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Modeling and Analysis of Spur Gear for Sugarcane Juice Machine under Static Load Condition by Using FEA

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Abstract : *This paper describes design and analysis of Spur gear. In the present work, it is proposed to substitute the metallic gear of sugarcane juice machine with plastic gears to reduce the weight and noise. For the purpose of two different types of plastic materials were considered namely Nylon and Polycarbonate and their viability are checked with their counterpart metallic gear (Cast iron). Based on the static analysis, the best plastic material is recommended for the purpose. Static analysis of a 3-D model has been performed using ANSYS 10.0. Compared to Cast iron spur gears Nylon gears are suitable for the application of sugarcane juice machine application under limited load conditions.*

Keywords: *Cast iron spur gears, Static analysis, Nylon Spur gears, and Polycarbonate spur gears.*

I. Introduction

According to the position of axes of the shafts the following are the different kinds of gears.

a. Parallel

- Spur gear
- Helical gear
- Rack and pinion

b. Intersecting

- Bevel gears

c. Non – Intersecting and Non parallel

- Worm gears

The gear materials used for the manufacture of gears depend upon the strength and service conditions like wear and noise etc. The gears maybe manufactured from metallic or non – metallic materials. The cast iron is widely used for the manufacture of gears due to its good wearing properties, excellent machine ability and ease of producing complicated shapes by casting method. The non – metallic materials like wood, rawhide, compressed paper and plastics like Nylon, Acrylic and Polycarbonate etc are used for gears, especially for reducing weight and noise.

Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The plastic materials have corrosion resistance, low electrical and thermal conductivity, easily formed into complex shapes, wide choices of appearance, colors and transparencies. The introduction of plastic materials was made it possible to reduce the weight of the spur gear without any reduction on load carrying capacity and stiffness.

The Nylon materials have high strength, good mechanical and abrasion resistance property, excellent wear resistance, resistant to most chemicals and self- lubricant. Polycarbonate materials have, high impact strength, good dimension stability and heat resistance. Since, Nylon and Poly carbonate have good properties as stated above the cast iron spur gears of sugarcane juice machine are being replaced by plastic spur gears. The plastic material offer opportunities for substantial weight saving but not always are cost-effective over their cast iron counter parts.

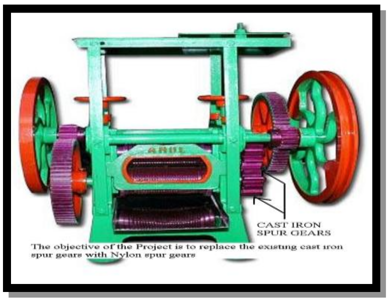


Fig. No. 1 Schematic diagram of a sugarcane juice machine.

II. Literature Review:

The review mainly focuses on replacement of Cast iron spur gears with the Nylon spur gear in the application of sugarcane juice machine.

R. Yakut, H. Düzcükoğlu*, M.T. Demirci et al

[1] In this study, load carrying capacity and occurring damages of gears which are made of PC/ABS blends were investigated. PC is hard material and ABS is soft material. The usage of materials limits these drawbacks. However PC and ABS polymers combine each other, the PC/ABS blends have suitable mechanical properties for gear applications in the industrial areas. In this study, usability of PC/ABS composite plastic materials as spur gear was investigated. PC/ABS gears were tested by applying three different loading at two different numbers of revolutions on the FZG experiment set.

J.L. Moya, A.S. Machado, J.A.Velásquez, R. oytisolo, A.E.Hernández, J.E. Fernández, and J.M. Sierra et al [2] In this study they have performed a theoretical analysis of a procedure to determine the Lewis Factor and also performed the contact analysis of spur gears to find the stress distribution between gear tooth.

Alexandre Luís Gasparin[I]; Leandro Luís Corso[I]; Eduardo Kirinus Tentardini[II]; Regina Célia Reis Nunes[III]; Maria Madalena de Camargo Forte[IV]; Ricardo Vinicius Bof de Oliveira, et al [3] The focus of this paper is to establish a characterisation method for seven polyamide (PA) grades to determine the major material to manufacture an automotive worm gear. The composite properties were measured according to the worm gear loadings: tensile strength, Young's modulus, abrasion and impact resistance. They were also correlated to the PA moisture absorption and its glass fibre (GF) reinforcement. The data from mechanical tests were applied in the finite element analysis (FEA) using the von Mises stress criterion. Before the rig tests of the PA worm gears, the injection process was evaluated, through the capillary rheometry. A higher difficulty to process PA 6/6 30% GF was found, due to its lower apparent viscosity. In the end, the influence of moisture absorption was as decisive to the gear's material selection as the GF to the pinion. Thus, the PAs with the best performance were: PA 6 with 30% GF (gear) and with PA 60% GF (pinion).

III. Specification Of The Problem

In this project work it is proposed to substitute the metallic gear of sugarcane juice machine with plastic gears to reduce the weight and noise. For the purpose of two different types of plastic materials were considered namely Nylon and Polycarbonate and their viability are checked with their counterpart metallic gear (Cast iron). Based on the static analysis, the best plastic material is recommended for the purpose**.** A virtual model of spur gear was created in Pro-E. Model is imported in ANSYS 10.0 for analysis by applying normal load conditions. After analyis a comparison is made among exisisting Cast iron spur gear. Based on the deflections and stresses from the analysis we choose the best one between the Nylon and Polycarbonate spur gears.

IV. GEARS

Gear is nothing but a toothed wheel which is useful to transmit power from one shaft to another shaft. They are suitable when two machine parts are nearer to each other. They give exact ratio of transmission of motion, slip cannot takes place between gears, they are useful for high torque transmission.

In spur gear teeth is parallel to axis of rotation. Spur gear transmit power from one shaft to another parallel shaft.

4.1 Matrials for Gears :

The gear materials used for the manufacture of gears depend upon the strength and service conditions like wear and noise etc. The gears maybe manufactured from metallic or non – metallic materials. The cast iron is widely used for the manufacture of gears due to its good wearing properties, excellent machine ability and ease of producing complicated shapes by casting method. The non – metallic materials like wood, rawhide, compressed paper and plastics like Nylon, Acrylic and Polycarbonate etc are used for gears, especially for reducing weight and noise.

4.2 Theoretical calculations of conventional Cast iron Spur gear:

In the present analysis the maximum torque, allowable stress and tangential load of the spur gear are calculated based on the desired sugarcane juice machine motor specifications and are as following below:

4.3 Specifications of sugarcane juice machine motor:

Power (P) = 1.5 kW = 1500watt
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/mm^2
Where 'σb' is the allowable stress
'y' is the Lewis form factor
'Pc' (Circular pitch) = π * module
'b' is the face width of the gear
'd' is the pitch circle diameter of the gear
The Maximum allowable stress as per the design of the desired spur gear, σb = 0.648 N/mm^2
Allowable stress of Cast iron (high grade) =
= Ultimate tensile strength / 3
= 320 / 3 = 106.67 N/mm2 > 0.648 N/mm^2
Allowable stress of Nylon =
= Ultimate tensile strength / 3
= 69/3 = 23 N/mm2 > 0.648 N/mm^2
Allowable stress of Polycarbonate =
= Ultimate tensile strength / 3
= 62/3 = 20.67 N/mm2 > 0.648 N/mm^2

SO the design is safe
(Reference 1: www.professionalplastics.com
Reference 2: p.s.g data book pageno: 25.33,
Page no 8.21)

V. Geometric details of desired spur gear:

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

5.1 Calculation of gear tooth proportions:

- Pitch circle diameter (p.c.d)= z*m
 = 18*10 = 180mm
- Base circle diameter (Db)= D Cos α
 = 180Cos20 = 169.145mm
- Out circle diameter = (Z+2)*m
 = (18+2)*10 = 200 mm
- Clearance = Circular pitch/20
 = 31.4/20 = 1.57mm
- Dedendum =
=Addendum+ clearance = 10 + 1.57
= 11.57 mm.

- Module =D/z
  =180/18 = 10mm.

- Dedendum circle diameter
  = p.c.d–2*dedendum = 80- 2*11.57
  = 156.86 mm.
- Fillet radius = circular pitch/8 = 31.4/8 = 3.9 mm
- Pich circle diameter (Pc) =
  m*z= 10 * 18 = 180mm
- Hole depth = 2.25 * m = 2.25 * 10
  = 22.5mm
- Thick ness of the tooth
  = 1.571* 10=15.71mm
- Face width (b) = Ψ*a = 0.3*180 = 54 mm

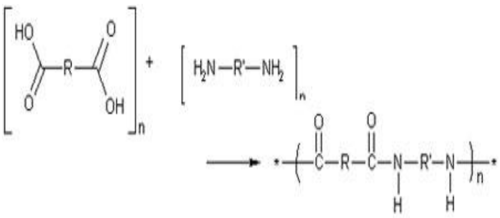
Where 'a' is the centre distance between two gears = (180+180 /2) 180 mm and assume Ψ = 0.3)
Diametral pitch = Number of teeth/ P.C.D
= 18 / 180 = 0.1 mm

VI. Specification Of Existing Cast Iron Gear:

The typical chemical composition of the cast iron material : Carbon - 2.5 to 3.7%, Silicon - 1.0 to 3.0%, Manganese - 0.5 to 1.0%, Phosphorus - 0.1 to 0.9% and Sulphur - 0.07 to 0.10%

6.1 SPECIFICATIONS OF NYLON AND POLYCARBONATE PLASTIC MATERIALS:

Chemical composition of Nylon:

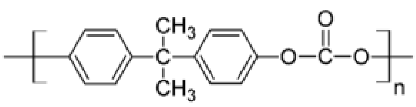


Its properties are determined by the R and R' groups in the monomers. In nylon 6. 6, R' = 6C and R = 4C alkanes, but one also has to include the two carboxyl carbons in the diacid to get the number it donates to the chain.

The majorities of nylons tends to be semi-crystalline and are generally very tough materials with good thermal and chemical resistance. The different types give a wide range of properties with specific gravity, melting point and moisture content tending to reduce as the nylon number increases. Nylons can be used in high temperature environments. Heat stabilized systems allow sustained performance at temperatures up to 185oC.

Chemical composition of Polycarbonate:

The main polycarbonate material is produced by the reaction of bisphenol A and phosgene COCl2. The overall reaction can be written as follows:



Polycarbonates received their name because they are polymers containing carbonate groups (–O–(C=O)–O–). Most polycarbonates of commercial interest are derived from rigid monomers. A balance of useful features including temperature resistance, impact resistance and optical properties position polycarbonates between commodity plastics and engineering plastics

.

Table: 1 Material properties of cast iron, Nylon and Polycarbonate:

Material Property	Cast Iron	Nylon	Polycarbonate
Young's Modulus (N/mm^2)	1.65e5	2.1e5	2.75e5
Poisson's ratio	0.25	0.39	0.38
Density (Kg/mm^3)	7.2e-6	1.13e-6	1.1e-6
Co-efficient of friction	1.1	0.15-0.25	0.31
Ultimate Tensile strength (Mpa)	320-350	55-83	55-70

VII. Finite Element Analysis Of Spur Gear :

Finite element modeling is described as the representation of the geometric model in terms of a finite number of element and nodes. It is actually a numerical method employed for the solution of structures or a complex region defining a continuum. Solutions obtained by this method are rarely exact. However, errors in the approximate solution can be minimized by increasing the number of equations till the desired accuracy obtained. This is an alternative to analytical methods that are used for getting exact solution of analysis problems. The solution of general problem by finite element method always follows an orderly step-by-step process. for analysis in ANSYS 10.0. The loading conditions are assumed to be static. The element choosen is solid Brick 8 node45.

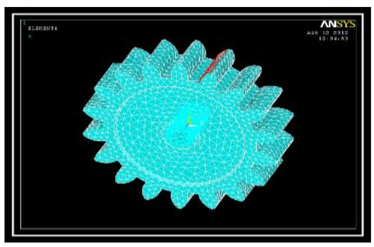


Fig1: Loads and boundary conditions of the gear

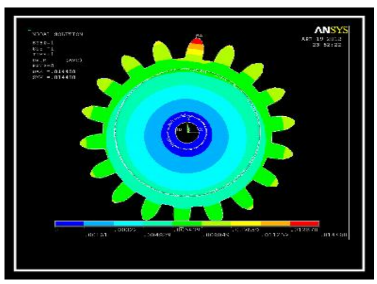


Fig 2: Displacement pattern for Cast iron gear

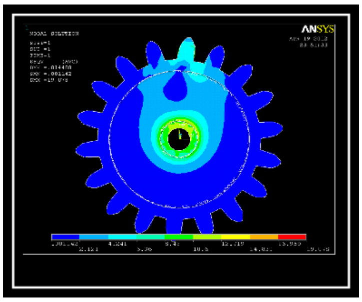


Fig 3: Stress distribution for Cast iron gear

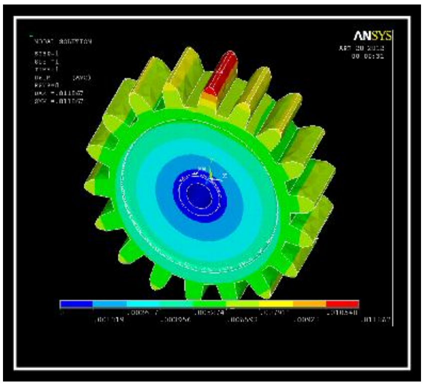


Fig4: Displacement pattern for Nylon gear

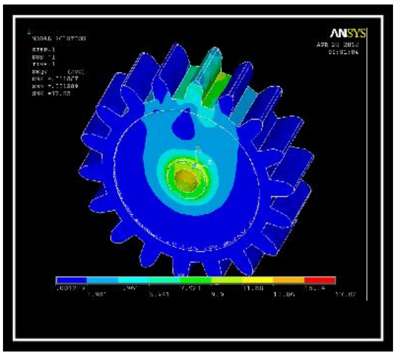


Fig 4 Stress distribution for Nylon spur gear

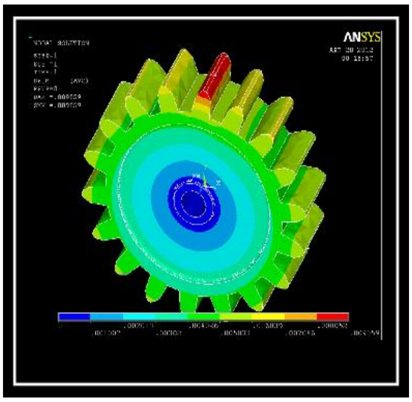


Fig 5: Displacement pattern for Polycarbonate spur gear.

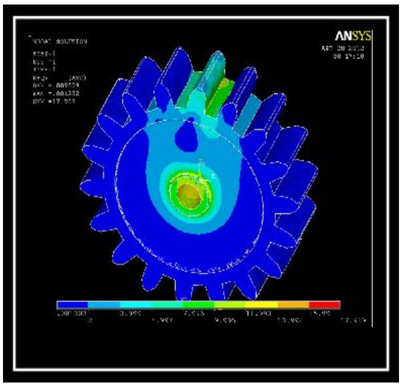


Fig 6: Stress distribution for Polycarbonate spur gear.

VIII. Results Obtained From Ansys:

From the static analysis using ansys the deflections and vonmise stress and strain values for the cast iron, Nylon and polycarbonate are obtained as following below tables.

For Cast Iron Spur gear:

Pressure (N/mm^2)	Vonmise Stress (N/mm^2)	Deflection (mm)	Strain
1	3.832	0.002905	2.21e-4
2	7.665	0.005811	4.41e-4
3	11.497	0.008716	6.62e-4
4	15.33	0.011622	8.82e-4
5	19.078	0.014488	1.14e-3

For Nylon Spur gear:

Pressure (N/mm^2)	Vonmise Stress (N/mm^2)	Deflection (mm)	Strain
1	3.582	0.002381	2.19e-4
2	7.163	0.004762	4.37e-4
3	10.745	0.007143	6.56e-4
4	14.327	0.009524	8.74e-4
5	17.82	0.011867	1.29e-3

For Polycarbonate Spur gear:

Pressure (N/mm^2)	Vonmise Stress (N/mm^2)	Deflection (mm)	Strain
1	3.615	0.001817	2.20e-4
2	7.863	0.003635	4.45e-4
3	10.846	0.005452	6.61e-4
4	14.462	0.007274	8.82e-4
5	17.989	0.009059	1.38e-3

Graphs:

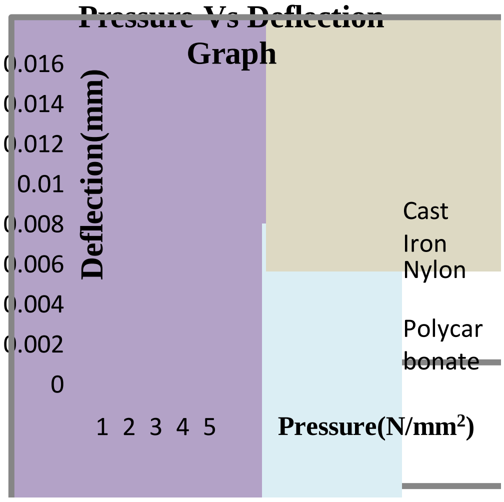


Fig 1: Pressure Vs Deflection graph

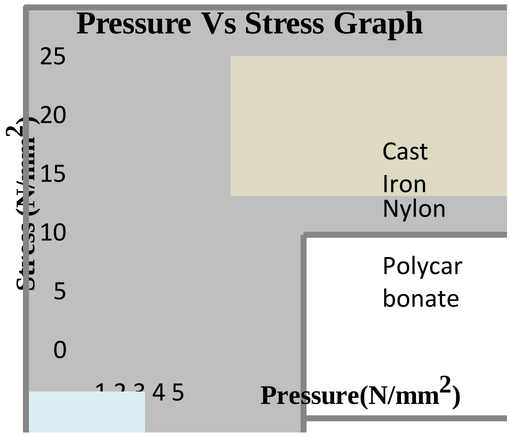


Fig 2: Pressure Vs Stress graph

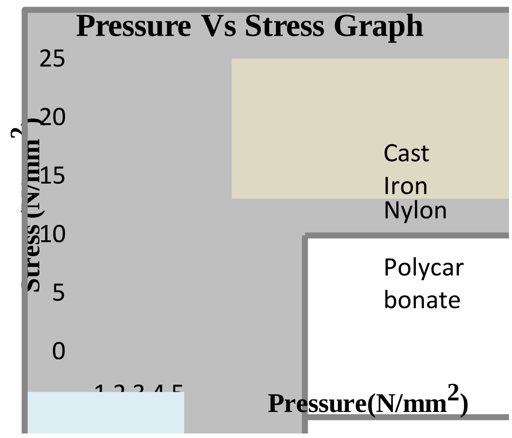


Fig 3: Stress Vs Strain graph

Results and discussion

From the static analysis by increasing the pressure on the tooth flank surface we observed that the vonmise stresses and deflection values of the spur gear were increased. And the minimum stress values are obtained for Nylon spur gear compared with Cast iron and Polycarbonate. According to the study, analysis, results and graphs we recommend the best plastic material is Nylon and Nylon gears are suitable for the application of sugar cane juice machine under limited load conditions.

IX. CONCLUSIONS:

To find the suitable design gears with less weight and less cost, corrosion resistance, frictionless also. To design and manufacture a sugarcane juice for a common people including women. With less cost, self lubricating neat and clean hygienic juice. With more material removal of deflection and stress are increased. So for safe operation of my design is more appropriate under limited load conditions for Nylon gear.

References:

10.1Journals Papers:

[1] R. Yakut, H. Düzcükoğlu*, M.T. Demirci Mechanical Education Department, University of Selcuk, Campus, Konya, Turkey, Received 30.09.2009; published in revised form 01.11.2009

[2] K. Mao, A new approach for polyamide composite gear design, Wear 262 (2007) 432-441.

[3] M.H. Tsai, Y.C. Tsai, A method for calculating static transmission errors of plastic spur gears using fem evaluation, Finite Elements in Analysis and Design 27 (1997) 345-357.

[4] C.H. Kim, Durability improvement method for polyamide spur gears, Tribology International 39 (2006) 1454-1461.

[5] S. Senthilvelan, R. Gnanamoorthy, Effect of rotational speed on the performance of unreinforced a glass fibre reinforced nylon 6 spur gears, Materials and Design 28 (2007) 765-72.Analysis". and Testing *Materials Science*, 12 (3), 2006, 220-225.

10.2 Books:

[6] Machine drawing by N.D.BHATT

[7] Machine design by S.M.D.JALALUDEEN.

[8] Design data book compiled by PSG College of Technology, COIMBATORE.

[9] Machine design by BANDARI.

[10] Theory of machines by KHURMI.

[11] Van Me lick , H.G.H. " Tooth Bending Effects in plastic Spur Gears," Gear Technology.

[12] White, J., D . Walton and D.J. Weale. "The Beneficial effect of Tip Relief on Plastic Spur Gears," ANTEC Conf. Proc. Society Plastics Engineers (1998).

[13] Rosler, J. "Zur Tragfahigkeitssteigerung Thermoplasticher Zahnrader mit Fullstoffen," PhD thesis, berlin University of Technology, 2004.

[14] Plastic Gears are more reliable when engineers account for material properties and manufacturing process during design. Zan Smith: Motion System Design, July 2000.