Failure analysis of clutch disc in a two-ton truck

Análisis de falla del disco de embrague de un camión de 2 ton

Recibido: 12-03-2013 Aceptado:19-04-2013

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Abstract

This article presents the failure analysis of a clutch disc in a two-ton truck. The failure part was made of high-carbon steel for springs. Although the failure surface was very thin and difficult to interpret, the fracture surface examination revealed chevron marks and the presence of faint beach marks. The failure parts were made of hardened 1070 carbon steel. The cushioning plate experienced shear and bending alternating stress. The end failure is caused by shock load.

Keywords: Truck, Transmission, Clutch, Failure analysis.

Resumen

Este artículo muestra el análisis de la falla presentada en el disco de embrague de un camión para transporte de 2 Ton. El elemento que presentó la fractura estaba fabricado de acero para resortes de alto carbono. Aunque la zona de falla era muy delgada y de difícil interpretación, el examen de la superficie de fractura reveló marcas chevron y presencia mínima de marcas de playa muy tenues. La parte de falla (cushioning plate), fabricada de acero al carbono 1070 templado, estaba sometida a esfuerzos alternantes cortantes y flexión. La falla final fue causada por carga de impacto.

Palabras clave: Camión, Transmisión, Embrague, Análisis de falla.

Introduction

The primary objective of this analysis is to determine the root cause of automotive clutch disc's failure which has operated 56000 Km (approximately 1550 hours of service or 170000 cycles). The root cause can normally be assigned to design, materials, parts manufacturing, assembly faults, operating habits and/or maintenance problems. For design case some common failures found in mechanical parts include fatigue as a result of stress concentrations. For manufacturing case any failure can be misalignment or mismatch of mating parts. The failure due material quality may originate on undesirable micro structural conditions such as: Porosity, inclusions and others micro structural defects. For operating conditions case is a wide topic because it depends on the driver operating habit.

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The second purpose of this failure analysis is to establish operational rulers that prevent premature failure of automotive mechanical transmission parts.

In trucks, the clutch disc is located between the engine and the gearbox. Then the clutch disk is transmitting varying torsion loads between the flywheel and the gearbox, as illustrated in Figure 1.

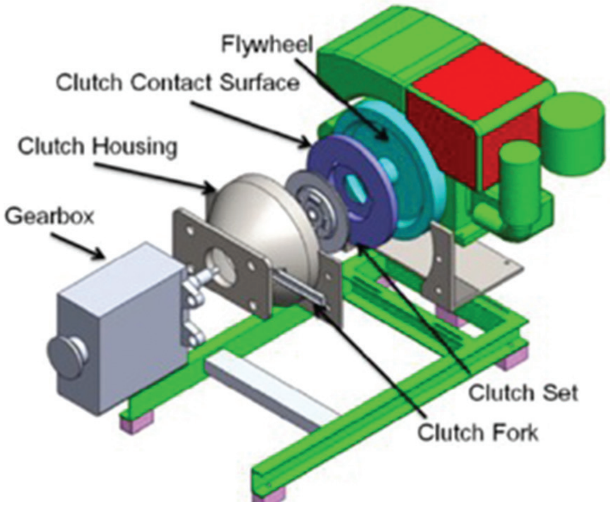


Figure 1. Engine – clutch – gearbox assembly (Koocharoenprasit, 2011)

The parts of clutch disc assembly are named by (EXEDY, 2010) shown in Figure 2.

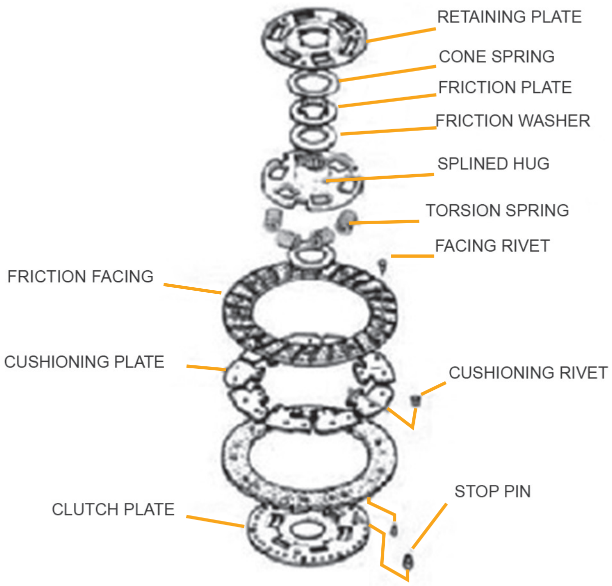


Figure 2. Clutch disc assembly.
Font: EXEDY, 2010

The cushioning plate was transmitting varying loads and presented the fault shown in Figure 3.

Figure 3. Failure parts

Materials and methods

Loads

The principal specification of the selected diesel engine shows in Table 1.

Table 1. Engine technical data

Engine parameters	Value
Maximum power	92 HP / 3600 RPM
Maximum torque	20.6 Kg-m / 2300 RPM

For establish the variation of loads we have SAE J227 urban driving cycle, which includes the accelerations, cruising speed, deceleration, braking and stops. This cycle is named in (Gclunavic, 2011) shown in Figure 4 and Table 2.

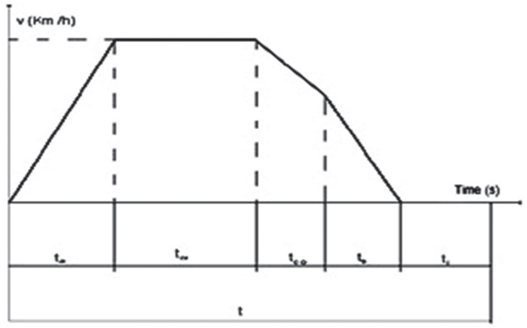


Figure 4. SAE J227 CYCLE

Table 2. Values for the cycle SAE J227

	A	B	C	D
V	16±1.5	32±1.5	48±1.5	72±1.5
ta	4±1	19±1	18±2	28±2
tcr	0	19±1	20±1	50±2
tco	2±1	4±1	8±1	10±1
tb	3±1	5±1	9±1	9±1
ti	30±2	25±2	25±2	25±2
T	39±2	72±2	80±2	122±2

We can choose column B according to (Moller, 2006) for Cali city.

If we set the daily journey of the vehicle in 170 Km and clutch disc was under fully reversed loads, we have the following cycle's number, shows in Table 3:

Table 3. Calculation of cycle's number

For V = 32 Km/h		
	t (s)	x (m)
ta	19	84,4
tc	19	168,9
tda+tb	9	79,2
ti	25	
Tot	72	332,3
Daily Journey (km)		172
Cycle's number (Day)		518

To find the maximum stress on the failure parts, first it finds the shear V. Shows in Figure 5:

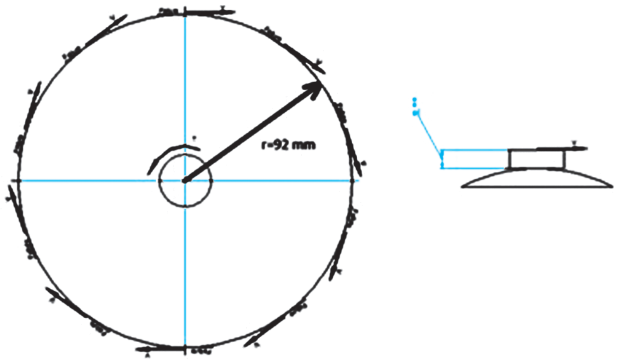


Figure 5. Free body diagram

$$V = \frac{T}{10.r} = \frac{20.6\_Kg-m}{10x0.092\_m} = 22.4\_Kg = 219.5N$$

The shear stress is $\tau = \frac{V}{A} = \frac{219.5\_N}{(0.001*.003)\_m^2} = 7.3\_MPa$

The bending stress is

$$\sigma = \frac{Mc}{I} = \frac{219.5*0.01*0.015\_Nm^2}{2.14e-9\_m^4} = 15.4\_MPa$$

Then the stress state by Von Mises:

$$\sigma = \sqrt{\frac{(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_z-\sigma_x)^2+6(\tau_{xy}{}^2+\tau_{yz}{}^2+\tau_{zx}{}^2}{2}}$$

Is $\sigma_a = \sqrt{15.4^2+6*7.3^2} = 23.6\_MPa$

Now according to (Shigley & Mitchel, 1983), the hardened 1070 steel is not recommended for shock load applications and $S_{ut} = \frac{A}{d^m}\_m = 0.186\_A = 1880\_MPa$

Then $S_{ut} = \frac{1880}{d^{0.186}} = 1898\_MPa$ And the fatigue limit is:

$$S_{e'} = 0.25S_{ut} = 0.25*1898 = 475\_MPa$$

According to (Shigley & Mitchel, 1983) the correction factors of fatigue limit are:

$$C_{Size} = 1.189d^{-0.097} = 0.189*0.184^{-0.097} = 0.71$$

For hot rolled material

$$C_{Surface} = AS_{ut}{}^{b}\_A = 57.7\_b = -0.718$$

$C_{Surface} = 57.7*1898^{-0.718} = 0.26$ Then:

$$S_e = C_{Size}C_{Surface}S_{e'} = 0.71*0.26*475 = 88\_MPa$$

Our specimen has notches sensibility and according to (Shigley & Mitchel, 1983) Kt = 1.6 and

$q = \frac{1}{1+\frac{0.04}{\sqrt{5}}} = 0.98$ Then:

$K_f = 1+0.98(1.6-1) = 1.6$; Therefore,

$$\frac{S_e}{K_f} = \frac{88}{1.6} = 55\_MPa$$

And finally, the safety factor is: $SF = \frac{55}{23.6} = 2.3$ This indicates that the design is good.

Macroscopic analysis

An initial macroscopic observation was conducted to identify possible contributing factors to the failure. In parts from clutch was observed:

- The friction facing (see Figure. 2) not have wear, because likes new, as shows in Figure. 6.
- The broken parts (cushioning plate) are thin sheets of carbon steel, with a lot of oxidation shown in Figure 3.

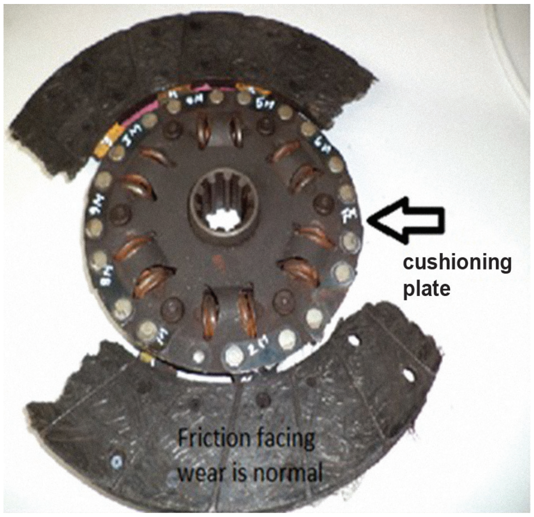


Figure 6. Friction facing

Selection of specimens for microscopic analysis

The clutch assembly is dismantled and selected 14 pieces with the presence of failure, shown in Figure 7 and Table 3, for:

1. The study of fractured surface by visual observations.
2. One specimen was removed for metallographic analysis, and
3. One specimen was removed for hardness measurement.

Figure 7. Cushioning plate from clutch disc.

Table 4. Overall dimensions from cushioning plate (mm)

Name	Length	Height	Thickness
#M	40	15	0.95
#	60	55	0.95

Results

Examination of fracture surface

Since this component is very thin (0.95 mm), the beach marks (Avner, 1987) are not well defined, but can see in Figure 8. The end fault zone is very large.

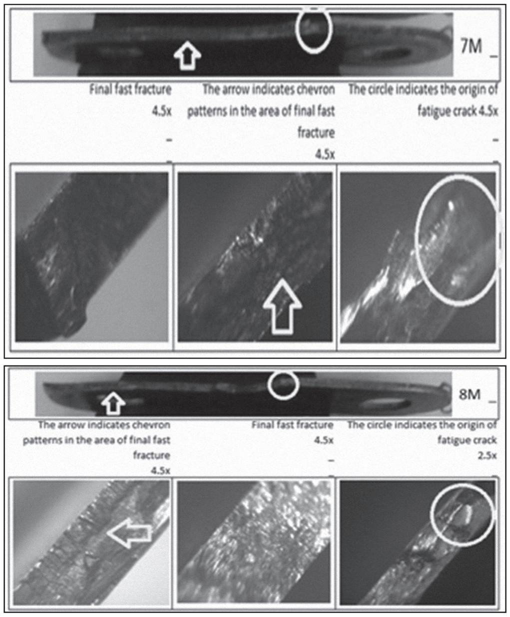


Figure 8. Fracture surface

Metallography

Metallography results reveal that structure is mainly tempered martensite, with some free ferrite (White) as seen in the (ASM INTERNATIONAL, 1992a) and Figure 9

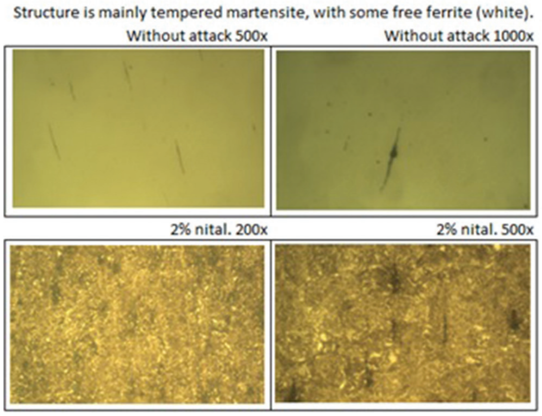
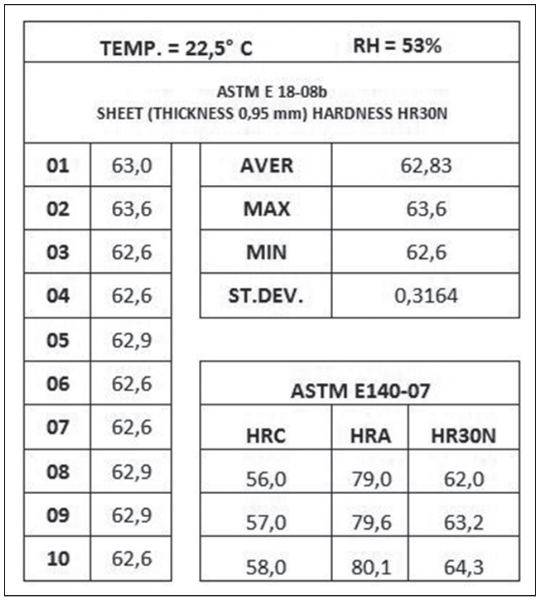


Figure 9. Metallography

Hardness

According to the results of the Metallography and the hardness of the cushioning plate; the material is hardened 1070 carbon steel according to the Figure 9, Table 5 and (ASM INTERNATIONAL, 1992)

Table 5. Hardness



TEMP. = 22,5° C RH = 53%

ASTM E 18-08b
SHEET (THICKNESS 0,95 mm) HARDNESS HR30N

01	63,0
02	63,6
03	62,6
04	62,6
05	62,9
06	62,6
07	62,6
08	62,9
09	62,9
10	62,6

AVER	62,83
MAX	63,6
MIN	62,6
ST.DEV.	0,3164

ASTM E140-07		
HRC	HRA	HR30N
56,0	79,0	62,0
57,0	79,6	63,2
58,0	80,1	64,3

Conclusions and Recommendations

From the failure analysis, the following conclusions and recommendations can be made:

- The initial failure was presented in cushioning plate by fatigue loads and then was accompanied by a sudden fracture.
- The driver can generate the shock load of ultimate failure.
- The surface finish of the cushioning plate can be improved by blasting.
- It is recommended that when starting a vehicle is made smoothly.
- It is recommended that automotive marketers provide training on the operation to users.
- The Metallography reveals inclusions in the materials.

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