \sum_{j=1}^{N} C_j \prod_{i=1}^{n} {x_i}^{a_{ij}}$$

$$x_i \geq 0$$

$$C_j > 0$$

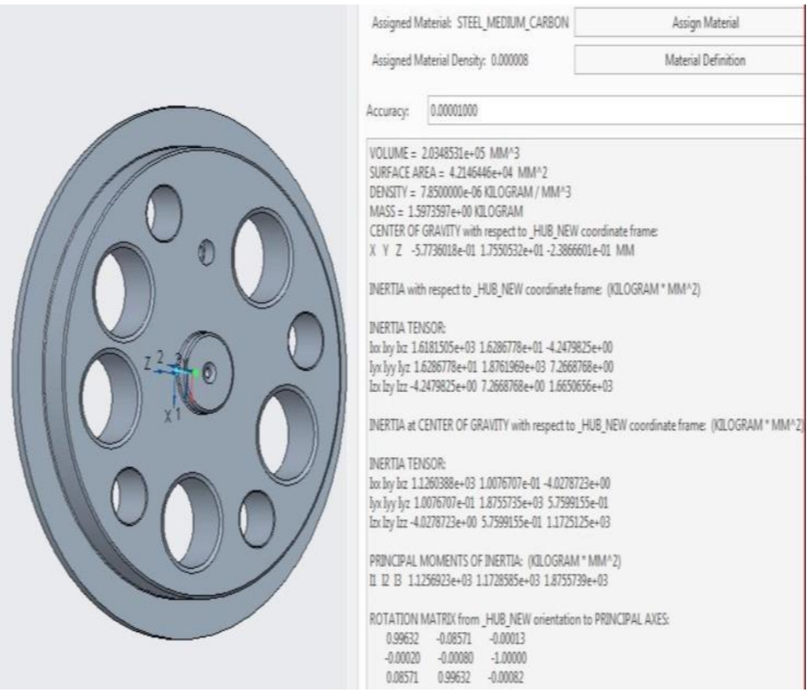
$$a_{ij} \text{ is real}$$

The earlier design of the Hub Idle Gear is shown in the is CAD model and includes all design specifications. Here it can be clearly seen that the old design contains a six through hole at various locations along the area of the component. In this design the wall thickness was found to be 10 mm.

It is necessary to calculate all such important responses like outer diameter, cross hole, depth and total length because they all represent competing requirements in the design process. The key element in formulating an optimization problem is the selection of the independent design variables that are necessary to characterize the design of the system. Normally, it is good to choose those variables that have a significant impact on the objective function. As listed above, typical constraints here include limits on bending strength, surface durability, scoring, weight, size, contact ratio, interference and width-to-diameter ratio. One of the design capabilities developed as part of this study is for hub idle gear.

Sl no.	Critical Parameter	Range	
		Minimum in mm	**Maximum in mm**
1.	Big outer diameter	89.975	89.958
2.	Small outer diameter	15.9942.	15.983
3.	Cross hole	11.4	11.8
4.	Depth	28.1	28.2
5.	Total Length	37.8	38.2

Table -1: Critical Parameters involved in the optimization



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Assigned Material:  STEEL_MEDIUM_CARBON
Assigned Material Density:  0.000008
Accuracy:   0.00001000

VOLUME =  2.0348531e+05  MM^3
SURFACE AREA =  4.2146446e+04  MM^2
DENSITY =  7.8500000e-06 KILOGRAM / MM^3
MASS = 1.5973597e+00 KILOGRAM
CENTER OF GRAVITY with respect to _HUB_NEW coordinate frame:
X  Y  Z   -5.7736018e-01  1.7550532e+01 -2.3866601e-01  MM

INERTIA with respect to _HUB_NEW coordinate frame:  (KILOGRAM * MM^2)

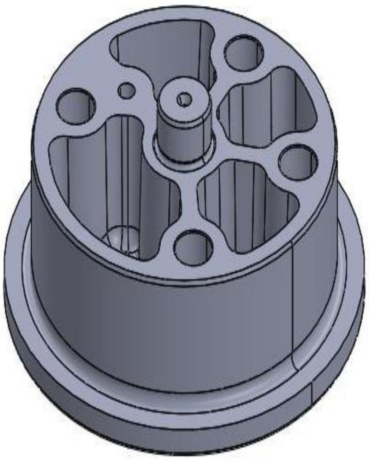
INERTIA TENSOR:
Ixx Ixy Ixz 1.6181505e+03 1.6286778e+01 -4.2479825e+00
Iyx Iyy Iyz 1.6286778e+01 1.8761969e+03 7.2668768e+00
Izx Izy Izz -4.2479825e+00 7.2668768e+00 1.6650656e+03

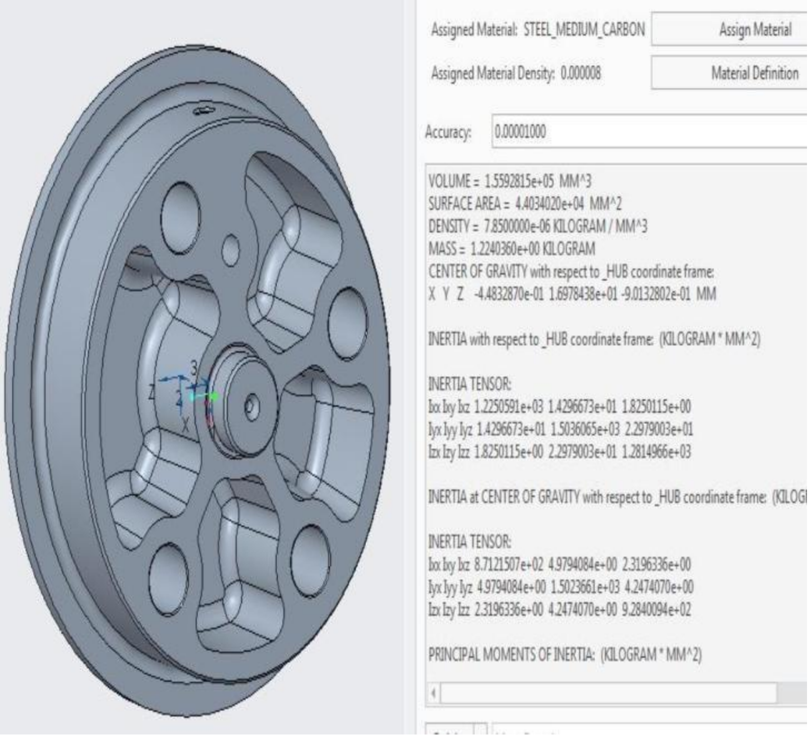
INERTIA at CENTER OF GRAVITY with respect to _HUB_NEW coordinate frame:  (KILOGRAM * MM^2)

INERTIA TENSOR:
Ixx Ixy Ixz 1.1260388e+03 1.0076707e-01 -4.0278723e+00
Iyx Iyy Iyz 1.0076707e-01 1.8755735e+03 5.7599155e-01
Izx Izy Izz -4.0278723e+00 5.7599155e-01 1.1725125e+03

PRINCIPAL MOMENTS OF INERTIA:  (KILOGRAM * MM^2)
I1  I2  I3  1.1256923e+03 1.1728585e+03 1.8755739e+03

ROTATION MATRIX from _HUB_NEW orientation to PRINCIPAL AXES:
    0.99632     -0.08571     -0.00013
   -0.00020     -0.00080     -1.00000
    0.08571      0.99632     -0.00082
```





```
Assigned Material:  STEEL_MEDIUM_CARBON
Assigned Material Density:  0.000008
Accuracy:   0.00001000

VOLUME =  1.5592815e+05  MM^3
SURFACE AREA =  4.4034020e+04  MM^2
DENSITY =  7.8500000e-06 KILOGRAM / MM^3
MASS =  1.2240360e+00 KILOGRAM
CENTER OF GRAVITY with respect to _HUB coordinate frame:
X  Y  Z   -4.4832870e-01  1.6978438e+01 -9.0132802e-01  MM

INERTIA with respect to _HUB coordinate frame:  (KILOGRAM * MM^2)

INERTIA TENSOR:
Ixx Ixy Ixz  1.2250591e+03  1.4296673e+01  1.8250115e+00
Iyx Iyy Iyz  1.4296673e+01  1.5036065e+03  2.2979003e+01
Izx Izy Izz  1.8250115e+00  2.2979003e+01  1.2814966e+03

INERTIA at CENTER OF GRAVITY with respect to _HUB coordinate frame:  (KILOG

INERTIA TENSOR:
Ixx Ixy Ixz  8.7121507e+02  4.9794084e+00  2.3196336e+00
Iyx Iyy Iyz  4.9794084e+00  1.5023661e+03  4.2474070e+00
Izx Izy Izz  2.3196336e+00  4.2474070e+00  9.2840094e+02

PRINCIPAL MOMENTS OF INERTIA:  (KILOGRAM * MM^2)
```

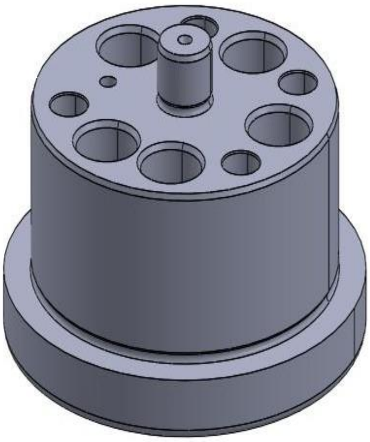


Figure -5: a) CAD Model of the old design Hub Idle Gear
b) CAD Model of the old design Hub Idle Gear

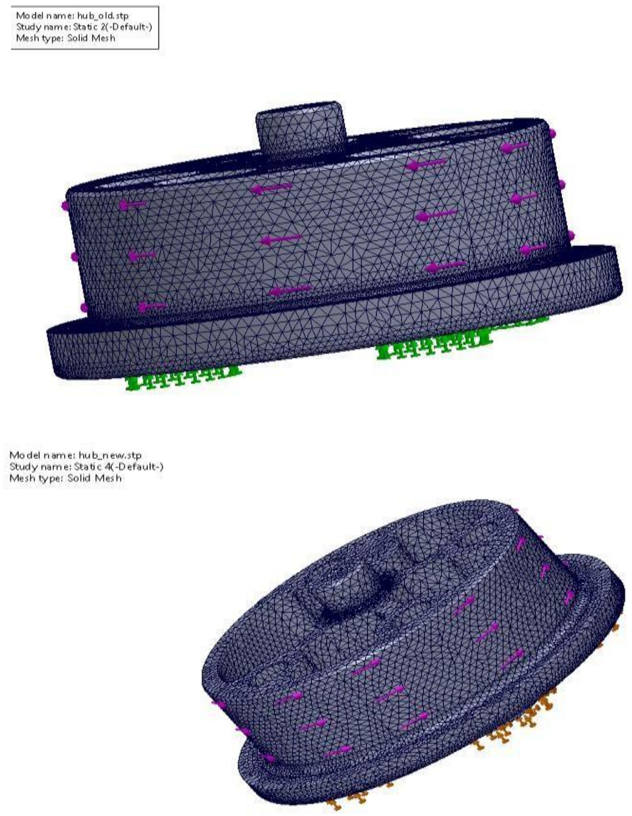
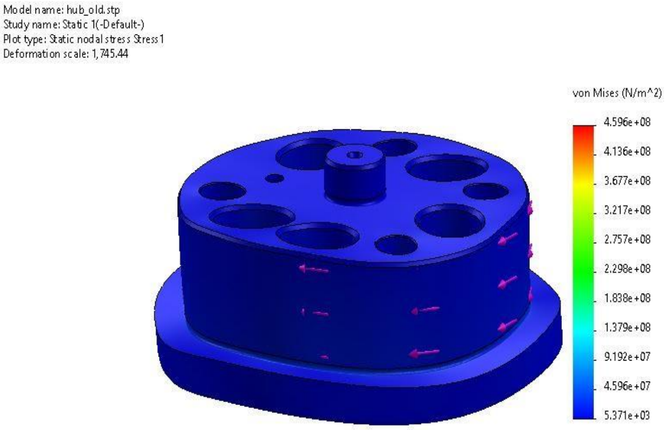


Figure -6: a) Applied Boundary Condition and Torque on old design Hub Idle Gear b) Applied Boundary condition and Torque on old design Hub Idle Gear



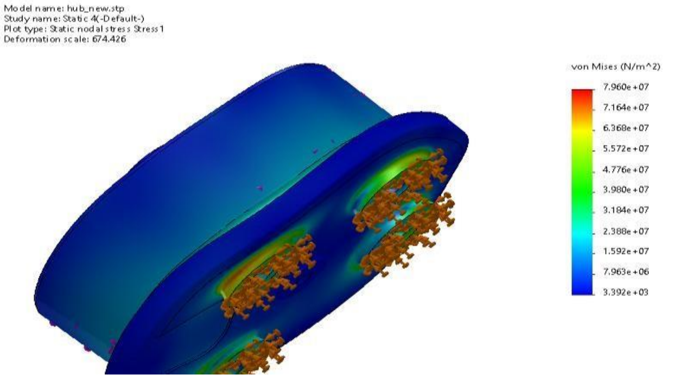


Figure -7: Contour plot showing the von Misses stress of old design Hub Idle Gear &Contour plot showing the von Misses stress of new design Hub Idle Gear

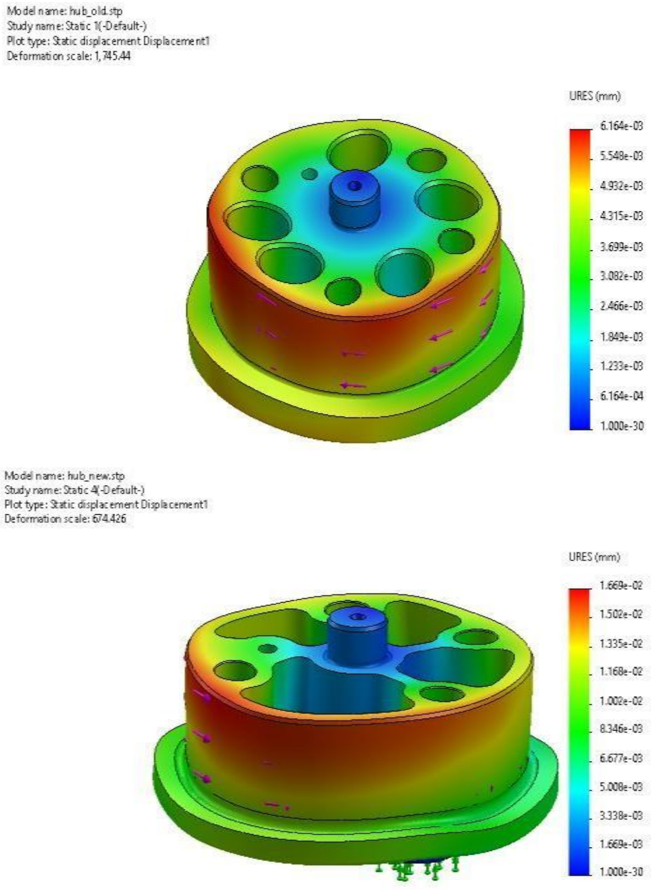


Figure -8: Contour plot showing the displacement of old design Hub Idle Gear & Contour plot showing the displacement of old design Hub Idle Gear

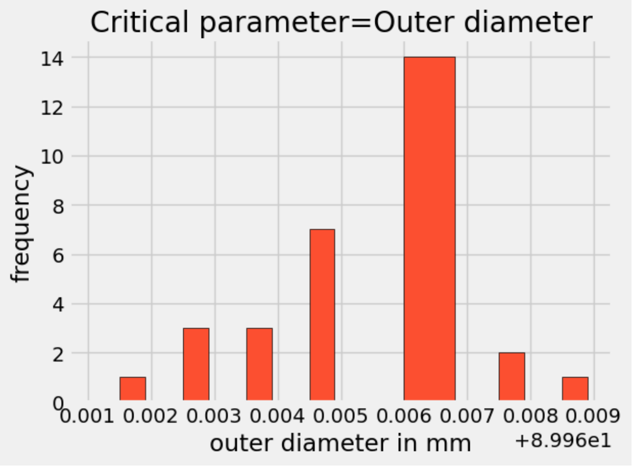


Figure-9: The histogram of the outer diameter vs frequency

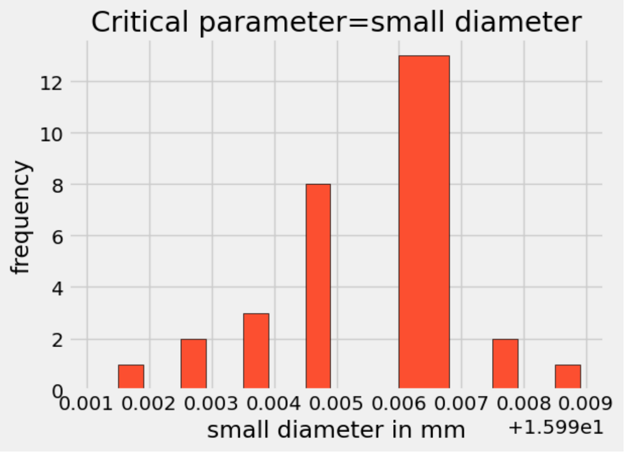


Figure -10: The histogram of the small diameter vs frequency

5.) CONCLUSIONS

The design optimization of hub idler gear the part which is used in specialized Volvo buses & trucks IC engines was carried out. It consists of old design which had circular cut-outs at specified locations. The design considerations like intermediate wall thickness 2.5 mm, big outer diameter 89.965mm, Small outer diameter 15.989 mm, cross hole 11.6mm, depth 28.15mm & total length 38mm were chosen. By incorporating these constraints, the part design was build which had flower design cut-outs.The CAD model of both old & new design of hub idler gear drafted using computer software as per the requirements. The parts were meshed using solid mesh the elements used were the combination of linear & parabolic tetrahedron further finite element analysis was carried out.

The boundary conditions were to fix the holes at the bottom surface of the parts all DOFs. The torque 4.9 Nm was applied on the circumference in clockwise direction.

The results showed that the von mises stress of the new part was found to be 0.079 GN/m^2 which is 8.76% of reduced stress compared to old part design. The results showed that the displacement of the new part was found to be 0.01669mm which is 14% reduced displacement compared to old part design. The results showed that the strain of the new part was found to be 9.213X10^{-04} which is 4% reducedstrain values compared to old part design.

These above comparisons of values indicate that the new part design of hub idler gear can potentially be the strong replacement for the old design.

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