Use of Side Door Intrusion Test Facility for TYRE Strength Test

Amey G Badar, Sagar B Bangar, Vinayak Sudalai

Abstract— For the certification of any tyre to be declared legal and safe to be used on roads it is mandatory that it is tested at an accredited homologation lab. One of the mandatory test for this purpose is the plunger test where the tyre is tested for its strength. Also present in homologation labs is the side door intrusion test which is in use less frequently. This paper deals with the design, fabrication and testing of an adapter assembly by which we are able to increase the utility of the side door intrusion test facility by using it to conduct the tyre strength test. This project was conducted at the Homologation lab at The Automotive Research Association of India (ARAI), Pune. The ARAI is a Research Institute of the Automotive Industry with the Ministry of Heavy Industries & Public Enterprises, Government of India.

Index Terms— Adaptor, Automotive Certification, Plunger Test, Side-door Intrusion test, Tyre strength test.

I. INTRODUCTION

ARAI has been providing various services to the Indian Automotive Industry in the areas of design & development and know-how for manufacture & testing of components / system to national / international standards for which it needs to perform various tests. The SHL division conducts the following tests in regards to tyres:

- Endurance test
- Tyre Strength test
- Bead Unseating Resistance test

There is usually Heavy load on the Plunger testing facility. Hence there is a need to distribute the load on a new test rig. This can be done with minimum cost and with minimum changes to the existing shop floor layout by the following solution:

- The Safety and Homologation Lab has a Side door intrusion test rig used to conduct side impact tests on vehicles to test for safety.
- This test facility has comparatively less load than the Plunger test facility.

Hence, an adapter assembly can be used to conduct the Plunger test on the side-door intrusion test rig.

II. THE TYRE STRENGTH TEST

In India, all tyres to be safe and hence road legal, they should satisfy the norms laid down in INDIAN STANDARD [IS 15633:2005].

A section of the above said standard is as follows:

AUTOMOTIVE VEHICLES — PNEUMATIC TYRES FOR COMMERCIAL VEHICLES — DIAGONAL AND RADIAL PLY — SPECIFICATIONS

ANNEX G

(*Clause* 4.6.1)

TYRE STRENGTH TEST (PLUNGER TEST)

- *Apparatus :*

The equipment consists of a cylindrical steel plunger, having a hemispherical end of a diameter specified in Table (1) and a device to force the plunger rod into a tyre at the rate 50 ± 1.5 mm/min.

- *Preparation of Tyre for the Test :*

The tyre with a tube shall be mounted and inflated on a test rim of the recommended size and shall be conditioned at approximately the temperature of the room in which the test is to be conducted for at least 3 hours after which the pressure shall be adjusted, if necessary, to the test inflation pressure specified in Table (1).

SR No. (1)	Tyre Size Nominal Section Width (2)	Plunger Diameter mm (3)	Inflation Pressure kPa (4)	Minimum Breaking Energy J(Kg-cm)
(i)	Under 160	19 ± 1.6	180 ± 5	220 (2245)
(ii)	160 or more	19 ± 1.6	180 ± 5	295 (3010)

Table (1)

The plunger rod shall be forced into the tread of the tyre/wheel assembly mounted perpendicularly/horizontally over a tread element at the centre line of the tread, or as near as possible to avoiding penetration into a tread groove. The rate of travel of the plunger; shall be 50 ± 1.5 mm/min until the tyre breaks or the plunger is stopped by the rim (bottoming of the plunger against the rim), in which case the tyre shall be deemed to have passed the test regardless of energy value. Measurement of force and penetrationat break (or bottoming against the rim) shall be made at 5 points nearly equally spaced around the tyrecircumference. The arithmetic mean energy absorbed shall be calculated from the five energy values obtained at the break, using the formula:

$$W = \frac{F \times P}{2} \times 10^{-3} \quad \ldots(1)$$

W= energy at break (or bottoming), in J (Joule)

F = force at break (or bottoming), in N; and

P = penetration at break (or bottoming), in mm.

As an option, for purpose of conformity, if the plunger energy measurements meet or exceed the minimum value

Manuscript received on April, 2013.

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specified, it is not necessary to continue penetration of the plunger to break the tyre.

III. DESIGN

A. Design Of Shaft:

M_c=0
(R_B x 441.5) + (10000 x 763) =0
R_B= -17281.99 N
ΣF_Y= 0
∴ R_C=7281.99 N

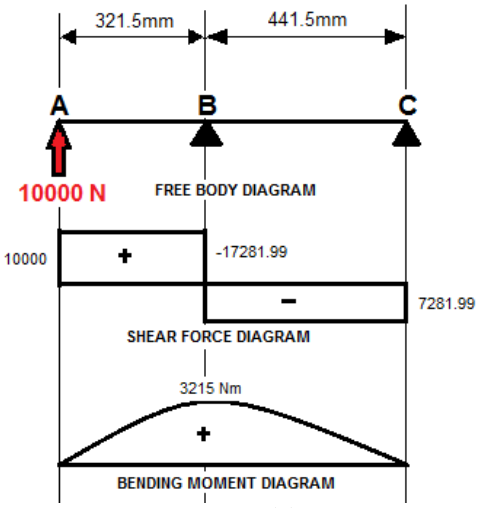


Fig (2)

Bending Moment @ A= 0
Bending Moment @ C= 0
Bending Moment @ B = (10000 x 0.3215) Nm

$C = P \times (L_{10})^{0.3}$

$= 18000 \times 60^{0.3}$
C =61477.74 N

= 3215 Nm

ASME code:
Maximum Shear stress theory:
Material: Mild Steel
S_{yt} = 400N/mm^2
τ_{max} = 0.30 x S_{yt}
=120 N/mm^2

K_b= Bending Factor
=1.5 (for gradually applied load)

$\tau_{max}=\frac{16(Kb.Mb)}{\pi d^3}$

$120=\frac{16(1.5*3215*10^3)}{\pi d^3}$

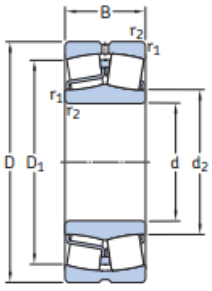
=58.9mm ≈ 60mm
N_f =1.8
Diameter=(60*1.8)mm
Diameter of shaft=110mm

B. Selection Of Bearing:

Notations:
L_{H10}= Life in hours of 90% bearings
n = Speed of shaft in rpm
L_{10} = Life in million revolutions of 90% bearings
P = Load (force) on bearings in Newton
C = Dynamic Load bearing Capacity

Calculations:
L_{H10}= 10000 Hrs
Force= 18 kN
n= 100 rpm
$L_{10}= (60nL_{H10})/10^6$
$= (60x100x100000)/10^6$
= 60 million revolutions

Spherical roller bearings
d **85 – 130** mm

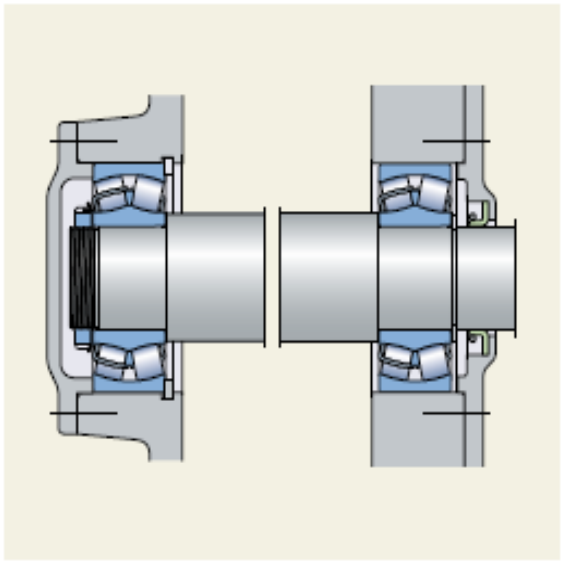


Cylindrical bore

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed ratings Reference speed	Limiting speed	Mass	Designations Bearing with cylindrical bore	tapered bore
d	D	B	C	C_0	P_u					
mm			kN		kN	r/min		kg	–	
100	150	50	285	415	45,5	2 800	4 000	3,15	24020 CC/W33	24020 CCK30/W33
	165	52	365	490	53	3 000	4 000	4,55	23120 CC/W33	23120 CCK/W33
	165	65	455	640	68	2 400	3 200	5,65	24120 CC/W33	24120 CCK30/W33
	180	46	425	490	49	3 400	4 500	4,90	22220 E	22220 EK
	180	60,3	475	600	63	2 400	3 400	6,85	23220 CC/W33	23220 CCK/W33
	215	47	425	490	49	3 400	4 500	8,60	21320 E	21320 EK
	215	73	815	950	88	2 400	3 000	13,5	22320 E	22320 EK

Fig (3) Bearing Used: 22220E (SKF)

Fig (4)



Fig(5)

C. Adapter Sleeve: H320 (Skf)

Adapter sleeves for metric shafts

Principal dimensions d_1	d	d_3	B_1	G	Designations Adapter sleeve with nut and locking device	Appertaining lock nut	Appertaining locking device	Appropriate hydraulic nut
mm					-	-		
90	100	130	71	M 100x2	H 320	KM 20	MB 20	HMV 20 E

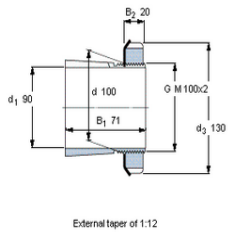
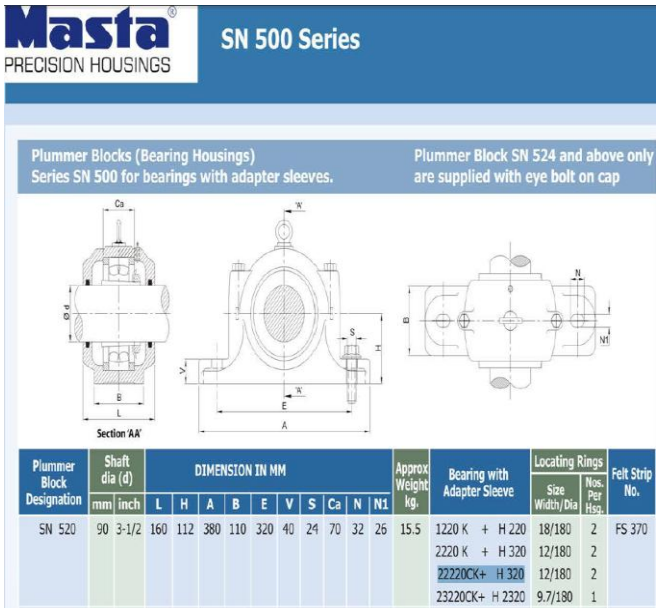


Fig (6)

D. Bearing Housing:



Plummer Block Designation	Shaft dia (d) mm	Shaft dia (d) inch	DIMENSION IN MM L	H	A	B	E	V	S	Ca	N	N1	Approx Weight kg.	Bearing with Adapter Sleeve	Locating Rings Size Width/Dia	Locating Rings Nos. Per Hsg.	Felt Strip No.
SN 520	90	3-1/2	160	112	380	110	320	40	24	70	32	26	15.5	1220 K + H 220	18/180	2	FS 370
														2220 K + H 320	12/180	2	
														22220CK+ H 320	12/180	2	
														23220CK+ H 2320	9.7/180	1	

Fig (7)

E. Design Of Frame:

Width (B) of Bearing on Face Plate = 46 mm
Minimum Thickness required= 46 mm.
Safety analysis of plate and adapter by Finite Element Analysis:

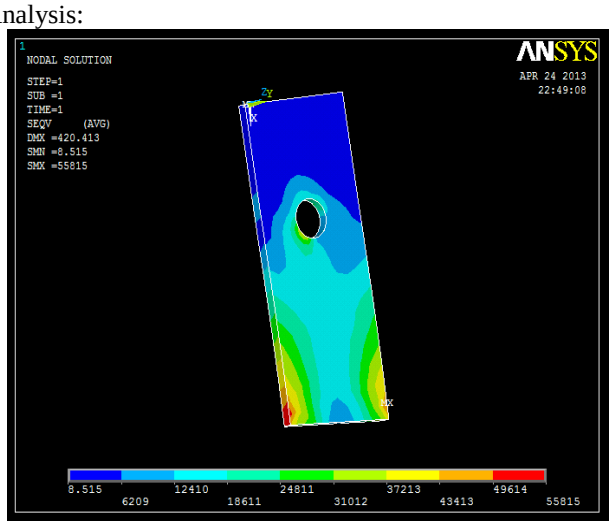


Fig (8)

F. Design Of Connecting Bolts:

Notations:
S_{yt}= Maximum yield strength
σ_{all}= Maximum allowable tensile stress
d= diameter of bolts
n= number of bolts
Calculation:
$S_{yt}=400N/mm^2$
$\sigma_{all}=400/3 = 133.33N/mm^2$
n= 4

$$\sigma_{all} = \frac{20000}{\left(\frac{\pi}{4}\right)\cdot d^2 \cdot n}$$

$\therefore d=6.9mm$
$\approx 8mm$

IV. EXISTING FACILITY

Fig (9)

V. FINAL DESIGN AND ASSEMBLY:

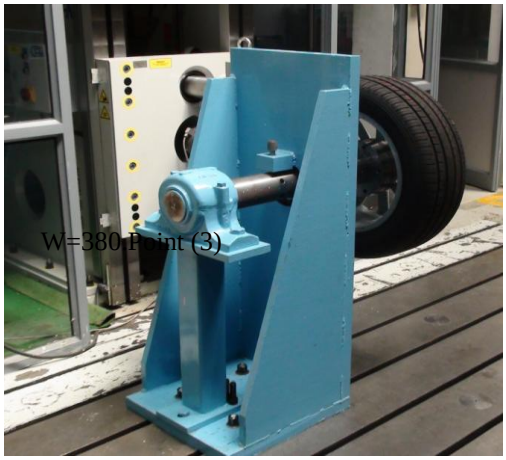


Fig (10.A)

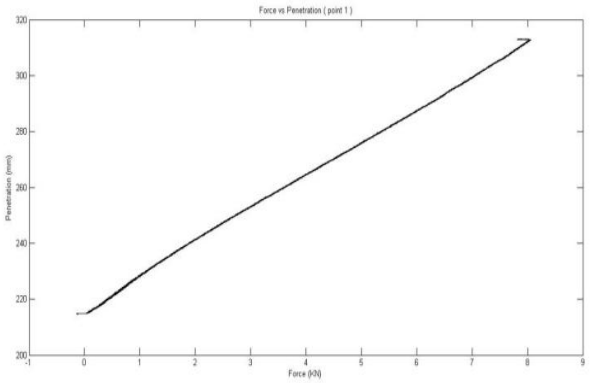
Fig (10.B)

VI. TESTING AND CALCULATIONS:

Name of Manufacturer: Pirelli Tyres
To be used on: Sports Utility Vehicle (SUV)
Test Tyre Specifications:
Section width in mm: 235mm
Aspect ratio: 55
Type of ply: Radial
Maximum Load Rating: 775Kg @ 51psi
Test is performed according to Indian Standard as mentioned on page (1).

VII. RESULTS

Point (1)
Penetration=98.203 mm
Force=7.82347 kN



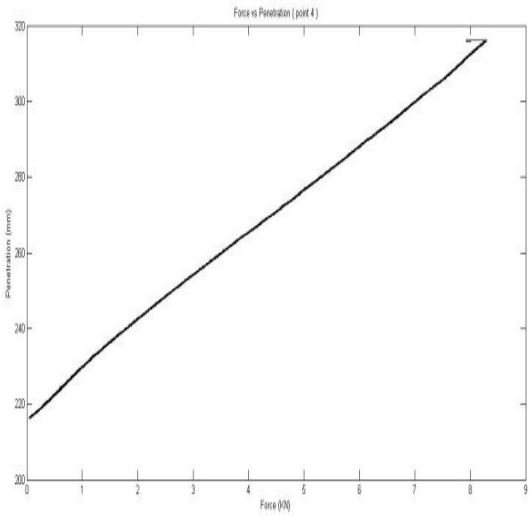
W=384.121 J

Point (2)
Penetration=99.05 mm
Force=7.68053 kN

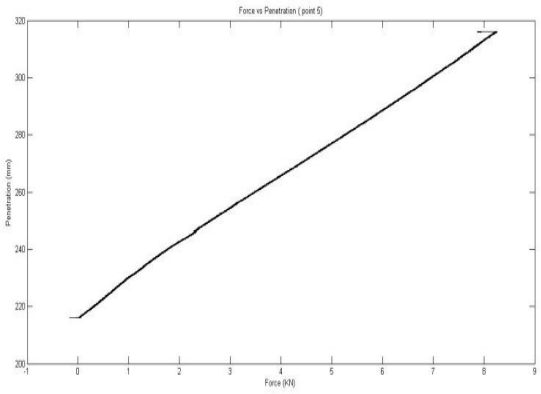
Penetration=99.708mm
Force=8.05259kN

W=401.453 J

Point (4)
Penetration=99.628mm
Force=7.93056kN



W=395.052 J
Point (5)
Penetration=99.937mm
Force=7.90184kN



W=394.84 J
Arithmetic Mean

$$= \frac{384.121+380.378+401.453+395.052+394.84}{5} =$$

391.169 J

Value of Minimum Breaking Energy given in Indian Standard: 295 J (Ref. Table 1)

∴Tyre has PASSED strength test.

VIII. CONCLUSIONS

(1) The adapter assembly has been designed, fabricated and tested successfully.
(2) Load on existing Plunger testing machine has reduced significantly. Thus time of testing entire lot has decreased.
(3) The utility of Side-door Intrusion test rig has increased.

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