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Comparative Study of Polymer with Existing Metallic Material of Spur Gear for Sugarcane Juice Machine

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Abstract: ***This paper describes design and analysis of Spur gear. In this given work, the metallic spur gear used for sugarcane juice machine is substituted by polymer gear. The main aim to use a polymer gear is the reduction of weight and noise. For the study, polycarbonate spur gear is considered to check the satisfactory condition with existing cast iron spur gear. The static and dynamic analysis is achieved through FEA to check that recommended polymer gear is suitable for this particular application.***
Keywords: Cast iron spur gear, Polycarbonate spur gear, Static analysis, Dynamic analysis, FEA.

I. INTRODUCTION

Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. So it is important to select the material and the perfect model size according to the application. The properties of a gear depend upon the material used for the manufacturing of gear. The gears may be manufactured from metal or non-metal like polymers. Several polymers are used for gear manufacturing like acetal, PEEK, polycarbonate, nylon etc. These polymers are especially used for weight and noise reduction, they have corrosion resistance, self-lubricated and can resist towards moisture. Complex shapes can be achieved precisely from the plastic material. Plastic gears are the huge development in the mechanical industry because it gives a large benefits of weight reduction and abrasion resistance

II. PROBLEM SPECIFICATION

From the literature study we have found that polymer materials in many applications have advantage in terms of different properties (noise, weight, stress) to replace the existing metallic gear. So for our study, we have selected the polymers Polycarbonate, which have good tensile strength and low density in comparison to metallic gear (i.e. used in sugar cane machine) and did a comparative study under the criteria of bending stress analysis for static and dynamic loading. The modelling of spur gear is done in Solid works and the analysis is carried out by FEA. On the basis of these analysis, it is decided that the recommended polycarbonate gear is suitable for this application.

III. THEORETICAL ANALYSIS

A. Geometric details of spur gear:

1) Module (m) = 10 mm
2) Addendum = 1 module
3) Dedendum = 1.157*module
4) Pressure angle (α) = 20 degrees
5) Tooth thickness(t) =1.571 * module
6) Whole depth = 2.25 * module
7) Face width(b) = 5.4 * module
8) Fillet radius = 3.9 * module
9) No of teeth(z) =18

B. Material Properties

TABLE I

Material properties	Cast iron	Polycarbonate
Density (Kg/mm^3)	7.2e-6	1.1e-6
Poisson's ratio	0.25	0.38
Friction coefficient	1.1	0.31
Tensile strength (mpa)	320-350	55-70
Young's modulus (N/mm^2)	1.65e5	2.75e5
Compressive strength (mpa)	400	70

C. Specifications of Sugarcane Juice Machine Motor

Required power(P)= 1.5 KW
Speed(N)= 1400 rpm
Power (P) = 2*π*N*T / 60
1500 = (2*π*1400*T) / 60
Torque (T) = (1500*60)/ (2*π*1400)
T= 10.2313 N-m
T= 102313 N-mm
T= F * (d/2)
F= T/ (d/2)
F= 10231/90
F= 113.677 N
Where F is the Tangential load
Using Lewis equation Tangential load F = σb*y*Pc*b
113.677= σb*0.1034*(π*10)*54
σb = 113.677 / (0.1034*(π*10)*54
σb = 0.648 N/mm2
where σb is the allowable stress for desired spur gear.
Allowable stress for Polycarbonate:
Polycarbonate= ultimate tensile strength/3 = 62/3 = 20.67 N/mm^2 > 0.648 N/mm^2
Allowable stress for cast iron:
Cast iron= ultimate tensile strength/3= 320/3= 106.67 N/mm^2 > 0.648 N/mm^2
Design satisfactory condition = Allowable stress of material used > Allowable stress of desired spur gear
So, the design of spur gear for both material cast iron and polycarbonate is safe.

IV. FEA ANALYSIS OF SPUR GEAR

The model of desired spur gear is modelled in solid works. The static and dynamic analysis of spur gear is carried out by solid works.

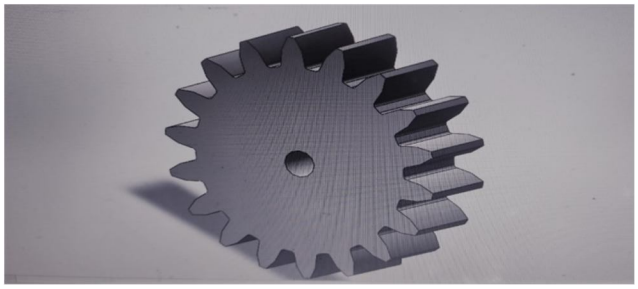

Fig. 1 Model of spur gear

A. Static analysis of cast iron

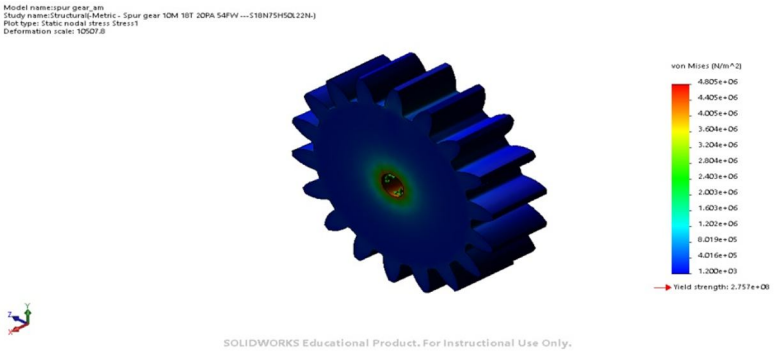

Fig. 2 structural analysis of cast iron spur gear

B. Static analysis of Polycarbonate

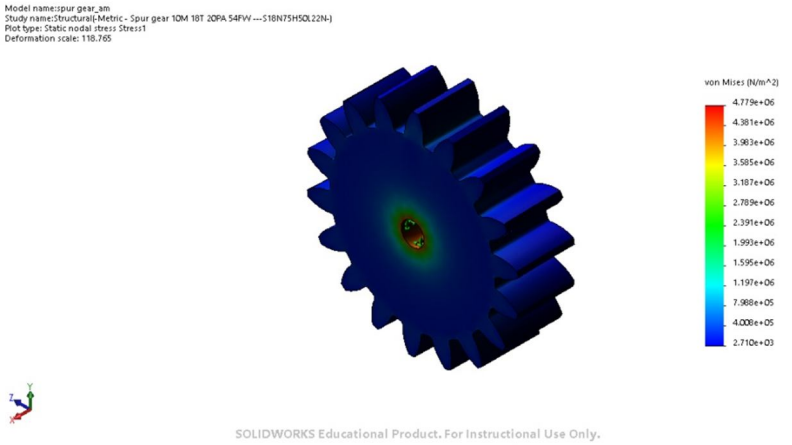

Fig. 3 Structural analysis of polycarbonate spur gear

Table II

Material	Von-mises stress (N/m^2)	Displacement (mm)	Strain
Cast iron	4.805e+6	1.923e-3	1.704e-5
Polycarbonate	4.779e+6	1.702e-1	1.508e-3

V. DYNAMIC ANALYSIS

Dynamic load is defined as the load which varies in magnitude, direction or point of application with respect to time. Dynamic load in the mechanical components causes the generation of fluctuating stresses. In case of spur gear the load acting on gear tooth is constant in magnitude as well as in direction but varies in point of application of load. Thus, spur gear are the important power transmitting elements in mechanical system and hence sudden failure of gear tooth may lead to danger. Therefore, it is necessary to perform the dynamic analysis of spur gear teeth are subjected to fluctuating stresses and lead to fatigue failure.

A. Dynamic Analysis of Cast Iron spur Gear

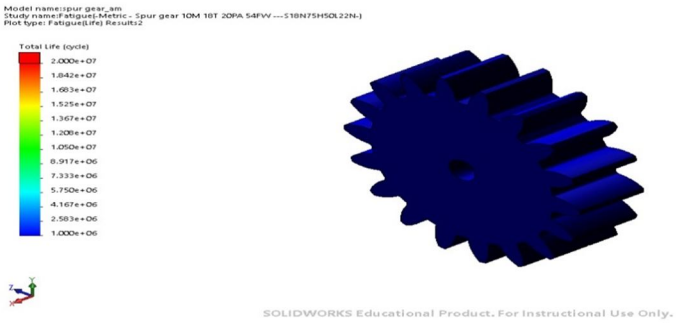

Fig. 4 Fatigue result of cast iron spur gear

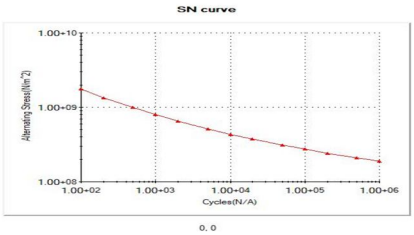

Fig.5 S-N curve of cast iron spur gear

B. Dynamic Analysis Of Polycarbonate Spur Gear

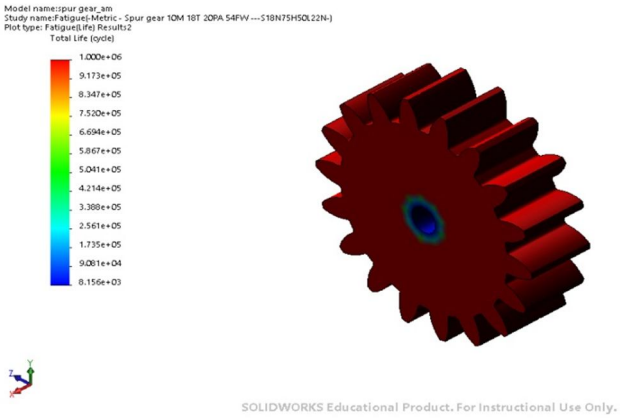

Fig.6 Fatigue result of polycarbonate spur gear

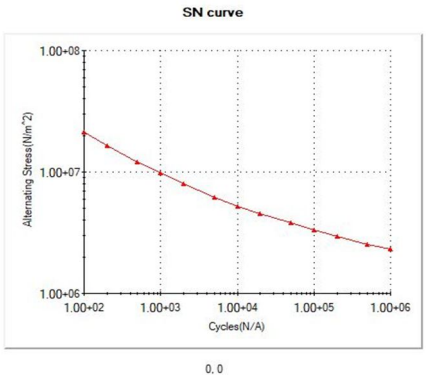

Fig.7 S-N curve of polycarbonate spur gear

Table III

Material	Life plot (min)	Life plot (max)
Cast iron	1.000e+06	1.000e+06
Polycarbonate	8.156e+03	1.000e+06

VI. RESULTS AND DISCUSSION

From the static analysis of both cast iron gear and polycarbonate gear, it is observed that the von-mises stress of polycarbonate spur gear is less than the existing material, cast iron. The minimum value of strain of polycarbonate spur gear is obtained. Through the dynamic analysis, it is observed that the min life cycle of polycarbonate spur gear is nearest to the cast iron spur gear and max life cycle for both gears are same. So, it is concluded that the existing material which is cast iron can be substituted easily by polycarbonate for the sugarcane juice machine.

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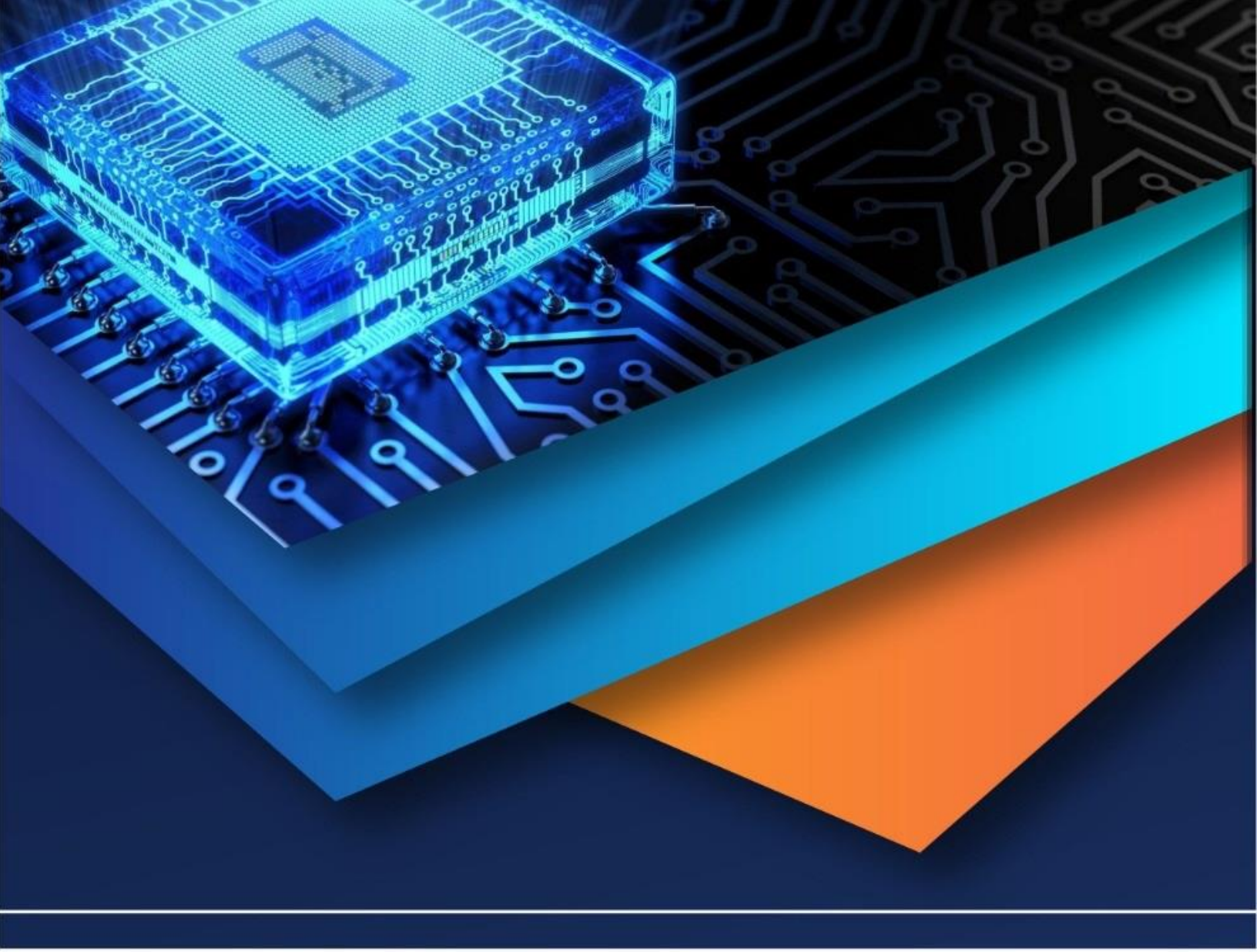

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