Ain Shams Engineering Journal (2012) 3, 279–287

Ain Shams University

Ain Shams Engineering Journal

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MECHANICAL ENGINEERING

Automotive brake pipes characteristics and their effects on brake performance

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Received 29 March 2011; revised 12 February 2012; accepted 14 February 2012
Available online 26 March 2012

KEYWORDS
Brake pipes;
Characteristics;
Efficiency;
Force balance;
Inner diameter

Abstract During the operation of the brakes the behavior of the brake fluid in the brake piping is one element that has a large effect on feel and on transient pressure characteristics. This paper investigates the effect of fitting a brake pipe with different inner diameters to each wheel at the rear axle on the brake performance.

Theoretical analysis and road tests were conducted and applied on a Fiat 128 vehicle to investigate the changes in brake efficiency and brake force balance.

The theoretical and experimental results showed the improvement of the car brake efficiency and the brake balance when fitting a brake pipe with the same inner diameter for each rear wheel.

1. Introduction

The improvements seen in the power and dynamic performance of vehicles in recent years have made the enhancement of braking performance an important issue. Attaining better braking performance requires improvements in the characteristics of the various elements of the brake system as well as optimization of the overall system. The distribution of the brake fluid pressure between axle wheels is one element that has a large effect on braking performance and vehicle dynamic behavior during braking [1,2]. Khan et al. [3] presented models of analytic dynamics for vehicle brake system with proportioning valve. Fitting one load sensing valve for each wheel at rear and front axle improves brake efficiency for the vehicle in its straight motion and in its cornering motion depending on the variation of load distribution, road curvature and moving speed [4,5]. Ahn and Park [6] introduced a new braking force distribution control system that improves vehicle dynamics behavior during braking through the generation of a yawing moment by adjusting the distribution of braking force to all four wheels. Marting and Colarelli [7] investigated the measurement of brake force on each wheel to determine brake balance. It also provides a measure of side to side variation on both the front and rear axle. Imbalance side to side can spot a potential handling problem in a panic brake application. Antanaitis et al. [8] introduced the basic construction of automotive brake hoses, the test meth-

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Peer review under responsibility of Ain Shams University.
doi:10.1016/j.asej.2012.02.002

Production and hosting by Elsevier

Nomenclature

A_{mc}	master cylinder cross-section area	H	pressure head
a	distance from vehicle center of gravity to the front wheels center	h_f	non-constant viscosity resistance
B_f	brake factor	h	height of center of gravity
b	distance from vehicle center of gravity to the rear wheels center	J	complex number
c	velocity of sound	k	volume elastic modulus of brake fluid
F_{xf}	brake force on front axle	p	average pressure at piping cross section
F_{xr}	brake force on rear axle	Q	flow rate
F_{xlf}	brake force on front left wheel	L	wheel base
F_{xrf}	brake force on rear right wheel	R	tire radius
F_{xrl}	brake force on rear left wheel	r	drum or effective disk radius
F_{xrr}	brake force on rear right wheel	t	time
$F_{xf,\max}$	maximum brake force on front axle	u	average flow velocity at piping cross section
$F_{xr,\max}$	maximum brake force on rear axle	V	vehicle longitudinal speed
F_y	centrifugal force	W	vehicle weight
F_{zf}	vertical force on the front axle	x	axial coordinates of piping
F_{zr}	vertical force on the rear axle	$\ddot{x}$	deceleration (m/s^2)
F_{zlf}	normal force on front left wheel	Z	deceleration (g-units)
F_{zlr}	normal force on rear left wheel	ρ	brake fluid density
F_{zrf}	normal force on front right wheel	μ	coefficient of ground adhesion
F_{zrr}	normal force on rear right wheel	η	braking efficiency
g	acceleration of gravity	η_c	wheel cylinder efficiency
		ϕ_f	front brake force ratio
		ϕ_r	rear brake force ratio

odologies and test results used to quantify brake hose fluid consumption under various operating conditions, and it illustrates the influence of hose performance on the vehicle – level using simple analysis on sport car. Aliabadi et al. [9] performed stress analysis by FEM to the crimped portion of hydraulic pressure brake hose in order to promote the development of the automobile hoses more efficiently. In [10] new analysis procedure has been developed to evaluate a brake system performance based on analysis of transient characteristics and frequency characteristics in the brake piping. Using this procedure, analysis were made on the effect of ABS operation on brake pressure changes and on the influence of the orifice on the pressure transmission characteristics.

The aim of the present paper is to investigate the effect of fitting a brake pipe with different inner diameters to each wheel of the car at rear axle on brake efficiency and brake force balance between wheels, as compared to the conventional case of fitting the same inner diameter to each wheel on the rear axle.

2. Theoretical analysis

This section can be divided, into two main groups: dynamic characteristics analysis procedure of brake piping influence of the orifice on the pressure transmission characteristics and braking force distribution for each wheel. The details of each group is given below.

2.1. Dynamic characteristics analysis of brake piping analytic model

Fig. 1 shows the brake piping system model that was used in transient characteristics analysis of anti-lock brake. Details about this analytic model are given in [10].

The following assumptions were made in applying the characteristics curve method.

1. Flow in the piping is laminar.
2. Since flow in the piping is symmetric to the axis, radial flow can be ignored.
3. The temperature of the brake fluid is constant.
4. The basic equations of motion that are to be solved are obtained by applying the foregoing assumption to the Navier–Stokes equation and continuity, which are the basic equations of flow.

$$g\frac{\partial H}{\partial x} + U\frac{\partial U}{\partial t} + gh_f = 0 \qquad (1)$$

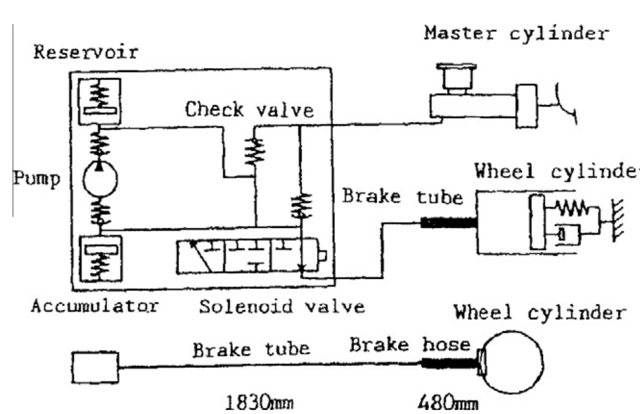

Figure 1 Analysis model of anti-lock brake system [10].