

A Case Study of Reaction Time Reduction of Vehicle Brake System

2011-01-2379

Published
09/18/2011Anshuman Gupta and Badal G. Bisen
Tata Motors Ltd.

Copyright © 2011 SAE International

doi:10.4271/2011-01-2379

ABSTRACT

There has to be a good co-relation/ relationship between the pedal effort applied, pedal travel, deceleration level achieved and stopping distance for “good brake feel”. Brake feel also depend upon the time lag between the force applied on brake pedal and the response of braking system. Hence “brake feel” can be improved by reducing the response time of the brake system. Many vehicles are having “poor brake feel” complaints, pertaining to the above mentioned reasons.

This paper relates to an improved brake system for automobile in which reduction in reaction time was done by artificially increasing differential pressure head across vacuum booster diaphragm.

Brake booster is given an input of compressed air to the valve body during actuation, thereby increasing the differential pressure across the diaphragm. The compressed air is bled from turbocharger-intercooler of the vehicle which is stored in a reservoir, with one way valve, while cruising. However, same compressed air is utilized by the brake booster during brake application. Additionally, the compressed air reservoir acts as a cooler for stored air.

By virtue of this mechanism, the overall reaction time of the brake booster reduces significantly for the same testing conditions.

The whole circuit is provided with a pressure switch which detects any failure in the compressed air circuit and opens it up to the atmosphere, making booster work to its conventional capability.

Using this concept on vehicle, marked reduction in stopping distance with improvement in “brake feel” was observed.

INTRODUCTION

It is a general thumb-rule that the customer satisfaction should be the first criteria to be successful in today's competitive automotive market. A customer will not be satisfied if he cannot brake his car safely, smoothly and quietly under all circumstances, regardless of type approval certificate or other documents conforming to the braking system legal requirements. Safety on roads depends on properly harmonizing the driver - vehicle environment system i.e. the vehicle should be able to response to the driver's intent. If any time lag is perceived between the driver's command & vehicle's response, the behavior is said to be un-harmonized. The present case discusses a concept which could reduce the reaction time of vehicle braking system, thereby increasing harmony between driver and vehicle. The concept presented has been tried on one of the SUVs with following brake system specifications:

Table 1. Brake system details of the vehicle tested

Vehicle type	SUV
Vacuum booster size	8" + 9"
TMC (Tandem Master Cylinder)	Ø 26.99 mm
Front caliper size	C48 + 48
Rear drum	295 mm
Wheel cylinder size	26.99 mm
Maximum vacuum level generated	670 mm of Hg
Fuel type	Diesel
GVW	2850 kg

GENERAL WORKING OF A BRAKE BOOSTER

The vacuum booster in vehicles is used to give the required assist or boost during braking. It works on the principle of

differential pressure. A diaphragm separates the two chambers inside the vacuum booster. The push rod side of the vacuum booster has a provision for air inlet and the other side is connected to the tandem master cylinder. When the engine is running, the vacuum pump helps in maintaining equal level of vacuum on both sides of the diaphragm. Vacuum booster is connected to vacuum pump through a vacuum hose and a non return valve. When the brake pedal is applied, the push rod of the vacuum booster moves in through the valve assembly of vacuum booster thereby closing the valve between the two chambers and allowing atmospheric air to come into the push rod side of the diaphragm. This creates a pressure difference between the two chambers and therefore the diaphragm is pushed forward, giving an assist to the brake force applied by the driver. Vacuum booster is connected to tandem master cylinder, which generates hydraulic pressure due to forward movement of booster pushrod. This hydraulic pressure gets divided into two hydraulic circuits giving clamping force to brake assembly to stop the automobile.

DESCRIPTION OF THE CONCEPT

Brake system response time of one the SUVs was poor & there were constraints on increasing vacuum pump size, foundation & actuation size. To increase the differential pressure across the diaphragm of vacuum booster (using same size vacuum pump), increase in the inlet air pressure was thought. Since, conventionally input air is bled from atmosphere, there was a need to have air at elevated pressure. To achieve this, air from turbocharger intercooler of the vehicle was bled as this air always remains above atmospheric pressure level. As conceptually this model was working, effort was taken up to practically prove the idea.

The concept of such improved brake system, *fig.-1*, broadly comprises of a compressed air source (turbocharger), brake boost control module, brake booster & brake pedal assembly. The compressed air source, brake boost control module and the brake booster are pneumatically connected. The connection between the brake pedal assembly and the brake boost module is electrical.

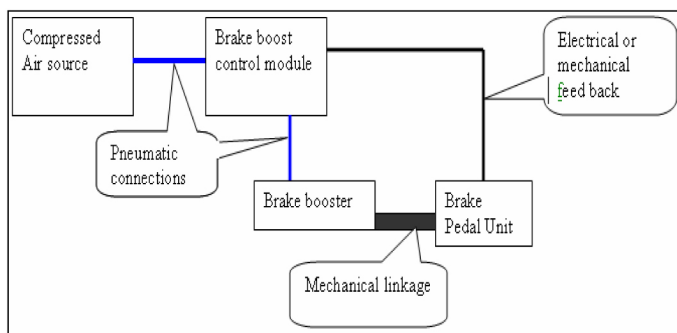


Fig.1. Block diagram of the concept

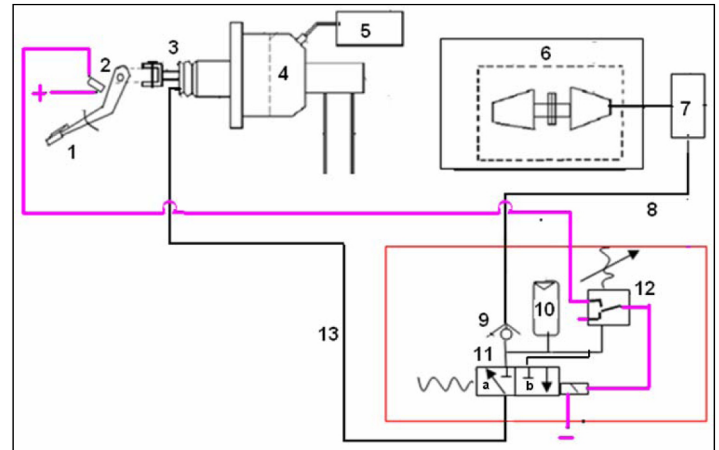


Fig.2. Layout of brake system in accordance with the concept

The set-up for reducing reaction time in conjunction with conventional brake actuation layout has been shown in *fig.2*. Referring to the *figure.2*, brake pedal (1) with brake light switch (2), vacuum brake booster (4) with valve body (3) and vacuum pump (5) forms the conventional brake actuation system. Turbocharger (6) with intercooler (7) forms a part of conventional engine system. Integration of both systems has been done with flexible hoses (8 & 13), one way valve (9), compressed air accumulator (10), pressure switch (12) and control valve (11).

The concept takes forward the same working principle of brake booster but with different kind of air input. Air at elevated pressure is used in place of air at atmospheric pressure. In this concept, some amount of air coming out of the intercooler of turbo-charging system is bled and sent through the non return valve to the compressed air reservoir. During engine running condition, compressed and cooled air passes through the one-way valve and gets accumulated in the accumulator. When the brake light switch is activated, the pressure switch compares accumulator pressure against the atmospheric pressure. If the pressure of accumulator is greater than atmospheric pressure then the control valve opens the passage-‘a’ through compressed air line. The compressed air is directed to the booster valve body, by the use of flexible hose, which increases the air-flow rate inside the booster chamber during the brake application. The air flow through control valve stops the moment input from brake light switch is cut and signal reached pressure switch. The calculations initially showed that there could be a phenomenal benefit, leading to a flow rate of around 3.9 Lt/sec. However, pressure drop along the length of flexible hose and valves were identified as constraints to achieve calculated flow rate. To achieve better results, the control valve arrangement was packaged close to the booster valve body to reduce the delay associated with the air flow between control valve and booster valve body. However, in case of any