Abstract - Gear drives are critical components in mechanical power transmission system that has fascinated the attention for intensive explore of researcher and engineers. They are advantage over belt, rope and chain drives. Gears are most commonly used for power transmission in all the modern devices. They have been used extensively in the high-speed marine engines. Gear design has evolved to a high degree of perfection, the constant pressure to build less expensive, quieter running, lighter weight, reliable, less cost and more powerful machinery has lead to steady change in gear design. Today, the most significant new gear developments are in the area of materials. The objective of the present work is to focus on investigating the effects of face width, gear ratio, normal module, speed and helix angle on compressive stress of steel alloy(40 Ni2 Cr1 Mo28) helical gear for marine applications.

Index Terms— Buckingham equation, Compressive stress, Design optimization, Dynamic tooth load, Helical gear design, Lewis equation.

I. INTRODUCTION

Gears are a means of changing the rate of rotation of a machinery shaft. Today, the most significant new gear [1] developments are in the area of materials. Modern metallurgy has greatly increased the useful life of industrial and automotive gearing to new levels of accuracy, reliability and quiet operation. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of gear technology. In the present era of sophisticated technology[2] gear design has evolved to a high degree of perfection. The design and manufacture of precision cut gears, made from materials of high strength, have made it possible to produce gears which are capable of transmitting extremely large loads at extremely high circumferential speeds [6] with very little noise, vibration and other undesirable aspects of gear drives. Helical gears are the modified form of spur gears, in which all the teeth are cut at a constant angle, known as helix angle, to the axis of the gear, whereas in spur gear, teeth are cut parallel to the axis. The following are the requirements that must be met in the design of gear drive, the gear teeth should have sufficient strength, so that they will not fail under static and dynamic loading during normal running conditions. The gear teeth should have clear characteristics so that their life is satisfactory, the use of space and material should be economical. The alignment of the gears and deflections of the shafts must be considered, because they affect the Performance of the gears. The lubrications of the gears must be satisfactory.

Marine engines are among heavy-duty machineries, which need to be taken care of in the best way during prototype development stages. These engines are operated at very high speeds [3] which induce large stresses and deflections in the gears as well as in other rotating components. For the safe functioning of the engine, these stresses and deflections have to be minimized. In this study parametric approach analysis on a high speed helical gear used in marine engines using steel alloy material is undertaken. The results obtained in theoretical and a conclusion has been and manufacture of precision cut gears, made from materials of high strength, have made it possible to
are relatively complex and there is a number of design parameters involved in gear design. The design of gears requires an iterative approach [5] to optimize design parameters [6] which govern both the kinematics as well as the strength performance. Due to the complex combination of these parameters, conventional design office practice tends to become complicated and time consuming. It involves selection of appropriate information from a large amount of standard data [11] available in engineering catalogues [7] and design handbooks [8],[9]. Current popular standards are ISO and AGMA. These standards vary in selected approaches as well as models and methods resulting in different design solutions [10] obtained for the same gear under the same set of working conditions. While the knowledge in gearing design [11] is vast, there is still an acute paucity of research on comparative analysis between various standards and engineering practices. Considering their reliability and efficiency as some of the most important factors, problems of distributions of loads and stresses in the whole gear transmission [12],[13], particularly in teeth of mating gears, need to be thoroughly analyzed.

**Nomenclature**

\[ \sigma_c = \text{compressive stress in Kgf/cm}^2 \]
\[ \sigma_b = \text{bending stress Kgf/cm}^2 \]
\[ \sigma_{b0} = \text{design Bending stress in Kgf/cm}^2 \]
\[ E = \text{young's modulus in Kgf/cm}^2 \]
\[ [Mt] = \text{design torque in Kg-cm} \]
\[ \beta = \text{helix angle in degrees} \]
\[ F_d = \text{dynamic tooth load of the gear Kgf} \]
\[ F_D = \text{design tooth load kgf} \]
\[ m_n = \text{normal Module mm} \]
\[ Y_v = \text{lewis Form factor} \]
\[ b = \text{face width in mm} \]
\[ N = \text{speed in rpm} \]
\[ i = \text{gear ratio} \]

**II. DESIGN METHODOLOGY**

The helical gear is design based on AGMA Procedure: According to Lewis equation for beam strength of helical gear tooth.

\[ F_b = \left[ \sigma_c \right] \cdot b \cdot m_n \cdot Y_v \]

Number of teeth \( Z_v = \left( \frac{Z}{\cos^3 \beta} \right) \)

Design tooth load by

\[ F_{Dv} = F_t \cdot K_v \cdot C_v = \left( F_t \cdot K_v \cdot C_v / v \right) \]

The dynamic load by Buckingham equation

\[ F_d = F_t + \frac{21v(Cb \cos^2 \beta + F_t) \cos \beta}{21v + \sqrt{C_b \cos^2 \beta + F_t}} \]

The wear tooth load is given by the expression

\[ F_w = \frac{d_1 \cdot b \cdot Q \cdot K_w}{\cos^2 \beta} \]

The flow chart is showing the process of helical gear design:
III. RESULTS AND DISCUSSIONS

To arrive at optimum values of compressive stress to get low cost manufacturing for Steel alloy (40 Ni2 Cr1 Mo28) gear have been carried out.

3.1 The effect of helix angle, module, gear ratio, face width on compressive stress for steel alloy:

The variation of compressive stress for different input variables are shown in figs. 1(a) – (d). The speed is kept constant. The fig 1(a) shows the graphical relation between compressive stress and gear ratio. The helix angle, face width, and module are kept constant. When gear ratio is increased from 4 to 8, the corresponding Compressive stress decreased from 6860kgf/cm² to 6508kgf/cm². The fig 1(b) shows the relationship between compressive stress and face width. The Helix angles, gear ratio, module are kept constant. When face width is increased from 41 to 49, the corresponding compressive stress decreased linearly from 6860kgf/cm² to 6275kgf/cm². The fig 1(c) shows relationship between compressive stress and helix angle. The face width, gear ratio, corresponding to maximum value obtained earlier and module except are kept constant. When helix angle is increased from 15° to 35°, the corresponding Compressive stress decreased from 6860kgf/cm² to 5819kgf/cm². The fig 1(d) shows the relationship between compressive stress and module. The values of face width, gear ratio, and helix angle for maximum compressive stress are kept constant. When module is increased from 16mm to 24mm, the corresponding Compressive stress decreased from 6060kgf/cm² to 4575kgf/cm². Thus the maximum compressive stress 6860 kgf/cm² is obtained for input parameters viz. gear ratio(i) =4, face width (b) = 41, helix angle (β) = 150, and Module (Mn) =16.

3.2 Optimum parameters for maximum compressive stress:

The effect of gear ratio, face width, helix angle, and module for optimum compressive stress is carried out. The helix angle, face width, speed and module are kept constant, and when the gear ratio is increased, the corresponding compressive stress decreases. The gear ratio 4, corresponding to maximum compressive stress is taken as constant. Keeping the helix angle, gear ratio, speed, module except face width is kept constant and for variation of face width, the compressive stress decreased linearly. In the next step the face width 41cm, corresponding to maximum compressive stress, the gear ratio, speed and module are kept constant and helix angle is increased, the corresponding compressive stress decreased. The helix angle 15°, corresponding to maximum compressive stress is taken for further optimization. The face width, gear ratio, speed and helix angle are kept constant and module is varied, the corresponding compressive stress is decreases. The module 16mm, corresponding to maximum compressive stress is taken as constant.
IV. CONCLUSIONS

The study helps to focus the effect of compressive stress on the optimum design of helical gears for high speed applications. The analysis yielded compressive stress of 6860 kgf/cm² is obtained for input parameters viz. gear ratio (i) = 4, face width (b) = 41, helix angle (β) = 15°, and Module (Mn) = 16. The helical gear parameters that constitute the design are found to be safe from strength and rigidity point of view. Hence Steel alloy material (40 Ni2 Cr1 Mo28) is best suited for high speed marine applications.

V. REFERENCES