DESIGN & ANALYSIS OF STEERING SYSTEM DRAG LINK AGAINST BUCKLING LOADS FOR TIPPER APPLICATION

Yuvraj N. Doke
Scholar, M.E. Mechanical Design, V. V. P. Institute of Engineering and Technology, Solapur, India
Prof. Sameer M. Shaikh
Asst. Professor, Dept. of Mechanical Engineering,V. V. P. Institute of Engineering and Technology, Solapur, India

ABSTRACT

For tipper application, motion from steering wheel transferred to stub axle via steering column, steering gear box, pitman arm, drag link & steering arm to stub axle. Drag links are mainly subjected to compressive loads, which causes buckling failure of drag link tubes. This paper describes calculation of buckling strength for drag link. Also analysis of drag link tubes against compressive loads shown. Relations of various design parameters with buckling strength are shown, which will be useful for optimization of design parameters.

Keywords—design; drag link; ; linkages; steering; buckling; loads; force; analysis.

INTRODUCTION

Drag links are generally made up of hollow tubes with both ends connected by ball joints. Ball joints are spherical shaped, to swivel inside socket connected to pitman arm and steering arm. Motion from steering wheel transferred to stub axle via steering column, steering gear box, pitman arm, drag link & steering arm as shown in Fig.1.

In tipper applications most drag link failures are observed at ball joint & due to bending of tubes. This bending of tubes is caused because of buckling failure of drag link tube against compressive loads.

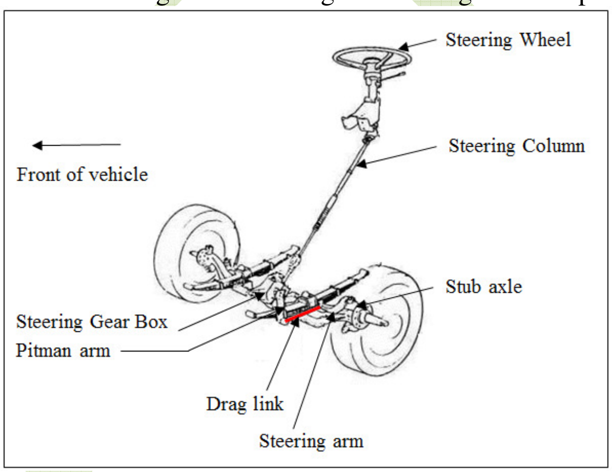

Fig. 1. *Steering system linkages*

Force generated at road wheels is transferred to steering arm. as both ends of drag links are fixed, i.e. one end is fixed in pitman arm & other end is fixed in steering arm. Which causes drag link to act in compressive loads. Failure of drag link due to bending of tubes is of prime concern for this research.

CALCULATION OF BUCKLNG STRENGTH FOR DRAG LINK TUBES AGAINST COMPRESSIVE LOADS

A. *Input for design*

Force at the steering arm ball joint (Fs),

Fs = 2706 Kg

Force generated at steering arm ball joint because of turning forces in dynamic condition is 2706 Kg. For design of drag link against compressive loads, buckling strength must be more than the force generated at steering arm ball joint.

Center to center distance (C) = 785mm

ISSN: 2394-3696
27th Feb-2016

Offset of drag link tube (X) = 34mm

B. Assumptions

Ball joint is a rigid part of drag link tube. There will be no relative motion between ball joint and tube.

C. Calculations

Selecting the diameter of drag link as follows,
Outer diameter of tube (Do) = 50 mm
Inner diameter of tube (Di) = 38 mm

Selecting material st52
Mechanical Properties of st52 material are,
Tensile strength = 520 to 620 N/mm^2
(Reference: PSG design data book p.no. 1.12)
Yield stress = 350 N/mm^2
Yield stress = 35.67 Kg/mm^2

Working Stress (σ) = Yield stress / FOS
= 35.67 / 2
σ = 17.83 Kg/mm^2

Table 1 Chemical Composition For Material St52

Content	%
C	0.22
Si	0.55
Mn	1.60
P	0.050
S	0.050

Moment of inertia,
$I = (\pi / 64) * Do^4 - Di^4$
$= (\pi / 64) * 50^4 - 38^4$
$I = 204.442 * 10^3$ $Kg\text{-}mm^4$

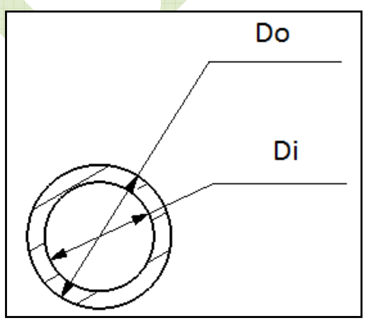

Fig.2 Cross section for drag link tube

Area,
$A = (\pi / 4) * (Do^2 - Di^2)$
$A = (\pi / 4) * 50^2 - 38^2$
$A = 829.38$ mm^2

Radius of gyration,
k = SQRT (I / A)
= SQRT (204.44×10^3 / 829.38)
= SQRT 246.49
k = 15.70 mm

ISSN: 2394-3696
27th Feb-2016

Section modulus,
Y = Do / 2
= 50 / 2
Y = 25mm

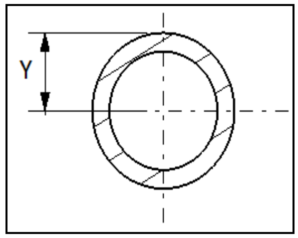

Fig.3. Section modulus for drag link tube

Buckling strength,
By using Rankine's formula for drag link

$$= \frac{(\sigma * A)}{\left(1 + \frac{C^2}{6500 * k^2} + \frac{(X * Y)}{k^2} \right)}$$

$$= \frac{(17.83 * 829.38)}{\left(1 + \frac{785^2}{6500 * 15.70^2} + \frac{(34 * 25)}{15.70^2} \right)}$$

= 3051.38 Kg ~ 3051 Kg

Buckling strength = 3051 Kg

Stress against buckling loading = Buckling strength / area
= 3051 / 829.38
= 3.67 kg/mm^2
= 36.08 N/mm^2 ~ 36 N/mm^2

Stress against buckling loading = 36 N/mm^2

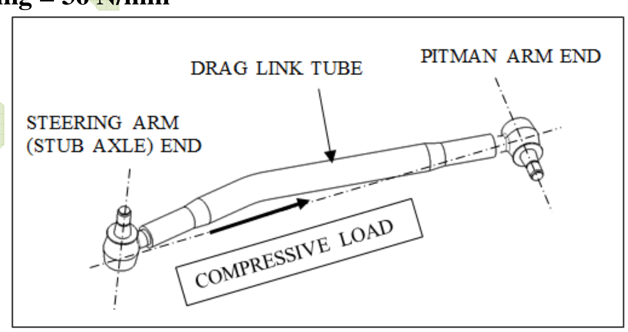

Fig.4 Compressive load on drag link tube

From the above calculations,
Force at the steering arm ball joint = 2706 Kg.
Buckling strength or Load = 3051 Kg.
As Buckling strength or Load > Force at the steering arm ball joint,
Hence design is safe.

ANALYSIS

D. *Modeling of drag link as per design dimensions*

Modeling of drag link is a preprocessing part of analysis. The model gives clarity about how the part will look like physically.

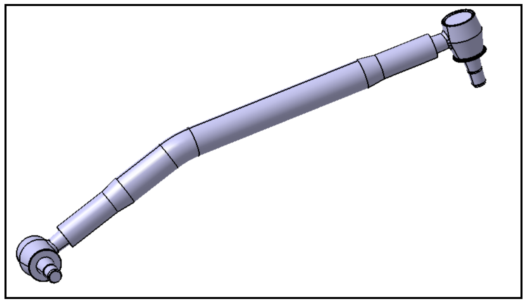

Fig.5 Three dimensional model of drag link as per design dimensions

E. *Meshing*

Meshing is second step for preprocessing. Fig.6 shows meshing of three dimensional model

Fig.6 Meshing of three dimensional model

F. *Setting design parameters*

Material as st52 assigned for further analysis. with properties as specified in section II - B .

G. *Apply fixed support & load*

Fixed support is selected as shown in Fig.7

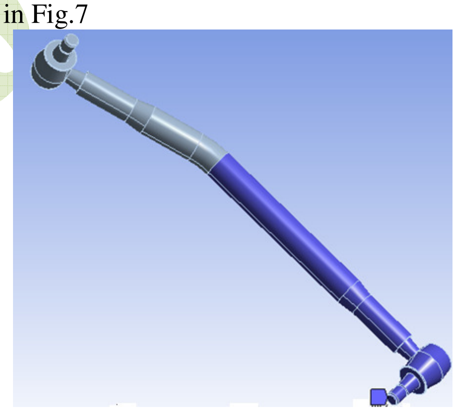

Fig.7 Fixed support

Compressive Load 3051 Kg = 29931 N applied on drag link tube as shown in Fig.8.

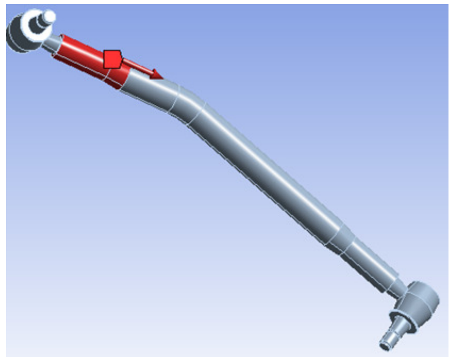

Fig.8 Compressive load on drag link tube

Analysis for stresses

Maximum principal stress = 35.345 N/ mm^2

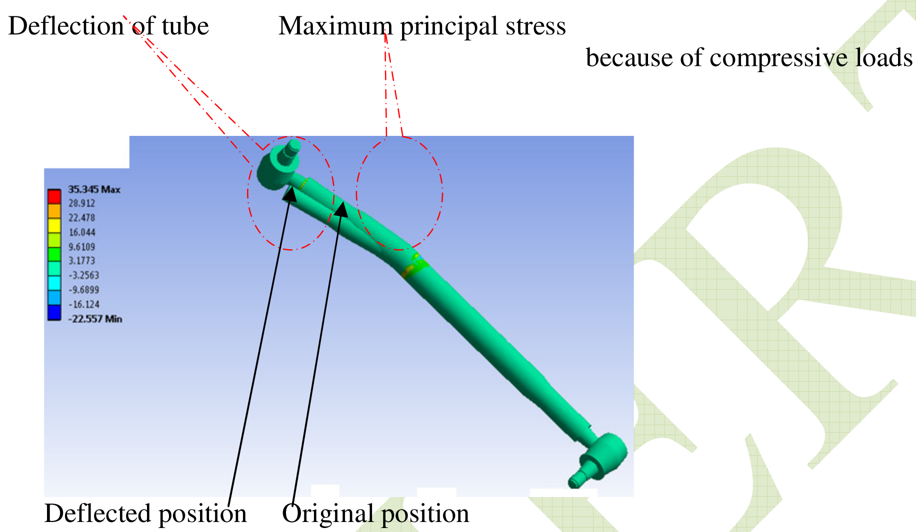

Fig.9 Maximum principal stress

RESULT

H. Results of theoretical calculations

1) Force at the steering arm ball joint (Fs),
   Fs = 2705.91 Kg
2) Buckling strength or Load = 3051 Kg
3) Stress against buckling loads = 36.08 N/mm^2

I. Results of analysis

1) Maximum principal stress = 35.345 N/mm^2
2) Minimum principal stress = 4.74 N/mm^2
3) Total deformation = 0.11991
4) Equivalent stress = 184.99 N/mm^2

RESULTS INTERPRETATION

Based on results obtained, few more calculations have done, by changing various design parameters. This will be useful to correlate the design parameters with the buckling strength. Following are the relation of design parameters with buckling strength gives clarity & perfect base for optimization. If the required buckling strength is less than the available or vice versa, by using the relations obtained designer can change parameters in accordance with the need.

ISSN: 2394-3696
27th Feb-2016

J. *Outer diameter of tube Vs. Buckling strength*

Table 2 Buckling Strengths For Outer Diameters

Outer diameter of tube (mm)	Buckling strength (Kg)
35	1330
40	1836
45	2411
50	3051
55	3750
60	4503
65	5306
70	6156

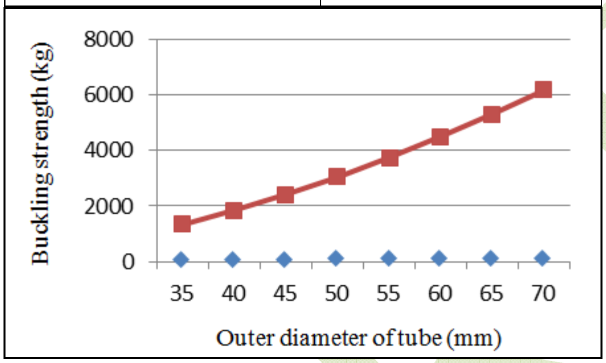

Fig.10 Graph outer diameter of tube Vs. Buckling strength

Thickness of tube Vs. Buckling strength

Table 3 Buckling Strengths For Tube Thickness

Thickness of tube (mm)	Buckling strength (Kg)
4	2261
5	2681
6	3051
7	3374
8	3654
9	3895

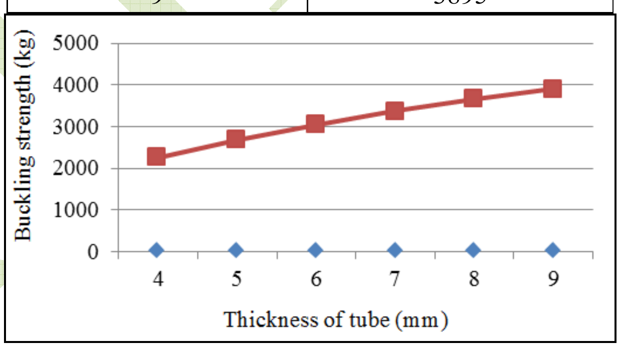

Fig.11 Graph outer diameter of tube Vs. Buckling strength

Offset of tube Vs. Buckling strength

Table 4 Buckling Strengths For Tube Offsets

Offset of tube (mm)	Buckling strength (Kg)
30	3329
32	3184
34	3051
36	2928
38	2815

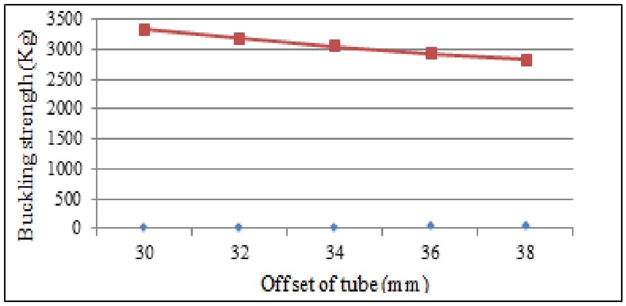

Fig.12 Graph outer diameter of tube Vs. Buckling strength

CONCLUSION

- A detailed design procedure for the calculation of drag link tubes buckling strength shown.
- Outer diameter of tube is directly proportional to buckling strength.
- Thickness of tube is directly proportional to buckling strength.
- Offset of tube is inversely proportional to buckling strength.

Acknowledgment

We would like to express our sincere thanks to our friends Mr.Amol Gavada & Mr. Mahesh Patil for providing most useful support for completion of this research, apart from being a constant source of motivation.

References

[1] Gang Qin, Ying Sun, Yunqing Zhang and Liping Chen, "*Analysis And Optimization Of The Double-Axle Steering Mechanism With Dynamic Loads*", The Open Mechanical Engineering Journal, (Suppl 1-M2), Issue 6, 2012, P.No. 26-39.

[2] Abdullah F. Al-Dwairi, "*Design Of Centric Drag-Link Mechanisms For Delay Generation With Focus On Space Occupation*", Journal Of Mechanical Design, Vol. 131 / 011015, January 2009.

[3] Yousif E. A. Bagadi , Abdelwahab M. Fadol & Prof. Gao Deli, "*A Study On Effect Of Drag & Torque On Buckling Of Drillstring In Horizontal Wells*", IJRRAS , Volume 11,Issue 1, April 2012, P. No. 121-131.

[4] Kiran S Sankanagoudar, Dr.H.K.Amarnath, Prashant D. Bagalkot, Mukund Thakur, "*Finite Element Analysis Of Tie-Rod For Spacecrafts*", Ijates, Volume No.2, Issue No. 06, June 2014, P. No. 299-307.

[5] Thomas D. Gillespie, "*Fundamentals Of Vehicle Dynamics"* , Society Of Automotive Engineers,Inc. 400 Commonwealth Drive, Warrendale, Pa 15096-0001.

[6] Dr.Kripal Singh, "*Automobile Engineering*", Standard Publishers Distributors, Delhi, Vol.1, Edition 2004.

[7] Douglas C. Montgomery, "*Design and Experimentation Analysis of Experiments*", Jhon Willy And Sons, 5th Edition, 2000.

[8] Klaus-Jurgen Bathe, "*Finite Element Procedures*", Prentice Hall Of India Pvt. Ltd. New Delhi, Edition 2007.

[9] Faculty of Mechanical Engineering PSG College, "*Design Data: Data Book Of Engineers*", Kalaikathir Achchagam, Coimbatore, Edition 1978.

[10] V.B. Bhandari, "*Design of Machine Elements*", Tata Mcgrew Hill Publishing Company Ltd., New Delhi, 2nd Edition, 2007.