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RESEARCH ARTICLE

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REDESIGN OF SPRING OF FUEL PUMP BLEED VALVE FOR TYPICAL JET ENGINE

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ABSTRACT

The largest and most important fluid system in a jet engine is the fuel system. This fuel system consists of fuel pump, there are many components assembled in the fuel pump. Among that Bleed valve is one which plays an important role in the fuel pump. The main function of this valve is to bleed the air bubble from the fuel lines. The bleed valve is operated manually by a plunger or pin before every start of an engine. This bleed valve after working for some times or some cycles there is a slit leakage in the valve which in turns results in effecting the performance of the engine. Sometimes damages to the engine systems. This leakage is mainly due to spring which is losing its stiffness. I have redesigned the spring and changed the material for spring of bleed valve which resulted in increases stiffness and life of spring, which in turns comparatively reduced the material cost of spring and maintenance cost of the bleed valve.

Keywords: *Bleed valve, fuel pump, spring, turbine engine, and plunger.*

INTRODUCTION

The gas turbine is an internal combustion engine that uses air as the working fluid. Turbojets are the oldest kind of general-purpose jet engines. Turbojets are rotary engines that extract energy from a flow of combustion gas. They produce thrust by increasing the velocity of the air flowing through the engine and operate on Newton's third law of motion "For every action there is an equal and opposite reaction". All powered aircraft require fuel on board to operate the engine(s). A fuel system consisting of storage tanks, pumps, filters, valves, fuel lines, metering devices, and monitoring devices. Each system must provide an uninterrupted flow of contaminant free fuel regardless of the aircraft's attitude. The fuel load can be a significant portion of the aircraft's weight; a sufficiently strong airframe must be designed. Varying fuel loads and shifts in weight during manoeuvres must not negatively affect control of the aircraft in flight. The bleed valve is located in jet engine fuel pump. The main function of bleed valve is to prevent fuel flow to the fuel nozzles and bleeds the fuel manifold at engine shutdown to prevent post-shutdown fires. It also bleeds the air bubbles in the fuel line of fuel pump.

DEFINITION OF SPRING

A spring is an elastic object used to store mechanical energy. Springs are elastic bodies (generally metal) that can be twisted, pulled, or stretched by some force. They can return to their original shape when the force is released. In other words it is also termed as a resilient member. A spring is a flexible element used to exert a force or a torque and, at the same time, to store energy.

TYPES OF SPRINGS

1. **Push Types Springs**


Helical compression spring


Belleville spring


Torsion spring


Flat spring


leaf spring

2. **Pull Types Springs**


Helical extension spring


Torsion spring


Flat spring`


Draw bar spring


constant – force spring

3. Radial torque types springs

Garter spring


spring clamp

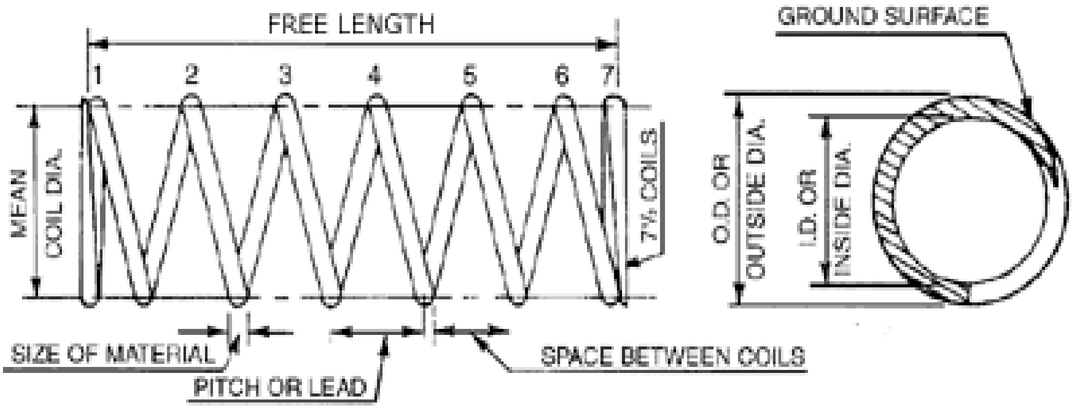

Torsion spring


Power spring

3. DESIGN OF SPRING

Definition

It is made of wire coiled in the form of helix having circular, square or rectangular cross Section.



Symbols Used In Helical Spring

H_f = free length of spring

H_s= solid length of spring

d = Diameter of spring wire

D = Mean diameter of coil

D_o = Outer diameter of coil

D_i = Inner diameter of coil

p = Pitch

N = Number of active coils

N_t = Total number of coils

P = load on the spring or Axial force

τ = Permissible stress or design shear stress

y = Deflection

G = Modulus of Rigidity
c = spring index
k = Curvature factor or Wahl's stress factor
Ko or Fo =Stiffness of spring or Rate of spring
Design of Helical Springs

The design of a helical compression spring involves the following considerations:

- Modes of loading – i.e., whether the spring is subjected to static or infrequently varying load or alternating load.
- The force deflection characteristic requirement for the given application.
- Is there any space restriction.
- Required life for springs subjected to alternating loads.
- Environmental conditions such as corrosive atmosphere and temperature.
- Economy desired.

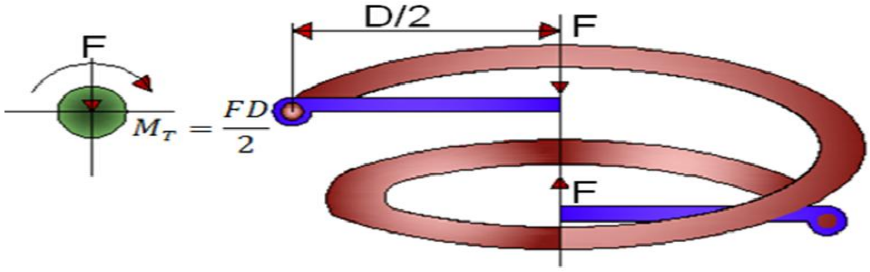
Considering these factors the designer select the material and specify the wire size, spring Diameter, number of turns spring rate, type of ends, free length and the surface condition. Springs which cannot be designed buckle- proof must be guided in a sleeve or over an arbor If,

$$\frac{Free\ length}{Mean\ coil\ diameter} \leq 2.6[Guid\ not\ necessary]$$

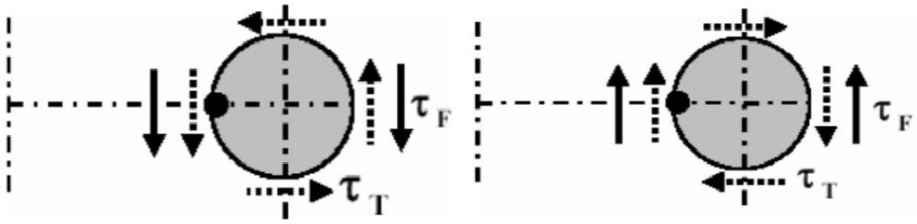
$$\frac{Free\ length}{Mean\ coil\ diameter} \geq 2.6[Guid\ required]$$

Stresses in the helical spring wire

From the free body diagram, we have found out the direction of the internal torsion T and Internal shear force F at the section due to the external load F acting at the centre of the coil.



The cut sections of the spring, subjected to tensile and compressive loads respectively, are shown Separately in the figure.



The broken arrows show the shear stresses arising due to the torsion T and solid arrows Show the shear stresses due to the force F.
It is observed that for both tensile load as well as compressive load on the spring, maximum

Shear stress always occurs at the inner side of the spring. Hence, failure of the spring, In the form of crake, is always initiated from the inner radius of the spring.

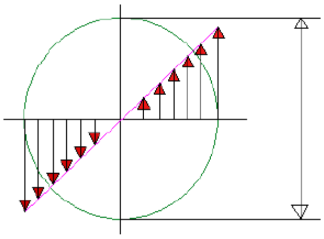
The radius of the spring is given by D/2. Note that D is the mean diameter of the spring. The Torque T acting on the spring is

$$T = Fx\frac{D}{2}$$

If d is the diameter of the coil wire and polar moment of inertia,

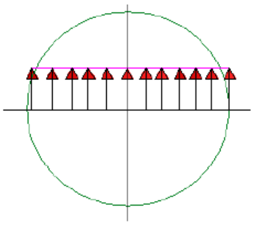
$$I_p = \frac{\pi d^4}{32}$$

The shear stress in the spring wire due to torsion is



$$\tau_T = \frac{Tr}{I_p} = \frac{Fx\frac{D}{2}x\frac{d}{2}}{\frac{\pi d^4}{32}}$$

Average shear stress in the spring wire due to force F is



$$\tau_F = \frac{F}{\frac{\pi d^2}{4}} = \frac{4F}{\pi d^2}$$

Therefore, maximum shear stress in the spring wire is

$$\tau_T + \tau_F = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2}$$

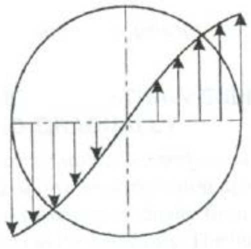
or $\tau_{max} = \frac{8FD}{\pi d^3}\left(1 + \frac{1}{\frac{2D}{d}}\right)$ or $\tau_{max} = \frac{8FD}{\pi d^3}\left(1 + \frac{1}{2C}\right)$

Where, C=D/d is called the spring index

finaly $\tau_{max} = \frac{8FD}{\pi d^3}K_s$

$$K_s = \left(1 + \frac{1}{2C}\right)$$

The above equation gives maximum shear stress occurring in a spring. Ks are the shear stress Correction factor. The resultant diagram of torsional shear stress and direct shear stress is shown



From the above equation it can be observed that the effect of direct shear stress i.e.,

$$\tau = \frac{8FD}{\pi d^3}\frac{1}{2c}$$

Design of existing spring

Spring specification

Material Phosphorus Bronze PB102H (BS2874)

Outer diameter Do=2.9mm

Wire diameter d=0.37mm

Free length Hf=5.6mm

Load when spring length is 5mm P=0.556N

Physical properties

Hardness 210-240VHN

Density ρ=8850kg/m^3

Modulus of elasticity E=121000MPa

Shear modulus G=45488MPa

Melting point temp T=930℃

Tensile strength Ut=650MPa

Design procedure

1. **Mean coil diameter**

   Mean coil diameter D = Do-d

   = 2.9-0.37

   = 2.53mm

   Inner diameter Di = Do-2d

   = 2.9-2*0.37

   =2.160mm

2. **Diameter of wire**

   Spring index c=D/d

   = 2.53/0.37

   = 6.838

Wahl's stress factor $k = \frac{4C-1}{4C-4} + \frac{0.615}{C}$

$= \frac{4*6.838-1}{4*6.838-4} + \frac{0.615}{6.838}$

= 1.218

Shear stress $\tau = \frac{8PDk}{\pi d^3}$

$$\tau = \frac{8*0.556*2.53*1.218}{\pi*0.37^3}$$

= 86.17MPa

3. Number of coils or turns

Axial Deflection $y = \frac{8PD^3N}{Gd^4}$

$$0.6 = \frac{8*0.556*2.53^3*N}{45488.7218*0.37^4}$$

N = 7.103 ≈ 7

4. Solid length $Hs = d(N+2)$

= 0.37(7+2)

=3.33mm

5. Deflection per active coil at load P

$$Y = \frac{8PD^3}{Gd^4}$$

$$= \frac{8*0.556*2.53^3}{45488.7218*0.37^4}$$ = 0.085mm

6. Lead when free $L = \frac{Hf-2d}{N}$

$$= \frac{5.6-2*0.37}{7}$$

= 0.694mm/coil

7. Pitch of coil

$$p = \frac{Hf}{Nt-1}$$

$$= \frac{5.6}{8-1}$$

= 0.8

8. Rate of spring

$$K = \frac{Gd^4}{8ND^3}$$

$$= \frac{45488.7218*0.37^4}{8*7*2.53^3}$$

= 0.93N/mm

Redesign of the spring

Material selection for redesign of the spring

The existing spring was designed for phosphorus bronze, but now we are designing for stainless steel because for availability point of view stainless steel is easily available material and lee cost compare to phosphorus bronze and stainless steel is having more stiffness compare to phosphorus bronze.

PROPERTIES OF COMMON STAINLESS STEEL SPRING MATERIALS

Material	Modulus of Elasticity E (MPa x 10^3)	Modulus in Torsion G (MPa x 10^3)	Max. Operating Temp. ℃	Description
AISI 302	193	81.37	204.4	Stainless steel withstand all ordinary rusting and under cold drawn the permeability of stainless steel 302 increases.
ASTM A 313	203	73.5	343	Cold drawn and precipitation Hardened after fabrication. High strength and general purpose Corrosion resistance.
AISI 316	198	69	288	Cold drawn. Heat resistant and better corrosion resistance than 302. Magnetic in spring temper.

Based on the application point of view, wire diameter, availability of vendors and especially for aerospace application from the above table stainless steel 302 is preferred for the spring design.

Redesign of the spring

Spring specification

Material stainless steel AISI 302 AMS 5866

inner diameter Di =2mm

Wire diameter d=0.29mm

Free length Hf=5.6mm

Load when spring length is 5mm P=0.556N

Physical properties

Hardness 150BHN

Density ρ=8027.172kg/m^3

Modulus of elasticity E=193050MPa

Shear modulus G=81370MPa

Max. Operating Temp. T=204.4℃

Tensile strength Ut=620.5MPa

Design procedure

1. **Mean coil diameter**

   Mean coil diameter D = Di +d

= 2+0.29

= 2.29mm

Inner diameter Do = Di +2d

= 2+2*0.29

= 2.58mm

2. Diameter of wire

Spring index c = D/d

= 2.29/0.29

= 7.89

Wahl's stress factor $k = \frac{4C-1}{4C-4} + \frac{0.615}{C}$

$= \frac{4*7.89-1}{4*7.89-4} + \frac{0.615}{7.89}$

= 1.186

Shear stress $\tau = \frac{8PDk}{\pi d^3}$

$= \frac{8*0.556*2.29*1.186}{\pi*0.29^3}$

= 258.32MPa

3. Number of coils or turns

Axial Deflection $y = \frac{8PD^3N}{Gd^4}$

$$0.6 = \frac{8*0.556*2.29^3*N}{81370*0.29^4}$$

N= 6.43$\approx$6

4. Solid length $Hs = d(N+2)$

= 0.29(6+2)

= 2.32mm

5. Deflection per active coil at load P

$$Y = \frac{8PD^3}{Gd^4}$$

$$= \frac{8*0.556*2.29^3}{81370*0.29^4}$$

= 0.09mm

6. Lead when free $L = \frac{Hf-2d}{N}$

$$= \frac{5.6-2*0.29}{6}$$

= 0.834mm/coil

7. Pitch of coil

$$p = \frac{Hf}{Nt-1}$$

$$= \frac{5.6}{7-1}$$

=0.933mm

8. Rate of spring

$$K = \frac{Gd^4}{8ND^3}$$

$$= \frac{81370*0.29^4}{8*6*2.29^3}$$

= 0.998N/mm

4. ANALYSIS OF SPRING

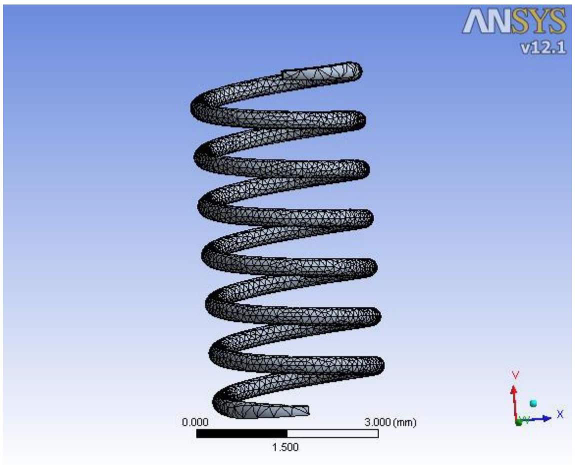


Figure: Mesh generation

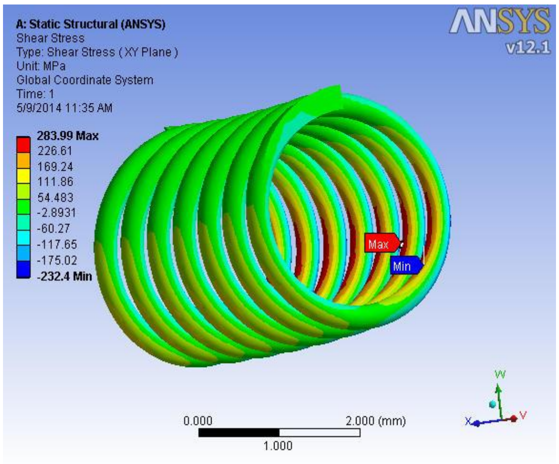


Figure: Shear stress

CONCLUSION

In this project we have redesigned spring for Bleed Valve and increased the stiffness of the spring compare to the existing spring and we have also changed the spring material which in turns results in cost reduction of spring and maintenance cost also. We have designed spring for stainless steel material which the life period of the spring also has been increased. By increasing the stiffness of the spring we have controlled the leakage from the bleed valve. Stress analysis is done using Finite element technique using ANSYS to evaluate stresses under typical engine loading conditions. Based on analysis it was found that the maximum stresses are well within the permissible limits. Hence the design is considered as valid and acceptable.

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