An evaluation of ANCAP frontal offset score reduction in older cars

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Abstract

The Australasian New Car Assessment Program's (ANCAP's) ratings provide crucial information to consumers on the relative safety of new vehicles. However, there is debate whether the ANCAP safety rating of a vehicle remains unchanged as the vehicle ages, especially considering the vehicle deterioration while in service. This study was undertaken to evaluate the reduction (if any) in ANCAP frontal offset score of a nine-year-old old car compared to when it was new. The Ford Falcon AU2 four-door sedan (manufactured in 2000) was selected as the subject vehicle since it was one of the most popular passenger cars in early 2000 and it performed reasonably well in the frontal offset crash test. During this program, three Ford Falcon AU2 sedans in typical, used but undamaged, condition were tested using the ANCAP frontal offset test protocol. The results of these three tests were then compared to those obtained when the vehicle was initially tested in 2001. The results indicate that the reduction on the frontal offset ANCAP score of the nine year old cars is low. However, based on the dummy measurements, this study suggests that when compared to new vehicle there is an increase of injury risk on the occupants' lower body region. This increase is likely due to subtle deterioration of the vehicle and its components.

Introduction

ANCAP was established in 1993 to provide information to the general public on the safety performance of new vehicles to assist them choosing safer cars. The program is supported by all Australian and New Zealand governments and motorist organisations, who share a common interest in improving safety for vehicle occupants as well as other road users.

ANCAP carries out laboratory crashes of new cars using frontal, side and pedestrian impact tests together with an optional side pole test if the vehicle meets certain requirements. In frontal impact, the vehicle is crashed into a deformable barrier at 64 km/h with a 40% overlap to the driver's side. Two adult dummies (50th percentile Hybrid–III) are placed in the front seats (driver and passenger) and two child dummies representing 18 months old and 3 years old children in appropriate child restraints are placed at the rear seat. For each adult dummy, forces impacting four main body areas are measured: 1) head and neck, 2) thorax, 3) femur and knee, 4) lower leg and ankle. In side impact, a deformable mobile barrier hits the driver side of the vehicle between the A and C pillars aligned with the driver's seat R-point at 50 km/hr. Results from four body regions are considered: head, chest, abdomen and pelvis. If the vehicle has performed well in these two tests and is fitted with a head protecting side airbag, it can be subjected to an optional side pole impact test - where the vehicle is crashed against a rigid pole at 29 km/hr.

As the name implies, ANCAP is aimed to only test new vehicles. To the knowledge of the authors, no study has been conducted to re-assess the safety score of ANCAP or other similar programs using older vehicles. The focal question is then, does the ANCAP safety rating of a vehicle remain unchanged as the vehicle ages (especially considering vehicle deterioration while in service)?

It is hypothesised that the level of crash-protection offered by an old car would be less than when it was new. Therefore, the main objective of this study is to evaluate the ANCAP frontal offset score of a considerably older car compared to when it was new.

Methodology

For this study, only the ANCAP frontal offset test is investigated.

To meet the objectives of this study, a series of ANCAP 40% offset frontal crash barrier tests were conducted using a passenger vehicle model with which its age represented the average age of passenger vehicles registered in Australia. When the testing was conducted in 2009, the average age of passenger cars registered in Australia was 9.7 years (Australian Bureau of Statistics, 2009). In this regard, it was decided to choose Ford Falcon AU2 manufactured in 2000 as the subject vehicle. This car was considered one of the most popular passenger vehicles in 2000 and it performed adequately well in the frontal offset test with an overall ANCAP score of 3 stars. This model vehicle is fitted with frontal airbags for both driver and front passenger seating positions. It is also fitted with seatbelt pretensioners and load limiters in the front seating positions.

Three used but undamaged Ford Falcons AU2 were purchased for this study. All the safety features such as airbags and seatbelt pretensioners were inspected and considered to be in good condition. Although the vehicle models were 9 years old, they had been used extensively as shown on the vehicles' odometers which varied from 164,000 km to just under 400,000 km. Considering that motor vehicles registered in Australia travelled an average of 14,000 kilometres per year (Australian Bureau of Statistics 2012), these vehicles had been used 1.3 to 3 times more than the average.

All tests were conducted at the Roads and Maritime Services' Crashlab. The same test setup as specified under Euro NCAP frontal offset test protocol was used in each test. Two Hybrid III 50th percentile male dummies were placed in the driver and passenger seating positions as per the requirements of the ANCAP/Euro NCAP test protocol. A variation to the Euro NCAP protocol was made where no child dummies were used in the test series as it was considered that they would not affect the evaluation results of the vehicle or adult dummies. The mass of the child dummies and their restraints was replaced with the equivalent ballast mass.

A test matrix detailing the tests is shown in Table 1.

Table 1. Test Matrix

Test No	Test Description	Run Number	Vehicle Age	Vehicle Mileage (km)
1	Initial ANCAP Frontal Test	01014	A new Car	14
2	Vehicle 1	09021	9 year old	164,000
3	Vehicle 2	09022	9 year old	212,982
4	Vehicle 3	09023	9 year old	398,853

Head and chest acceleration data in each of the *x*, *y* and *z* axes were recorded and filtered. These were then used to calculate the resultant head and chest accelerations. Resultant head accelerations were used to calculate the Head Injury Criterion (HIC) over a 36ms window. Neck force and neck moment data along the *x*, *y* and *z* axes were also recorded and filtered then used to calculate resultant neck force and neck moments. Chest and knee, deflection measurements were recorded, as were femur and tibia forces and moments.

Results for the dummy data measurements from these tests were compiled and compared with the initial ANCAP frontal test scores when the vehicle was new.

Results and Discussion

Ford Falcon AU2 Initial ANCAP Frontal Offset Test

ANCAP tested a Ford Falcon AU2 in 2001 and provided this car with an overall score of 3 stars which equated to a moderate risk of serious injury or death to the driver and a lower risk of serious injury to the front passenger.

In the frontal offset test, it scored 11.07 out of 16 with commentary as follows.

> *"The FORD FALCON AU II performed reasonably well in the offset crash test (score 11.07 out of 16). The passenger compartment held its shape well except for brake pedal movement and intrusion of the road wheel into the driver's footwell. Injury measurements indicated a low risk of injury to all body regions but there was a risk of foot and lower leg injury due to excessive brake pedal movement.*
>
> *The passenger compartment held it shape very well in the offset crash test, except for the footwell and brake pedal. The road wheel pushed into the footwell which ruptured and, in places, was pushed rearwards 320mm. Despite this deformation the injury measurements on the dummy's lower legs were quite low. This may have been due to a tray-like insert under the carpet that is designed to isolate the feet from shock loads and deforming panels. The brake pedal moved rearwards by 280mm, ending up within 100mm of the seat. The dash moved 90mm towards the driver. The width of the driver's doorway shortened by 50mm. All doors remained closed during the crash. After the crash all doors could be opened with normal effort.*
>
> *Airbags cushioned the driver and passenger. Contact was stable for both. The driver's seat tilted forwards substantially. The ignition barrel was within the knee impact zone but was reasonably protected by the design of the steering column lower shroud."*

Summary of the dummy measurements from the initial ANCAP frontal offset test along with the detail scoring are presented in Table 2 and Table 3

Table 2. Dummy Measurements

	Driver	**Passenger**
Head/Neck Area		
HIC (g)	381	276
3ms Head Clip (g)	52.5	43.1
Neck Shear (kN)	0.28	0.64
Neck Tension (kN)	0.77	1.07
Neck Extension (Nm)	9.5	16.4
Chest		
Compression (mm)	26	28.5
Viscous Criteria (m/s)	0.09	0.12
Knee/Femur Area		
Femur Compression (kN)	3.05	0.57
Knee Displacement (mm)	1.79	0.03
Lower Leg		
Tibia Index	0.67	0.56
Tibia Compression (kN)	2.86	2.5

Table 3. Initial ANCAP Frontal Offset Score

Body Region	
Head/Neck	4
Chest	3.07
Knee/Femur	4
Lower Leg	0
Frontal ANCAP Score	**11.07**

ANCAP Protocol Frontal Offset Tests for 9 Years Old Falcon

Results from dummy measurements from the three ANCAP protocol frontal tests along with their average values and percentage changes with respect to the initial ANCAP frontal offset are summarised in Table 4.

Table 4. Dummy Measurements and percentage change relative to the initial ANCAP test

	Vehicle 1		Vehicle 2		Vehicle 3		Average Vehicles 1-3		Percentage Change	
	Drivr	Passgr	Drivr	Passgr	Drivr	Passgr	Drivr	Passgr	Drivr	Passgr
Head/Neck Area										
HIC (g)	443	403	456	388	396	285	432	359	13%	30%
3ms Head Clip (g)	51.6	54	54.9	49.6	49.3	45.6	51.93	49.73	-1%	15%
Neck Shear (kN)	0.43	1.02	0.44	0.85	0.38	0.56	0.42	0.81	49%	27%
Neck Tension (kN)	1.08	1.43	1.01	1.47	1.09	0.92	1.06	1.27	38%	19%
Neck Extsion (Nm)	28.1	30.3	8.5	20.6	11.1	18.8	15.90	23.23	67%	42%
Chest										
Compression (mm)	28.6	31.7	27.1	28.7	31.3	28	29.00	29.47	12%	3%
Visc Criteria (m/s)	0.1	0.09	0.1	0.09	0.13	0.11	0.11	0.10	22%	-19%
Knee/Femur Area										
Femur Comp (kN)	2.01	0.3	2.47	1.17	2.74	0.41	2.41	0.63	-21%	10%
Knee Displ (mm)	4.06	0.45	7.53	0.6	6.55	0.25	6.05	0.43	238%	1344%
Lower Leg										
Tibia Index	0.88	0.44	1.01	0.45	0.82	0.51	0.90	0.47	35%	-17%
Tibia Comp (kN)	4.06	1.88	4.24	2.08	3.59	2.31	3.96	2.09	39%	-16%

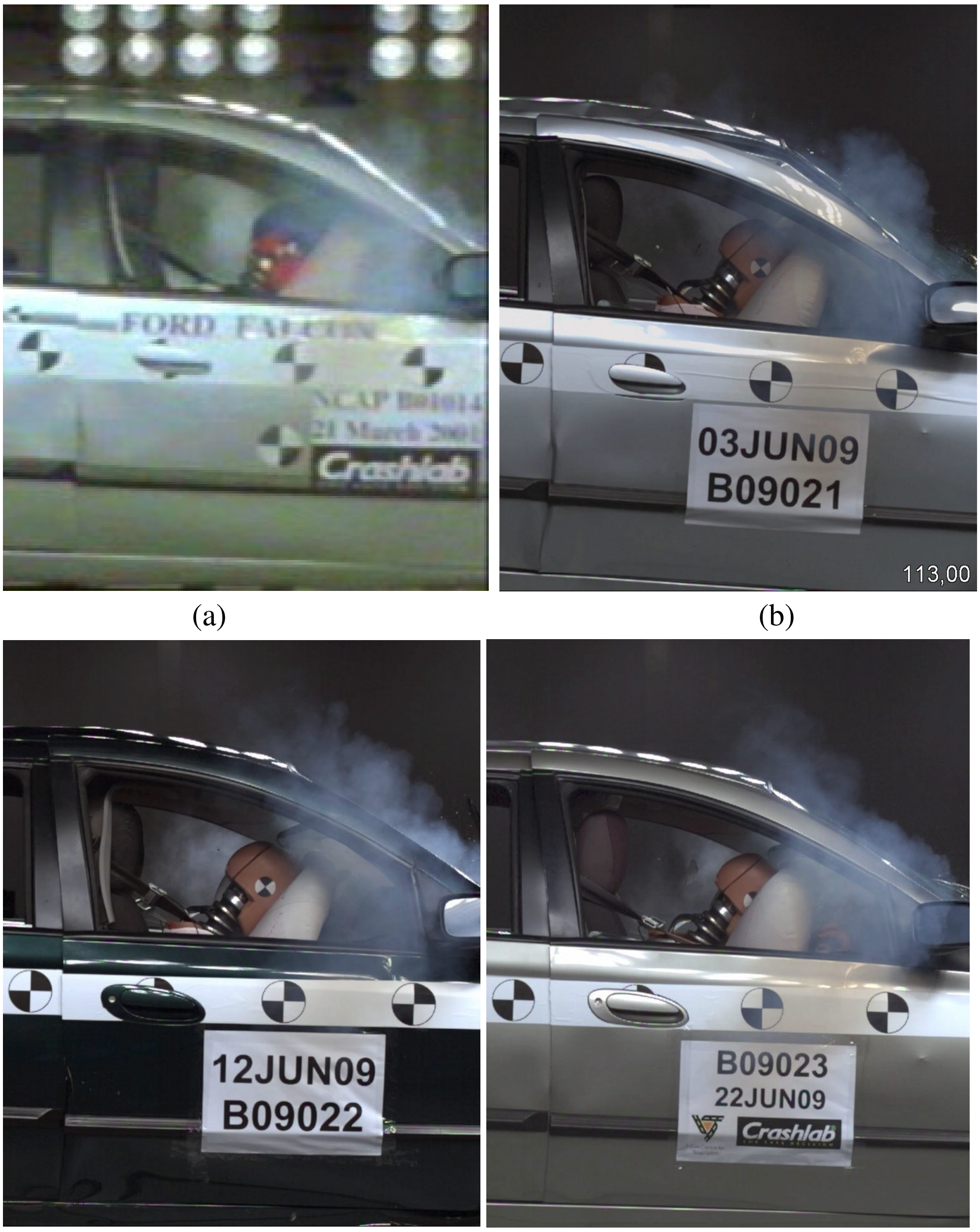
Figure 1 shows the still images for all four tests taken from high-speed crash movies at about 113 milliseconds (ms) from when the vehicle contacted the deformable barrier. The still image of the initial ANCAP test is shown in Figure 1a while the three used vehicle tests are shown in Figures 1b, c, d. In all four tests, both the driver's and passenger's airbags were deployed at approximately the same time of 32 ms from the first contact. Both frontal airbags in all four tests were also able to prevent the dummies from contacting the vehicle interior. Observations from the front view for all tests were made to indentify the seatbelt pretensioners' activation. It was found that in all four tests the pretensioners were activated at approximately 27 ms from the first contact.

Dummy and Vehicle Measurements

Results from dummy individual body regions along with vehicle measurements are discussed in the following:

Head/Neck Area

In all tests the HIC results for both the driver and passenger are below the Euro NCAP lower limit of 650 though there is a slight increase in older cars (13% for driver and 30% for passenger). These low HIC results are mostly contributed to the proper deployment of both the frontal airbags and seatbelt pretensioners in the driver and passenger seating positions.



(a) (b) (c) (d)

Figure 1. Still images of driver side view at 113 ms from the first contact.

Chest

The driver's chest compressions on the three older vehicle tests ranged from 27.1 to 31.3mm with an average of 29.0mm and for the passenger ranged from 28.0 to 31.7mm with an average of 29.5mm. In the initial ANCAP test the driver's and passenger's chest compression were 26.0mm and 28.5mm respectively. The Euro NCAP system assigns a good rating for compression of 22mm or less and a poor if more than 50mm. A minor increase in chest compression was shown in the three older vehicles (12% for driver and 3% for passenger). The generally low chest compression results for the vehicle are attributed to the presence and correct operation of seatbelt pretensioners and load limiters in the front seats.

Knee/Femur

In Table 4, the highest percentage change in dummy measurement is the driver knee displacement which is almost 2.5 times than the one in the initial ANCAP test. It ranges from 4.06mm to 7.53mm while the initial ANCAP test was 1.79mm. Authors of this paper are of the view that this increase may have been caused by the reduction on the seat cushion stiffness which would have occurred due to the vehicles' use causing the dummy's pelvis to be positioned slightly lower than the one in a new car allowing the dummy's pelvis to slide further forward.

Brake Pedal Movement

Residual rearward displacement of the brake pedal gives an indication of potential injury to lower legs and feet. Under the Euro NCAP system a good result is obtained if the displacement is less than 100mm and a poor result is given if the displacement is 200mm or more. As shown in Table 5, in all tests including the initial ANCAP test, the rearward displacements of the brake range between 236mm to 282mm all of which are exceeding the lower Euro NCAP limit. As a result the lower leg area for all the three tests was scored 0 (zero). It is also worth noting that the front driver side wheel on all three tests deformed rearwards towards the driver's footwell by between 408mm to 465mm while in the initial ANCAP test it was 477mm.

Table 5. Vehicle Measurements (mm)

Item	ANCAP Initial Test	Vehicle 1	Vehicle 2	Vehicle 3	Average Vehs 1-3
Brake pedal rearward movement	282	236	251	239	242
Brake pedal upward movement	52	22	36	0	19
Front wheel movement relative to datum	477	408	465	458	444
Dash driver rearward movement	92	90	79	67	78
Dash passenger rearward movement	33	38	6	32	35
A-pillar mid driver rearward movement (measured at a height of 100 mm below the lowest level of the side window aperture)	56	85	109	69	88

A-Pillar Movement

In the three tests, the rearward displacements of the A pillar ranged between 85mm to 109mm. In Vehicle 2, the driver's A-pillar rearward movement was 109 mm which exceeded the Euro NCAP lower limit A-pillar modifier and as a result the chest score for this vehicle could be deducted. However, it was decided not to apply any modifiers in this study due to some changes in Euro NCAP assessment protocols in the period between 2000 and 2009. In this regard the ANCAP score comparison used in this investigation is based on the injury risk only.

ANCAP Frontal Offset Scoring Comparison

After applying all the relevant dummy and vehicle measurements, the frontal offset scores for all four tests are tabulated in Table 6.

Table 6. ANCAP Frontal Impact Score Calculations

	Initial ANCAP Test	Vehicle 1	Vehicle 2	Vehicle 3	Average ANCAP scores from Vehicles 1-3	ANCAP score from averaged dummy responses
Head/Neck	4	4	4	4	4	4
Chest	3.07	2.61	3.03	2.67	2.77	2.93
Knee/Femur	4	4	3.32	3.75	3.69	3.98
Lower Leg	0	0	0	0	0	0
Frontal ANCAP Score	**11.07**	**10.61**	**10.35**	**10.42**	**10.46**	**10.91**

The average ANCAP frontal score for vehicles 1 to 3 is obtained by averaging all ANCAP frontal scores of the three tested vehicles which gives an average score of 10.46. This demonstrates a 5.5% reduction on the ANCAP frontal score when compared with the initial ANCAP score.

An alternate method would be to assess the crashworthiness of the tested vehicles by using averaged dummy responses as an indicator of injury risk and then feed the responses back into the ANCAP scoring protocol. Results obtained using this approach are tabulated in the last column of Table 6 in which the ANCAP frontal score obtained using this approach is 10.91, which gives a 1.5% reduction on the ANCAP frontal score.

Unlike the first approach, the latter takes into account individual outlying results above and below the ANCAP threshold. In the first method, outlying values which are above the ANCAP performance limits will lose points but those which are below the threshold will not get “bonus points” for being below the performance limit. Hence the first approach may result in subtracting too many points especially if the variations are very wide.

In addition, one could argue that the initial ANCAP test is based only on 1 (one) test in which such ‘filtering’ of outlying results process cannot be applied to it. In response to this argument and considering the results of this study, it would be reasonable to assume that there should be less variation in a brand new car.

Conclusions

Based on the dummy and vehicle responses which were converted into ANCAP frontal offset scoring, the results of this study suggest that there is a small reduction in the average ANCAP frontal offset score of 5.5% in an older vehicle model compared to when it was new. However, if the evaluation were done using the crashworthiness approach, this would result a 1.5% reduction. Nevertheless, both results demonstrate a notably small reduction in the ANCAP score. This illustrates a minor degradation of vehicle features, however the vehicle safety features such as airbags, seatbelt pretensioners and load limiter in the older vehicles still continue to work and provide protection to the vehicle occupant.

Limitations

The results presented in this paper are made from observations of one model of passenger vehicle. Other vehicles may behave differently.

As the original ANCAP frontal test was conducted using one model vehicle, it is assumed that the dummy responses in the original test were consistent.

It should be noted in that the 9-year-old vehicles were not randomly sampled from within the fleet. Only vehicles with working airbags and intact structures were selected and used.

References

EuroNCAP (2004), Frontal Impact Testing Protocol, version 4.1. March 2004.

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