International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 9 ǁ September 2022 ǁ PP. 539-546

Soft Target Vehicles for active evaluation of ADAS Testing

QI YUAN[*1], ZHIPING GUO [2]
[*1] *College of Energy and Power Engineering, Inner Mongolia University of Technology, Hohhot, CO 010050 China*
[2] *College of Mechanical Engineering, Inner Mongolia University of Technology, Hohhot, CO 010050 China*

Abstract
Soft target vehicles play an important role in the automotive advanced driving assistance system (ADAS) testing and improve the safety and efficiency of the tested intelligent vehicles. In the dangerous test process, use soft target vehicles instead of actual vehicles are a safe and efficient method for the development and testing of ADAS, including automatic emergency braking systems. This paper introduces the development process of the full-scale soft target vehicles, focusing on the design of the shape and structure of the soft target vehicles, material selection and the design of the traction device. The developed soft target vehicle has good performance, which provides a reference for the development and use of the soft target vehicle.
Keywords: *Soft target vehicle; ADAS; Automobile testing; Test equipment.*

Date of Submission: 10-09-2022 Date of acceptance: 25-09-2022

I. INTRODUCTION

Due to the rapid development of automotive ADAS technology [1], the demand for functional testing of automotive ADAS has also increased. Based on the consideration of safety and test efficiency, the actual vehicle is generally not used as the target vehicle to participate in the test, but an alternative that satisfies the recognition characteristics of vehicle sensors, has high dynamic characteristics, does not damage the tested vehicle during collision, and has a trajectory following function. The test equipment of the target vehicle is also called a soft target vehicle because the main part of the collision of the replacement Surrogate Vehicles (SV) is usually composed of airbags or foams. Autonomous Emergency Braking (AEB) is also called collision avoidance, collision mitigation, advanced braking, etc. It uses radar, camera, and vehicle-to-road communication to detect impending collision hazards, and can automatically detect potential collisions ahead. Active safety system that is dangerous and activates the vehicle braking system and automatically takes measures to avoid or mitigate vehicle collisions. According to the research data of the American Highway Safety Insurance Association, the AEB system can reduce 27% of traffic accidents [2], Euro NCAP and ANCAP published "Showing the effectiveness of AEB in rear-end collisions in the world" research report shows that the AEB system can be used in the real world. Reduced 38% of rear-end collisions [3]. In March 2016, the National Highway Traffic Safety Administration (NHTSA) and the National Highway Safety Insurance Association announced that 99% of American automakers agreed to include automatic emergency braking systems in the standard configuration of all new vehicles in the United States by 2022 middle. Within the European Union, an agreement on automatic emergency braking systems was reached in 2012. The United Nations Economic Commission for Europe (UNECE) has announced that beginning in 2015, the automatic emergency braking system will become a mandatory requirement for the application of new heavy-duty trucks [4]. In China, starting from April 2019, in accordance with the requirements of the "Technical Conditions for the Safety of Operating Passenger Cars", operating passenger cars above 9 m should be equipped with the AEB system [5]. This puts forward requirements for the testing and evaluation of automotive active safety technologies including the AEB system. Automotive safety evaluation is no longer just a traditional passive safety test and evaluation, but a comprehensive evaluation that includes active safety and passive safety evaluation. The research and development of the soft target vehicles by relevant institutions in the United States, the European Union and other countries has been relatively mature and can basically meet the test requirements, but there are still many problems in the test process, and the price is expensive. There is no mature the soft target vehicle in China, and it basically relies on foreign equipment. Some domestic automobile manufacturers often adopt some simple self-made the soft target vehicle when doing AEB system tests. The simulation capabilities are very limited, and they do not have dynamic simulation capabilities, and the test stability is poor, which is far from meeting the test requirements. Therefore, it is very important to research and develop advanced soft target vehicles.

Autonomous Emergency Braking (Autonomous Emergency Braking, AEB) is also known as collision avoidance, collision mitigation, advanced braking, etc. It is a way of detecting impending collision hazards using radar, camera, and vehicle-to-road communication, and can automatically discover potential ahead It is an active safety system that is dangerous and activates the vehicle's braking system and automatically takes measures to avoid or mitigate vehicle collisions [1]. According to the research data of the American Highway Safety Insurance Association, the AEB system can reduce traffic accidents by 27% [2]. The Euro NCAP and ANCAP "show the effectiveness of AEB in rear-end collisions in the world" research report shows that the AEB system can be used in the real world. Reduced 38% of rear-end collisions [3]. In March 2016, the National Highway Traffic Safety Administration (NHTSA) and the National Highway Safety Insurance Association announced that 99% of American automakers agreed to include automatic emergency braking systems in the standard configuration of all new vehicles in the United States by 2022 middle. Within the European Union, an agreement on automatic emergency braking systems was reached in 2012. The United Nations Economic Commission for Europe (UNECE) has announced that starting in 2015, automatic emergency braking systems will become mandatory requirements for the application of new heavy-duty trucks [4]. Starting from April 2019, according to the requirements of the "Technical Conditions for the Safety of Operating Passenger Cars", domestic operating passenger cars with a height of 9m or more should be equipped with the AEB system [5].

This puts forward requirements for the testing and evaluation of automotive active safety technologies including automatic emergency braking systems. Automotive safety evaluation is no longer just traditional passive safety testing and evaluation, but should include active safety and passive safety evaluation. Comprehensive evaluation.

According to the relevant test requirements, the test of the AEB system must be carried out with a simulated target vehicle, which must be able to simulate the characteristics of the real vehicle in the test conditions. The research and development of the soft target vehicles in related foreign institutions has been relatively mature and can basically meet the test requirements, but there are still many problems in the test process, and the price is expensive. There is not yet a mature the soft target vehicle in China, which basically relies on foreign equipment. Some domestic auto manufacturers often adopt some simple self-made the soft target vehicle when doing AEB system tests. The simulation capabilities are very limited, and they do not have dynamic simulation capabilities, and the test stability is poor, which is far from meeting the test requirements. Therefore, it is very important to research and develop advanced the soft target vehicles.

1.1 The development of the soft target vehicles

The development of soft target vehicles is constantly improving with the testing requirements of active safety technologies including AEB systems. Some OEMs and suppliers, such as Continental and Bosch, were the first to carry out related research and development [6]. With the advancement of technology, the simulation test target vehicle has developed from the initial static profiling target vehicle to the high simulation test target vehicle with dynamic performance and intelligence.

1.2 ASSESS project soft target vehicles

From July 2009 to December 2012, research institutions such as Daimler, Bosch, Toyota, German BAST, TRW, CHALMERS and the company jointly launched the ASSESS project, in which the test target vehicle was developed. ASSESSOR, as shown in Figure 1 [7]. The test target vehicle is composed of air-filled hoses, and its mass is only about 90 Kg. It has good collision tolerance and can withstand 200 impacts at a speed of 50 Km/h. The test target vehicle is divided into a half-type test target vehicle and a full-size test target vehicle. Compared with the full-size target vehicle, the half-type target vehicle has a lighter weight. It is mainly used for rear-end testing. The full-size test target vehicle can be used Various test conditions including frontal collisions. The surface of the target vehicle is pasted with a radar reflective material made of metal foil, so that it has radar reflective performance. It has good simulation performance and can be well recognized by the AEBS system with radar sensors.

(a) Half-type soft target vehicle （b）Full-size soft target vehicle

Fig.1 ASSESSOR soft target vehicle

1.3 IDIADA soft target vehicle

Figure 2 shows the simulated target vehicle of IDIADA. The structure of the simulated target vehicle is basically the same as that of ASSESSOR [6]. By fixing a boom similar to the tower crane structure on the tractor, the simulated target vehicle is suspended on the boom, so that the simulated target vehicle has dynamic performance, and has the advantages of speed accuracy and easy control of lateral offset. However, the boom and the actual car must be covered with absorbing materials to avoid interference with the radar system.

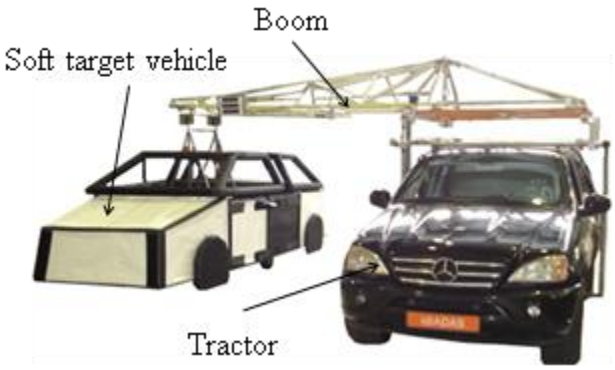

Fig2. IDIADA vehicle target

1.4 Euro NCAP balloon car

The soft target vehicle originally used by Euro NCAP for the AEB system test is a balloon vehicle with a vehicle shape, which was developed by the German Continental Corporation. The appearance and internal structure are shown in Figure 3. This kind of balloon car has front and rear arches, and they are connected by four pipes. The four connecting pipes are placed horizontally. The balloon car has two upper and lower positions. They play a role in resisting deformation and the effect of reducing the impact force can withstand the blow of high-speed airflow [8]. There is an inflator valve on both sides of the balloon car. When the test vehicle collides at a high speed, the internal gas can be released to protect the balloon car and the test vehicle from being damaged. Moreover, the outer surface of the balloon car is printed with a high-definition vehicle pattern, which makes it have the visual effect of a actual car, can be recognized by a variety of sensors including a camera, and has excellent simulation performance.

（a）（b）

Fig.3 Euro NCAP balloon car

2 Functional requirements of the soft target vehicles

The most basic functional requirement of the simulated target vehicle is that during the test, the characteristics of the simulated target vehicle recognized by the AEBS sensor should be highly similar to the characteristics of the actual vehicle. Therefore, the simulated target vehicle for testing must be designed in accordance with the following three principles: ① the similarity of the shape and structure; ② the high simulation of the characteristics of the actual vehicle; ③ the dynamic performance. Among them, the simulation of the characteristics of the actual car is the most important, which determines whether the simulated target vehicle can replace the actual car for the test test, and whether the AEBS performance test result is accurate. The simulation target should have the following characteristics:

1) The size and shape of the simulated target vehicle conform to the statistical data of the actual vehicle;

2) The characteristics of the simulated target vehicle recognized by the AEBS sensor should be highly similar to the characteristics of the actual vehicle;

3) The simulated target vehicle should have crash resistance and flexibility. After the test vehicle collides with the simulated target vehicle at a certain speed, neither the test vehicle nor the simulated target vehicle should be damaged.
4) The simulated target vehicle should have certain dynamic performance.
5) The simulated target vehicle should be easy to use and have the ability to quickly resume testing.

3 Development of the soft target vehicle

The development of the soft target vehicle involves many disciplines, such as physics, materials science, optics, sensor technology and manufacturing technology.

3.1 Dimensional design of the soft target vehicle

There is no uniform standard for the external dimensions of the soft target vehicle. According to relevant test experience, the soft target vehicle should refer to the external dimensions of the A-class vehicle for the following reasons:
1) This model is a mainstream model with the highest market retention rate;
2) Smaller dimensions, in order to better detect the performance of sensors such as radars and cameras.
The soft target vehicle is based on the domestic Chery QQ car, and its external dimensions are shown in Figure 9.

Fig.9 Dimensions of vehicle target

3.2 Structural design of soft target vehicle

3.2.1 Inflatable model

The soft target vehicle adopts an inflatable model with an air ribbed membrane structure. The length, width, and height of the inflatable model are 3300×1600×1530 mm, and the allowable dimensional tolerance is ±20 mm. The inflatable structure has high rigidity and can withstand high-speed airflow without major deformation. The outside of the inflatable model must be wrapped with a layer of absorbing material to prevent radar waves from penetrating the inflatable model and affecting the test results.

3.2.2 Corner reflector and reflective film

In order to make the simulated target vehicle have good radar wave reflection performance, it is necessary to paste the metal reflective film and install corner reflectors on the front and rear of the simulated target vehicle, so that the simulated target vehicle has the same radar reflection area as the actual vehicle. Since the reflection area of the radar at the front and rear of the actual vehicle is different, the size of the reflective film pasted on the front and rear of the simulated target vehicle is different, and the position height is also different. The specific dimensions are shown in Figure 12 and Figure 13. The inner side of the corner reflector is 55 *mm* long, and the reflection area of the 77 Ghz radar is 2.5 m^2. Its structure is shown in Figure 10.

Fig.10 The corner reflector Fig.11 The reflective film

3.2.3 Car clothing and reflective film

In order to enhance the 3D visual effect, the inflatable target vehicle is wrapped with a layer of jersey printed with a 1:1 high-definition vehicle pattern. At the corresponding positions before and after the simulated

target vehicle, actual vehicle license plates are hung, which can improve the simulation degree of the target vehicle.
In order to adapt to the AEB system with optical radar (LIDRA) sensors, the front headlights, taillights, high-position brake lights and other parts of the simulated target vehicle need to be pasted with reflective films. The pasting positions of the reflective films are shown in Figure 12 and Figure 13.

3.2.4 Other accessories

① License plate
The simulated target vehicle is suspended from a simulated license plate made of soft material, and the size of the license plate is the same as the size of the actual vehicle license plate. The simulated license plate is printed with the same paint as the actual license plate, which can well simulate the relevant characteristics of the actual license plate.
②Tire shadow
Paste 4 pieces of black absorbing materials on the front and rear of the target vehicle to simulate the shadow effect of the wheels.
③Shadow stickers
At the front and rear of the simulated target vehicle, in order to simulate the shadow effect of the bottom of the actual vehicle in the natural environment and reduce the radar reflection area here, a shadow sticker made of wave-absorbing material is pasted on the surface of the simulated target vehicle. The positions are as shown in Figure 12 and Figure below. 13 shown. Since the ground clearance of a sports car is less than 100 mm, the height of the shadow sticker must be less than the ground clearance of a sports car. Wheel stickers and shadow stickers can also block the metal parts of the lower part of the target vehicle, avoid increasing the radar reflection area and affecting the accuracy of the test results.

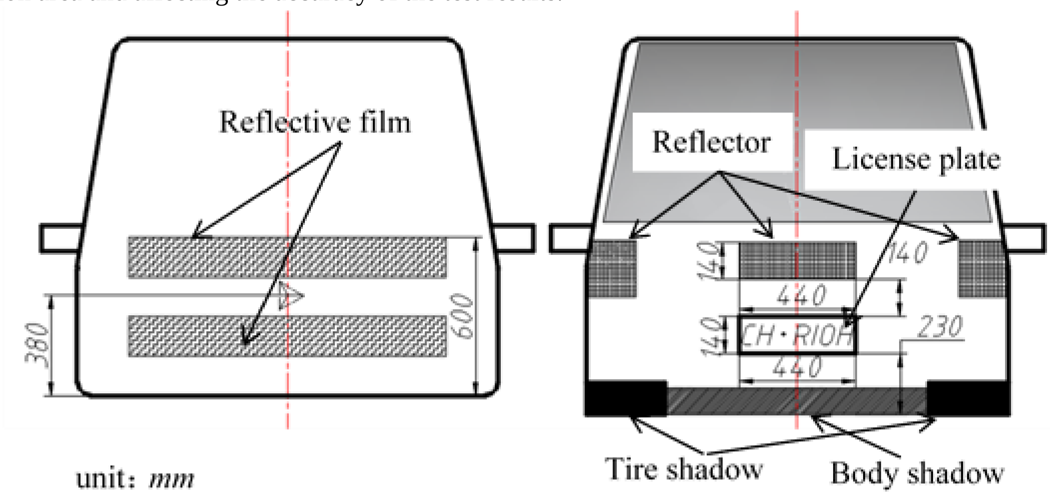

Fig.12 Front view of vehicle target

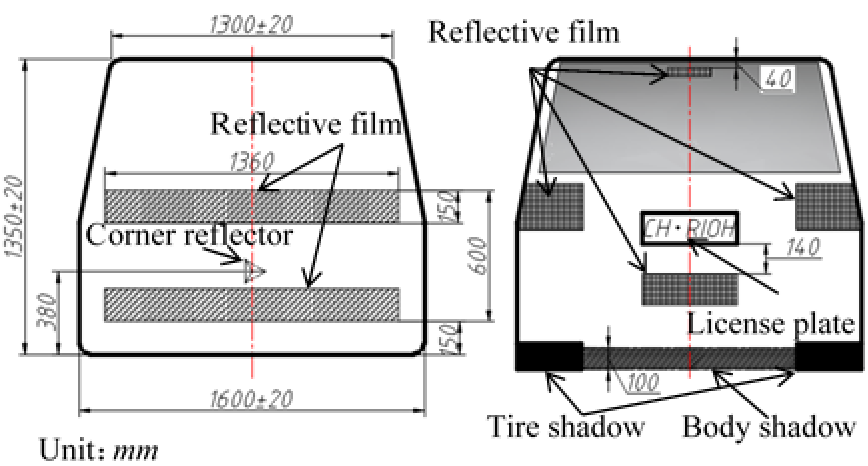

Fig.13 Rear view of soft target vehicle

3.3 Material selection

Table 1 shows the material types of each part of the soft target vehicle. The material of the inflatable model should have good air-tightness, elasticity, toughness and tear resistance, and good cushioning performance. A suitable inflatable model can be selected through experiments. High-performance glue should be used for the pasting of the reflective plate and the reflective film, which can withstand impact and airflow without falling off.

Tab.1 The material of vehicle target

Name	Material
Inflatable	TPU、EVA、PVC、PE、
Reflective film	PVC、PU
Absorbing material	Polyurethane foam
License plate	Polyester
Cover	PVC

3.4 Traction device

In order to meet the requirements of the test conditions for the dynamic performance of the simulated target vehicle, the Institute of Highway Science of the Ministry of Transportation is developing an intelligent high-speed mobile platform whose function is similar to the ground robot of the American DRI company. The platform can be used to carry a simulated target vehicle and simulate the simulated target vehicle used for AEB system testing, as shown in Figure 14. It can move along a straight line or a predetermined curve path at a certain speed, and its specific performance parameters are shown in Table 2. The platform is a multi-purpose ground mobile platform that can be equipped with simulated target vehicles, simulated non-motor vehicles, and target people to perform performance tests of a variety of automotive active safety systems including AEB systems.

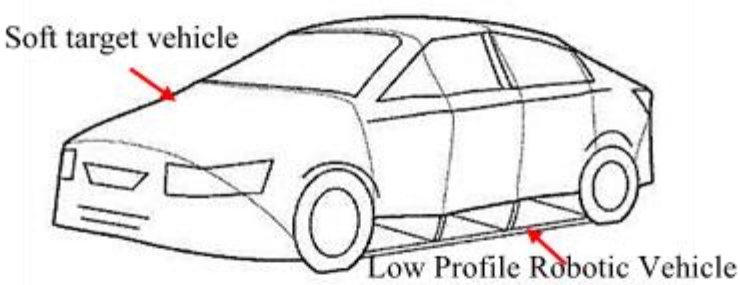

Fig.14 Soft target vehicle

Tab.2 The performance of dynamic motion element

Rated load（*Kg*）	120
Maximum ground clearance（*mm*）	30
Maximum speed（*Km/h*）	>80
Maximum impact speed（*Km/h*）	>110
Longitudinal acceleration（*g*）	+0.11, -0.8
Lateral acceleration（*g*）	±0.8（Peak value）
Path following accuracy（*cm*）	5 (steady state)
The farthest control distance（*m*）	1000
Position control accuracy（*cm*）	2
Turning radius（*m*）	<5

The intelligent high-speed mobile platform is mainly composed of three parts: the upper platform, the platform frame and the control system. The front-wheel drive can be used for differential control (the rear wheels can have a certain degree of free movement along their axis), so that the intelligent high-speed mobile platform has the ability to steer. A control system is set in the framework of the platform, and the control system is composed of a navigation module, a main control module, and a driving module. The main control module of the platform receives the position, speed, time and other data from the navigation module and the wireless communication data from the remote control device, compares it with the established path of the program in the module, gives the drive system control signal, and performs differential speed on the front wheels Control, make it drive or turn according to the established route, and complete the acceleration, deceleration, turning, running and stopping of the platform.

The platform can implement various collision test methods such as rear-end collision, head-on collision and side collision on the tested vehicle. At the same time, after the collision, the test vehicle can unobtrusively crush the high-speed intelligent mobile platform, and it will not affect the test vehicle. Causes a greater impact, and can withstand a weight of up to 3t without being damaged.

3.5 Experimental results

In order to verify the simulation performance of the soft target car, this paper conducted tests and comparison tests on the balloon car. The test conditions are: the target vehicle is stationary, and the vehicle is approaching the target vehicle at a speed of 20Km/h. The test results are shown in Figure 6. The first line is the recognition characteristics of Volkswagen Touran by radar and camera, and the second line is the recognition characteristics of the balloon car based on Touran. Different gray levels represent different credibility levels, and the number 5 corresponds to gray levels. Is the best, and the number 0 corresponds to the worst gray scale. The number in front of the ribbon represents the shortest distance (collision avoidance distance) that can be detected, and the number at the end is the longest distance that can be detected. The comparison results show that the balloon car has radar reflection characteristics and camera recognition characteristics similar to the height of the actual car.

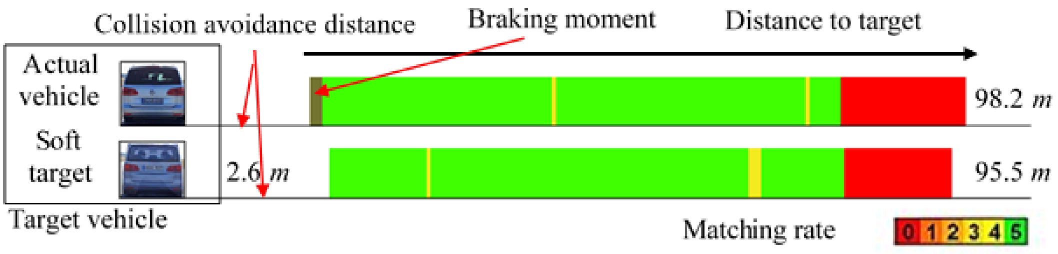

Fig.6 System outputs confidence level of an object based on radar and visual attributes

4 Conclusion

The soft target vehicle developed at present meets the requirements of various test conditions for the soft target vehicle in terms of the shape and structure design, material selection and design of the traction device. It has high simulation and good dynamic performance. The soft target vehicle as a testing tool, it can test and evaluate the performance of the AEB system.

Compared with foreign simulated target vehicles, this simulated target vehicle has front and rear simulation capabilities, which can implement various collision test methods such as rear-end collision, head-on collision and side collision of the tested vehicle. Because of its inflatable structure, it has good collision tolerance and will not cause damage to the test vehicle. Compared with assembling a target vehicle, it does not require an assembly process and can recover the test capability more quickly. Compared with the high price of foreign related test equipment, the simulated target vehicle has a higher cost performance. It can be said that the development of this the soft target vehicle has realized the leapfrog development of my country's automobile active safety test equipment.

Acknowledgements

This work was financially supported by Inner Mongolia Department of Science and Technology funding with grant No. [2017ZD02].

References

[1]. Kopetz H, Poledna S. Autonomous Emergency Braking: A System-of-Systems perspective//Dependable Systems and Networks Workshop. IEEE, 2013:1-7.
[2]. Huang Heng. Research on Effectiveness of Pedestrian Protection by Autonomous Emergency Braking Systems Based on Accident Reconstructions. Shanghai University of Engineering Science, 2015.
[3]. Fildes B, Keall M, Bos N, et al. Effectiveness of low speed autonomous emergency braking in real-world rear-end crashes. Accident; analysis and prevention, 2015, 81:24.
[4]. ECE R131.Uniform provisions concerning the approval of motor vehicles with regard to the Advanced Emergency Braking Systems (AEBS).
[5]. JT/T 1094-2016, Safety specifications for commercial bus.
[6]. Volker Sandner. Development of a test target for AEB systems Development process of a device to test AEB systems for consumer tests[C]. 23rd International technical conference on the enhanced safety of vehicles: ESV 2013, Seoul, Republic of Korea, May 27-30, 2013ADAC,2013:1892-1898.
[7]. Aparicio A, Baurès S, Bargalló J, et al. Pre-Crash Performance of Collision Mitigation and Avoidance Systems: Results from the Assess Project. Physics Procedia, 2012, 50(50):238-247.
[8]. Euro NCAP. Euro NCAP Test protocol-AEB systems, Version 1.1. Belgium: Euro NCAP, 2015.06. http://www.euroncap.com
[9]. Lijun Jiang. Research on the Test and Evaluation Method of Autonomous Emergency Breaking System. Tongji University, 2014.
[10]. Kelly J, Broen P, Silberling J, et al. Devices, systems, and methods for testing crash avoidance technologies: US, US8583358. 2013.