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Design, Development and Testing of Active Electro-Solenoid Thruster for Application in EBA System in Conjunction with ABS in Automobiles

Ketan S. Apte[1], Rupam M. Thakare[2], Ankirt A. Bhosale[3], Jigar K. Shah[4]
Department of Mechanical Engineering, MCOE, SP Pune University, India
ketanaapte@gmail.com[1], rupam09thakare@gmail.com[2], ankirtbhosale@gmail.com[3], shahjigaar@gmail.com[4]

Abstract - Anti-lock braking system (ABS) is an automobile safety system that permits the wheels on a motor vehicle to maintain tractive contact with the road surface according to driver inputs while braking, preventing the wheels from locking up and avoiding uncontrolled skidding. Emergency brake assist (EBA) based on the speed and force with which the brake pedal is pressed, detects an emergency. The brake assist system increases the brake pressure until the ABS regulation intervenes to prevent the wheels from locking. This way the greatest possible braking effect can be achieved, and the brake path can be shortened significantly. Hybrid braking system results are verified experimentally and analytically to determine the breaking strength. Amalgamation of ABS and EBA will apply more efficient braking force with the help of Solenoid Thruster mechanized in EBA. Thruster is designed and analyzed with the help of Catia and Ansys software respectively. Solenoid Thruster increases the force applied on the brakes in case of emergency which will lead in lower number of accidents.

Keywords - ABS, EBA, Solenoid Thrusters, Catia, Ansys

1. INTRODUCTION

Stopping a car in a hurry on a slippery road can be very challenging. Anti-lock braking systems (ABS) take a lot of the challenge out of this sometimes-nerve-wracking event. ABS generally offer improved vehicle control and decreases stopping distances on dry and slippery surfaces for many drivers however, on loose surfaces like gravel or snow-covered pavement, ABS can significantly increase braking distance, although still improving vehicle control. In fact, on slippery surfaces, even professional drivers can't stop as quickly without ABS as an average driver can with ABS. Since initial widespread use in production cars, anti-lock braking systems have evolved considerably. Recent versions not only prevent wheel lock under braking, but also electronically control the front-to-rear brake bias. This function, depending on its specific capabilities and implementation, is known as electronic brake force distribution (EBD), traction control system, emergency brake assist, or electronic stability control (ESC). There are many different variations and control algorithms for ABS systems. We will discuss how one of the simpler systems works.

Emergency brake assist (EBA) based on the speed and force with which the brake pedal is pressed, detects an emergency. The brake assist system increases the brake pressure until the ABS regulation intervenes to prevent the wheels from locking. This way the greatest possible braking effect can be achieved, and the brake path can be shortened significantly. The system comprises of the brake lever which when operated at first operate the conventional solenoid braking of ABS types i.e. the brake will cycle between 'ON' & 'OFF' condition to prevent the skidding of the vehicle, preventing accidental locking of braking owing to excessive heating because of continuous contact of disk brake and calliper shoes. But in case of emergency when the driver forces the pedal beyond predetermined limit the EBA-sensor (proximity sensor) will detect the condition and actuate the electro-hydraulic thruster which will operate at high speed to develop brake force in multiples of the human effort and apply the brake to bring the vehicle to stop.

2. PROBLEM STATEMENT

"Design, Development and Testing of Active Electro-Solenoid Thruster for Application in Emergency Brake Assist System Along with Anti-lock braking System in Automobiles." When the brake is pressed beyond the ABS limit the EBA-limit switch is operated which will actuate the solenoid mounted on the master cylinder of the EBA system. The master cylinder injects high pressure oil into the brake calliper, this will close the calliper fully thereby applying emergency brake and preventing the head on collision with the front vehicle.

3. OBJECTIVES

1. Design Development & analysis of electro - hydraulic thruster mechanism with three step operation modes.
2. 3-D cad modeling using Unigraphix and analysis for strength of critical components of the thruster

3. using ANSYS such as piston, piston rod, thruster cylinder, facing lug and pressure lug.
4. Design & development of Emergency brake assist system test rig to test the electro-hydraulic thruster to determine following parameters
   a) Braking distance determination for different speed stages i.e., different vehicle speeds.
   b) To determine the effectiveness of EBA system.
   c) Comparative study of the theoretical braking force and braking distance to experimental braking force and braking distance and there by validation of result.

4. METHODOLOGY

It is seen that the development of the emergency brake assist system will largely depend upon the design and development of the active type of brake actuator mechanism which should have the following properties:7

- Fast actuation of the brake a system as reaction time is very low.
- Large braking force development to bring about the emergency braking of the vehicle.

Hence the design and development of an active electro- hydraulic thruster for application in emergency brake assist system is necessary. The system comprises of the brake lever which when operated at first operates the conventional braking of ABS types i.e., the brake will cycle between 'ON &'OFF' condition to prevent the skidding of the vehicle, preventing accidental locking of braking. Locking of braking also leads to excessive heating of because of continuous contact between disk brake and calliper shoes. But in case emergency when the driver forces the pedal beyond predetermined limit the EBA-sensor (proximity sensor) will detect the condition and actuate the electro-hydraulic thruster which will operate at high speed to develop brake force in multiples of the human effort and apply the brake to bring the vehicle to stop.

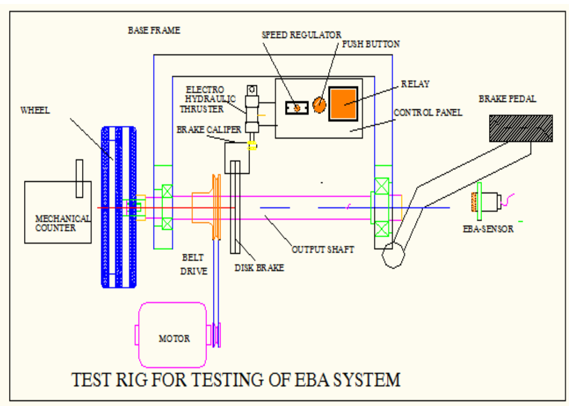

Fig. 1: Schematics of test rig of EBA system

- System design for electrically powered active suspension system
- Fabrication of set-up.
- Results and Discussion

5. ADVANTAGES

- Basically, applicable for all categories of vehicles like Light commercial, Medium commercial and Heavy commercial vehicles.
- Suitable for LMV (light motor vehicles) like Motor Bikes, Mopeds etc.
- Extremely useful in Racing/Sports cars in Racing sports and industries.
- Use of ABS with EBA will avoid and reduce accident caused during transportation of goods and services from Heavy trucks, Trailers, etc.

6. ANALYSIS AND RESULT OF THRUSTER BODY

a. Analysis of Thruster Body (Using Ansys)

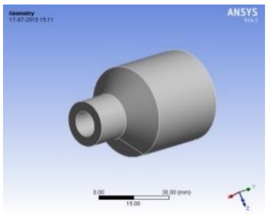

Fig. 2: 3D Geometry

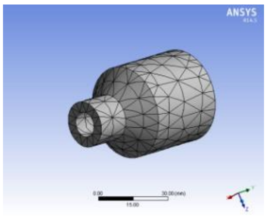

Fig. 3: Meshing

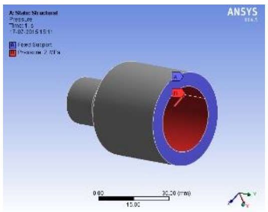

Fig. 4: Fixed support & Load Application on Thruster Body

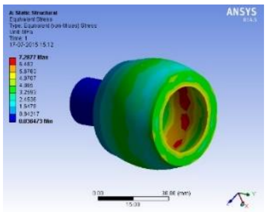

Fig. 5: Equivalent Stress (Von – Mises) of Thruster Body

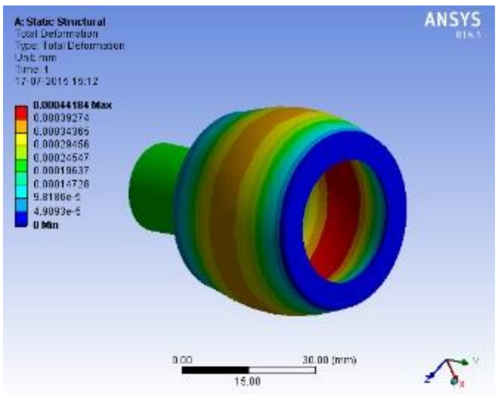

Fig. 6 : Total Deformation of Thruster Body

b. Result Of Cad Analysis

Table 1. Result of Thruster body.

Part Name	Maximum theoretical stress (N/mm^2)	Von-misses stress (N/mm^2)	Maximum deformation (mm)	Result
Thruster body	4.66	7.8	0.0004	Safe

- Maximum stress by theoretical method and Von-misses stress are well below the allowable limit, hence the Thruster body is safe.
- Thruster body shows negligible deformation.

7. EXPERIMENTAL OF ABS-EBA SYSTEM

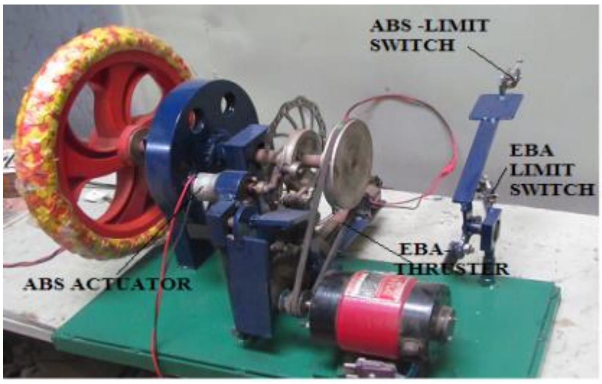

Fig. 7: Experimental Setup

Shaft is connected to a single-phase D.C. Motor by using V-Belt, which is than connected to brake capiller. Thruster, brake pedal, actuator and limit switch are all integrated and finally connected to 12V Battery.

a. Anti-lock braking systems (ABS)

i. PROCEDURE for ABS:

1. Start motor maintain speed of shaft @ 1300 rpm.
2. Note no load speed.
3. Load 0.5 kg in to load pan.
4. Note speed @ 0.5 kg load.
5. Add 0 kg load up to 2.5 kg and not the readings of speed

ii. OBSERVATION TABLE for ABS

Table 2. Result of ABS.

Load	Speed actual	Speed Theoretical	Torque	Brake power Absorbed	% slip
0.5	826	830	0.367875	31.82477	0.481
1	406	416	0.73575	31.28537	2.404
1.5	265	275	1.103625	30.63038	3.636
2	198	207	1.4715	30.51479	4.348

7.2.3 CONCLUSION AND GRAPHS for ABS:

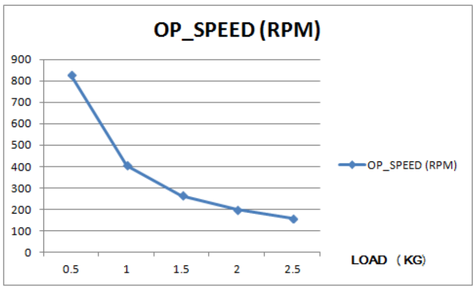

Fig. 8: Speed Vs Load

- Output speed drops with increase in load.
- There is considerable retardation with increase in brake load indicating good effectiveness of brake.

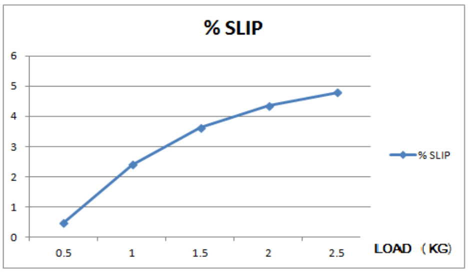

Fig. 9: Slip Vs Load

- Percentage slip increases with increase in load.
- There is slight increase in slip indicating slight drop in performance of brake but negligible as compared to other friction brakes.

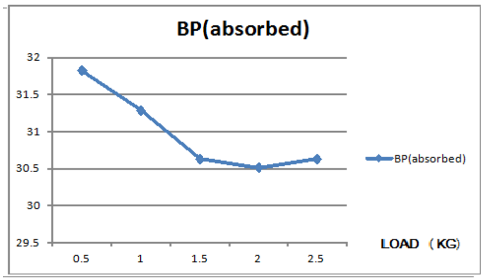

Fig. 10: Brake Power Vs Load

- Brake power absorbed remains almost constant with change in load.
- The brake performs consistently over load range with slight drop in power with increased load though very negligible.

b. Emergency Brake Assist System (EBA)

i. PROCEDURE for EBA system:

1. Start motor maintain speed of shaft @ 1300 rpm.
2. Note no load speed.
3. Load 0.5 kg in to load pan.
4. Note speed @ 0.5 kg load.
5. Add 0 kg load up to 2.5 kg and not the readings of speed.

ii. OBSERVATION TABLE for EBA System:

Table 3. Result of EBA System.

Load	Speed Actual	Speed Theoretical	Torque	Brake Power Absorbed	% Slip	Break Distance	VIB-Vel.	VIB-Acc.
0.5	560	564	0.55	32.257	0.70	4.46	0.405159	1.00412
1	278	281	1.11	32.3	1.06	3.35	0.747716	1.849342
1.5	186	189	1.56	30.57	1.58	3.35	1.044453	4.279816
2	135	139	2.23	31.527	2.87	4.46	1.306193	3.048947
2.5	115	119	2.78	33.48	3.36	4.469	1.540327	3.735268

iii. *CONCLUSION AND GRAPHS* for EBA System:

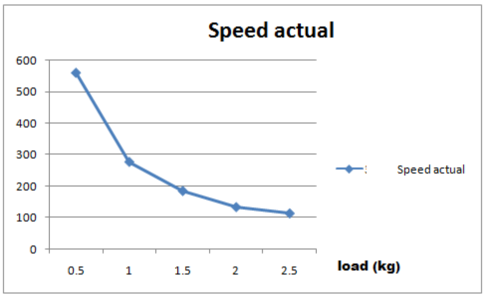

Fig. 11: Speed Vs Load

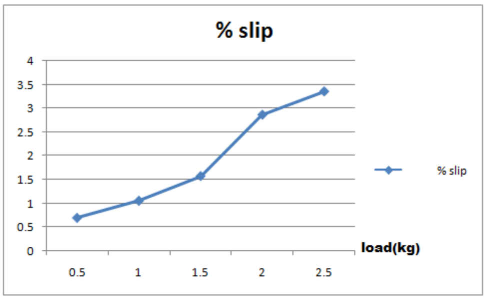

Fig. 12: Slip Vs Load

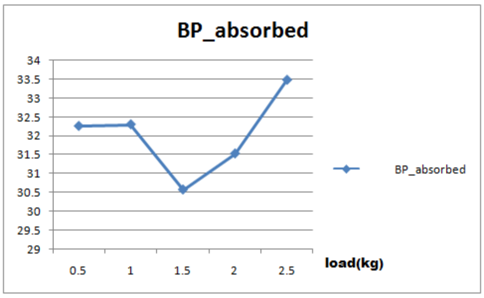

Fig. 13: Brake Power Vs Load

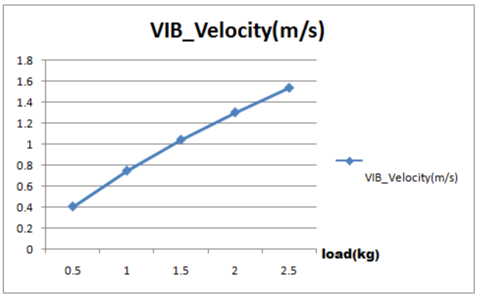

Fig. 14: Velocity Vs Load

c. Braking Comparison

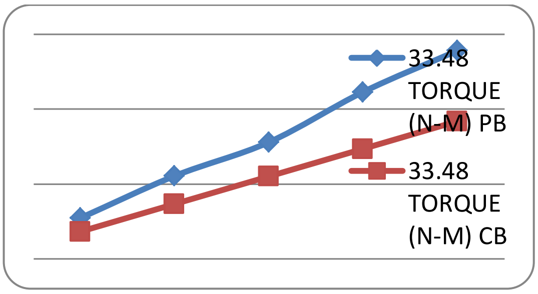

Fig. 15: Comparison between PB and CB

- Fig. 15 illustrates the comparison between Partial Braking (PB) and Combined Braking (CB).
- In Partial Braking systems (ABS), brakes are applied gradually and hence result in less effective.
- Whereas Combined Braking systems (ABS+EBS), ABS assist with EBA which tends to stop the vehicle in short time of interval without skidding of vehicle.
- Clearly, it is seen Combined Braking system is more efficient than Partial Braking system over controlling the vehicle in emergency.

8. CONCLUSION

1. It can be concluded that work of sophisticated (EBA) HYDRAULIC BRAKING SYSTEM can be duplicated by using Solenoid thrusters and electronic components with few sensors, such as proximity sensors, and few switches.

2. As costly sensors are eliminated cost of the system is drastically reduced compared to conventional (EBA) HYDRAULIC BRAKING SYSTEM.
3. Finally, we conclude that one can reduce the stopping distance by implementing the Emergency brake assist with antilock braking system and hence accidents are decreased.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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