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RESEARCH ARTICLE

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# FAILURE ANALYSIS OF BEATER SHAFT OF DOUBLE ROLLER GINNING MACHINE USING FEM ANALYSIS APPROACH AND ITS VALIDATION BY USING MATHEMATICAL APPROACH

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**ABSTRACT**

Ginning, in its strictest sense, refers to the process of separating cotton fibres from the seeds. The cotton gin has as its principal function the conversion of a field crop into a salable commodity. Thus, it is the bridge between cotton production and cotton manufacturing. Ginning is the first and most important mechanical process by which seed cotton is separated into lint (fibre) and seed and machine used for this separation is called as gin. It consists of two spirally grooved leather roller ,two moving blades combined with seed grids called as beater assembly. During the ginning operation the shaft fails at certain location. The actual failure position of shaft shown in fig no A was studied by using FEM analysis and the FEM results were validated by using mathematical approach.

**Keywords:** Ginning machine, beater shaft, theories of failure, CAD model of beater shaft, FEM analysis , failure analysis.



## 1.0 INTRODUCTION

India ranks first in area under cotton cultivation (9.0 million hectares) and is the second largest producer of cotton fiber in the world producing 4.59 million tonnes during 2006-07. Ginning is the process by which seed cotton is separated into lint (fibers) and seed and machine used for its separation is called as gin. Thus ginning is the first engineering activity that cotton undergoes on its way from cotton field to textile mills 3. There are mainly two types of gin viz; (i) roller (rotary knife and double roller) gin (ii) saw gin. In India, mostly roller gins are used for commercial ginning. About 50,000 double roller (DR) gins are operating in India for ginning and producing 5.1 million tonnes of fibers (90 % of total cotton lint production) on DR gin in year 2006-2007. Further only 10 % of seed cotton is ginned on saw gins particularly in northern part of India and since last five years the saw gins are being replaced by the roller gins.

A cotton gin is a machine that quickly and easily separates cotton fibers from their seeds, allowing for much greater productivity than manual cotton separation. The fibers are processed into clothing or other cotton goods, and any undamaged seeds may be used to grow more cotton or to produce cottonseed oil and meal. The cotton gin is a machine used to separate cotton fibers from the seed. The double roller ginning machine consists of various parts such as beater shaft, leather roller,

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moving knife, fixed knife, feeder ,etc. Ginning is the first and most important mechanical process by which seed cotton is separated into lint (fibre) and seed and machine used for this separation is called as gin. It consists of two spirally grooved leather roller pressed against a fixed knife, are made to rotate at about 90-120 rpm. Two moving blades combined with seed grids constitutes a central assembly known as beater which oscillates by means of a crank or eccentric shaft, close to the fixed knife. When the seed cotton is fed to the machine in action, fibres adhere to the rough surface of the roller are carried in between the fixed knife and roller in such a way that the fibres are partially gripped between them. The oscillating knife beats the seed and separates the fibres. This process is repeated for number of times and due to push-pull-hit action the fibres are separated from the seed, carried forward on the roller and dropped out of machine. The ginned seeds drop down through the grid which is oscillating along with beater.


Fig.1.0. Double Roller Gin machine

The beater assembly is the innermost and major part of the double roller gin and is sandwiched symmetrically between the stationary knives as shown in fig. It is composite unit consisting of moving knives and seed grids situated on the either side of the beater shaft. It has anchor shaped coss section and its axle is situated 100cm above ground and 15cm from each roller. Beater trough with perforations having concave edge with radius of 565cm and angle of 144 degree between two arms is provided to stop unginned cotton to fall down into seed chute.

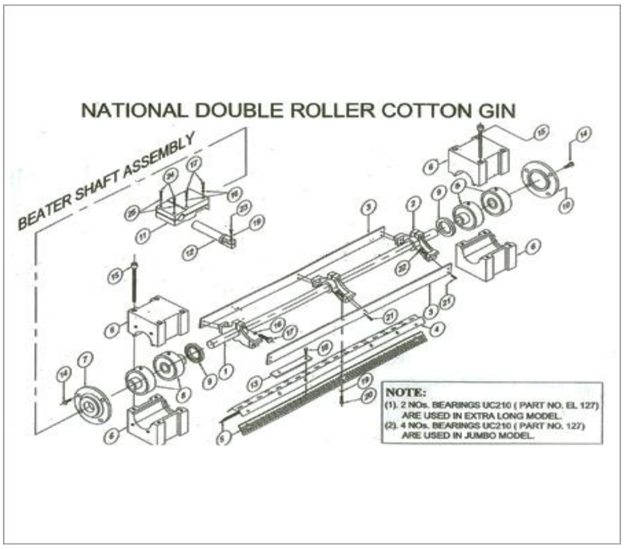



Fig.1.1. BEATER SHAFT ASSEMBLY

In DR gins the shaft of the oscillating knife is coupled to three beater arms. The motion of the reciprocating knives is symmetric about the fixed knives. The allignment of the beater and moving knives should be such that it should not touch the roller or the stationary knife and back knife at any working position. The driving mechanism in the DR gin is fully controlled from the gearbox. At present in the most of the double roller gins, the roller speed is around 90 to 100 rpm while the beater oscillates with the frequency of 900 to 1000 per minute. Uniform spacing should be maintained between the two moving knives throughout the length of the beater. This is to be effected by inserting or removing thin packing between the knife arms and beater knives.

**2.0 OBJECTIVES**

- 3-D modelling and force calculations of the beater shaft using ProEsoftware.
- Finite element analysis of beater shaft using ANSYS software.
- Failure analysis of beater shaft.
- Validation of FEM results using mathematical approach

**3.0. MATHEMATICAL ANALYSIS OF BEATER SHAFT DESIGN CALCULATION:**

- **POWER REQUIRED:-**

$P=2\pi NT/60$

Where,

P=5hp ,N=Speed=5.93rpm,T=torque

$5*0.736*10^3 = 2*\pi*N*T/60$

[ T=6000 N-m]

- **TORQUE TRANSMITTED:-**

$T=\pi/16 * d^3 * \tau$

Where,

$6000*10^3= \pi/16* 58^3* \tau$

[ $\tau$ =156.61 MPa ]

**FORCE CALCULATION:-**

Force on first arm,

T= F1*L

$6000*10^3$=F1*62

[ F1 = $96.774*10^3$N ]

Force on second arm,

T= F2*L

$6000*10^3$=F2*800

[ F2 = $7.5*10^3$N ]

Force on third arm,

T= F3*L

$6000*10^3$=F3*1404

[ F3 = $4.273*10^3$N ]

$\sum F = 0$,

R1- 96.774-7.5-4.273+ R2 = 0

[ R1 + R2 = 108.547 KN ]

Moment @ A ($\sum MA$) = 0,

$-96.774*10^3*62-7.5*10^3*800-4.273*10^3*1404+R2*1600= 0$

[R2 = $11.249*10^3$N]

[R1=$97.299*10^3$N]

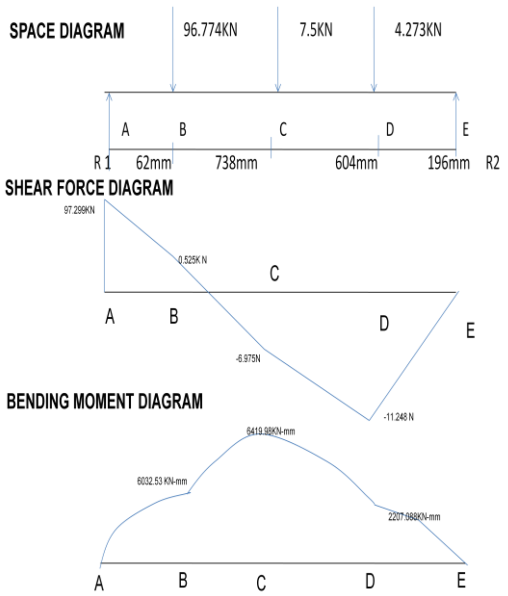



Fig.3.0. SFD and BMD of beater shaft

**Shear force calculation:**

S.F.at A = 97.299K N

S.F. at B = 97.299 96.774=0.525K N

S.F.at C = 0.525-7.5 = -6.975 KN

S.F.at D = -6.975-4.273= -11.248K N

S.F.at E = -11.248+11.248= 0 KN

**Bending Moment calculation:-**

B.M. at A & E = 0 , end support

B.M. at B = 97.299*62=6032.538KN-mm B.M. at C= 97.299*800-96.774*738=6419.98KN-mm

B.M. at D= 97.299*1404-96.774*1342-7.5*604 =2207.088KN-mm

**Material Properties :**

The material of the beater shaft is bright steel and the properties are as given below:

i) BRIGHT STEEL (B250)

- Youngs Modulus = 204 GPa
- Poission Ratio = 0.33
- Tensile Yield Strength = 230 MPa
- Tensile Ultimate Strength = 410 GPa

**Factor of Safety in Torsion,**

from PSG data book,

$\eta t= \tau_{-I}$ / kt * Bsize* ⍰

Where,

$\tau_{-I}$=Endurance limit stress in torsion

$\tau_{-I}$= 6e * Ks

6e=Endurance limit

For steel,

6e=0.8 to 0.9 6yt ,(From Machine design by khurmi & gupta)

Ks= load correction factor

For ductile =0.8

⍰ = shearing stress

Bsize=size factor =1.5 (from PSG databook)

Kt=stress concentration factor=1(from D.B.)

**For Bright Steel Material,**

Sut=410 Mpa, Syt= 230 MPa, E=204 GPa

Factor of safety,

$\eta t= \tau_{-I}$ / kt * Bsize* $\tau$

$\tau$ = 128.21 Mpa

$\tau_{-I}$=6e*ks

6e=0.9 Syt=0.9*230=207 Mpa

$\tau_{-I}$=207*0.8=165.6 Mpa

F.O.S., $\eta t$=165.6/1*1.5*128.21

[$\eta t$=0.861≈1]

## 4.0 USING THEORIES OF FAILURE

Maximum principal or normal stress theory ,

Considering, F.O.S.=2

6t= Syt / F.O.S.

6t= 230/2

[6t=115 MPa]

Maximum shear stress theory ,

τmax=6yt/ 2*F.O.S

=230/2*2

[τmax=57.5 MPa]

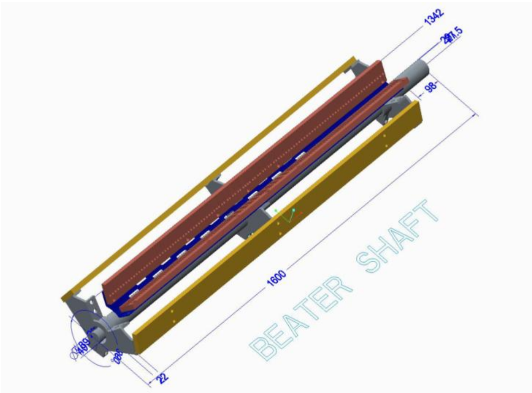
Maximum principal strain theory,

εmax=6yt/E*F.O.S.

=230/204*10^3*2

[εmax=0.002254]

## 5.0 VIEW OF BEATER SHAFT ASSEMBLY

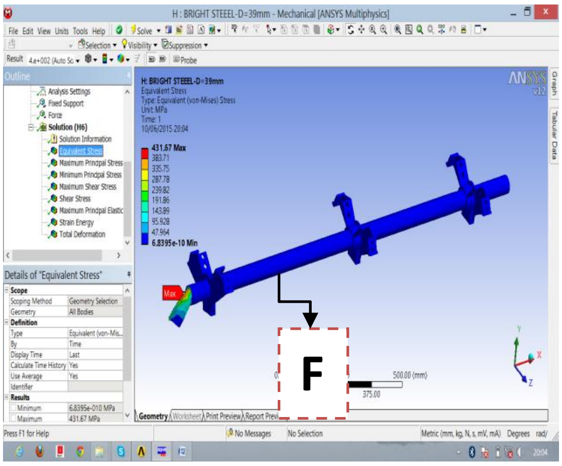



## 6.0. RESULTS OF BEATER SHAFT ANALYSIS

**1)** When, D=39mm, material=BRIGHT STEEL

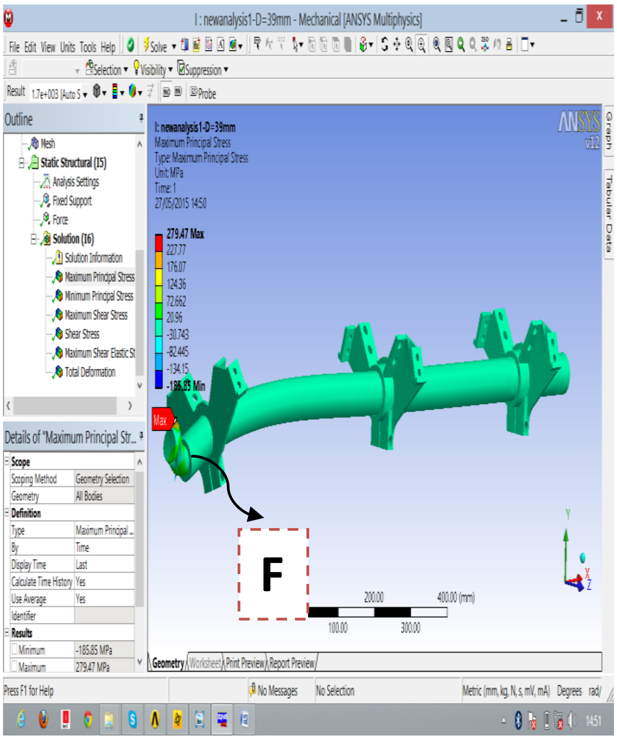
i) von-Mises Stress

Max.= 431.67Mpa



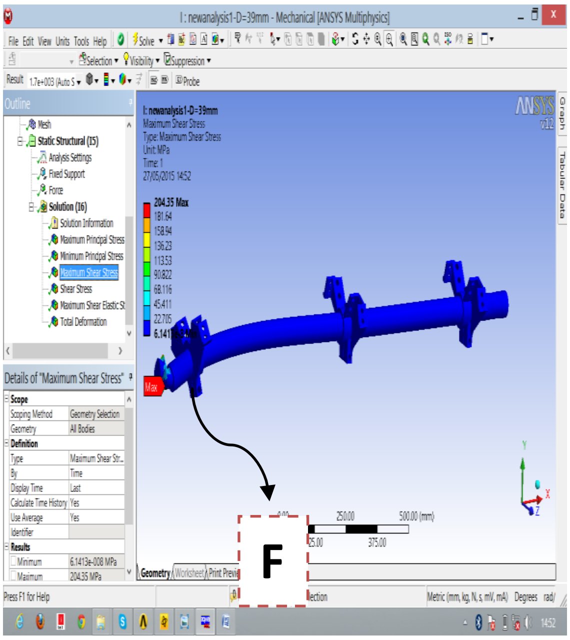

Ii) Principle stress

Max=279.47MPa

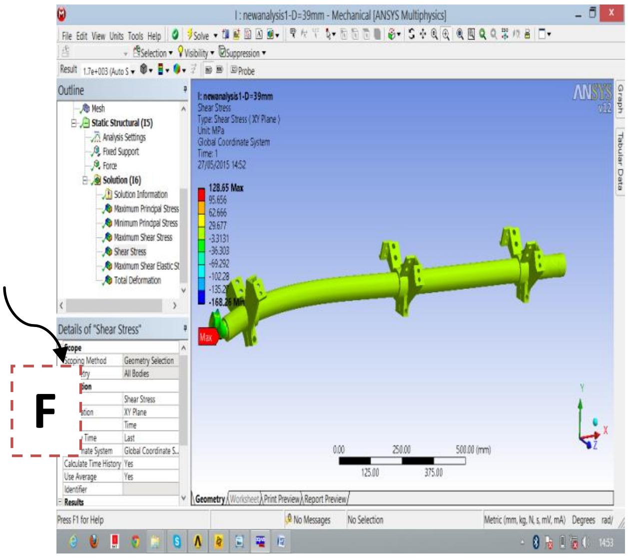



iv)Shear stress

Max= 204.35MPa



v)Shear stress=128.65MPa




### 6.1 RESULTS OF BEATER SHAFT ANALYSIS

Table 6.1 The stresses generated in the Beater shaft

| Sr N | Material | Allowable stress (MPa) | Design stress (MPa) (Assuming, FOS=2) | Von-mises stress (MPa) |
|---|---|---|---|---|
| 1 | Bright steel | 230 | 115 | 431.67 |

| Max Principle stress MPa | Max shear stress Mpa | Shear stress MPa | Max principle strain |
|---|---|---|---|
| 279.47 | 204.35 | 128.65 | 0.002254 |

### 7.0 ANALYSIS

After carefully study of the result tabulated in table no 1.1 and result of FEA analysis . The conclusions are as below:

- The maximum value of stress in torsion is 230MPa and of the presently material being used is bright steel and the maximum stress obtained in FEM is 279.47MPa.
- The maximum stresses generated by FEA analysis is more than the allowable stress.
- The place of failure actually seen and the place of maximum concentration of stress shown by mathematical analysis and by FEA analysis coincides.

### 8.0 CONCLUSION

- The failure which is occurring in the shaft was because of the stress generation were maximum as comparing to the allowable stress. Hence, the failure is occurring.
- The point of failure seen in the actual specimen coincides by the failure indicated by the FEA model and it validated by the mathematical approach.Failure indicated by the FEA model and mathematical approach that justifies correctness of the approach.

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