Fatigue Behaviour Of Gear Wheels With Different Loading Conditions

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Abstract- *Gears are used in automobiles, marine vessels, industrial equipment, etc. to transmit power and motion between the shafts by successively engaging teeth. Generally, the gear failure is caused by either due to the excessive bending stresses or contact stresses generated during the power transmission. Helical gears, in which teeth are cut at a certain angle (helix angle), are preferred at high speeds due to the smooth operation and reduced noise during the power transmission. Gears transmit motion, without a connector or intermediate link, by direct contact. The tangential contact is made between the surfaces of mating gears, which have either rolling/sliding motion along the point of contact. When two bodies, having curved surfaces, are pressed together, the tangential contact changes the contact area resulting in the development of three-dimensional stresses. The contact stresses develop when each meshing body has a double radius of curvature, i.e. when the radius in a perpendicular plane is different from the radius in the plane of rolling.*

In this work we have studied the fatigue behaviour of gear wheels under different loading conditions with and without crack, loading conditions are mainly deferred by the location of application of load i.e., top edge, teeth face lower edge, side edge, top corner, also two materials structural steel and aluminium are considered.

I. INTRODUCTION

A gear is a rotating machine part having cut teeth or, in the case of a cogwheel, inserted teeth (called cogs), which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source. Gears almost always produce a change in torque, creating a mechanical advantage, through their gear ratio, and thus may be considered a simple machine. The teeth on the two meshing gears all have the same shape. Two or more meshing gears, working in a sequence, are called a gear train or a transmission. A gear can mesh with a linear toothed part, called a rack, producing translation instead of rotation.

The gears in a transmission are analogous to the wheels in a crossed, belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage.

When two gears mesh, if one gear is bigger than the other, a mechanical advantage is produced, with the rotational speeds, and the torques, of the two gears differing in proportion to their diameters.

In transmissions with multiple gear ratios—such as bicycles, motorcycles, and cars—the term "gear" as in "first gear" refers to a gear ratio rather than an actual physical gear. The term describes similar devices, even when the gear ratio is continuous rather than discrete, or when the device does not contain gears, as in a continuously variable transmission.

II. LITERATURE SURVEY

The first concept to understand before embarking on this tutorial is the definition of the term fatigue within the confines of this guide. Very often the terms Fatigue, Fracture, and Durability are used interchangeably. Each does, however, convey a specific meaning.

Although many definitions can be applied to the word, for this manual, fatigue is failure under a repeated or otherwise varying load that never reaches a level sufficient to cause failure in a single application.

It can also be thought of as the initiation and growth of a crack, or growth from a pre-existing defect, until it reaches a critical size, such as separation into two or more parts.

Fatigue analysis itself usually refers to one of two methodologies: either the Stress-Life (S-N) or S-N method, commonly referred to as Total Life since it makes no distinction between initiating or growing a crack, or the Local Strain or Strain-Life (e-N) method, commonly referred to as the Crack Initiation method which concerns itself only with the initiation of a crack.

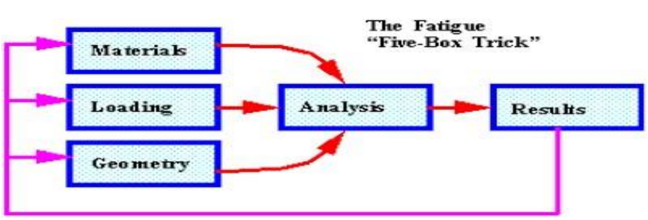
Fracture specifically concerns itself with the growth or propagation of a crack once it has initiated. MSC Nastran fatigue analysis concerns itself only with the prior two types of fatigue analysis and is not applicable for crack growth or propagation. For this capability, you are referred to MSC Nastran's cohesive zone modeling and/or virtual crack closure technique (VCCT) or MSC Fatigue, which uses a LEFM method for crack growth prediction.

Durability is then the conglomeration of all aspects that affect the life of a product and usually involves much more than just fatigue and fracture, but also loading conditions, environmental concerns, material characterizations, and testing simulations, to name a few. A true product durability program in an organization takes all of these aspects (and more) into consideration.

Note: Fatigue cracks initiate and grow as a result of cyclic plastic deformation. Without plasticity, there can be no fatigue failure. All attempts are made in this guide to explain how plasticity is taken into account when determining fatigue life from linear elastic finite element analysis.

The Fatigue Analysis "Five Box Trick"

These fatigue analysis example exercises are constructed around the concept of the fatigue "five-box trick." The illustration below depicts this well. For any life analysis whether it be fatigue or fracture there are always three inputs. The first three boxes are the inputs; box four is the analysis, and box five the results.

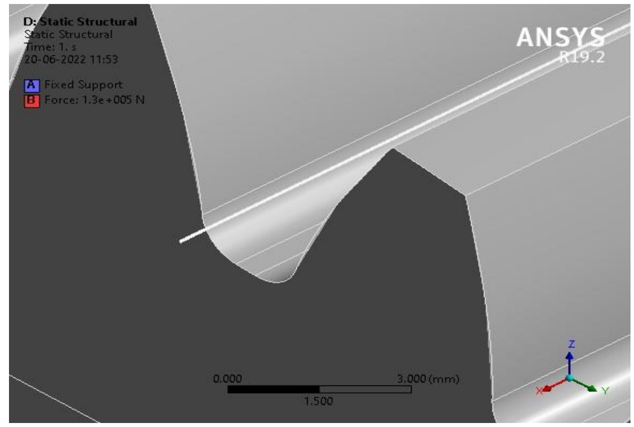


Cyclic Material Information: Materials behave differently when they are subject to cyclic as opposed to monotonic loading. Monotonic Properties are the result of material tests where the load is steadily increased until the test coupon breaks. Cyclic Properties are obtained from material tests where the loading is reversed and cycled until failure at various load levels. These parameters differ depending on the fatigue analysis type involved.

BOUNDARY CONDITIONS

Total five loading conditions are studied in this work for better understanding of the fatigue behaviour of the gear wheels.

Geometry of Crack



III. ANALYSIS RESULTS

Tabular comparison for gear made with ss material without crack

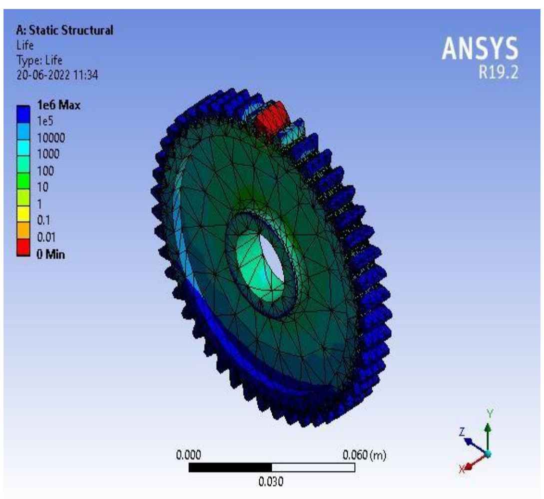
without crack	Total Deformation (mm)			Equivalent Elastic Strain (mm/mm)			Equivalent (von-Mises) Stress		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
LINE CONTACT	0	1.5544	0.32668	2.67E-07	9.65E-02	2.56E-03	0.05	19044	462.64
FACE CONTACT	0	0.9745	0.30488	3.25E-07	5.85E-02	1.96E-03	6.51E-02	11610	356.3
EDGE CONTACT	0	0.5673	0.28743	4.49E-07	5.58E-02	1.63E-03	8.99E-02	10382	295.7

without crack	Life			Damage			Safety Factor		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maxim um	Average

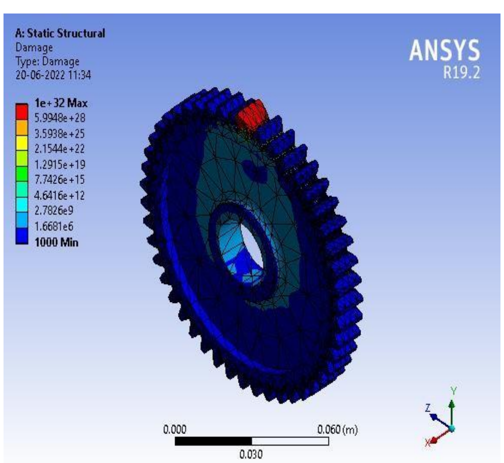
LINE CONTACT	0	1.00E+06	3.79E+05	1000	1.00E+32	1.89E+30	4.53E-03	15	1.8794
FACE CONTACT	0	1.00E+06	3.92E+05	1000	1.00E+32	1.13E+30	7.42E-03	15	1.9497
EDGE CONTACT	0	1.00E+06	4.05E+05	1000	1.00E+32	4.79E+29	8.30E-03	15	2.0272

LINE CONTACT SAFETY FACTOR

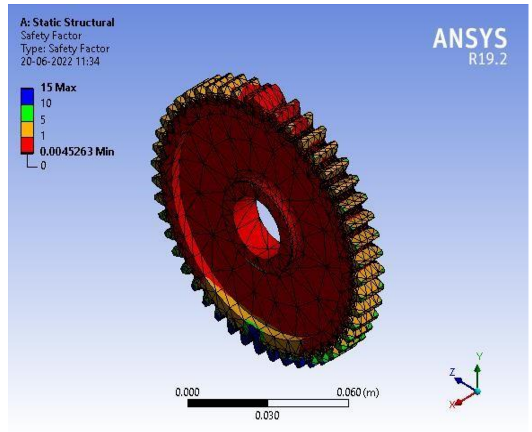
Life



Damage

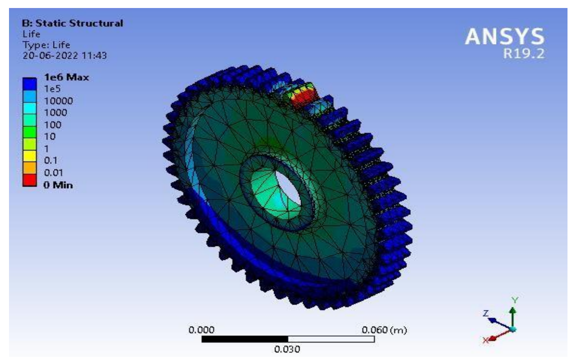


Safety Factor

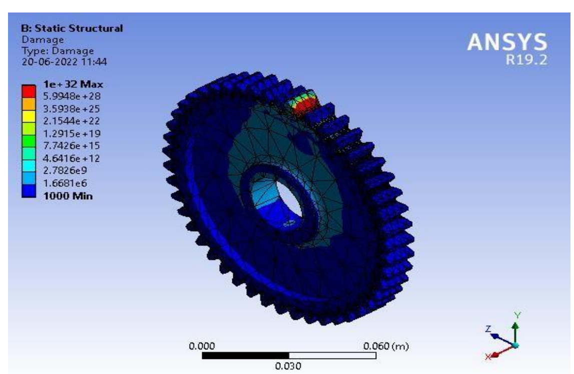


FACE CONTACT SAFETY FACTOR

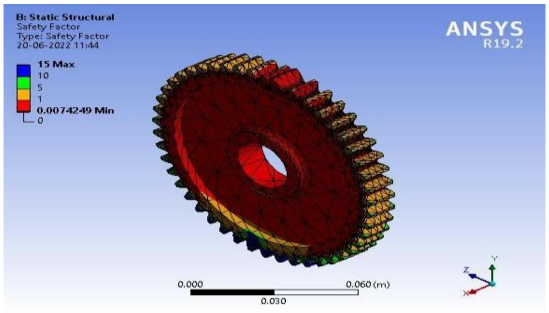
Life



Damage

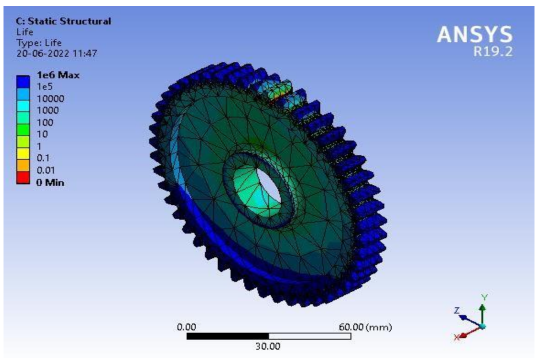


Safety Factor

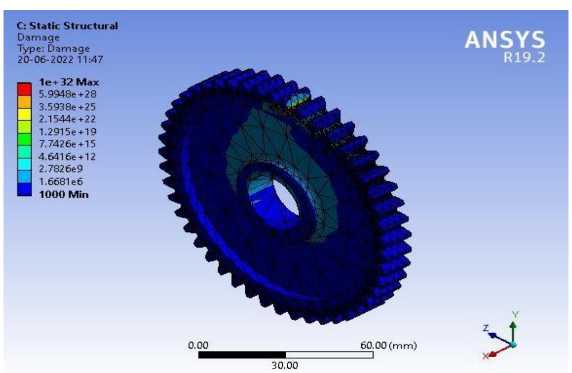


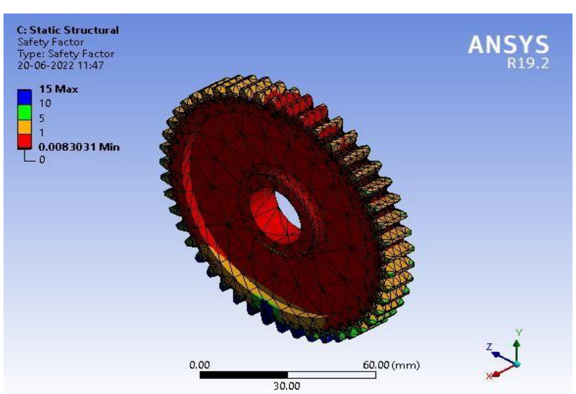
EDGE CONTACT SAFETY FACTOR

Life



Damage

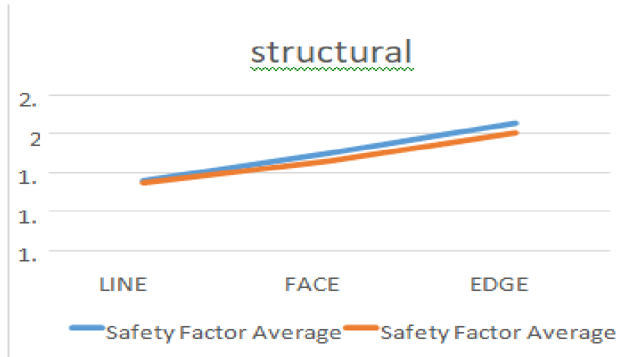


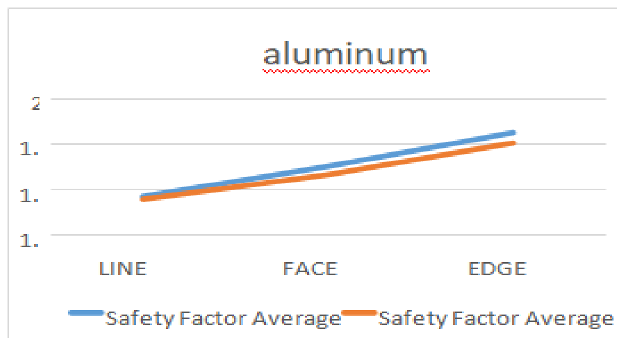


Safety Factor

IV. CONCLUSION

In this work we have studied fatigue behaviour of gear wheels under different loading conditions, and under presence of crack loading conditions are mainly deferred by the location of application of load i.e., top edge, teeth face lower edge, also two materials structural steel and aluminium are considered. The observations made during the study are discussed below.





- The above graphs show the safety factor in structural steel and aluminum gear wheels for different loading conditions and presence of crack
- Maximum fatigue life of structural steel gear is 1e6 and aluminum alloy is 1e8 in all cases but here the game changer is minimum life, in some case minimum life became zero.
- Based on the results proper meshing of gears is important to avoid failure and increase life.
- Presence of crack shows similar results in all loading conditions irrespective of crack location
- Tough aluminum alloy has high fatigue life it can with stand only in fewer loading conditions, here the gears should mesh properly.

V. FUTURE SCOPE

In this thesis only general structural steel is studied due to availability of stress life data and S-N curve, it is suggested to continue this work with all the materials that are used in gear manufactured. Also, experimental work with theoretical validation is highly recommended.

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