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DESIGN OF LIFT AXLE SUSPENSION SYSTEM

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***Abstract*: A lift axle is an additional axle located on the truck that has the ability to be raised or deployed based on the Gross Vehicle Weight. Lift axles allow the truck to carry substantially higher payloads for a small increase in vehicle cost. There is much concern in the lift axle operation (the rise and deployment) based on weight, it could have a significant effect on the condition of pavement and bridge structures. These lift axles are classified into two types, the PUSHER lift axle and the TAG lift axle suspension systems. The pusher-lift axle suspension system, engage the axle to road by various mechanisms.**

The mechanism for lifting the axle includes a pivotal connection located below the longitudinal frame member of the vehicle and a pair of plates, one pivotally attached and the other rigidly attached in the suspension. An air bellow located between the pair of plates and a link member functionally attached between the axle and pivotally attached plate such that expansion or retraction of the bellows lifts the axle and the opposite operation allows the axle to be lowered.

The main purpose of implementation of the pusher lift axle system is to reduce fuel consumption, reduce the wear of tyres, improvement of ride quality when the vehicle is empty, decrease the rolling resistance of the tyre and reduce scrub when cornering and also to improve the tyre life.

Keywords—*Lift Axle, Suspension, frame, Hanger Bracket*

I. INTRODUCTION

In today's highway network, there is an abundance of lift axle vehicles. The rise in this new innovative source of technology has been a large benefit to vehicle manufacturers allowing them to increase Gross Vehicle Weight while still meeting the Government Regulations. While lift axles allow trucks to carry more weight and assist in distributing it equally, concerns still arise. One concern is the increase in overweight vehicles.

The purpose of lift axle is to distribute the load on the vehicle equally to all the axles. If the load is not distributed properly the roads may get damaged, so it is important for the lift axles to be employed properly. Apart from overweight vehicles, the rise and deployment of the lift axle also presents some concern. If the driver raises the lift axle and neglects to deploy it at the appropriate time, this then adds more weight on the back tandem axles or rear axles. Essentially this may have the potential for a substantial amount of highway damage to both pavement and bridge structures.

In order to avoid such problems, the automatic systems have been introduced. If the driver have control he may fail to lift or lower the axle during heavy loads which leads to overload of primary axle which are always in contact with road surface, which may cause damage to the suspension system. So automatic control system for lowering and raising of the retractable systems have been proposed.

II. WORKING PRINCIPLE

A lift axle suspension system comprises of a vehicle frame, an axle assembly and a control arm connected to the axle assembly. The control arm also being connected to the vehicle frame via a hanger bracket, and a lift air bellow connected between the vehicle frame and the control arm, the lift air bellow being connected to the vehicle frame at a position spaced apart from the hanger bracket. Whereas the extension of the lift bellow lifts the axle assembly towards the vehicle frame, when the unladen condition exists in the vehicle, the retraction of the bellows helps the ride bellows to expand which brings the axle down to the running condition. This is done when the vehicle carries an additional load.

Towards mistake-proofing, automatic control systems for the retractable axle have been introduced.

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III. DESIGN OF IN-HOUSE PUSHER LIFT AXLE SUSPENSION SYSTEM

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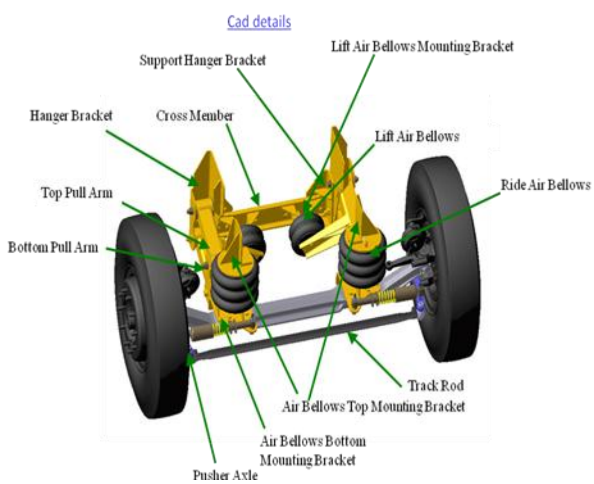

Fig. 1 MODEL DESIGN OF LIFT AXLE SUSPENSION

An air suspension supports the vehicle on the axles with an arrangement of air bellows instead of some type of steel spring, leaf or coil, or some type of torsion spring arrangement. The air bellows are sometimes referred to as air springs suspensions that have steel or torsion springs that are supplemented by the use of air bellows are not considered as air suspension.

IV. DESIGN CALCULATIONS

DETERMINATION OF THE SIZE (DIAMETER) OF BOLT IN HANGER BRACKET

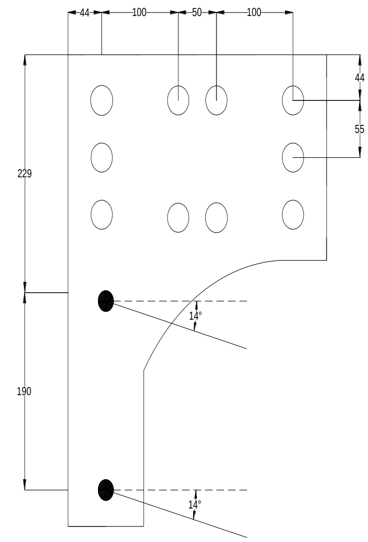

Fig. 2 HANGER BRACKET

CG of the bolt group: (169, 99)
Direct shear load on each bolt:
Primary shear force (P_s):

$P_s =$ P

P = 6ton (through control arm)

= 6×1000×9.81=58680 N

= 58680 N

Turning moments resisted by 10 bolts:
$F_1, F_2, F_3 \ldots\ldots\ldots F_{10}$ be the secondary shear load
Let $l_1, l_2, l_3 \ldots l_{10}$ be the length of each bolts from the C.G. of the bolt group.

$l_1 = l_4 = l_7 = l_{10}$ => 177.72mm
$l_2 = l_3 = l_8 = l_9$ => 60.41mm
$l_5 = l_6$ => 125mm

Secondary shear force on the bolts:
Force resisted by bolt1,

$$P_a \times e = \left(\frac{F_{1a}}{l_1}\right) \times [l_1{}^2 + l_2{}^2 + l_3{}^2 + .. l_{1(}$$

$$58680 \times 132.178 = (\frac{F_1}{177.72}) \times [4(l_1{}^2) + 4(l_2{}^2) + 2(l_5{}^2)]$$

$$1944999.27 \times 177.72 = F_1 \times [4(177.72^2) + 4(60.41^2) + 2(125^2)]$$

$$345665270.3 = F_1 \times [172185.06$$
$$F_{1a} = 4015.04$$

$$P_b \times e = \left(\frac{F_{1b}}{l_1}\right) \times [l_1{}^2 + l_2{}^2 + l_3{}^2 + \ldots l_{1(}$$

$$4787672.4 \times 177.2 = F_{1b}[172185.06$$
$$F_{1b} = 9833.146N$$
$$F_1 = 13898.186N$$
$$F_1 = F_4 = F_7 = F_{10} = 13898.186N$$

Similarly,
Force resisted by bolt2:

$$P_a \times e = \left(\frac{F_{2a}}{l_2}\right) \times [l_1{}^2 + l_2{}^2 + l_3{}^2 + \ldots l_{1(}$$
$$1944999.27 = \left(\frac{F_{2a}}{60.41}\right) \times [172185.066]$$

$$F_{2a} = 1364.186N$$

$$P_b \times e = \left(\frac{F_{2b}}{l_2}\right) \times [l_1{}^2 + l_2{}^2 + l_3{}^2 + \ldots l_{1(}$$

$$F_{2b} = 3359.44N$$
$$F_2 = 4724.22N$$
$$F_2 = F_3 = F_8 = F_9 = 4724.22N$$

Similarly,
F_5 =>
$$1944999.27 \times 125 = F_{5a}[172185.066]$$
$$F_{5a} = 1411.99N$$
$$4787672.4 = F_{5b}[172185.066]$$
$$F_{5b} = 3475.67N$$
$$F_5 = 4887.66N$$
$$F_5 = F_6 = 4887.66N$$

Angle between primary and the secondary loads F & P_s:

$$\theta_1 = 25$$
$$\theta_2 = \theta_5 = \theta_8 = \theta_7 = 25$$
$$\theta_3 = \theta_4 = \theta_6 = \theta_9 = \theta_{10} = 7$$

Resultant load on bolt 1

$$R_1 = (P_s{}^2 + F_1{}^2 + 2P_sF_1 \cos\theta)$$
$$R_1 = (188283702.4)$$
$$R_1 = 13725.$$
$$R_1 = (A_b \times \sigma_y) \div (F.O.$$
$$R_1 = 13721.$$

Take F.O.S = 4,

$$13721.65 = (\pi/4 \times d^2) \times 320$$

Diameter of the bolt, d = 14.47 mm.

Nearest standard size = 14 mm (Refer: PSG Design data book)

DESIGN CALCULATION FOR THE SUPPORT BRACKET

Fig.3 SUPPORT BRACKET

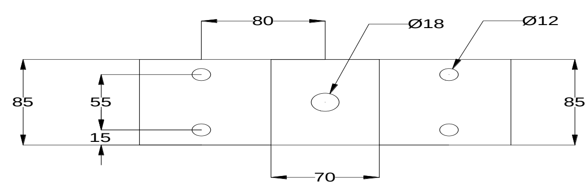

Fig. 4 FRONT VIEW OF SUPPORT BACKET

Taking moment,

$$4 \times 65 = 2(F \times l_1{}^2) + 2(F \times l_2$$

$$4 \times 10^3 \times 6 = 2(F \times 70^2) + 2(F \times 15$$
$$260 \times 10 = 2F(70^2 + 1$$
$$260 \times 10 = F(10{,}25$$
$$F = 25.$$

$= 253.6\ \mathrm{N/n}$

Tensile force taking maximum limit,

$F_2 = F \times$

$= 253.6 \times$

$= 1775$

Directload

$= \frac{40\times}{4}$

$= 100 \times 1$

$$(F_t)_{max} = \frac{F_t}{2} + \frac{1}{2}[(F_t{}^2) + 4(F_s{}^2)]$$

$$= \frac{10000}{2} + \frac{1}{2}[(17752)^2 + 4(10000)^2]$$

$$= 5000 + \frac{1}{2}(315133504 + 4)$$

$$= 18370.9$$

W.K.T,

Where F.O.S = 5

$18370 = \sigma_t \times \pi/4 \times$

$d^2 = 18370 \times 4 \times 5/\pi \times 6$

$d = 13.31\ \mathrm{n}$

Considering

$d = 14\mathrm{n}$

$\sigma = P$

$\sigma = \frac{18370.}{(\pi/4\times 1}$

$= 119.5\ \mathrm{N/m}$

Considering

$d = 12\ \mathrm{n}$

$\sigma = \frac{18370.}{(\pi/4\times 1}$

$= 162.4\ \mathrm{N/m}$

So M12 bolt is selected,

Since the induced stress is less than the allowable stress.

Shear across the plate due to applied force:

$\sigma = P$

$= 17752/(15 \times 1$

$= 118.34\ \mathrm{N/m}$

BOLT PRELOAD CALCULATIONS

Say, external load

P_E = 7 TON.

Plate thickness

= (10 + 8) = 18mm

$\sigma_y = 460\ \mathrm{N/mm^2}$

E = 210 GPa

Additional load

$= P_E \times C$

$C = K_b/(K_b + K$

$$K_b = \left(\frac{\pi}{4}\right) \times d^2 \times$$

$= (\pi/4) \times 14^2 \times 2 \times$

$= 1466.076 \times 10^3\ \mathrm{N/n}$

$= 1466.076 \times 10^3\ \mathrm{N/n}$

$$K_m = \frac{\pi\times E_c\times d}{2\ln[5\times(l_g+0.5d)/(l_g+2.5}$$

$$= \frac{\pi\times 2\times 10^5\times 14}{2\ln[5\times(18+0.5\times 14)/(18+2.5\times}$$

$$= \frac{879.64\times 1}{2\ln(5\times 0.4}$$

$$= \frac{879.64\times}{1.713}$$

$= 513.484 \times 10^4\ \mathrm{N/n}$

$$C = \frac{1466.076\times 10^3}{(1466.076\times 10^3+513.484\times 1}$$

W.K.T,

Additional load $= P_E \times$

$= 7 \times 10^4 \times 0.2$

$= 1554$

Additional load = Final load – Initial load

15540 = x – 0.75x

(Take Final load = x, Initial load=75% of final load)

0.25x = 15540

x = 62160 N

= 6.21 TON

Final load F_L = 6.21 TON

Pre load $P_L = 0.75\times F_L$

= 4.6 TON

E_L = 7 TON

W.K.T,

$F = C\ A_T\ S_P$

$= 0.75 \times (\pi/4 \times (14)^2 \times 0.85 \times 46$

F = 4.5 TON (Pre load tension force)

WELDING STRENGTH CALCULATION FOR CONTROL ARM

Fig. 5 AIR SUSPENSION CONTROL ARM

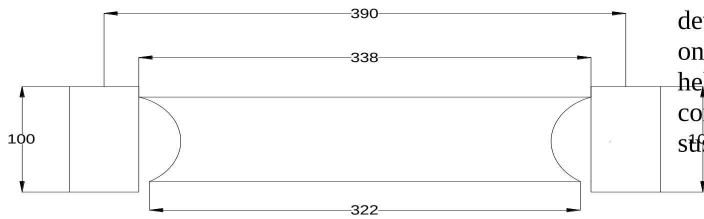

Fig. 6 DRAWING FOR CONTROL ARM

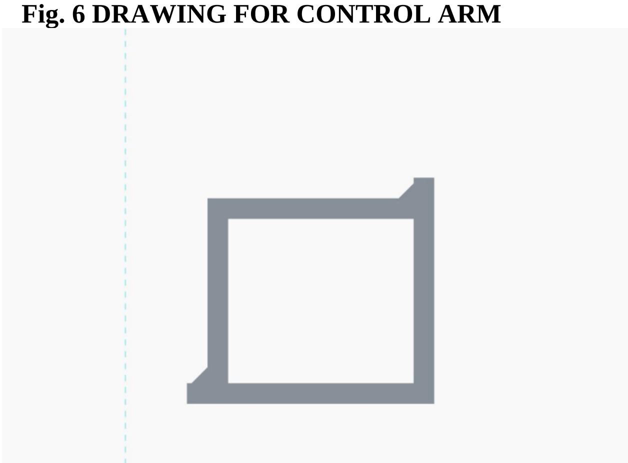

Fig. 7 CROSS SECTION OF CONTROL ARM

Total length of the weld = 330 mm [(95 × 2) + (70 × 2)]

Weld size = 8 × 0.707

= 5.656 mm

W.K.T,

$$\sigma = \frac{P}{2 \times h \times l \times 0.}$$

Where,

Area of the weld A = 2 × h × l × 0.707

= 2 × 5.656 × 330 × 0.707

= 1866.48 mm^2

999 Maximum load supported by the control arm

P = 746592 N

= 746592/8

= 9.3 TON

V. CONCLUSION

A new mechanism for lift axle has been conceptualized, designed, analysed and developed by the AL design team with the help of support functions. The development resulted in cost reduction of Rs 16988/- per axle and weight reduction of 8 Kgs. There is a net saving of Rs 3.4 Crores (Rs 16988 x 2000) approximately per annum for AL business .The development has helped minimizing the dependency on external source for volume supplies. Also it has helped in demonstrating the in-house skill and competence for design and development of lift axle suspension system for multi-axled vehicles.

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Biographies and Photographs

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