Design of novel dual valve spring compressor tool for valve seal replacement

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Abstract— *A valve spring compressor tool useful for removing two valve springs from an overhead valve of an internal combustion engine while the cylinder head is either mounted to the engine block within the vehicle of the type having a threaded rocker arm plate for compression of the valve spring is designed and analyzed. The tool comprises of a crank down nut that has a socket portion for connection to a wrench and a neck portion which. Passes through an oblong aperture in a compressor plate. The crank down nut has a threaded counter bore in its neck portion. A pressure plate is progressively positioned on the two diametrically opposite valve springs that are supposed to be compressed in order to expose the internal valve stem seals. A nut is threaded on to the upright bolt in a manner that forces the pressure plate and the valve guides downward onto the valve springs. The compressor plate contacts a retainer cap on the valve spring to compress the spring without interfering with the valve stem or a keeper on the valve stem, which allows for removal of the keeper and in turn the stem seals while the spring remains compressed. The present paper gives design procedure of the various parts of the newly fabricated dual valve spring compressor tool for valve seal replacement and removal.*

IndexTerms—internal combustion engine, engine block, crank, counter bour.*(keywords)*

I. INTRODUCTION

For some or the other reason it becomes mandatory to remove or replace the many components on internal combustion engines for automobiles wear out over time. These components include the valve stem seals that are positioned on the engine cylinder heads. Typically, such repairs only can be brought about by getting rid of the valve spring surrounding the valve stem (1). To remove the valve spring, it is mandatory to displace the washer and keeper located on the end of the valve stem. However, the washer and keeper cannot be removed until the valve spring is compressed (2).

The review (3) on valve seal replacement tools reveals that it is very difficult to carry out the task of removal and replacement of the valve stem seals manually as it may cause accidents and may hurt the person doing the job. So a number of tools were designed and fabricated to facilitate the job (4). There are tools which can help manually compress the valve springs by removing the whole assembly from the engine head which is again time consuming only the risk of hurting the person is lowered by making use of such tools. On the other hand, tools with multiple valve compressor assembly (5) are quite bulkier and difficult to carry and fix on the engine head. In order to solve this problem, a newly designed and fabricated dual valve spring compressor tool is introduced in this paper. The detailed description for the design of the various parts of the tool is discussed herewith in this paper.

II. DESCRIPTION OF THE TOOL:

The proposed tool provides the faster and easier method for replacement of valve stem seals with dual spring compressing technique. This saves the time of setting of tool position as compared to single valve spring compressor. The tool assembly consists of base with threaded shaft, Compression plate, Nut, Bearing and retainer spring. The tool base is fixed on the cylinder block and retainer spring, compression plate, bearing and nut is fit in the shaft respectively. With the downward movement of the nut starts over the threaded shaft, it lowers the compression plate against the retainer spring and the valve spring gets compressed two at a time. Due to this the force on the valve seal lock is released thereby making the valve seals replacement job easy.

III. DESIGN DETAILS AND DRAWING:

Calculation for spring

Solid length of Spring (Ls):

Ls = Number of Turns (n) x Wire Diameter of Spring (d)

Ls = 8 x 5 mm

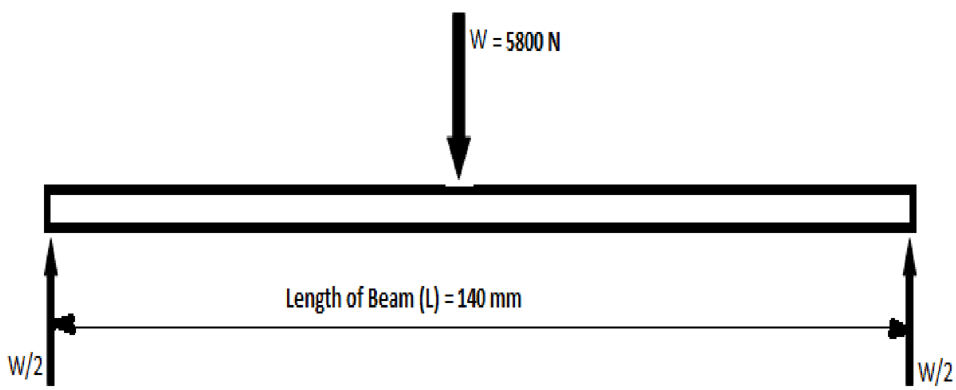
Ls = 40 mm

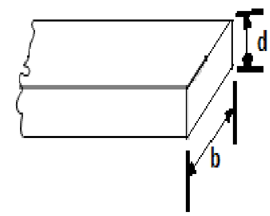
Free Length of Spring (Lf):
Lf = 74.7 mm
Deflection of Spring (δ):
δ = Free length of Spring – Solid Length of Spring
= 74.7 – 40
34.7 mm.
Force Exserted by the Spring (F):

$$F = \frac{8\,F\,D_m^3\,n}{G\,d^4}$$

$$34.7 = \frac{8\,F\,(29.7)^3 \times 6}{78 \times 10^3 \times 6^4}$$

103 x 3507753.6 = 1257507.5 F
The force required for compression of spring i.e.
F = 2.789 103 N
= 2789 N
If we want to compress two springs simultaneously then the force required to compress the springs is
W = 2 x 2789 N
= 5578 N
Now taking W = 5800 N because we have to design for the higher load.
Let, the given condition or situation is relate with the simply supported beam.





Cross section of Beam

The above figure shows the simply supported beam in which the two upward forces at two ends are the force exerted by the spring and the downward force is the force required to lower or compress the springs by twisting the nut.

$$Ixx = \frac{b\,.\,d^3}{12}$$

$$Ixx = \frac{41 \times d^3}{12}$$

$$Ixx = 3.4166\,d^3$$

$$M = \frac{W \times L}{4}$$

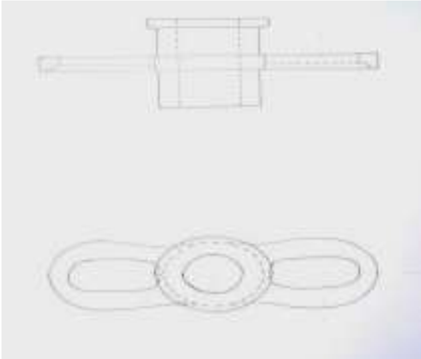
$$M = \frac{5800 \times 140}{4}$$

M = 203 x 103 N-mm.
The plate is made of alloy steel of permissible tensile stresses 115 N/mm^2
$\sigma_{max} = \sigma_t$ for plate = 115 N/ mm^2 &
y = d/2
Where,
d = thickness or height of the beam
b = Width of the beam
By Applying Flexural Formula

$$\frac{M}{I} = \frac{\sigma_{max}}{y}$$

$$\frac{203 \times 10^3}{3.4166 \times d^3} = \frac{115\ N/mm^2}{d\ /\ 2}$$

$$101500\ d = 392.90\ d^3$$
$$d^2 = 258.33$$
$$d = 16.07\ mm.$$



Selection of material of Nut and Screw

Let, The material of Screw will be steel and for Nut Cast Iron which has following properties.------------------Selected from Design Data Book By B.D. Shiwalkar from Page No. 94. Table IX-2 (Design Data for Power Screws)

$$W = 5800\ N$$
$$\mu = 0.15$$
$$\sigma c = 42\ N/mm2$$
$$\tau s = 28\ N/mm2$$
$$\tau n = 21\ N/mm2$$
$$Pb = 14\ N/mm2$$

Design of Screw

$$\sigma_c = \frac{W}{\frac{\pi}{4}\, d_c^2}$$
$$42 = \frac{5800}{\frac{\pi}{4}\, d_c^2}$$
$$d_c^2 = 175.\ 8283$$
$$d_c = 13.26\ mm$$

As the screw is subjected to twisting moment the heigher value of core diameter is selected from the talbe of square thread nornal series.

$$d_c = 18\ mm$$
$$\text{Pitch } (p) = 5\ mm$$
$$d_o = dc + p$$
$$d_o = 18 + 5$$
$$d_o = 23\ mm$$
$$\text{Mean diameter } (d) = d_o - \frac{p}{2}$$
$$d = 23 - \frac{5}{2}$$
$$d = 20.5\ mm$$

Consider single start square thread

$$\alpha = \tan^{-1}\left(\frac{p}{\pi \times d}\right)$$
$$\alpha = \tan^{-1}\left(\frac{5}{\pi \times 20.5}\right)$$
$$\alpha = 4.4390$$
$$\varphi = \tan^{-1} \mu$$
$$\varphi = \tan^{-1} (0.15)$$
$$\varphi = 8.53070$$

Torque required to raised the leaver

$$T_1 = W \times \tan(\varphi + \alpha)\frac{d}{2}$$
$$T1 = 5800 \times \tan(8.5307 + 4.439)\frac{20.5}{2}$$
$$T_1 = 13692 \text{ N-mm}$$

For Check

i)The direct compressive stress due to axial load $\sigma_c = \frac{W}{A_c}$

$$\sigma_c = \frac{W}{\frac{\pi}{4} \times (d_c)^2}$$
$$\sigma_c = \frac{W}{\frac{\pi}{4} \times (18)^2} \quad \text{N/mm2}$$
$$\sigma_c = 22.7925 \ \text{N/mm2}$$

Shear stress due to twisting moment T1 (τ):

$$\tau = \frac{16\ T_1}{\pi \times (d_c)^3}$$
$$\tau = \frac{16 \times 13692}{\pi \times (18)^3}$$
$$\tau = 11.9569 \text{ N/mm2}$$

According to maximum principal shear stress theory.

$$\tau \max = \frac{1}{2}\left[\sqrt{\sigma_c{}^2 + 4\,\tau^2}\right]$$
$$\tau \max = \frac{1}{2}\left[\sqrt{(22.7925)^2 + 4 \times (11.9569)^2}\right]$$
$$\tau \max = \frac{1}{2}\left[\sqrt{519.49 + 571.86}\right]$$
$$\tau \max = \frac{1}{2}[33.0355]$$
$$\tau \max = 16.5177 \text{ N/mm2.}$$

As the permissible shear stress for screw is 28 N/mm2 and the design shear stress for the screw is 16.5177 N/mm2.

i.e. The permissible shear stress for screw is greater than design shear stress.

τ max < τ allowable for screw

So, the design of the screw is safe.

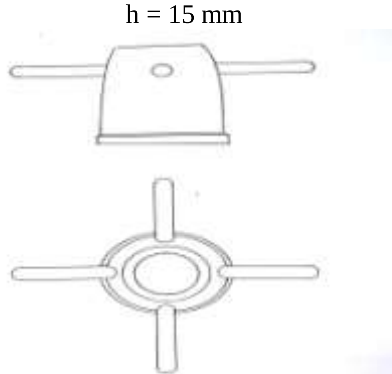
Design for the nut:

Assuming load is uniformly distributed over the cross sectional area of Nut, the bearing pressure (Pb)

$$Pb = \frac{W}{\frac{\pi}{4}[d_o{}^2 - d_c{}^2] \times n}$$
$$14 = \frac{5800}{\frac{\pi}{4}[(23)^2 - (18)^2] \times n}$$
$$14\ n = \frac{5800}{161.006}$$
$$n = 2.57 \text{ or } 3 \text{ threads}$$

The total height of nut (h) = n x p2.

$$h = 3 \times 5$$
$$h = 15 \text{ mm}$$



Shear induced in the nut thread (τ_n):

$$\tau_n = \frac{W}{\pi\, x d_o\ x\, t\, x\, n}$$

$$\tau_n = \frac{5800}{\pi\, x 23\ x \frac{5}{2} x\ 3}$$

τ_n = 10.7025 N/mm2.

The permissible shear stress for nut is 21 N/mm2 and design value of shear stress for nut is 10.7025 N/mm2.

Here, design value f shear stress is less than the permissible shear stress i.e.

τ n < τ allowable for nut

So the design of nut is safe.

ii) Shear induced in the nut thread (τ_s):

$$\tau_s = \frac{W}{\pi\, x d_c\ x\, t\, x\, n}$$

$$\tau_s = \frac{5800}{\pi\, x 18\ x \frac{5}{2} x\ 3}$$

τ_s = 13.6755 N/mm2.

The value of permissible shear stress for screw is 28 N/mm2 and the value of calculated design shear stress for screw is 13.6755 N/mm2.

The value of design shear stress is smaller than the permissible shear stress i.e.

τ s (design) < τ allowable for screw.

So, screw is safe against shear failure.

Design of Nut Collar :

The allowable tensile stress for nut.

$$\sigma_{nut} = 2\ x\ \tau_{nut}$$

$$\sigma_{nut} = 2\ x\ 21$$

$$\sigma_{nut} = 42\ N/mm^2.$$

D1 = outer diameter of Nut.

D2 = Outer diameter of Nut collar.

T1 = Thickness of nut collar.

1) Nut collar is subjected to tearing due to tensile strength.

$$\sigma_t = \frac{W}{\frac{\pi}{4}[D_1{}^2 - d_o{}^2]}$$

$$14 = \frac{5800}{\frac{\pi}{4}[(D_1)^2 - (23)^2]}$$

32.9867 (D12 - 232) = 5800

32.9867D12 – 17449.9643 = 5800

32.9867D12 = 5800 + 17449.9643

32.9867D12 = 23249.9643

D12 = 704.8284

D1 = 26.54

D1 = 28 mm

ii) Considering shearing failure of nut collar

$$\tau = \frac{W}{\pi\, x D_1\ x\ t_1}$$

$$21 = \frac{5800}{\pi\ x\ 28\ x\ t_1}$$

1847.2564 t1 = 5800

t1 = 3.139

t1 = 4mm

iii) Crushing failure of nut collar

$$\sigma_c = \frac{W}{\frac{\pi}{4}[D_2{}^2 - D_1{}^2]}$$

$$42 = \frac{5800}{\frac{\pi}{4}[D_2{}^2 - 28^2]}$$

32.9867 (D22 - 784) = 5800

32.9867 D22 – 25861.5728 = 5800

32.9867 D22 = 5800 + 25861.5728

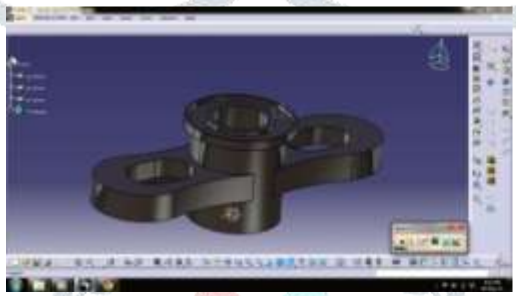
$$D22 = \frac{31661.5728}{32.9867}$$

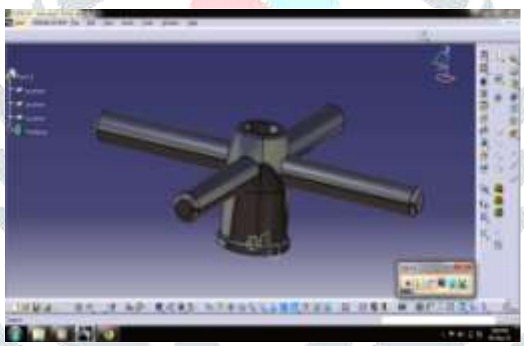
D22 = 959.8284.

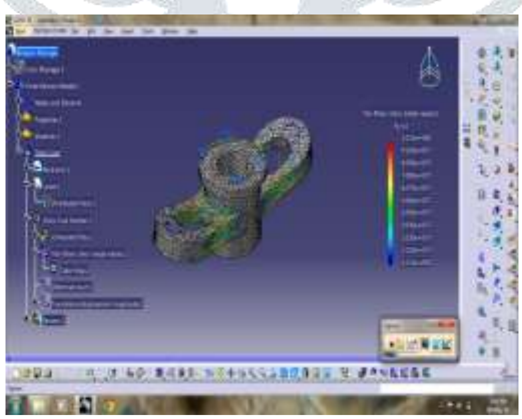
D2 = 30.9810 mm

D2 = 34 mm.

IV. DESIGN AND ANALYSIS OF TOOL IN CATIA







V. CONCLUSION:

The paper describes a novel dual valve spring compressor tool for removal and replacement of two valve stem seals at a time thereby consuming less time at higher safety. The design of the tool is so done by keeping in mind the necessary safety requirement and also the time consuming nature of the procedure to be undertaken while doing the job. The tool so designed `shows acute safety pressure plate as it is kept closed with an oblong bore where the spring to be compressed can easily fix and remain in that compressed position for a considerable amount of time without holding the tool. It shows a four way hold able handle which gives the tool a better grip and easy exertion of necessary amount of force for compression of valve springs. Moreover the tool is portable and can compress two diametrically opposite valve springs at a time thereby saving time of inspection without the displacement of engine assembly. The same design can be extended by engaging an x-shaped compression plate for compression of a gang of four valve springs at a time.

VI. REFERENCES:

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