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Investigation of Braking System (Efficiency) of Converted Mercedes Benz Buses (207)

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ABSTRACT

Road accidents as a major cause of misery, morbidity and mortality in Africa particularly in Ghana have been of considerable concern to the general public. More worrying is the accidents involving Benz 207 buses. Mercedes Benz "207" bus when brought into the country is converted to passengers' bus by artisans in 'fitting workshops' in and around the country. This conversion increases the gross weight, affects the suspension and the stability of the vehicle. Also, a serious effect is that the performance of the braking system may be affected. This paper highlights the braking efficiency of the converted Mercedes Benz 207 bus as against that of the original and compared to the safest degree of efficiency required for these buses. The gross weight of the original bus was increased by an average of 20% after conversion. The results show that 60% of the buses have no parking brakes and between 20%-30% were having defective or no rear brakes. Also, 70% of the converted buses have their braking efficiencies decreased whilst 20% had increased braking efficiency with rest remaining unaffected. It was again observed that 60% of the original buses tested fell within the standard value required for the front imbalance and 50% of the converted buses exceeded the maximum value for the front imbalance.

Key words: *207 bus, conversion, Brake efficiency*

1. INTRODUCTION

In Ghana, Mercedes Benz buses are popularly called '207 buses' and they are commercial vehicles used for carrying commuters. Originally, the Mercedes Benz buses were made as cargos for conveying goods before they are converted to passenger buses in Ghana. These buses which fall under the category of light commercial vehicles carry passengers not exceeding twenty-three (23) persons and have gross and net weights not exceeding 5720 and 900 kg respectively. They come in various sizes and shapes depending on the model. The models include 207D, 208, 307D, 308, 410 etc. The bus employs either the non-chassis (integral) or separate chassis and body construction but majority of the 207 buses use separate chassis construction. The dimensions of the wheel base and vehicle length vary according to the type of model.

The Mercedes-Benz van is converted to passenger bus in order to satisfy the domestic transport needs. During the conversion, the occupancy space of the vehicle may be is increased by extending the chassis in between the wheels. The act of extending the chassis of the vehicle calls for discarding of some of the original components like propeller shaft and replacing it with another one. Seats are also produced and fixed into the vehicle without any anthropometric consideration and the number of leaf springs in the suspension of the vehicle is increased arbitrarily. All these components add to the gross weight of the vehicle. This in turn affects the suspension and the stability of the vehicle since the centre of gravity is altered. Also, the modifications may render the brakes ineffective and performance of the braking system (efficiency) compromised. According to Hillier et al (2004) an increase in weight of a vehicle has a direct bearing on the power required for the vehicle and braking efficiency. Theoretically, brake efficiency is defined as ratio of the braking force to the weight of the vehicle. Efficient braking of vehicle is one of the principal factors in securing the safe operation of the brakes (Lateef et al, 2008). It is therefore clear that the braking efficiency is compromised with changes in gross weight.

2. METHODS AND MATERIALS

Vehicle braking efficiency is the ratio of the retardation or deceleration of the vehicle to the acceleration due to gravity, expressed as a percentage. Retardation and acceleration due to gravity, g, are both measured in units of metre per square second (m/s^2) and braking efficiency may be obtained from the relation:

$$\text{Braking efficiency} = \frac{\text{retardation(a)}}{\text{acceleration due to gravity(g)}} \times 100 \quad - \quad - \ (1)$$

$$\text{Braking efficiency (BE)} = \frac{\text{braking force}}{\text{weight of vehicle}} \times 100$$

If the retardation were equal to acceleration due to gravity the braking efficiency would be 100%, a value seldom found in practice.

In practice, braking efficiency may be determined by:

a) Measuring the stopping distance for a given speed,
b) Using a decelerometer such as the Tapley or Ferodo meters and
c) Using a roller or plate form brake-testing machine (Mudd, 1972)

The roller brake testing machine is a machine used to determine the braking efficiency of a vehicle. The rollers are of steel and have a diamond tread pattern. They are arranged in pairs at each side of the machine and each pair is driven by an electric motor in a way that their torque reaction can be measured. The reactions are transmitted by gauges by a hydraulic system and the gauges are calibrated in hundreds of newtons. This machine tests front and rear brakes separately. The motors are set running and the gauges zeroed. The vehicle is driven onto the machine in such a way that the front wheels contact the rollers and the brakes are then applied. The resistance the wheels offer to the rotation of the rollers results in a torque reaction which is indicated on the dials. The two gauge readings are recorded and the gauge zeroed again for the rear brake test, the vehicle being driven forward to bring the rear wheels on to the rollers. The total retardation force is the sum of the separate braking forces. The braking efficiency is then calculated from the formula. The vehicle weight must be known. The brake roller tester at Kumasi Technical Institute (KTI) was used to conduct the test.

(a) Display cabinet

(b) Roller

Figure 1: Brake Testing machine (a. display cabinet and b. rollers)

3. CONVERSION AT SUAME MAGAZINE

Suame magazine is a suburb in Kumasi, the Ashanti Region of Ghana and a local vehicle modification site where automobile services, repairs, fabrication of metal works, spare parts and scraps are carried out. The following modifications are undertaken in Suame magazine:

i. Chassis extension or wheel base alteration
ii. Conversion of petrol injection to carburetor system
iii. Propeller shaft extension
iv. Increase in vehicle capacity so as to carry more passengers or goods
v. Radiator change and thermostat removal
vi. Complete conversion of one vehicle type to another (cargo truck to tipper truck)
vii. Conversion of 207 van to commercial vehicle
viii. Building or mounting of bodies on naked chassis (as it is done to get the Metro mass vehicle)
ix. Conversion of automatic transmission to manual transmission
x. Changing of motor cycle to tricycle
xi. Changing of left hand drive vehicle to right hand drive vehicle
xii. Conversion of transistorized ignition system to the coil ignition system
xiii. Conversion of one door car to multiple door cars
xiv. Various structural cosmetic changes such as modifying of body styles, fixing of glasses, painting or spraying works, coloured head lamp and tinted glass
xv. Conversion of petrol engine vehicle to gas (LPG) engine vehicle or vice versa

4. RESULTS AND DISCUSSION

4.1 Braking forces for original 207 buses

The table 1 shows the results of the testing done on the various original 207 buses to determine the braking force exerted by each brake. It can be seen from the table that the braking force concentrated in the front brakes is higher than those in rear brakes. The hand brake recorded the least braking force. That is about 60% of the braking was applied on the front wheels only. The total braking force was achieved by adding the braking force at the front and the rear when the service and hand brakes were applied. From the table 1, the total braking force varied from model to model with an average braking force of 23.4 kN

Table 1: Results of braking forces for original '207' buses

Vehicle	Service Brake				Hand brake		Total Braking Force (kN)
	Front brakes (kN)		Rear brakes (kN)		Rear brakes (kN)		
	Near side (NS)	Off side (OS)	Near side	Off side	Near Side	Off side	
310D	6.8	5.8	4.5	4.0	3.2	3.1	27.4
208D	5.5	5.0	3.3	3.5	1.2	1.4	19.9
308D	6.1	6.4	5.0	4.4	2.0	2.2	26.1
210D	5.0	5.9	2.5	2.0	1.4	1.6	18.4
207D	3.6	3.2	2.4	2.6	1.0	0.8	13.6
310D	6.6	6.2	5.6	5.2	4.0	4.1	31.7
307D	5.8	5.0	3.5	3.8	1.5	1.3	20.9
Sprinter	6.1	6.5	4.2	4.5	2.5	2.2	26.0
410D	7.0	6.8	5.2	5.6	4.2	4.5	33.3
207D	4.5	5.1	2.0	2.2	1.4	1.5	16.7

4.2 Results of braking force, gross weight and braking efficiency (original)

The table 2 shows the total braking force measured using the roller brake testing machine, the gross weight from manufacturers manual, and using eq1 the braking efficiency was calculated. The average gross weight for the original bus was found to be about 3340kg. The maximum efficiency of about 82.33% was obtained and close to 60.44% was found to be the least braking efficiency for the original buses. The average efficiency of 70% was obtained for the buses.

Table 2: Results of braking force, gross weight and braking efficiency (original)

Vehicle	Total Braking force (N)	Gross weight (N)	Braking Efficiency (%)
310D	27400	38000	72.10
208D	19900	25400	78.35
308D	26100	35000	74.57
210D	18400	28000	65.71
207D	13600	22500	60.44
310D	32700	38500	82.33
307D	20900	32000	65.31
Sprinter	26000	42500	61.18
410D	33300	47500	70.10
207D	16700	24500	68.16

4.3 The results of percentage imbalance at front and rear brakes (original)

The table 3 shows that the average percentage front imbalance was lower than the average percentage rear imbalance with the lowest being 2.8% for the front brakes while 5.7% was found for the rear brakes. 15.2 % was the highest imbalance obtained for the front brakes and 20% represented the maximum imbalance calculated for the rear brakes of the original bus.

Table 3: The results of percentage imbalance at front and rear brakes (original)

Vehicle	Service Brake		Front Percentage imbalance	Rear Percentage imbalance
	Front brake out balance (kN)	Rear brake out of balance(kN)		
310D	1.0	0.5	14.7	11.1
208D	0.5	0.2	9.1	5.7
308D	0.3	0.6	4.7	12.0
210D	0.9	0.5	15.2	20
207D	0.4	0.2	11.1	7.7
310D	0.4	0.4	6.1	7.1
307D	0.2	0.3	3.4	7.9
Sprinter	0.4	0.3	6.2	6.7
410D	0.2	0.4	2.8	7.1
207D	0.6	0.2	11.7	9.1

4.4 The results of total braking forces (converted 207 buses)

The table 4 shows the total braking force applied for the converted buses. Out of the ten vehicles tested, six was found to be without a hand brake which represented about 60% of the buses without effective hand brake. About 20% of the buses were found to be without rear brakes. 70% of the braking force was applied to the front brakes. The highest braking force was found to be 28.8 kN and the least found to be 14 kN.

Table 4: The results of total braking forces (converted 207 buses)

Vehicle	Service brake				Hand brake		Total Braking force (kN)
	Front brakes (kN)		Rear Brakes (kN)		Rear brake (kN)		
	Near side	Off side	Near Side	Off side	Near off	Off side	
310D	6.4	7.1	5.6	6.2			25.3
208D	6.8	7.2	-	-			14.0
308D	6.0	5.5	5.0	4.0	2.5	2.0	27.5
210D	6.0	5.2	5.0	4.2			20.4
207D	6.3	5.2	4.0	3.0	2.5	2.0	24.5
310D	6.5	5.5	5.0	4.2	3.0	2.5	28.8
307D	7.0	6.3	5.5	5.0			23.8
Sprinter	5.2	6.5	4.8	3.8			20.3
410D	6.8	5.2	4.0	4.5	3.2	2.8	26.5
207D	7.3	7.8	-	-			15.1

4.5 Results of braking force, gross weight and braking efficiency (converted)

The table 5 shows the total braking force determined using the roller brake testing machine, the gross weight determined using weight bridge together with the relevant relation and with appropriate formula the braking efficiency was calculated. The average gross weight for the converted bus was found to be about 4122.6kg. The maximum efficiency of 69.01% was obtained and 41.86% was found to be the least braking efficiency for the converted buses.

Table 5: Results of braking force, gross weight and braking efficiency (converted)

Vehicle	Braking force (N)	Gross weight(N)	Efficiency (%)
310D	25100	47260	53.11
208D	14000	30500	45.90
308D	27500	48000	57.29
210D	20400	32250	63.26
207D	24500	35500	69.01
310D	28800	47500	60.63
307D	23800	37750	63.05
Sprinter	20300	48500	41.86
410D	26500	52500	50.48
207D	15100	32500	46.32

4.6 Results of percentage imbalance at front and rear brakes (converted)

The table 6 shows, the average percentage front imbalance was lower than the average percentage rear imbalance with the lowest being 5.5% for the front brakes while 9.1% was found for the rear brakes. 23.5 % was the highest imbalance obtained for the front brakes and 20.8% was found to be the maximum imbalance calculated for the rear brakes of the converted bus. There was no percentage imbalance for two rear brakes since there were no rear brakes.

Table 6: Results of percentage imbalance at front and rear brakes (converted)

Vehicle	Service Brake		Front Percentage imbalance	Rear Percentage imbalance
	Front brake out balance (kN)	Rear brake out of balance(kN)		
310D	0.7	0.6	9.9	9.7
208D	0.4	-	5.5	-
308D	0.5	1.0	8.3	20
210D	0.8	0.8	13.3	16.0
207D	1.1	1.0	17.9	25
310D	1.0	0.8	15.3	16
307D	0.7	0.5	10	9.1
Sprinter	1.3	1.0	20	20.8
410D	1.6	0.5	23.5	11.1
207D	0.5	-	6.4	-

4.7 Results of comparison of gross weight of original and converted 207 buses

The graph of figure 3 shows that the gross weight of the original bus was increased when the bus was converted. The average percentage increase on the original bus was found to be 20%. The least and the highest percentage increases were found to be 9.52 % and 36.61% respectively.

Table 7: Results of comparison of gross weight of original and converted 207 buses

Vehicle	Gross weight original(N)	Gross weight converted(N)	% Increase
310D	38000	47260	19.59
208D	25400	30500	16.72
308D	35000	48000	27.08
210D	28000	32250	13.18
207D	22500	35500	36.61
310D	38500	47500	18.95
307D	32000	37750	15.23
Sprinter	42500	48500	12.37
410D	47500	52500	9.52
207D	24500	32500	24.62

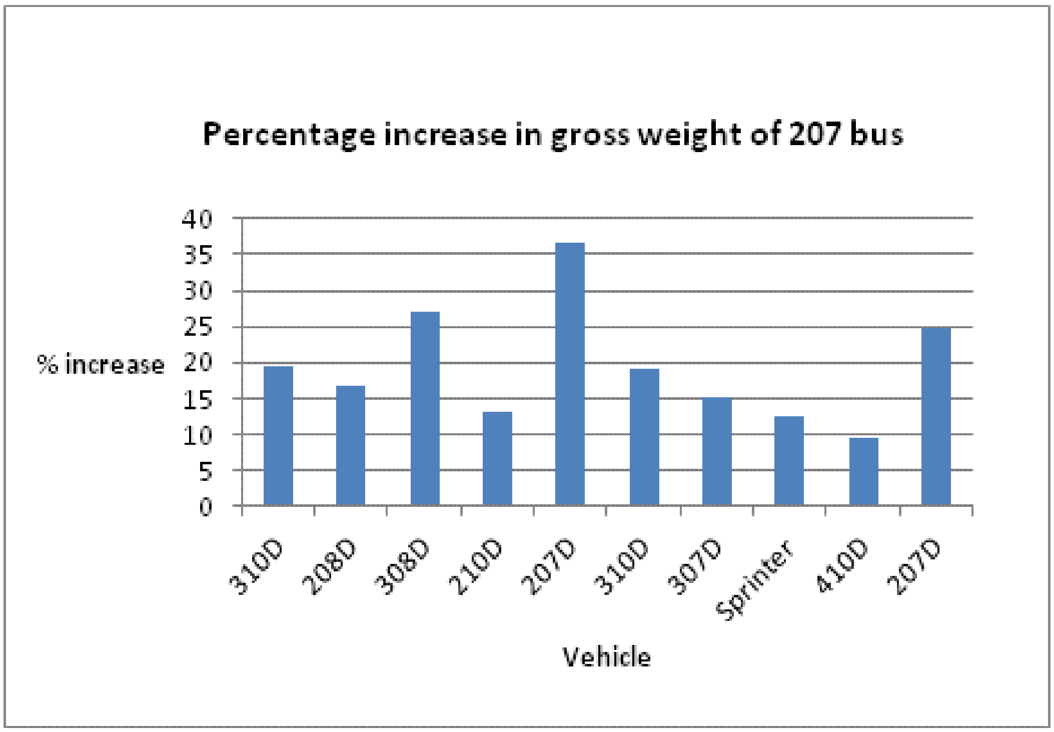

Figure 3: Graph of percentage increase in gross weight of 207 bus

4.8 Comparison of front imbalances of original and converted 207 bus

The graph of figure 4 shows the front imbalances of the converted, original buses and compares it with the maximum standard front imbalance allowed. It can be seen from the graph that, out of the ten original buses tested six (6) of them fell within the standard value required for the front imbalance and for the converted five (5) of them exceeded the maximum value for the standard front imbalance.

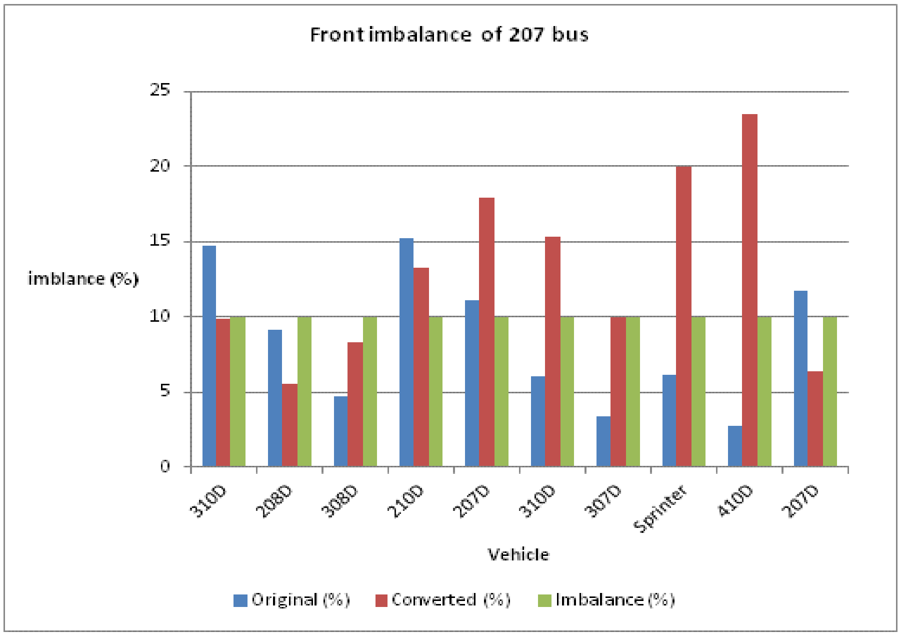

Figure 4: Graph of front imbalances of original and converted 207 bus

4.9 Comparison of rear imbalances of original and converted 207 bus

The graph of figure 5 reveals that out of the total original bus tested almost all of them were within range except 210D.This is because some of these buses are not brought fresh from the factory. And out of the ten buses tested when the buses were converted, five of them were above the maximum standard value required for rear imbalance and no value was showed for buses 208D and 207D since there were no rear brakes.

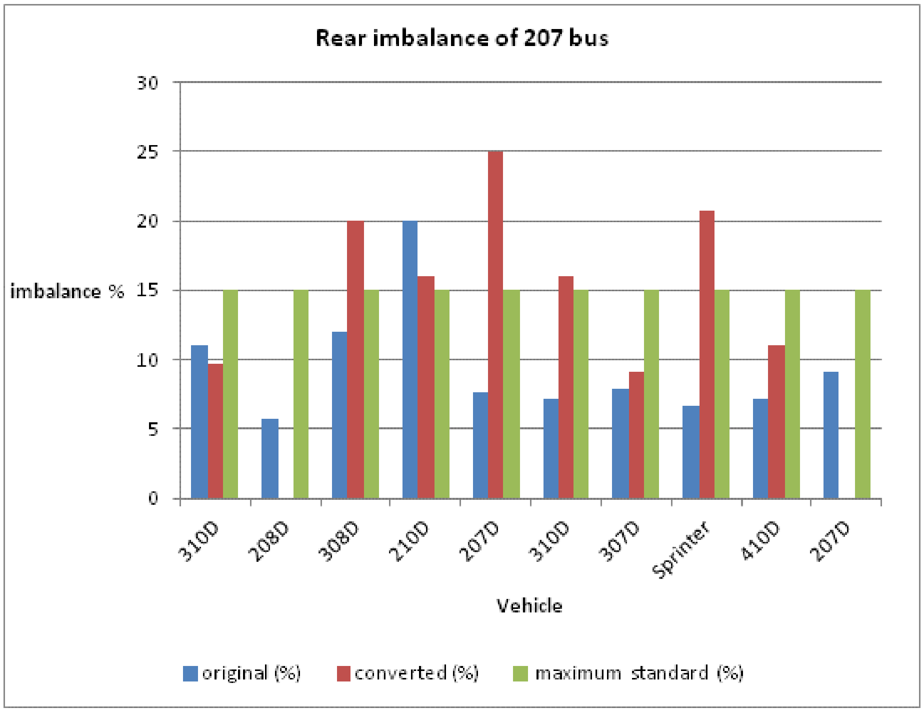

Figure 5: A graph of rear imbalances of original and converted 207 bus

4.10 Comparison of efficiency of original and converted 207 bus

The graph of figure 6 compares the efficiency of the original bus and the converted bus. It can be deduced from the graph that out of the ten buses tested the efficiency has decreased for seven of them when the bus was transformed from cargo to the passengers' bus. Only one bus showed an increase in efficiency when the bus was converted and two buses showed slight change in efficiency when the bus went through the conversion process.

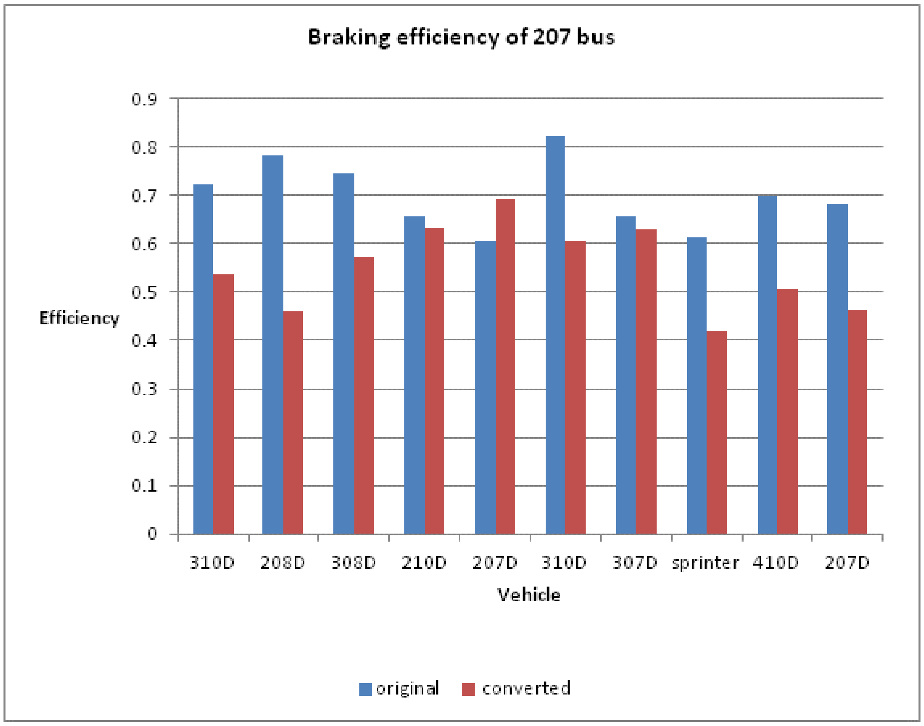

Figure 6: A graph of efficiency of original and converted 207 bus

5. CONCLUTION AND RECOMMEDATIONS

The conversion of Mercedes-Benz 207 buses from cargo into commuter buses carried out by artisans in and around workshops in Kumasi particularly at Suame Magazine. The artisans do not follow any laid down procedure in engineering design during the conversion process. The right or required machine, tools, materials and methods were not used when undertaking the modifications. The average ground height of the bus was increased and it was found to be between 60.9 cm to 76.2 cm (2 to 2.5 feet) when the suspension (leaf spring) of the bus was altered. The gross weight of the converted bus was increased by an average of 20% and out of the buses tested 70% of them were having no hand brakes and between 20-30% were having defective or no rear brakes. When the efficiencies of the original and converted were compared, seven out of the ten buses tested had their efficiencies decreased, one had no change in efficiency and two converted buses had their efficiencies higher than the efficiencies of original buses.

In view of the stated results it recommended that (1) future research should carried out with higher sample size to help obtain more and better information on the 207 buses regarding their brake system and (2) The converted 207 buses should as much as possible be subject to brake efficiency test before licensing to operate on the road.

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