Journal of Mechatronics and Robotics

Review

Mechatronic Systems to the Braking Mechanisms

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Article history
Received: 27-07-2020
Revised: 15-08-2020
Accepted: 18-08-2020

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Abstract: With the evolution of technology, the construction and geometry of the piston, together with the materials from which it is made, as well as the related manufacturing technologies, have been continuously improved. Thus, modern engines have become less polluting, working at higher temperatures and pressures. Body aerodynamics have been improved, leading to lower resistance forces from the air. Also, the internal losses of the engines, generated by friction, as well as those at the level of the tire-road interface were diminished. All these improvements to motor vehicles have led to a proportional decrease in native braking capacity. Moreover, this decrease is evident in tonnage vehicles, which are disadvantaged in terms of the small contact area of the friction elements in conventional braking systems. For these reasons as well as due to the attempts to coordinate the platoon of cars, the decrease of the fuel consumption, the increase of the safe speed of movement resulted in the necessity of the development of new auxiliary braking systems, or the improvement of the already existing ones.

Keywords: Machines, Engines, Robots, Automation, Mechatronic Systems, Kinematics, Dynamics, Engine Design, Dynamic Coefficient, Braking Capacity, Development of New Auxiliary Braking Systems

Introduction

Appearing in the second half of the 19th century, the automobile revolutionized transportation and concentrated the most significant scientific and engineering efforts to continually improve its performance.

More and more mechatronic systems (for engine management, ABS, ESP, active suspension, etc.,) have earned their place in the construction of modern cars, so that, in the end, the whole car can become one of the most representative mechatronic systems (by interconnecting subsystems with appropriate buses - for example, CAN-Bus, navigation systems, X-by Wire, telematics, etc.,).

Much of the effort of vehicle designers and manufacturers are directed towards increasing passenger safety and comfort and involves sophisticated mechatronic subsystems.

The intelligent systems used to ensure a higher degree of safety for the vehicle and especially the driver can be active or passive and have several very important roles: Effective collision avoidance; minimizing the effects of collisions and avoiding trauma, both for the vehicle's passengers and for the pedestrians involved in the accident. Active safety systems serve to prevent collisions and minimize their effects.

The braking systems of the cars are in permanent evolution, looking for the improvement of the safety and of the best compromise between performances, comfort, costs and mass on the vehicle. The main characteristics pursued by the manufacturers are:

- Comfort, or driving pleasure: Perceived effectiveness: Progressiveness: Stroke and accuracy of the brake control: The absence of noise and vibration
- Performances, real efficiency: Stopping distance: Thermal endurance: Stability and ability to maintain the trajectory during braking the vehicle;
- Costs (viewed through the vehicle manufacturer's perspective): System cost per vehicle (on delivery): Maintenance (leased vehicle fleets)
- Mass of the braking system and its gauge on the vehicle: Decrease the fuel consumption of the vehicle by reducing the mass of the system (40 kg, 0.1 l/100 km): permanent control of the residual braking force (15N residual force, 0.1 l/100 km); finding the largest volume of the system location and the minimum occupancy of the vehicle, by reducing and densifying the technical volumes
- Ever-increasing security and regulatory requirements

Science Publications

Lately, car manufacturers have placed a special emphasis on active safety systems and the results that vehicles obtain in impact tests. They pursue a very aggressive marketing policy in order to increase the number of units sold in a certain market, especially the poor ones and give up active safety systems, taking advantage of the low level of car culture in that market.

On surfaces with high grip, dry or wet, most cars equipped with ABS achieve better braking distances (shorter) than those without ABS, a driver with average skills on a car without ABS could by a cadence braking, reach the performance of a novice driver on an ABS car. However, for a significant number of drivers, the ABS improves braking distances in various conditions. The recommended technique for drivers in an ABS-equipped car in an emergency is to depress the brake pedal to the bottom and bypass any obstacles. In such situations, the ABS will significantly reduce the chances of skidding and loss of control. especially for heavy machinery.

On snow and macadam, ABS increases braking distances. On these surfaces, the locked wheels would deepen and stop the vehicle faster, but ABS prevents this. Some ABS models reduce this effect by increasing the cycling time, thus allowing the wheels to lock repeatedly for short periods of time. The advantage of ABS on these surfaces is improved car control and not braking, although a loss of control on these surfaces is still possible.

Once activated, the ABS will cause the pedal to pulsate. Some drivers, feeling this effect, reduce the pressure on the pedal and thus increase the braking distance. This helps to increase the number of accidents. For this reason, some manufacturers have implemented braking assistance systems that maintain the braking force in emergency situations.

The European Parliament has validated the European Commission's proposal to equip all cars, starting with 2009, with a Brake Assist System (ABS).

Therefore, since 2010, all new cars are equipped "from production" with ABS. According to statistics, if all the cars in the European car park had been equipped with this system, about 1,100 of the pedestrians involved in road accidents each year would have had their lives saved. This is given that, in October 2006, only 41% of new vehicles were equipped with ABS. The next step, in a vast European road safety improvement program, aims to introduce the standard Electronic Stability control system (ESP), starting in 2012.

The start of series production of the ESP electronic stability program in Europe ten years ago was a milestone in the development of brake control systems. Bosch was a major player in the leading development of this active safety system and in 1995, became the world's first supplier to ESP.

Since the start of series production, Bosch has continuously expanded the potential of ESP, which now allows the integration of new safety and convenience features.

The technical name of the system is ESP, meaning Electronic Stability Program, a name that suggests its usefulness quite well. However, the fact that most such systems installed on cars are manufactured by Bosch has led to its popularization under the name ESP, which the car electronics manufacturer has established since 1987 when it began developing it with Mercedes-Benz.

Road accident studies show that at least 40% of all fatalities are caused by skidding and, moreover, about 80% of all such accidents could have been prevented by using the ESP system.

Specialists cannot say for sure when the car was invented, because the car has undergone many changes over time and has been continuously improved. However, in order to have a more precise temporary reference, the date of January 29, 1886 was set as the moment when the car was invented. This is actually the date when engineer Carl Benz from Mannenheim obtained the patent for the first vehicle powered by an internal combustion engine.

Carl Benz could not know that this document would later be considered the birth certificate of the car, nor could he suspect that his patent would become the cornerstone for the construction of millions of cars around the world.

What did the "patented car" designed by Carl Benz look like? It didn't look like a car today, it was more like an open horse-drawn carriage. On the rear axle were two thin wheels, close to the height of a man, with hard rubber tires and wire spokes. In front of the footboard was a small spoke wheel, with which the vehicle could be driven by a system of levers. If anyone were to encounter such a tricycle on the street today, it would be hard for them to believe that it was a car and yet it was the first motor vehicle - that is, self-propelled!

Behind the bench was a sensational drive mechanism for that era: A 0.88 hp internal combustion engine with a cylinder and water-cooled. It moved the rear axle and wheels by means of belts, chains and shafts. The largest and most visible piece was a horizontal cast iron flywheel.

In his test trips, Benz had to start the engine with the steering wheel first. Then he quickly jumped forward, on the bench, engaged in the only speed and left, banging hard. Anyway, with 16 km/h! This bold ancestor of the car, created by Carl Benz, can still be seen today at the German Museum in Munich.

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Lately, car manufacturers have placed a special emphasis on active safety systems and the results that vehicles obtain in impact tests. They pursue a very aggressive marketing policy to increase the number of units sold in a given market, especially the poor ones and give up active safety systems, taking advantage of the low level of car culture in that market.

Today's car is a complex of mechatronic subassemblies designed to maximize the engine's operating parameters, increase traffic safety, protect the environment and increase passenger comfort.

This is possible with the help of hundreds of sensors, actuators and computers that control every subassembly of the vehicle. Even the lighting of a common light bulb is done with the help of a microcontroller (microchip with integrated software) to turn on the light gradually and not suddenly. The simple act of parking the car is assisted by parking sensors, video cameras, or more recently is performed automatically by the vehicle (Skoda Superb 2009).

Regarding traffic safety, there are numerous protection systems, among which we mention: Airbags (front, side, curtain, knee); ABS, which is an anti-lock wheel system for emergency braking, with the role of reducing the braking distance and keeping the car in the desired direction; ESP is a program that together with ABS ensures the stability of the car on slippery surfaces, etc. All these mechatronic systems require sensors, computers, software and actuators.

It goes without saying that the diagnosis and repair of modern cars require increasingly specialized staff, at the intersection of the three fields: Mechanics, electronics and computer science, in a word mechatronics.

Basically, from the car of 100 years ago, only the operating principles of the engines (Otto and Diesel) remain, but they will also disappear with the disappearance of oil resources when humanity will switch to electric cars.

As the density of road traffic and the average speed of traffic increased, so did the number of road events, thus increasing the degree of safety became a priority for carmakers.

This vast and complex field of security can be divided into three broad categories:

Active (primary) safety, which is the set of systems aimed at avoiding accidents. A field in which it is found: Connection with the ground, ergonomics, visibility, driver information. Examples: ABS, ESP, undercarriage, height-adjustable steering wheel, glazed surfaces.

Passive (secondary) security is defined as the set of systems aimed at protecting passengers during collisions.

Tertiary security is the set of systems with a role in accelerating the interventions of the security means and consists of the means of prevention of chain accidents, means of locating the vehicle and the way of access inside it. This category includes GSM emergency call system and GPS location (ODYSLINE), the lighting of emergency lights, firefighters' intervention model for adaptive airbags (Aabadi, 2019; Antonescu and Petrescu, 1985; 1989; Antonescu *et al*., 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001; Aversa *et al*., 2017a; 2017b; 2017c; 2017d; 2017e; 2016a; 2016b; 2016c; 2016d; 2016e; 2016f; 2016g; 2016h; 2016i; 2016j; 2016k; 2016l; 2016m; 2016n; 2016o; Cao *et al*., 2013; Dong *et al*., 2013; Comănescu *et al*., 2010; Franklin, 1930; He *et al*., 2013; Lee, 2013; Lin *et al*., 2013; Liu *et al*., 2013; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu, 2011; 2015a; 2015b; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e; 2011a; 2011b; 2012a; 2012b; 2013a; 2013b; 2013c; 2013d; 2013e; 2016a; 2016b; 2016c; Petrescu *et al*., 2009; 2016; 2017a; 2017b; 2017c; 2017d; 2017e; 2017f; 2017g; 2017h; 2017i; 2017j; 2017k; 2017l; 2017m; 2017n; 2017o; 2017p; 2017q; 2017r; 2017s; 2017t; 2017u; 2017v; 2017w; 2017x; 2017y; 2017z; 2017aa; 2017ab; 2017ac; 2017ad; 2017ae; 2018a; 2018b; 2018c; 2018d; 2018e; 2018f; 2018g; 2018h; 2018i; 2018j; 2018k; 2018l; 2018m; 2018n; Rulkov *et al*., 2016; Agarwala, 2016; Babayemi, 2016; Ben-Faress *et al*., 2019; Gusti, 2016; Mohamed *et al*., 2016; Wessels and Raad, 2016; Maraveas *et al*., 2015; Khalil, 2015; Rhode-Barbarigos *et al*., 2015; Takeuchi *et al*., 2015; Li *et al*., 2015; Vernardos and Gantes, 2015; Bourahla and Blakeborough, 2015; Stavridou *et al*., 2015b; Ong *et al*., 2015; Dixit and Pal, 2015; Rajput *et al*., 2016; Rea and Ottaviano, 2016; Zurfi and Zhang, 2016a-b; Zheng and Li, 2016; Buonomano *et al*., 2016a; 2016b; Faizal *et al*., 2016; Ascione *et al*., 2016; Elmeddahi *et al*., 2016; Calise *et al*., 2016; Morse *et al*., 2016; Abouobaida, 2016; Rohit and Dixit, 2016; Kazakov *et al*., 2016; Alwetaishi, 2016; Riccio *et al*., 2016a; 2016b; Iqbal, 2016; Hasan and El-Naas, 2016; Al-Hasan and Al-Ghamdi, 2016; Jiang *et al*., 2016; Sepúlveda, 2016; Martins *et al*., 2016; Pisello *et al*., 2016; Jarahi, 2016; Mondal *et al*., 2016; Mansour, 2016; Al Qadi *et al*., 2016b; Campo *et al*., 2016; Samantaray *et al*., 2016; Malomar *et al*., 2016; Rich and Badar, 2016; Hirun, 2016; Bucinell, 2016; Nabilou, 2016b; Barone *et al*., 2016; Bedon and Louter, 2016; Santos and Bedon, 2016; Fontánez *et al*., 2019; De León *et al*., 2019; Hypolite *et al*., 2019; Minghini *et al*., 2016; Bedon, 2016; Jafari *et al*., 2016; Orlando and Benvenuti, 2016; Wang and Yagi, 2016; Obaiys *et al*., 2016; Ahmed *et al*., 2016; Jauhari *et al*., 2016; Syahrullah and Sinaga, 2016; Shanmugam, 2016; Jaber and Bicker, 2016; Wang *et al*., 2016; Moubarek and Gharsallah, 2016; Amani, 2016; Shruti, 2016; Pérez-de

León *et al*., 2016; Mohseni and Tsavdaridis, 2016; Abu-Lebdeh *et al*., 2016; Serebrennikov *et al*., 2016; Budak *et al*., 2016; Augustine *et al*., 2016; Jarahi and Seifilaleh, 2016; Nabilou, 2016a; You *et al*., 2016; AL Qadi *et al*., 2016a; Rama *et al*., 2016; Sallami *et al*., 2016; Huang *et al*., 2016; Ali *et al*., 2016; Kamble and Kumar, 2016; Saikia and Karak, 2016; Zeferino *et al*., 2016; Pravettoni *et al*., 2016; Bedon and Amadio, 2016; Mavukkandy *et al*., 2016; Yeargin *et al*., 2016; Madani and Dababneh, 2016; Alhasanat *et al*., 2016; Elliott *et al*., 2016; Suarez *et al*., 2016; Kuli *et al*., 2016; Waters *et al*., 2016; Montgomery *et al*., 2016; Lamarre *et al*., 2016; Daud *et al*., 2008; Taher *et al*., 2008; Zulkifli *et al*., 2008; Pourmahmoud, 2008; Pannirselvam *et al*., 2008; Ng *et al*., 2008; El-Tous, 2008; Akhesmeh *et al*., 2008; Nachiengtai *et al*., 2008; Moezi *et al*., 2008; Boucetta, 2008; Darabi *et al*., 2008; Semin and Bakar, 2008; Al-Abbas, 2009; Abdullah *et al*., 2009; Abu-Ein, 2009; Opafunso *et al*., 2009; Semin *et al*., 2009a; 2009b; 2009c; Zulkifli *et al*., 2009; Marzuki *et al*., 2015; Bier and Mostafavi, 2015; Momta *et al*., 2015; Farokhi and Gordini, 2015; Khalifa *et al*., 2015; Yang and Lin, 2015; Demetriou *et al*., 2015; Rajupillai *et al*., 2015; Sylvester *et al*., 2015a; Ab-Rahman *et al*., 2009; Abdullah and Halim, 2009; Zotos and Costopoulos, 2009; Feraga *et al*., 2009; Bakar *et al*., 2009; Cardu *et al*., 2009; Bolonkin, 2009a; 2009b; Nandhakumar *et al*., 2009; Odeh *et al*., 2009; Lubis *et al*., 2009; Fathallah and Bakar, 2009; Marghany and Hashim, 2009; Kwon *et al*., 2010; Aly and Abuelnasr, 2010; Farahani *et al*., 2010; Ahmed *et al*., 2010; Kunanoppadon, 2010; Helmy and El-Taweel, 2010; Qutbodin, 2010; Pattanasethanon, 2010; Fen and Yunus, 2011; Thongwan *et al*., 2011; Theansuwan and Triratanasirichai, 2011; Al Smadi, 2011; Tourab *et al*., 2011; Raptis *et al*., 2011; Momani *et al*., 2011; Ismail *et al*., 2011; Anizan *et al*., 2011; Tsolakis and Raptis, 2011; Abdullah *et al*., 2011; Kechiche *et al*., 2011; Ho *et al*., 2011; Rajbhandari *et al*., 2011; Aleksic and Lovric, 2011; Kaewnai and Wongwises, 2011; Idarwazeh, 2011; Ale Ebrahim *et al*., 2012; Abdelkrim *et al*., 2012; Mohan *et al*., 2012; Abam *et al*., 2012; Hassan *et al*., 2012; Abd Jalil and Sampe, 2013; Abou Jaoude and El-Tawil, 2013; Ali and Shumaker, 2013; Zhao, 2013; El-Labban *et al*., 2013; Djalel *et al*., 2013; Nahas and Kozaitis, 2013; Petrescu and Petrescu, 2014a; 2014b; 2014c; 2014d; 2014e; 2014f; 2014g; 2014h; 2014i; 2015a; 2015b; 2015c; 2015d; 2015e; 2016a; 2016b; 2016c; 2016d; Fu *et al*., 2015; Al-Nasra *et al*., 2015; Amer *et al*., 2015; Sylvester *et al*., 2015b; Kumar *et al*., 2015; Gupta *et al*., 2015; Stavridou *et al*., 2015b; Casadei, 2015; Ge and Xu, 2015; Moretti, 2015; Wang *et al*., 2015; Petrescu *et al*., 2017af-aj; 2018o-v; Petrescu, 2015c; 2018a-b; Petrescu and Petrescu, 2018a-b; Petrescu and Petrescu, 2014f; 2014g; 2014h; 2014i; Antonescu and Petrescu, 1985; 1989; Aversa *et al*., 2017c; 2017e; 2016d; Petrescu and Petrescu, 1995a-b; 1997a-c; 2000a-b; 2002a-c; 2005a-e; 2011b; 2013a-e; 2014a-d; 2014f-I; 2015c; 2016d; 2018b; Petrescu, 2011; 2015a-c; 2018a; Petrescu *et al*., 2016; 2017a-j).

Materials and Methods

The braking system is the main system that intervenes between two energy states of a moving vehicle by modifying the parameters of the initial energy state (kinetic energy Ec and V).

A haymaking system is an element that changes the energy of the vehicle from the moment it comes into action, either until it is canceled, in case of stopping, or until the kinetic energy given by the speed to be kept constant on a slope or the imposed speed.

The purpose of the braking system is to reduce the speed of the vehicle in whole or in part, to immobilize the stationary vehicle or to ensure a constant speed when descending a slope.

Slowing down or stopping the wheels is achieved by rubbing between a fixed element, connected in one way or another with the body or chassis of the vehicle (brake pads or clogs) and an element integral with the moving wheels (brake discs, drums).

The braking system must convert kinetic energy into caloric energy and dissipate this heat as quickly as possible.

It follows that the elements of the braking system between which there is friction must have good resistance to high temperature and good thermal conductivity.

Current braking systems are capable of achieving decelerations of 6 ... 6.5 m/s² for cars and 6 m/s² for trucks. The effect is maximum when the wheels are braked to the locking limit.

The braking system must meet the following conditions:

- To ensure safe braking
- To ensure the immobilization of the vehicle on a slope
- To be capable of certainly imposed decelerations
- Braking to be progressive, without shocks
- Not to require too much effort on the part of the leader
- The effort applied to the actuation mechanism of the braking system is proportional to the deceleration, in order to allow the driver to obtain the desired braking intensity
- The braking force to act in both directions of movement of the car
- Braking should be done only at the intervention of the driver
- To ensure the evacuation of the heat that arises during braking
- To adjust easily or even automatically

DOI: 10.3844/jmrsp.2020.156.190

- To have a simple and easy to maintain construction

The braking system serves to:

- Reducing the speed of the car to the desired value or even to its stop
- Immobilization of the car when stationary, on a horizontal road or on a slope
- Maintaining the constant speed of the car in case of descending long slopes

The efficiency of the braking system ensures the enhancement of the car's speed performance.

In practice, the efficiency of the brakes is assessed by the distance a car stops at a certain speed.

The braking system allows a maximum deceleration of 6-6.5 m/s^2 for cars and 6 m/s^2 for trucks and buses.

In order to achieve the shortest possible braking distances, all the wheels of the car must be fitted with brakes (full braking).

The braking effect is maximum when the wheels are braked to the locking limit.

Classification of Braking Systems

According to the role, it plays:

- The main braking system, or main or service brake or foot brake (used to reduce travel speed or to stop the car)
- Stationary braking system or parking brake, or parking brake, or parking brake, or auxiliary brake (keep the car stationary on a slope indefinitely in the absence of the driver, or replace the main system in the event of its failure. The parking brake must have its own actuating mechanism, independent of that of the main brake. The recommended deceleration for the parking brake must be equal to at least 30% of the deceleration of the main brake. In general, the parking brake also takes on the role of the safety brake
- the additional braking system or deceleration device, (has the role of maintaining a constant speed of the car, when descending long slopes, without the use of other braking systems contributing to reducing the wear of the main brake and increasing traffic safety. It is used for cars with large masses or intended to work in mountainous regions

By functional role:

a. Main or service brake (foot)
   - Slows down or stops the vehicle in motion
   - Obtain maximum decelerations of 6-6.5 m/s^2
   - ACTS on all wheels
b. Safety brake
   - Allows the vehicle to stop if the main braking system fails
   - Is operated without the driver lifting both hands from the steering wheel
c. Parking brake
   - Ensures the immobilization of the parked vehicle, in the absence of the driver, on time
   - Unlimited
   - Should have its own control system, separate from the main brake
   - Sometimes it can replace the safety brake
d. Auxiliary brake
   - Has the same role as the main brake
   - Used to increase the effect of the main brake
e. Idle brake
   - Reduces the stresses and wear of the main brake when descending slopes
   - Long and is used in heavy vehicles

Depending on the shape of the rotating part, the brakes can be:

- With disk
- With drum
- Both

According to the shape of the fixed parts, which produce the braking, they can be:

- With clogs
- With discs (usually disc sectors)
- With tape
- A combination

Depending on the type of drive, the following can be distinguished:

- With direct actuation, to which the braking force is due exclusively to the force exerted by the driver
- With mixed drive, to which the braking was due both to the force exerted by
- Conductor as well as the energy of an external agent (compressed air or oil under pressure)
- Servo-operated brakes, at which the braking moment occurs due to an agent
- Outside, the driver having only the role of adjusting the braking intensity

Depending on the location of the brake, they can be:

- Wheel brakes
- Transmission brakes

According to the number of circuits through which the effort is transmitted to the brakes themselves:

- Single-circuit brakes
- Multi-circuit brakes

Braking systems with multiple circuits significantly increase their reliability and traffic safety, which is why in some countries there is an obligation to "divide" the circuits for certain types of cars.

Composition of the braking system can be seen in the Fig. 1.

The control pressure is generated in an emitting cylinder starting from the force applied on the brake pedal. This effort is amplified by a pneumatic stress amplifier powered by the natural depression of the motor or by a vacuum pump. There are also hydraulic effort amplifiers, controlled by a generator or a high pressure accumulator. The main control cylinder (or transmitter) of the hydraulic braking circuits is separated by a plunger which delimits two isolated circuits that each control a part of the brake receivers. The system is completed by pressure regulating bodies:

- Hydraulic brake corrector, ordered not by the rear axle, between the emitting cylinder and the rear axle brakes, in order to constrain the rear wheel slip from remaining lower than the front wheel slip
- Adjusting block and ABS wheel speed sensors, allowing the limitation of the pressure in the wheel brakes, where the tendency to lock is noticed

The brake pedal transmits the force exerted by the driver's foot via the brake amplifier (brake booster) to the main brake cylinder. It generates and distributes the brake fluid under pressure through the valve block to the front and rear brakes, which transforms it with the help of the receiving cylinders into mechanical effort (friction) to slow down, stop or immobilize the wheels.

The brake assist or brake booster (brake booster) is located between the brake pedal and the brake pump in the engine compartment. The purpose of the brake amplifier (brake booster) is to increase the force exerted by the driver on the brake pump. The principle is to create a pressure difference between two chambers separated by a grace membrane:

- Depression in the intake manifold in the case of a petrol engine
- With the help of a vacuum pump in the case of a diesel engine

Disc brakes are universally used in cars for their stability as well as for their good heat absorption and cooling capacity. The cast-iron discs are generally ventilated on front axle and are dimensioned so as not to exceed temperatures of 600 to 700°C in the case of some successive braking sequences, such as:

- Alpine descents, which require the thermal capacity of the discs and their cooling possibilities
- Acceleration-braking chains, which implicitly require the thermal capacity of the discs. This type of test is systematically practiced by specialized magazines in Germany

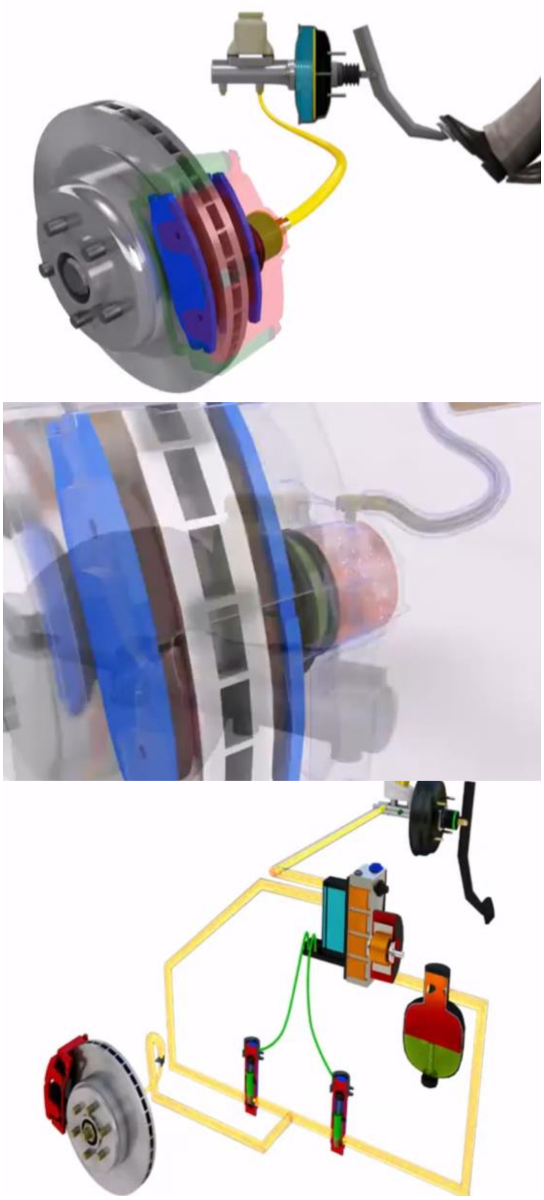

Fig. 1: Composition of the classic braking system

This is mainly the Auto Motor und Sport (AMS) test, which consists of, for example, chaining ten emergency brakes as quickly as possible, from 100 km/h to a stop, at a maximum load; the evaluation is made on the stopping space obtained at the last braking in the chain from ten. Consideration of this type of test is often predominant in sizing the brakes proper and their orders. The friction elements used in automobiles show significantly lower friction levels starting at about 300°C; it seeks to limit the temperatures reached during chain braking, especially with regard to increasing the thermal capacities of the discs. These being directly related to the geometric dimensions of the rotor, the current trend is to deal fully. In addition to the thermal properties, it is intended to develop many qualities in a brake, which are often contradictory:

- keeping under control the hot and residual deformations of the brake discs
- homogeneous distribution of pressure and wear of the friction pads
- reduced wear of the disc and of the friction skates
- high rigidity of the caliper, a small slide/disc play in the phases outside the braking and a reduced slip of the skate, in order to limit the hydraulic consumption
- the quality of the skates to neutralize the geometric defects present at the rotation of the disc
- low residual torque in the non-braking phases
- quiet operation, without vibrations

The progress made in these areas is the result of optimization and systematic control of the design parameters of the discs, of the friction elements and of the calipers. Spectacular developments or major technological innovations in the field cannot be highlighted. The last significant proposal is the subject of reinforced aluminum alloy discs, which have not been subject to a pre-established industrial application, due to functional limitations due to severe and costly demands.

Control of noise and vibration remains a major concern for car manufacturers and system components, suppliers.

These phenomena are not yet sufficiently predictable by calculation. The methods of characterization, analysis and treatment remain essentially the experimental ones; they are difficult to achieve, require a long analysis time and generally require test supports on the vehicle, so faithful that they end up being available in a developing project.

Drum brakes are limited due to their modest thermal performance, especially in what concerns the increase in brake absorption that accompanies the hot drum expansion. They are also of undoubted economic interest and remain present at the rear axle of small vehicles.

Economical, reliable and high-performance, pneumatic effort amplifiers are very widespread in automobiles. The assisting effort comes from the action of generating depression from the motor side to a vacuum pump. The amplification ratio generally varies from 4 to 6. The performances are limited by the available depression level and by the size of the pneumatic piston in play, which conditions the maximum assistance effort to be reached.

As the current trend is to reduce the depressions achieved by petrol engines and to increase braking performance, the volume available on the vehicle for the location of the amplifier risks becoming a serious handicap for this technology in the coming years.

Emergency brake assist is a quasi-generalized function provided by the brake booster. The development of this function was supported by the finding that a significant proportion (approximately 50%) of drivers would not have a behavior adapted to an emergency braking situation (Fig. 2).

One way to alleviate this situation is for the brake amplifier to detect the emergency condition, depending on the speed of actuation on the brake pedal, required to achieve the ABS intervention level and to maintain the high-pressure level until the actuation of the brake pedal is stopped. such a system allows the avoidance of 20% of collisions at intersections, according to an accidental analysis.

German car manufacturers have been equipping models with this function since the end of 1997. The other European manufacturers have started to systematically equip the proposed vehicles, since 2004. The current systems, based on electronics, remain expensive. Brake amplifier suppliers currently operate on mechanical systems, directly adapted to conventional pneumatic brake amplifiers. Anti-Lock Braking System (ABS) systems are wheel speed control and pressure limitation systems in the hydraulic braking system. For all European manufacturers, the application of these systems has become widespread, since 2008 being a regulatory condition for new models and since February 2011 they are applied to all models in production (Fig. 3).

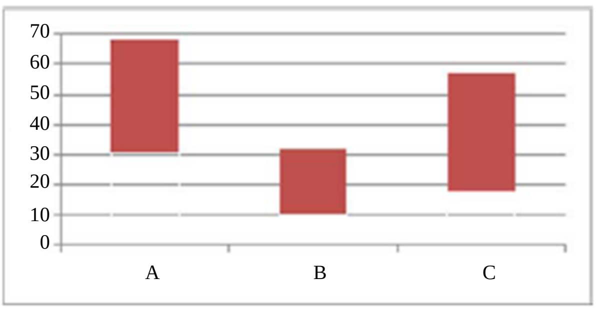

Fig. 2: Distribution of types of drivers braking in emergencies: A - good; B - hesitant; C - not adapted

DOI: 10.3844/jmrsp.2020.156.190

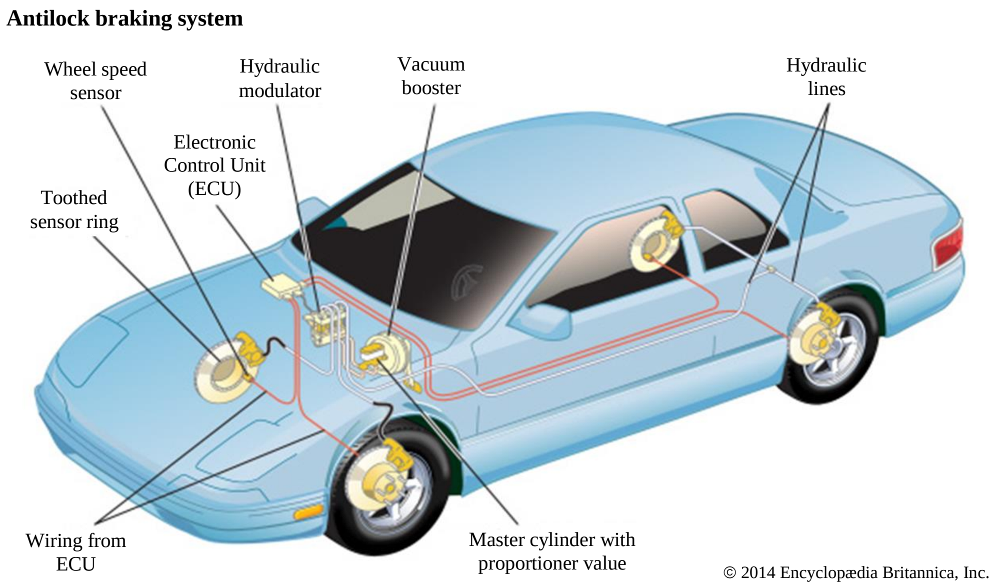

Fig. 3: ABS system

It works on the principle of threshold braking and cadence braking. Cadence braking and threshold braking is a technique by which a driver applies the brakes and releases it before the wheel locks, then applies to the brakes and releases it again before locking. This process of applying and releasing the brakes on the wheel is done in the form of pulses to prevent the vehicle from locking and stopping. The driver practices this technique to gain better control over the vehicle during instant braking and to stop the vehicle from skidding. The ABS system automatically applies this cadence braking to prevent the wheel from locking and slipping when the brakes are applied.

Understanding this in a better way allows us to take an incident. When you drive a car on a highway and suddenly an obstacle comes in front of you and apply the brake with maximum power. This will block the wheels of your car and your car will start to slip on the road and also during skidding, you have lost control of your direction and you cannot move the car in the desired direction. Eventually, you hit that obstacle and had an accident.

Let's take another situation, now drive a car that is equipped with an anti-lock braking system. When you encounter an obstacle on the road and suddenly apply the brakes. But this time your car's ABS system prevents the wheel from locking and prevents skidding. At this point you can control your direction and stop hitting the car in the obstacle. Thus, the abs system prevents the vehicle from slipping and ensures greater control over it and prevents accidents.

The Main Components of the ABS System

It has four main components:

1. Speed sensors
2. Valves
3. Pump
4. Controller

Speed Sensors

It is used to calculate the acceleration and deceleration of the wheel. It consists of a pinion and an electromagnetic coil or a magnet and a Hall Effect sensor to generate a signal. When the wheel or vehicle differences rotate, it induces a magnetic field around the sensor. The fluctuation of this magnetic field generates a voltage in the sensor. This generated voltage sends signals to the controller. With the help of the voltage, the regulator reads the acceleration and deceleration of the wheel.

Valves

Each ABS-controlled brake line has a valve. In some systems, the valve operates in three positions.

In position one, the valve remains open; and the pressure in the main cylinder passed through it to the brake.

In the second position, the valve locks the line and separates the brake from the main cylinder and this prevents the brake pressure from rising further. The valve operates in the second position when the driver applies the brake harder.

In the third position, part of the brake pressure is released from the valve.

Valve clogging is the major problem in ABS. When the valve is clogged, it becomes difficult to open, close, or change position. When the valve is running, it prevents the valve modulation module and brake pressure control.

Pump

The pump is used to restore pressure to the hydraulic brakes after the valve releases the pressure. When the controller detects wheel slip, it sends signals to release the valve. After the valve releases the supplied pressure from the driver, it restores the desired pressure to the brake system. The regulator modulates (adjusts) the condition of the pump so as to ensure the desired pressure and reduce wheel slip.

Controller

The controller used in the ABS system is of the ECU type. Its main function is to receive information from each individual speed sensor of the wheel and if a wheel loses traction with the ground, a signal is sent to the controller, the controller than limits the Braking force (EBD) and activates the ABS modulator. The ABS modulator is activated and stops the brake valves and varies the brake pressure.

The trajectory control (ESP = Electronic Stability Program) allows the correction of the vehicle's trajectory, by selective braking of the wheels and the reduction of the engine torque.

For this, the dynamic behavior of the vehicle (wheel speed, vehicle speed engaged on the path and transverse acceleration) is measured and compared with a calculated reference behavior having as input data the steering wheel angle and speed. The system intervenes when differences are identified between the actual behavior of the vehicle and the reference behavior. Although the cost of the system is still significant, it is mandatory in Europe, being applied to new vehicles since November 2011, this system.

The use of radar for traffic surveillance, installed in the front of the vehicle, allows the target vehicle to be stopped and the distance to it to be adjusted (automatic acceleration and braking). This type of system has been launched relatively recently; The price of the sensors still limits its development to certain vehicle segments only. A vehicle that does not have a right-of-way would be avoided.

The New Technologies

Brake by Wire

This principle consists in the complete decoupling of the brake pedal from the action applied to the brake. The first stage corresponds to Electro Hydraulic Brake (EHB), in the case of a system in a wedge, which keeps identical a hydraulic connection between the brake and the pedal.

This technology is widely used on all hybrid and battery-powered electric vehicles, including the Toyota Prius. The wired brake is also common in the form of the electric parking brake, which is now widely used on main vehicles.

The technology replaces traditional components such as pumps, hoses, liquids, vacuum and servo-belts and main cylinders with sensors and electronic actuators. Drive-by-wire technology in the automotive industry replaces traditional mechanical and hydraulic control systems with electronic control systems using electromechanical actuators and human-machine interfaces, such as pedal and steering emulators.

Some x-by-wire technologies have already been installed on commercial vehicles, such as steer-by-wire and accelerator-by-wire. Wired braking technology has been widely marketed with the introduction of battery-powered electric and hybrid vehicles, Toyota's most widely used high-volume application has been preceded by GM EV1, Rav4 EV and other EVs where technology is needed. For regenerative braking. Ford, General Motors and most other manufacturers use the same overall design, except for Honda, which has designed a very different design.

Brake-by-wire is used for all conventional hybrid and electric vehicles produced since 1998, including all Toyota, Ford and General Motors Electric and hybrid models. Toyota Synergy Drive and Rav4 EV use a system in which a modified ABS servomotor (anti-lock braking system) is coupled with a special hydraulic brake master cylinder to create a hydraulic system, coupled to the brake control unit (computer). The Ford system is almost identical to the Toyota system and the General Motors system uses different nomenclature for components, while the operation is virtually identical.

The hydraulic force generated by depressing the brake pedal is only used as a sensor input to the computer, unless a catastrophic failure occurs, including a 12-volt power loss. The brake actuator has an electric pump that provides hydraulic pressure to the system and valves to pressurize each wheel caliper to apply the friction brake when required by the system.

The system includes the full complexity of a Vehicle Stability Control system (VSC), an Anti-lock Braking System (ABS) and the requirement to use regenerative braking as the main mode of deceleration of the vehicle, excluding the battery pack). The state of charge is too high to accept additional energy or a panic stop or an ABS situation is detected.

Sensors monitored as inputs for the braking system include wheel speed sensors, traction battery charge status, fabric sensor, brake pedal, stroke sensor, steering wheel angle, hydraulic actuator pressure, hydraulic pressures of each caliper circuit and accelerator position. Other information and entries are also monitored.

The standard or typical operation is as follows:

- The vehicle operator depresses the brake pedal
- The main cylinder converts the movement of the brake pedal into hydraulic pressure

DOI: 10.3844/jmrsp.2020.156.190

- The stroke sensor measures the movement of the pedal to identify a "panic stop" state
- The pressure transducer provides the desired brake force

The brake control unit (computer) detects the inputs and then checks the wheel speed sensors to determine the vehicle speed and to determine if a wheel lock requires the ABS algorithm.

The brake control system then checks the rim sensor, steering wheel angle and traction battery charge status.

If the vehicle speed is higher than 7 MPH, the vehicle's traction generator is used as a generator to convert the kinetic energy into electricity and to store the energy in the battery. This slows down the vehicle.

If the operator (driver) presses the brake pedal harder, the system will apply hydraulic friction brakes to increase the brake force.

Once the vehicle speed drops below about 7 MPH, the hydraulic braking system will take over completely because regenerative braking does not work efficiently.

If the yaw sensor detects vehicle agitation, the system will initiate Vehicle Stability algorithms and processes (VSCs).

If the wheel speed sensors detect the wheel lock, the system will initiate an Anti-lock algorithm (ABS).

Normally, communication between the main emitting cylinder and the system is interrupted, the pedal movement and the pressure generated by the main emitting cylinder are measured and the brake pressure is generated by analog solenoid valves starting from the main control and other sensors that equip the vehicle. The sensors are the same as those of the ESP system. The generated pressure is distributed by a motor-pump group equipped with high Pressure (IP) accumulator with nitrogen that ensures very active and very effective braking. Due to the volume available in the battery, the system is no longer sensitive to heating and absorption of the brakes due to the change of position of the pedal (pedal stroke). As an advantage, the pedal pulsations are no longer felt in the operation of the ABS. Solenoid valve flows are available immediately, which allows optimization of response times. The stability limits of conventional braking systems can also be forced and brakes can be equipped with different types of friction linings, with a relatively low coefficient of friction at first but constant variations. temperature, which allows a noticeable increase in the life of the gaskets.

Compared to current, already high-performance solutions, this system offers a number of new possibilities (of course within the limits of technological possibilities), but their cost remains significant. The optimization of the architecture, in the sense of its optimization, will continue in the following years.

Electro-Mechanical Braking (EMB)

It is a system without hydraulics, which is still under study. The operation of Electro Mechanical Brake (EMB-Fig. 4) is based on a brushless electric motor, which uses an epicycloidal train and a cubic screw that drives the brake caliper. The system is installed on each brake to directly actuate the tightening of the pads. This system involves the installation of a large number of connectors and the use of electrical cables of the important sections, requiring generalization of the 42V standard on the vehicle. On the other hand, the use of EMB involves an overload of 2 kg at the level of each brake. The interest for such a solution, in terms of cost/benefit ratio, is quite poorly perceived at present. This technology can possibly be considered in the medium/long term (around 2020), while EHB is already present in some car manufacturers.

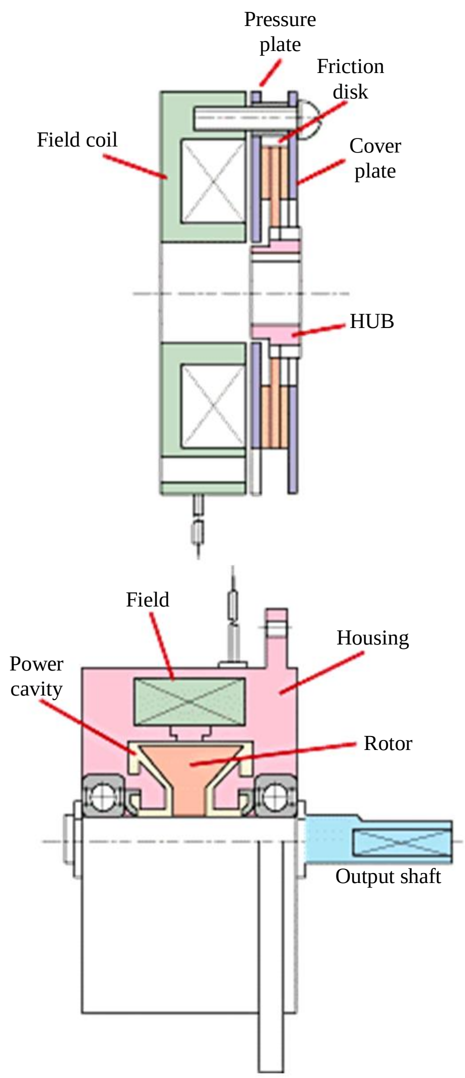

Fig. 4: Electro-Mechanical Braking (EMB)

Electromagnetic brakes (also called electromechanical brakes or EM brakes) slow down or stop the movement using electromagnetic force to apply mechanical resistance (friction). The original name was "electromechanical brakes", but over the years, the name was changed to "electromagnetic brakes", referring to the method of operating them. Since it became popular in the middle of the 20th century, especially in trains and trams, the variety of applications and braking models has increased dramatically, but the basic operation remains the same.

Both electromagnetic brakes and rotary brakes use electromagnetic force, but electromagnetic brakes ultimately depend on friction and current brakes will use magnetic force directly.

Automotive braking systems have evolved significantly in recent years. These developments will continue and even accelerate in the coming years. The optimization of wheel brakes will continue in the field of noise and vibration, residual torque and wear. Increasing performance and reducing costs in the field of electronics already allow the widespread use of ESP systems or the "brake by wire" system, associated, more advanced functions will follow. Is it possible that the braking will become fully electric tomorrow? A fault-tolerant electronic architecture would seem feasible today. It remains to develop these systems as well as the associated brakes themselves, with electric drive. We will talk more about this, probably at the end of the current decade.

For heavy vehicles, intended for urban transport, with frequent stops, or for traffic on mountain roads - where long slopes have to descend - it is necessary to provide additional brakes (deceleration devices), which will allow reducing the degree of brake demand on duty.

According to the principle of operation, they can be the motor, electrodynamic and hydrodynamic. Being simpler from a constructive point of view, the engine brake is used more.

ESP = Abbreviation is taken from English for Electronic Stability Program - Program for electronic control of the stability of a vehicle, working in collaboration with other electronic management programs for wheel skating (ABS, ASR, EDC, etc.). This program allows you to correct the trajectory of the vehicle by acting in a controlled manner on the braking system and on the fuel injection of the engine.

ESP is an active safety system provided onboard a machine, which allows its control and stability during critical maneuvers and corrects possible oversteer and understeer. ESP uses sensors to delineate the route the driver wants and update the route the vehicle travels. The electronic stability program ESP is the ultimate equipment. Equipment that interacts with all other equipment of the machine at the time of running. If you have ESP, the other technical systems related to active safety do not matter, because you certainly have them all.

It processes information from all sensors and makes decisions about the operating mode of the engine or other equipment, such as ABS. For example, in the case of curves taken too fast, the ESP extends the ABS function (reduces the risk of skidding) and punctual intervention on the engine management prevents a possible skidding of the vehicle. The ESP operates in the entire speed range and engages automatically each time the engine is started. This system can be switched on and off if necessary by pressing the ESP key.

The role of the ESP is to control the vehicle in difficult situations. ESP brings complementary support to ABS and anti-skid cornering systems, where the risk of accidents is higher. It allows all users to have "good reflexes" in critical situations because many users do not know how to react in case of loss of grip by the vehicle.

When driving the car, the driver has, in principle, three actuating elements (steering wheel, accelerator pedal and brake pedal) which constitute the human-machine interface. As a result of the action of these three elements, the car acquires a certain trajectory considered by the driver closest to the desired one. From the interaction between the vehicle and the road made through the tires, depending on external conditions, the driver's experience or the occurrence of unforeseen situations, the trajectory followed by the vehicle may differ from the estimated one.

Like any control system operating in the feedback loop, driving the car involves a driven element, the car, or a reaction element, in this case the driver, whose direct intervention occurs in response to the instability of the driving system.

Intelligent active safety systems are also designed to operate in closed-loop systems that maintain the human as a reaction element, but correct and improve the reaction time through an additional loop provided by sensors and digital computing devices.

Electronic Control Unit (ECU) - receives information such as machine speed, lateral accelerations, a moment of inertia (degree of rotation of the machine around the vertical axis, which alters its position in the direction of travel).

Steering wheel rotation sensor - analyzes the received information and calculates the trajectory imposed by the driver.

ESP hydraulic control unit - includes a computer. It receives information from various sensors and sends instructions to the braking system, accurately dosing the braking pressure. It also adjusts torque if necessary.

Electronic Stability Control (ESC), also called Electronic Stability Program (ESP) or Dynamic Stability Control (DSC), is a computer technology that improves vehicle stability by detecting and reducing traction losses (skidding). When the ESC detects a loss of steering control, it automatically applies the brakes to help "steer" the vehicle where the driver intends to go. Braking is automatically applied to individual wheels, such as the outer front wheel to control overload or the inner rear wheel to counteract. Some ESC systems also reduce engine power until control is regained. ESC does not improve the cornering performance of the vehicle; instead, it helps reduce the loss of control.

According to the US National Road Safety Administration and the Insurance Institute for Road Safety since 2004 and one-third of fatal accidents, respectively, could be prevented by using technology. ESC has been mandatory in new cars in Canada, the USA and the European Union since 2011, 2012 and 2014, respectively.

ESC systems - due to their complete control over the stability, traction and braking of the vehicle - often perform tasks to improve off-road traction (in addition to tolls) on passenger and commercial vehicles. The efficiency of traction control systems can vary significantly from one brand to another, due to the significant number of external and internal factors involved at a given time, as well as the extent of the manufacturer's programming and development. The brand with prominent legacies, such as Land Rover, Jeep and Toyota (among others), places a significant emphasis on the off-road capabilities of their vehicles and, as such, on the performance of the towing aid and stability.

At a rudimentary level, off-road traction varies from the typical operating characteristics of road traction, depending on the terrain encountered. In an open differential configuration, the power transfer has the lowest resistance path. In slippery conditions, this means that when a wheel loses traction, the power of that axle will be counterproductive instead of the one with a larger grip. CES focuses on brake wheels that rotate at a drastically different speed from the opposite axis. While the on-road application often complements fast intermittent braking, with a reduction in traction losses, off-road use will usually require a constant (or even increased) supply of energy to maintain the vehicle's momentum. while the vehicle's braking system is applied intermittently. Longer braking force to the sliding wheel until excessive wheel rotation is no longer detected

During off-road use, it is essential for safety that the vehicle's ESC disables Anti-lock Braking (ABS) systems. Although initially, it sounds counter-intuitive, extremely slippery, low traction situations encountered off-road can lead to a vehicle accident when climbing or descending on steep terrain. If the vehicle loses traction on steep terrain and brakes are applied, the inertia of the vehicle continues to move the vehicle while some wheels lock. The ABS system interprets this behavior as locking the wheels during "normal" braking and quickly releases and reloads the brake on the locking wheels. This leads to a very low braking efficiency, as the vehicle tries to avoid locking the wheels and instead rotates them constantly towards each other. If the reduced braking force is not enough to stop the vehicle (as is the case on even fairly steep terrain with low traction), the vehicle will continue to rapidly increase the momentum on the hill without slowing down. Such situations often lead to serious overturning accidents when the vehicle descends in a perfectly straight descent.

In intermediate level ESC systems, ABS will be disabled, or the computer will actively lock the wheels when brakes are applied. In these systems or in vehicles without ABS, the performance of emergency braking in slippery conditions is much improved, because the grip can change extremely quickly and unpredictably off-road when coupled with inertia. When the brakes are applied and the wheels are locked, the tires must not experience rolling of the wheels (which do not provide braking force) and braking repeatedly. The handle provided by the tires is constant and, as such, can use full traction wherever available. This effect is enhanced when more aggressive tread patterns are present, as the large tread pockets dig up imperfections on the surface or substrate and pull the dirt in front of the tire to increase it even more.

Electronic Stability Control (ESC) is the generic term recognized by the European Automobile Manufacturers Association (ACEA), the North American Society of Automotive Engineers (SAE), the Japan Automobile Manufacturers Association and other worldwide authorities. However, vehicle manufacturers may use a variety of different trade names for ESC.

What is the Electronic Stability Program or Electronic Stability Control (ESP/ESC)?

Imagine that you are driving a car at high speed and you will suddenly find an obstacle. In such a scenario, you will be forced to make a sudden turn or apply brakes to avoid a possible collision. As you do this, you may lose control and slip on the road. Thus, it can lead to an untrue incident, such as an accident. Also, the car you are driving can turn upside down. Thus, in order to avoid this situation, manufacturers use the Electronic Stability Program or the electronic stability control system. It is one of the active safety systems in a modern car.

The term ESP means the Electronic Stability Program, while the ESC means electronic stability control. It is an intelligent safety system that can predict driving intentions. First of all, ESP helps the driver to maintain the trajectory of the wheel. It does this by applying the brakes on the individual wheels. Second, it can also adjust engine performance in critical maneuvers. However, the ultimate goal of ESP is to increase vehicle stability. Thus, ESP improves stability by avoiding skidding.

The electronic stability program consists of the following components which are (Fig. 5):

- Hydraulic unit
- Wheel speed sensors
- Steering angle sensor
- Side speed and acceleration sensor
- Engine control unit

The wheel speed sensors detect the speed of each wheel. Furthermore, they send this data to ECU continuously. The steering angle sensor determines the position of the steering wheel by measuring the actual steering angle. Additionally, the Yaw rate and lateral acceleration sensors determine the exact location of the vehicle with reference to the driver's input. Afterward, the ECU processes this input data. However, if the sensor data varies suddenly, the ESP detects that the vehicle is facing a difficult driving condition. Thus, the system can detect that if there is an obstacle in the path or a very sharp turn. In such cases, the system applies the desired braking force only on the wheels in need and thus, it restores the driver control over the vehicle.

This system has more advantages compared to the ABS and TCS systems. This is because it can actually predict the driving behavior of the vehicle. When the Electronic Stability Program comes into action, it gives an indication in the form of a glowing indicator in the instrument cluster. In most of the cases, the driver does not feel any difference in the vehicle except the enhanced control when the ESP starts working (Fig. 6).

While referring to the Electronic Stability Program or Electronic Stability Control, the majority of vehicle manufacturers use term ESP. However, some manufacturers use the following custom acronyms.

ESP combines the ABS anti-lock braking system with ESP (skid acceleration control) as a whole. 25 times per second, ESP monitors and compares the actual movement of the vehicle with the driver's maneuvers and at the first signs of instability, when the driver turns too much or too little behind the wheel, ESP sensors detect this movement in a fraction of a second and help when restoring the vehicle position by selectively applying the braking pressure to one or more wheels and by intervening on the engine system.

Electronic Stability Control is actually a fairly intelligent system, but it works integrated with computerized electronic devices that control a car.

Respecting the laws of cybernetics, ESP uses as sources of information a series of sensors located on different dynamic components of a vehicle. In this way, the rotational speed of each wheel, the printed direction of the steering wheel and the extent to which the car body follows exactly this direction are known at all times.

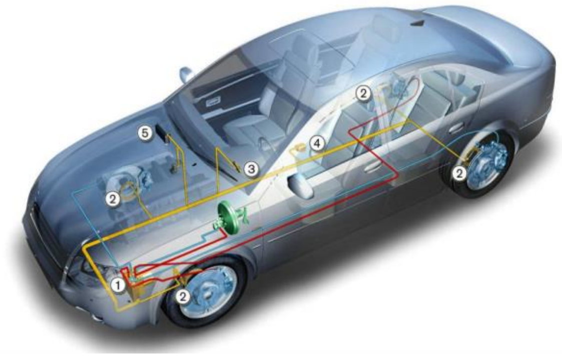

Fig. 5: Electronic stability program components

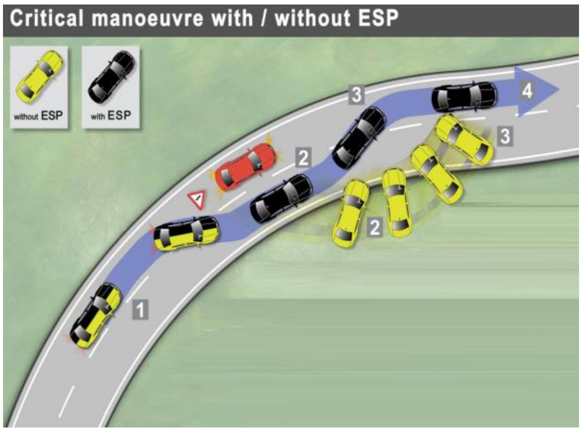

Fig. 6: Critical manoeuvre with and without EPS

For the traction component there are also simpler systems that only prevent one or more wheels from slipping. An integrated ESP will check not only the differences between the angular speed of the wheels but also the lateral movement of the machine. The response time is usually of the order of milliseconds so that the intervention can be considered quite prompt. For traction only, the action is limited to preventing the wheel/wheels from slipping, so that steering control is possible, similar to what an ABS does when braking. In the case of ESP, the moment the car skids, the system processes the information and acts where it should: The brakes intervene on one or more wheels, individually, to correct the trajectory and the engine is prevented from generating more torque, eliminating thus the forces that generated the displacement.

For example, if the front wheels begin to skid during cornering, producing what we call understeer (moving out of the curve), ESP brakes the rear wheel from the inside, so that the trajectory is corrected. If the rear wheels skid, i.e., the car overturns (starts to turn inwards on the curve), ESP brakes the front wheel from the outside, adjusting the trajectory.

Each time the acceleration is automatically reduced until the goal is reached. Simultaneously, the corresponding ESP lamp flashes on the vehicle, which warns the driver that the system is in full operation. Almost any vehicle equipped with ESP allows it to be disengaged from a button, the warning light being on in this case permanently. ESP decoupling is useful, for example, in the case of 4×4 vehicles that have to overcome a difficult obstacle, as the operation of the system is likely to reduce engine power and impede movement. The surfaces on which the intervention of the stability control system can be easily observed are wet asphalt and snow/ice.

In the automotive industry, wired brake technology is the ability to control the brakes by electric means. It can be designed to regularly supplement the service brakes or it can be a stand-alone braking system.

This technology is widely used on all hybrid and battery-powered electric vehicles, including the Toyota Prius. The wired brake is also common in the form of the electric parking brake, which is now widely used on main vehicles.

The technology replaces traditional components such as pumps, hoses, fluids, seat belts and servos and main cylinders with sensors and electronic actuators. Drive-by-wire technology in the automotive industry replaces traditional mechanical and hydraulic control systems with electronic control systems that use electromechanical actuators and human-machine interfaces, such as steering emulators.

Some x-by-wire technologies have already been installed on commercial vehicles, such as steer-by-wire and accelerator-by-wire. Wire braking technology has been widely marketed with the introduction of electric vehicles and battery-powered batteries. Toyota's most used high-volume application was preceded by GM EV1, Rav4 EV and other EVs where technology is needed for regenerative braking. Ford, General Motors and most other manufacturers use the same overall design, except for Honda, which designed a very different design.

Brake-by-wire is used for all regular hybrid and electric vehicles produced since 1998, including all Toyota, Ford and General Motors Electric and hybrid models. Toyota Synergy Drive and Rav4 EV use a system in which a modified ABS (anti-lock) servomotor is coupled to a special hydraulic brake cylinder to create a hydraulic system, coupled to the brake control unit (computer). The Ford system is almost identical to the Toyota system and the General Motors system uses different nomenclature for components, while the operation is virtually identical.

The hydraulic force generated by depressing the brake pedal is used only as a sensor input to the computer, unless a catastrophic failure occurs, including a 12-volt power loss. The brake actuator has an electric pump that provides hydraulic pressure to the system and valves to pressurize each wheel caliper to apply the friction brake when the system is needed.

The system includes the full complexity of a Vehicle Stability Control (VSC) system, an Anti-lock Braking System (ABS) and the requirement to use regenerative braking as the main vehicle deceleration mode, except for the traction battery (high voltage) the state of charge is too high to accept the extra energy or a panic arrest or ABS situation is detected.

Sensors monitored as inputs for the braking system include wheel speed sensors, traction battery charge status, fabric sensor, brake pedal, stroke sensor, steering wheel angle, hydraulic actuator pressure, hydraulic pressures of each caliper circuit and accelerator position. Other information and entries are also monitored.

The wire brake is available on heavy commercial vehicles under the name Electronic Braking System (EBS). This system ensures the electronic activation of all components of the braking system, including the retarder and the engine brake. EBS also accepts trailers and communicates between the towing vehicle and the trailer using the ISO 11992 protocol. Communication between the trailer and the towing vehicle will be via a dedicated ABS/EBS connector, according to ISO 7638-1 for 24V or ISO 7638 systems. -2 for 12V systems.

EBS still relies on compressed air for braking and controls air only through valves, which means it does not depend on higher voltages used by electromechanical or electro-hydraulic braking systems, where electricity is also used to apply brake pressure.

EBS improves braking accuracy compared to conventional braking, which reduces braking distance. The failure of an EBS system in the event of a malfunction is the use of the usual air brake control pressure so that even in the event of a malfunction of the electronics, the vehicle will be able to stop safely.

Results and Discussion

Bus Braking Study

Braking the bus is the process of reducing its speed to a certain value or to a stop.

The safer, more intense, faster and more controlled the braking, the safer the bus can travel at higher speeds. The possibility of increasing the average speed of the bus also depends on the braking capacity and the safety of the bus and its passengers also depends on it.

Every bus is constructively provided with a braking system that acts on each wheel separately, giving rise to braking moments on each wheel, moments that seek to immobilize each wheel separately.

The braking torque Mf (Fig. 7) occurs by rubbing a drum or disc 1 (solid with the wheel marked with 2) with some braking shoes integral with the fixed part of the axle (crankcase). The braking moment opposes the rotational movement of the wheel and seeks to immobilize it.

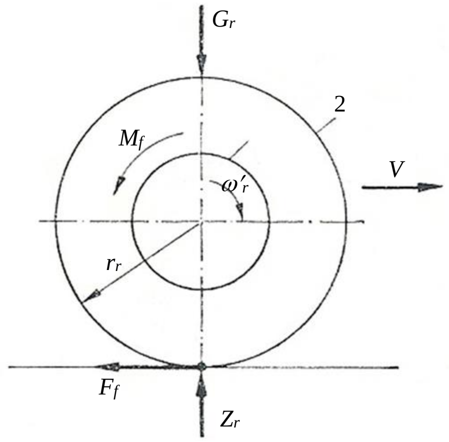

Fig. 7: The forces and moments acting on a braked wheel

During braking, the bus moves only under the action of inertial forces, consuming the kinetic energy produced and accumulated during acceleration.

Under the action of the braking moment M_f in the contact area of the wheel with the road, the reaction of the ground F_f directed in the opposite direction to the movement of the bus arises.

When braking the bus, in addition to the braking force, it contributes to the reduction of speed and endurance.

According to the principle of dynamic equilibrium in the case of bus braking, the relation (1) can be written, where F_i is the inertial force of the bus:

$$F_i = F_f + R_r \pm R_p + R_a \quad (1)$$

By replacing F_i and all the resistances with advance with their already known expressions, the expression (2) is obtained:

$$\frac{G_t}{g} \cdot \delta \cdot a_f = F_f + G_t \cdot f \cdot \cos\alpha \pm G_t \cdot p + \frac{K \cdot A \cdot V^2}{13} \quad (2)$$

Given that both rolling and air resistance when moving the bus at speeds less than 100 [km/h] are low compared to the braking force, both can be neglected so that relation (2) will get the simplified aspect (3):

$$\frac{G_t}{g} \cdot \delta \cdot a_f = F_f \pm G_t \cdot p \quad (3)$$

The braking capacity of a bus (as in any other vehicle) is characterized by the following parameters: Deceleration, braking space and braking time (possibly stopping).

Determination of Deceleration When Braking

The expression of deceleration results from relation (4):

$$a_f = \frac{g}{\delta \cdot G_t} \cdot \left(F_f \pm G_t \cdot p\right) \quad (4)$$

If it is considered that the braking is done with the engine disengaged from the transmission, the coefficient of influence of the rotating masses can be taken $\delta \cong 1$. For a road with a certain slope p, the obtained deceleration will be maximum when the braking force will have the maximum value (5):

$$\left(a_f\right)_{\max} = \frac{g}{G_t} \cdot \left(F_{f\max} \pm G_t \cdot p\right) \quad (5)$$

The maximum value of the braking force is limited by the grip (6), where G_{adf} is the braking weight of the bus:

$$F_{f\max} = G_{adf} \cdot \varphi \quad (6)$$

In the case of a bus (trolleybus) which has all the wheels braked when traveling on a slope, the relation (6) is written in the form (7):

$$F_{f\max} = G_t \cdot \varphi \cdot \cos\alpha \quad (7)$$

Replacing the expression (7) in relation (5) we obtain the relation (8) which defines the expression of the braking deceleration of the bus on a certain road, on a slope:

$$\left(a_f\right)_{\max} = g \cdot \left(\varphi \cdot \cos\alpha \pm p\right) \quad (8)$$

However, if the bus travels on a straight road at the time of braking, the expression of the deceleration when braking changes accordingly, simplifying to form (9), it being proportional to the gravitational acceleration g and to the rolling resistance coefficient:

$$\left(a_f\right)_{\max} = g \cdot \varphi \quad (9)$$

Determination of Braking Distance

During braking, according to the kinetic energy theorem, the variation of the kinetic energy is equal to the mechanical work (of the braking forces) corresponding to the braking space.

Considering that the braking takes place with the transmission engine disengaged, according to the kinetic energy theorem we can write the relation (10), where m is the mass of the bus, v^1 is the speed at the beginning of braking in m/s, v^2 is the speed at the end of braking in m/s and sf represents the braking space in *m*:

$$\frac{m \cdot \left(v_1^2 - v_2^2\right)}{2} = \left(F_f + R_r \pm R_p + R_a\right) \cdot s_f \quad (10)$$

DOI: 10.3844/jmrsp.2020.156.190

If the bus runs at speeds slower than 100 km/h when braking, the influences of rolling resistance R_r and air resistance R_a can be neglected so that the relation (10) acquires the simplified form (11-12), where the mass of the bus was substituted with G_t/g and all elements are measured in SI:

$$\frac{m \cdot \left(v_1^2 - v_2^2\right)}{2} = \left(F_f \pm R_p\right) \cdot s_f \tag{11}$$

$$s_f = \frac{G_t \cdot \left(v_1^2 - v_2^2\right)}{2 \cdot g \cdot \left(F_f \pm R_p\right)} \tag{12}$$

However, if we want to enter the two speeds in km/h, the relation (12) takes the form (13), where V^1 and V^2 are entered in km/h:

$$s_f = \frac{G_t \cdot \left(V_1^2 - V_2^2\right)}{26 \cdot g \cdot \left(F_f \pm R_p\right)} \tag{13}$$

The minimum braking distance (14), corresponding to a certain slope, is obtained when the braking force has the maximum value:

$$s_{f\,\min} = \frac{G_t \cdot \left(V_1^2 - V_2^2\right)}{26 \cdot g \cdot \left(F_{f\,\max} \pm R_p\right)} \tag{14}$$

For a bus that has all the wheels braked, replacing $F_{f\max}$ from relation (7) and $R_p = p.G_t$ is obtained for the minimum braking space relation (15), or when braking to a stop (when $V^2 = 0$) the expression (16):

$$s_{f\,\min} = \frac{\left(V_1^2 - V_2^2\right)}{26 \cdot g \cdot \left(\varphi \cdot \cos\alpha \pm p\right)} \tag{15}$$

$$s_{f\,\min} = \frac{V_1^2}{26 \cdot g \cdot \left(\varphi \cdot \cos\alpha \pm p\right)} \tag{16}$$

If the bus travels on a straight road, the expression (15) takes the form (17) and the relation (16) takes the simplified form (18), where (17) is the minimum braking space on a straight road and (18) represents the space minimum stop on a straight bus road:

$$s_{f\,\min} = \frac{\left(V_1^2 - V_2^2\right)}{26 \cdot g \cdot \varphi} \tag{17}$$

$$s_{f\,\min} = \frac{V_1^2}{26 \cdot g \cdot \varphi} \tag{18}$$

Determination of Braking Time

If it is considered that the bus has a uniformly slow motion during the braking period and if its deceleration is equal to (af) max, then the minimum braking time will be given by the relation (19), where all elements are given in the international system (v_1 and v_2 being introduced in m/s), so time will also result in *s*:

$$t_{\min} = \frac{v_1 - v_2}{\left(a_f\right)_{\max}} = \frac{v_1 - v_2}{g \cdot \left(\varphi \cdot \cos\alpha \pm p\right)} \tag{19}$$

In the case of braking to a stop ($v_2 = 0$), the minimum braking time will be given by the simplified relation (20):

$$t_{\min} = \frac{v_1}{\left(a_f\right)_{\max}} = \frac{v_1}{g \cdot \left(\varphi \cdot \cos\alpha \pm p\right)} \tag{20}$$

In reality, however, both the minimum braking distance and the minimum braking time have higher values than those calculated with the theoretically indicated relationships previously, because in the total braking time the time necessary for the bus driver's reaction and the time required to enter the action of the bus braking system.

Observation

The formulas previously determined have all been deduced from the assumption that all brakes instantly come into action with their full braking force.

Figure 8 shows the variation of the deceleration as a function of time, as well as the time intervals of the braking process.

The time t_1 is the reaction time of the driver and is equal to the time elapsed from the moment of noticing the need for braking to the moment of the actual start of braking. This time is between 0.4 s and 1 s, depending on both the physiological state of the driver and his skill and experience.

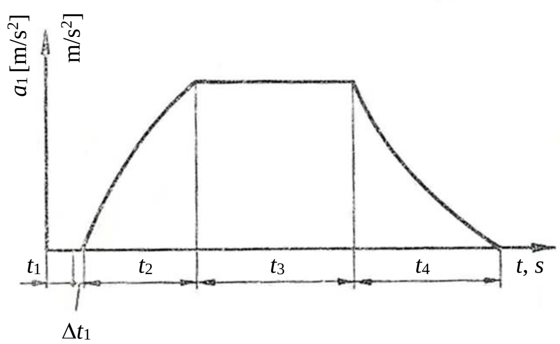

Fig. 8: Deceleration variation over time

DOI: 10.3844/jmrsp.2020.156.190

The t_1 brake delay time depends on the actuation time of the pedal brake transmission mechanism and is due to the play in the joints, the fluid leakage resistances through the pipes ..., being between 0.2 and 0.5 s.

Time t_2 is the time elapsed from the moment the braking force is applied until it reaches its maximum value. It varies between 0.1 and 1 s, depending on the type of brake control mechanism.

Time t_3 is the actual braking time at normal parameters, from the bus speed from the beginning of braking v_1 to the speed at the end of braking v_2 (which can be 0 in the case of braking to a stop).

Time t_4 is the time elapsed from the end of the press on the pedal to the cancellation of the braking force. It is between 0.2 and 2 s, but does not directly affect the previous braking space (during the actual braking), but only indirectly, when the braking has only slowed the bus and a new deceleration is required immediately (new braking), or even its stopping, its influence being only on the next immediate possible braking.

The additional space s_{f0} traveled by bus due to the specific braking delays is given by the relation (21), with the speed v_1 given in m/s and is expressed by the relation (22) if the speed V1 is entered in km/h:

$$s_{f0} = v_1 \cdot \left(t_1 + \Delta t_1 + t_2\right) \quad (21)$$

$$s_{f0} = \frac{V_1}{3,6} \cdot \left(t_1 + \Delta t_1 + t_2\right) \quad (22)$$

Benefits

Mercedes reduced the accident rate by 42% when the ESP was introduced. NHTSA studied from 1997 to 2002, data in five states, a study published in September 2004 and found passenger cars with ESP (many of them Mercedes) the number of damaged vehicles decreased by 35%, while the number of fatal accidents decreased by 30%.

They also studied the SUV which included ML320, ML430, ML350, ML500, G500 and G55 AMG. IIHS studied ESP in 2004 and found that all accidents were reduced by 7% and fatal accidents by 34%. Of course, accidents were reduced by 41% and fatal accidents by 56%. For IIHS the data were not large enough to allow a separate comparison between cars and SUVs, as a calculated risk. In 2006, IIHS expanded its research to include study data for an additional year between 2003 and 2004 and more vehicles, this time in 10 states. Overall, the results are consistent with previous results, but showed a greater reduction, even by 43% in fatal accidents. For the SUV vehicle the damages were reduced by 49% and by 33% for the cars. A single SUV vehicle was damaged in the proportion of 59% and does not differ significantly by 53% for the cars.

Regenerative Braking

Regenerative braking is one of the important steps towards independence from fossil fuels.

In the century when fossil fuels will run out (most likely), they are the basis on which we have built everything around us and in which the concern for carbon emissions reaches the highest levels, this efficiency of all products is crucial!

Every time the brake pedal is depressed, energy is wasted. Physics tells us that energy cannot be destroyed. So when the car slows down, the kinetic energy that propelled the vehicle forward must go somewhere. Much of it simply dissipates as heat and becomes useless. That energy, which could have been used, is simply wasted.

In this regard, automotive engineers have found the solution in a braking system that can capture much of the car's kinetic energy, converting it into electricity, so it can be used to recharge the battery/batteries. This system is called regenerative braking.

At present, these braking systems seem to equip almost all new models that appear on the market, whether they are electric or hybrid cars (for example BWM 7 Series Active Hybrid, Lexus RX400h, etc.). However, the technology was first introduced on trams and was later used on electric bicycles and even Formula 1 cars.

In a traditional braking system, the brake pads produce friction with the disc to slow down and stop the vehicle. In addition, friction occurs between the slow wheels and the tread. This friction converts the kinetic energy of the machine into heat.

In the case of regenerative braking, on the other hand, the system propelling the vehicle performs most of the braking. When the driver depresses the brake pedal of an electric or hybrid model, this braking system puts the electric motor in reverse mode, making it possible to turn it in the opposite direction, thus slowing down the car's wheels. As it spins backward, the motor behaves like an electric generator, producing electricity that often powers the batteries. These types of braking systems work and have different efficiencies at different speeds. In fact, they have maximum efficiency in the case of urban driving situations, with many stops and starts.

As a backup for situations where regenerative braking does not provide sufficient stopping power, hybrids and electric vehicles also have conventional braking systems. It is important for the mechanic to be aware that the brake pedal may respond differently to pressure. The pedal will sometimes have a longer stroke than normal, but this is normal.

In the following lines we will detail how the regenerative braking system works and we will argue the reasons why this braking time is more efficient than the conventional one.

An important property of the electric motor is that when it spins in one direction it converts electrical energy into mechanical energy that can drive the wheels and when it spins in the opposite direction, it becomes a generator, converting mechanical energy into electrical energy. This electricity can power the battery charging system.

In the case of the regenerative braking system, the kinetic energy of the car represents the mechanical energy that spins the electric motor in the opposite direction. Sophisticated electronic circuits are needed to decide when to turn the engine upside down, while specialization electrical circuits drive the electricity generated to the batteries. In some cases, the energy produced by these systems is stored in electric capacitors for later use. Moreover, since these vehicles also use conventional braking systems, ECUs must decide which system to use at a given time, depending on certain conditions. Because the control of the regenerative braking system is almost 100% electronic, it is possible for the driver to select certain settings that will determine the reaction of the vehicle in different situations. For example, in some cases the driver may select whether regenerative braking begins as soon as the foot has been removed from the accelerator pedal and whether the system will operate until the car comes to a complete stop or will let the car idle.

There is a general movement in the automotive industry towards so-called "brake-by-wire" systems where many of the functions of normally mechanically performed braking systems will be controlled by a computer. Currently, engineers in the automotive industry use several types of circuits to cope with the complexity of regenerative braking, but in all cases, the most important component of these systems is the braking system ECU.

Regenerative braking is a process of braking a vehicle by converting its kinetic energy into another form, energy that can be reused immediately or stored. The process differs from the conventional braking method, which dissipates this energy in the environment in the form of heat by friction in the brakes. In addition to increasing the energy efficiency of the vehicle by avoiding wastage of this energy, regenerative braking saves conventional braking systems.

Energy transformation and transmission are the two principles of energy recovery that occur when braking industrial vehicles. If a vehicle is braked, its kinetic energy is converted to heat brakes. This heat is then dissipated into the atmosphere. It can only be recovered if the vehicle is fitted with a regenerative brake. It converts the reduction of kinetic energy, which occurs during braking, into electrical energy, with the help of an electro generator and transmits it for storage to a battery of capacitors-buffer. This group of capacitors releases this energy to the electric traction motor of the electric vehicle or to hybrid drive.

Typically a regenerative braking system consists of an electric car that can be an electric motor running in reversible mode or an electric generator. These are driven by the wheels of the running gear coupled to them, producing electricity. During rail transport, including trams, the electricity produced is reintroduced into the supply system. In battery-powered electric vehicles, including hybrid electric vehicles, the recovered energy is stored in these batteries and in supercapacitors. In addition to electrical systems, the recovered energy can also be stored as kinetic energy in the steering wheels. Hybrid vehicles with hydraulic or pneumatic drive systems can store the recovered energy in their fuel systems.

Limitations

Vehicles with regenerative braking systems must also be equipped with conventional friction brakes because:

- The traditional braking system is a backup system in case of regenerative failure
- The braking capacity of the regenerative brakes decreases with speed, for the complete stopping of the vehicle another braking system is needed. It is also zero during parking
- Regenerative braking can produce an excess of energy, for example when descending slopes, an excess that cannot be taken up by storage systems and must be dissipated by conventional braking systems
- In emergency braking, all wheels must be braked at the road grip. The kinetic energy of the vehicle must be dissipated in a much shorter time than usual at acceleration, which can only be achieved with very high electrical powers, several times higher than the propulsion power, leading to impractical systems. Excess energy must be dissipated by conventional braking systems
- Usually, cars have only one drive axle and electric regenerative braking can only be applied to axles driven by electric motors. On the other axles, braking is done by classical methods

In order to achieve the desired braking effect, a coordination system between regenerative and conventional braking is needed. General Motors produced the first car, General Motors EV1, equipped in this way. In 1997 and 1998 engineers Abraham Farag and Loren Majersik registered two patents in this regard.

Conversion to Electricity: The Engine as a Generator

In vehicles powered by electric motors, during regenerative braking the engines work in generator mode, the current produced being applied to a consumer, who thus plays the role of the brake.

Electric regenerative braking is a three-stage process, the stage of recovering kinetic energy by generating electricity, the stage of storing it in accumulators or supercapacitors and the stage of using energy by transforming it back into kinetic energy. In all stages there are energy losses, the transformations being made with a certain efficiency.

The mechanical work absorbed by the generator is the difference in the kinetic energy of the vehicle.

Thus, the excess energy created is saved in the battery. It can then be used to power the electric motor or other components that run on electricity (such as air conditioning).

What does a Kinetic Energy Recovery System (KERS) mean?

This concept of the Kinetic Energy Recovery System is used by Formula 1 cars, mechanical cars and electric motors. It works very similar to Toyota Prius engines, trying to capture the remaining energy in the battery.

This system is mainly used for racing cars, where it works by generating electricity every time the car brakes. It is, in fact, a device that comes mounted on the wheels of a car. It is very popular in racing cars, where it began to be used in 2009.

Even if it is hard to believe, this system is not only used for racing cars, but also for engines and even certain trams. The only negative thing that could be said about KERS is that it adds a little extra weight to the vehicle on which it is assembled. In the future, it is speculated that this system will become more and more popular and will be common in everyday cars, not just racing cars.

Thus, it is good to be informed in advance about both regenerative braking and KERS, because if the future is as promising as it seems, it is possible that in a few years we will all have access to them.

Regenerative braking was widely used on the railway. In the 1930s it was used by the Transcaucasian Railways on the Baku-Tbilisi-Batumi line, especially in the steep and dangerous Surami Pass. In Scandinavia, on the Kiruna-Narvik line, iron ore is transported from the Kiruna mines in northern Sweden down to the Norwegian port of Narvik. During the lowering of the loaded wagons, a lot of electricity is produced by regenerative braking. In Norway, trains from the border from Riksgränsen to Narvik use only one-fifth of the energy thus generated, the rest being enough to bring the empty train back to Riksgränsen. The excess is introduced into the supply network, the railway being a net supplier of electricity.

In trams, in England the Raworth system of "regenerative control" was introduced in the early 1900s because it was advantageous. The system was applied to Devonport (1903), Rawtenstall, Birmingham, Crystal Palace-Croydon (1906) and others. Following a serious accident at Rawtenstall, in 1911 the system was banned, but was reintroduced 20 years later.

The main problem of regenerative braking is the difficulty of generating current at the parameters of the supply network - voltage in the case of direct current supply, respectively voltage, frequency and phase when supplying alternating current. instead of being sent to the mains is discharged on some electrical resistors that turn it into heat we are talking about dynamic braking. The process is found in electric forklifts, diesel-electric locomotives and trams.

The heat produced can be used to air-condition wagons or dissipated in the environment. An unusual application was to the experimental steam turbine locomotives of General Electric. For preheating the water supply to the steam boiler.

Mechanical braking energy recovery systems store the energy recovered in the form of the kinetic energy of steering wheels. Since there are no transformations kinetic energy -> electricity -> chemical energy -> electricity -> kinetic energy, if the reuse of stored energy is immediate the energy efficiency of these systems is higher than electricity. Over time, due to losses in the bearings, the steering wheel speed decreases, as a result its energy decreases, so the efficiency. To reduce these losses, the flywheels rotate in vacuum enclosures and the bearings are with magnetic suspension. Such a construction stores energy for up to an hour, the system being very efficient only for braking followed immediately by acceleration, such as city traffic. or participation in Formula 1-like circuits.

Such a system is known as a Kinetic Energy Recovery System (KERS). It was first used in Formula 1 in 2009. In subsequent editions the use of the system was optional, but since 2013 all teams use KERS.

The first system of this type was built by Flybrid. The system has a mass of 24 kg and can store the energy of 400 kJ. This energy can be delivered with a power of 60 kW in 6.67 seconds. The steering wheel has a diameter of 240 mm, a mass of 5.0 kg and rotates at a speed of up to 64,500 rpm. The maximum torque is 18 Nm.

The ECU is the deciding factor, based on predefined parameters influencing the moment of the braking start, braking stop or brake application speed. In towing situations, for example, the ECU of the braking system can provide coordination between the brakes of the trailer and those of the towing vehicle.

The monitoring mode of the regenerative braking system is similar to that of the ABS system, the most important factors in determining the decisions being the wheel speeds. In addition to this function of monitoring the speed of the wheels, the ECU of the braking system also has an important function of calculating how much torque - the rotational force - is available to generate electricity. During braking, the ECU directs the electricity produced by the motor into batteries or capacitors. It ensures that an optimal amount of energy is received by the batteries and at the same time that the energy received is not too much, or more than the batteries can handle.

The most important function of the controller is perhaps the one that decides when the engine is or is not able to provide enough force to stop the car. If it is not, the ECU also activates the conventional brake, preventing possible unpleasant incidents. Without this ECU, regenerative braking would simply not be possible.

How is a hybrid vehicle different from a fully electric one? Well, hybrid electric vehicles use both an electric and an internal combustion engine.

These types of vehicles combine the autonomy of the internal combustion engine with the efficiency and zero emissions of the electric motor. In order to be as efficient and environmentally friendly as possible, the battery of the hybrid vehicle must remain charged as long as possible.

Without battery power, only the internal combustion engine would propel the vehicle. At this time, the vehicle is no longer an active hybrid but just another conventional vehicle.

Automotive engineers have come up with several solutions to streamline energy consumption, such as aerodynamic shapes, lightweight materials, but one of the most important is regenerative braking. The internal combustion engine of course does not benefit at all from this system, energy produced during braking is transmitted to the batteries and from there to the electric motor.

Hydraulic Regenerative Braking

An alternative to the electronic braking system is the hydraulic regenerative braking system. There are currently two such systems, one developed by Ford Motor Company and Eaton Corporation and the other developed by Bosch Rexroth AG.

Ford's system is called Hydraulic Power Assist or HPA for short. In the case of HPA, when the driver depresses the brake pedal, the kinetic energy of the vehicle is used to drive a reversible pump, which sends hydraulic fluid from a low-pressure accumulator (a kind of tank) to a high pressure one.

This pressure is created by the nitrogen in the accumulator, which is compressed as the liquid is pushed into the space occupied by the gas.

The fluid remains under pressure in the battery until the driver depresses the accelerator pedal again, at which point the pump is reversed and the pressurized fluid is used to accelerate the vehicle, efficiently converting the car's kinetic energy before braking into mechanical energy that helps vehicle acceleration.

Some sources [www.HybridCars.com] claim that such a system can store up to 80% of the time lost by the vehicle during deceleration and can use it to accelerate the vehicle again. This percentage is impressive for such a system. Like electronic regenerative braking, this type of HPA braking is more for urban driving style, with frequent stops and starts.

Bosch's system, called HRB - Hydrostatic Regenerative Braking, works on the same principle, the constructive elements being similar.

Currently, these systems are used on heavy vehicles, but once they are improved, they will certainly be used on light vehicles.

The energy efficiency of a conventional vehicle is about 20%, the remaining 80% being converted to heat by friction. The miracle of regenerative braking is that it could capture up to half of the wasted energy. This would mean a 10 to 25% reduction in fuel consumption. Hydraulic regenerative braking would provide even more impressive gains, reducing consumption by 25 to 45%.

In the century when fossil fuels will run out (most likely), they are the basis on which we have built everything around us and in which the concern for carbon emissions reaches the highest levels, this efficiency of all products is very important.

The beginning of the 21st century could be the end of the internal combustion engine. Already, vehicle manufacturers are allocating increasing resources for the development of alternative solutions, such as high-performance batteries, hydrogen cells and even compressed air.

Regenerative braking is a small but very important step towards independence from fossil fuels. These types of brakes allow batteries to be used longer without the need to charge from an external source. They also increase autonomy. Thanks to this technology we now have cars like Tesla Roadster, electric cars with more than decent performance.

In a regenerative braking car, so many things are electronically controlled that even the driver has the ability to select certain settings that determine how the vehicle will react in certain situations.

For example, in some cars the driver may select the regenerative braking to start as soon as he takes his foot off the accelerator pedal.

The driver can then decide whether the regenerative braking will slow down the car to zero kilometers per hour or let the car run at low speed. In the automotive industry there has been a general trend towards braking systems called brake-by-wire in which a large part of the braking functions that have been mechanically actuated will be actuated electronically.

Volo Rent a Car believes that electric and hybrid cars will be the first users of this electronic brake-by-wire system.

The Braking Energy Recovery System

Along with the Start/Stop system it is an extra step in the direction of hybridizing vehicles. Practically in case of a deceleration of the vehicle its kinetic energy is converted into electricity by a generator (or by the electric propulsion system in the case of hybrid vehicles). In this way, some of the energy that is normally lost through heat dissipation in the braking process is recovered as electricity, stored in batteries and then used.

Engine Braking Simulation

In the case of highly hybrid cars *, in order to recover the braking energy, the internal combustion engine is disengaged and the engine braking is replaced by an equivalent torque generator of the electric motor (engine braking simulation). The energy thus released is stored.

If the internal combustion engine cannot be disengaged (in the case of moderately hybrid vehicles), alternatively a lower torque generator may be fitted to the drive chain, in addition to braking the internal combustion engine (increasing engine braking).

Braking Energy Recovery

As mentioned above, during braking the electric propulsion can accommodate an additional torque generator as if simulating braking with the engine thus increasing the braking force. With the brake pedal in the same position, the vehicle will have a higher deceleration compared to a similar conventional vehicle. However, considering the performance, no significant decelerations can be implemented.

However, the regenerative braking torque must be adjusted according to the degree of charge of the battery and the thermal state of the electrical system. If, for example, the battery temperature rises significantly after several successive braking, it is necessary for certain circumstances to recover regenerative energy system.

The powerful hybrid vehicle, unlike the moderate hybrid vehicle, can operate for short distances using only electric propulsion. During 100% electric propulsion, the internal combustion engine is stopped.

Braking Energy Recovery Systems

The kinetic energy recovery systems lost during braking are mechano-electrical systems that allow the recovery of energy lost when the vehicle starts to brake. The recovery of kinetic energy dissipated during braking is practically obtained from the transformation of mechanical energy into electrical energy made by these systems and stored by a group of batteries and capacitors. The most used form of energy recovery is represented by electric motors that are used as electric generators together with battery systems. These systems have been developed and ramped up in addition to the reason for protecting the environment, declining fossil fuel resources and due to the fact that mainly from the energy content of fuel burned in the engine, in the case of an urban route only about 13% reaches wheels and braking wastes almost half (6%) of this tiny percentage.

Types of Hybrid Vehicle Configurations

Parallel-hybrid systems include the conventional internal combustion engine and an electric motor connected to a transmission. The electric motor is located in parallel with the conventional motor, the electric one taking over the role of both alternator and starter (the transmission is between the two). Series-hybrid series systems are structurally similar to battery-only vehicles. In this case the internal combustion engine acts as a generator, which in turn acts to charge the batteries and supply electricity to the electric motor. Series-parallel hybrid systems - are hybrid vehicles with "distributed" power or have elements that are found on both parallel hybrids and series hybrids.

They have components that transmit power from either the mechanical or electrical motor. The dual-mode hybrid system includes two power transmission paths along with a gearbox that allows running in parallel hybrid modes. This system is used in parallel series hybrids. It has the following characteristics:

- It is provided with a secondary set of planetary gears
- varies the percentage of power transmitted mechanically or electrically depending on road conditions or the desire of the driver

Conclusion

Obviously, braking with the help of the engine brake is achieved in a much shorter time and achieves increased braking safety, when necessary, it being all the more efficient as the experience, skill and physiological condition of the bus driver. They are better. Gradually or directly shifting from the upper gears to the lower gears of the gearbox helps to brake effectively with the engine brake, usually shifting into third gear (from a higher gear) and possibly then into the same gear. two, if necessary. On slopes, especially when descending, at high starting speeds for braking and when the road is slippery, the use of the engine brake is also imperative.

Car braking systems have evolved significantly in recent years. These developments will continue and even accelerate in the years to come. Wheel brake optimization will continue in the field of noise and vibration, residual torque and wear. Increasing performance and reducing costs in the field of electronics already allow the widespread of ESP systems or the "brake by wire" system; associated, more evolved functions will follow. Is it possible for the brakes to become fully electric tomorrow?

Acknowledgement

This text was acknowledged and appreciated by Dr. Veturia CHIROIU Honorific member of Technical Sciences Academy of Romania (ASTR) PhD supervisor in Mechanical Engineering.

Funding Information

Research contract:

- 1-Research contract: Contract number 36-5-4D/1986 from 24IV1985, beneficiary CNST RO (Romanian National Center for Science and Technology) Improving dynamic mechanisms
- 2-Contract research integration. 19-91-3 from 29.03.1991; Beneficiary: MIS; TOPIC: Research on designing mechanisms with bars, cams and gears, with application in industrial robots
- 3-Contract research. GR 69/10.05.2007: NURC in 2762; theme 8: Dynamic analysis of mechanisms and manipulators with bars and gears
- 4-Labor contract, no. 35/22.01.2013, the UPB, "Stand for reading performance parameters of kinematics and dynamic mechanisms, using inductive and incremental encoders, to a Mitsubishi Mechatronic System" "PN-II-IN-CI-2012-1-0389"

Ethics

This article is original and contains unpublished material. Author declares that are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

References

Aabadi, M. M. L. (2019). Dynamic reliability analysis of steel moment frames using monte carlo technique. Am. J. Eng. Applied Sci., 12(2), 204-213.

Ab-Rahman, M. S., Guna, H., Harun, M. H., Zan, S. D., & Jumari, K. (2009). Cost-effective fabrication of self-made 1× 12 polymer optical fiber-based optical splitters for automotive application. Am. J. Eng. Applied Sci, 2, 252-259.

Abam, F. I., Ugot, I. U., & Igbong, D. I. (2012). Performance analysis and components irreversiblities of a (25 MW) gas turbine power plant modeled with a spray cooler. American Journal of Engineering and Applied Sciences, 5(1), 35-41.

Abdelkrim, H., Othman, S. B., Salem, A. K. B., & Saoud, S. B. (2012). Dynamic partial reconfiguration contribution on system on programmable chip architecture for motor drive implementation. Am. J. Eng. Applied Sci, 5, 15-24.

Abdullah, M. Z., Saat, A., & Hamzah, Z. (2011). Optimization of energy dispersive x-ray fluorescence spectrometer to analyze heavy metals in moss samples. American Journal of Engineering and Applied Sciences, 4(3).

Abdullah, M., Zain, A. F. M., Ho, Y. H., & Abdullah, S. (2009). TEC and scintillation study of equatorial ionosphere: A month campaign over sipitang and parit raja stations, Malaysia. Am. J. Eng. Applied Sci, 2, 44-49.

Abdullah, H., & Halim, S. A. (2009). Electrical and Magnetoresistive studies Nd doped on La-Ba-Mn-O sub (3) Manganites for Lowfield Sensor application. American Journal of Engineering and Applied Sciences, 2(2).

Abouobaida, H. (2016). Robust and efficient controller to design a standalone source supplied DC and AC load powered by photovoltaic generator. Am. J. Eng. Applied Sci, 9, 894-901.

Abu-Ein, S. (2009). Numerical and analytical study of exhaust gases flow in porous media with applications to diesel particulate filters. Am. J. Eng. Applied Sci, 2, 70-75.

Abu-Lebdeh, T. M., Leon, G. P. D., Hamoush, S. A., Seals, R. D., & Lamberti, V. E. (2016). Gas atomization of molten metal: part II. Applications. American Journal of Engineering and Applied Sciences, 9(2).

Abd Jalil, M. I., & Sampe, J. (2013). Experimental investigation of thermoelectric generator modules with different technique of cooling system. American Journal of Engineering and Applied Sciences, 6(1), 1-7.

Abou Jaoude, A., & El-Tawil, K. (2013). Analytic and nonlinear prognostic for vehicle suspension systems. American Journal of Engineering and Applied Sciences, 6(1), 42-56.

Agarwala, S. (2016). A perspective on 3D bioprinting technology: Present and future. Am. J. Eng. Applied Sci, 9, 985-990.

Ahmed, M., Khan, R., Billah, M., & Farhana, S. (2010). A novel navigation algorithm for hexagonal hexapod robot. Am. J. Eng. Applied Sci, 3, 320-327.

Ahmed, R., Khan, M., Haque, H., & Rahman, H. (2016). An approach to develop a dynamic job shop scheduling by fuzzy rule-based system and comparative study with the traditional priority rules. Am. J. Eng. Applied Sci, 9, 202-212.

Akhesmeh, S., Pourmahmoud, N., & Sedgi, H. (2008). Numerical study of the temperature separation in the Ranque-Hilsch vortex tube. American Journal of Engineering and Applied Sciences, 1(3).

Al-Abbas, I. K. (2009). Reduced order models of a current source inverter induction motor drive. Am. J. Eng. Applied Sci, 2, 39-43.

Al-Hasan, M. I., & Al-Ghamdi, A. S. (2016). Energy balance for a diesel engine operates on a pure biodiesel, diesel fuel and biodiesel-diesel blends. Am. J. Eng. Applied Sci, 9, 458-465.

Al Smadi, T. A. (2011). Low cost smart sensor design. Am. J. Eng. Applied Sci, 4, 162-168.

Al Qadi, A. N. S., ALhasanat, M. B., Dahamsheh, A. A., & Zaiydneen, S. A. (2016a). Using of box-benken method to predict the compressive strength of selfcompacting concrete containing Wadi Musa bentonite, Jordan. Am. J. Eng. Applied Sci, 9, 406-411.

Al Qadi, A. N., Alhasanat, M. B., & Haddad, M. (2016b). Effect of crumb rubber as coarse and fine aggregates on the properties of asphalt concrete. Am. J. Eng. Applied Sci, 9, 558-564.

Aleksic, S., & Lovric, A. (2011). Energy consumption and environmental implications of wired access networks. Am. J. Eng. Applied Sci, 4, 531-539.

Alhasanat, M. B., Al Qadi, A. N., Al Khashman, O. A., & Dahamsheh, A. (2016). Scanning electron microscopic evaluation of self-compacting concrete spalling at elevated temperatures. Am. J. Eng. Applied Sci, 9, 119-127.

Ali, K. S., & Shumaker, J. L. (2013). Hardware in the loop simulator for multi agent unmanned aerial vehicles environment. American Journal of Engineering and Applied Sciences, 6(2), 172.

Ali, G. A. M., Fouad, O., & Makhlouf, S. A. (2016). Electrical properties of cobalt oxide/silica nanocomposites obtained by sol-gel technique. Am. J. Eng. Applied Sci, 9, 12-16.

Al-Nasra, M., Daoudb, M., & Abu-Lebdeh, T. M. (2015). The use of the super absorbent polymer as water blocker in concrete structures. American Journal of Engineering and Applied Sciences, 8(4), 659.

Alwetaishi, M. S. (2016). Impact of building function on thermal comfort: A review paper. Am. J. Eng. Applied Sci, 9, 928-945.

Ale Ebrahim, N., Ahmed, S., Abdul Rashid, S. H., & Taha, Z. (2012). Technology use in the virtual R&D teams. American Journal of Engineering and Applied Sciences, 5(1), 9-14.

Aly, W. M., & Abuelnasr, M. S. (2010). Electronic design automation using object oriented electronics. American Journal of Engineering and Applied Sciences, 3(1).

Amani, N. (2016). Design and implementation of optimum management system using cost evaluation and financial analysis for prevention of building failure. Am. J. Eng. Applied Sci, 9, 281-296.

Amer, S., Hamoush, S., & Abu-Lebdeh, T. M. (2015). Experimental evaluation of the raking energy in damping system of steel stud partition walls. American Journal of Engineering and Applied Sciences, 8(4), 666.

Anizan, S., Yusri, K., Leong, C. S., Amin, N., Zaidi, S., & Sopian, K. (2011). Effects of the contact resistivity variations of the screen-printed silicon solar cell. Am. J. Eng. Applied Sci, 4, 328-331.

Antonescu, P., & Petrescu, F. (1985). Analytical method of synthesis of cam mechanism and flat stick. In Proceedings of the 4th International Symposium on Theory and Practice of Mechanisms,(TPM'89), Bucharest.

Antonescu, P., & Petrescu, F. (1989). Contributions to kinetoplast dynamic analysis of distribution mechanisms. Bucharest.

Antonescu, P., Oprean, M., & Petrescu, F. (1985a). Contributions to the synthesis of oscillating cam mechanism and oscillating flat stick. In Proceedings of the 4th International Symposium on Theory and Practice of Mechanisms,(TPM'85), Bucharest.

Antonescu, P., Oprean, M., & Petrescu, F. (1985b). At the projection of the oscillate cams, there are mechanisms and distribution variables. In Proceedings of the V-Conference for Engines, Automobiles, Tractors and Agricultural Machines, I-Engines and Automobiles,(AMA'85), Brasov.

Antonescu, P., Oprean, M., & Petrescu, F. (1986). Projection of the profile of the rotating camshaft acting on the oscillating plate with disengagement. In Proceedings of the 3rd National Computer-aided Design Symposium in the field of Mechanisms and Machine Parts,(MMP'86), Brasov.

Antonescu, P., Oprean, M., & Petrescu, F. (1987). Dynamic analysis of the cam distribution mechanisms. In Proceedings of the 7th National Symposium on Industrial Robots and Space Mechanisms,(RSM'87), Bucharest.

Antonescu, P., Oprean, M., & Petrescu, F. (1988). Analytical synthesis of Kurz profile, rotating the flat cam. Mach, Build. Rev.

Antonescu, P., Petrescu, F., & Antonescu, O. (1994). Contributions to the synthesis of the rotating cam mechanism and the tip of the balancing tip.

Antonescu, P., Petrescu, F., & Antonescu, D. (1997). Geometrical synthesis of the rotary cam and balance tappet mechanism. Bucharest, 3, 23-23.

Antonescu, P., Petrescu, F., & Antonescu, O. (2000a). Contributions to the synthesis of the rotary disc-cam profile. In Proceedings of the 8th International Conference on the Theory of Machines and Mechanisms,(TMM'00), Liberec, Czech Republic (pp. 51-56).

Antonescu, P., Petrescu, F., & Antonescu, O. (2000b). Synthesis of the rotary cam profile with balance follower. In Proceedings of the 8th Symposium on Mechanisms and Mechanical Transmissions,(MMT'00), Timişoara (pp. 39-44).

Antonescu, P., Petrescu, F., & Antonescu, O. (2001). Contributions to the synthesis of mechanisms with rotary disc-cam. In Proceedings of the 8th IFToMM International Symposium on Theory of Machines and Mechanisms,(TMM'01), Bucharest, ROMANIA (pp. 31-36).

Ascione, F., Bianco, N., De Masi, R. F., De Rossi, F., De Stasio, C., & Vanoli, G. P. (2016). Energy audit of health care facilities: Dynamic simulation of energy performances and energy-oriented refurbishment of system and equipment for microclimatic control.

Augustine, A., Prakash, R. D., Xavier, R., & Parassery, M. C. (2016). Review of signal processing techniques for detection of power quality events. Am. J. Eng. Applied Sci, 9, 364-370.

Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2017a). Nano-diamond hybrid materials for structural biomedical application. American Journal of Biochemistry and Biotechnology, 13(1), 34-41.

Aversa, R., Petrescu, R. V., Akash, B., Bucinell, R., Corchado, J., Chen, G., ... & Petrescu, F. I. (2017b). Kinematics and forces to a new model forging manipulator. American Journal of Applied Sciences, 14(1), 60-80.

Aversa, R., Petrescu, R. V., Apicella, A., Petrescu, F. I., Calautit, J. K., Bucinell, R., & Akash, B. (2017c). Something about the V engines design. American Journal of Applied Sciences, 14(1), 34-52.

Aversa, R., Parcesepe, D., Petrescu, R. V., Berto, F., Chen, G., Petrescu, F. I., ... & Apicella, A. (2017d). Processability of bulk metallic glasses. American Journal of Applied Sciences, 14(2), 294-301.

Aversa, R., Petrescu, R. V., Akash, B., Bucinell, R., Corchado, J., Chen, G., ... & Petrescu, F. I. (2017e). Something about the balancing of thermal motors. American Journal of Engineering and Applied Sciences, 10(1), 200-217.

Aversa, R., Petrescu, F. I., Petrescu, R. V., & Apicella, A. (2016a). Biomimetic finite element analysis bone modeling for customized hybrid biological prostheses development. American Journal of Applied Sciences, 13(11), 1060-1067.

Aversa, R., Parcesepe, D., Petrescu, R. V. V., Chen, G., Petrescu, F. I. T., Tamburrino, F., & Apicella, A. (2016b). Glassy amorphous metal injection molded induced morphological defects.

Aversa, R., Petrescu, R. V., Petrescu, F. I., & Apicella, A. (2016c). Smart-factory: Optimization and process control of composite centrifuged pipes. American Journal of Applied Sciences, 13(11), 1330-1341.

Aversa, R., Tamburrino, F., Petrescu, R. V., Petrescu, F. I., Artur, M., Chen, G., & Apicella, A. (2016d). Biomechanically inspired shape memory effect machines driven by muscle like acting NiTi alloys. American Journal of Applied Sciences, 13(11), 1264-1271.

Aversa, R., Buzea, E. M., Petrescu, R. V., Apicella, A., Neacsa, M., & Petrescu, F. I. (2016e). Present a mechatronic system having able to determine the concentration of carotenoids. American Journal of Engineering and Applied Sciences, 9(4), 1106-1111.

Aversa, R., Petrescu, R. V., Sorrentino, R., Petrescu, F. I., & Apicella, A. (2016f). Hybrid ceramo-polymeric nanocomposite for biomimetic scaffolds design and preparation. American Journal of Engineering and Applied Sciences, 9(4).

Aversa, R., Perrotta, V., Petrescu, R. V., Carlo, M., Petrescu, F. I., & Apicella, A. (2016g). From structural colors to super-hydrophobicity and achromatic transparent protective coatings: Ion plating plasma assisted TiO 2 and SiO 2 nano-film deposition. Available at SSRN 3074477.

Aversa, R., Petrescu, R. V., Petrescu, F. I., & Apicella, A. (2016h). Biomimetic and evolutionary design driven innovation in sustainable products development. American Journal of Engineering and Applied Sciences, 9(4).

Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2016i). Mitochondria are naturally micro robots-a review. American Journal of Engineering and Applied Sciences, 9(4).

Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2016j). We are addicted to vitamins C and EA review. American Journal of Engineering and Applied Sciences, 9(4), 1003-1018.

Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2016k). Physiologic human fluids and swelling behavior of hydrophilic biocompatible hybrid ceramo-polymeric materials. American Journal of Engineering and Applied Sciences, 9(4), 962-972.

Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2016l). One can slow down the aging through antioxidants. American Journal of Engineering and Applied Sciences, 9(4).

Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2016m). About homeopathy or≪ Similia similibus curentur≫. American Journal of Engineering and Applied Sciences, 9(4).

Aversa, R., Petrescu, R. V., Apicella, A., & Petrescu, F. I. (2016n). The basic elements of life's. American Journal of Engineering and Applied Sciences, 9(4), 1189-1197.

Aversa, R., Petrescu, F. I., Petrescu, R. V., & Apicella, A. (2016o). Flexible stem trabecular prostheses. American Journal of Engineering and Applied Sciences, 9(4).

Babayemi, A. K. (2016). Thermodynamics, non-linear isotherms, statistical modeling and optimization of phosphorus adsorption from wastewater. Am. J. Eng. Applied Sci, 9, 1019-1026.

Bakar, R. A., Mohammed, M. K., & Rahman, M. M. (2009). Numerical study on the performance characteristics of hydrogen fueled port injection internal combustion engine. Am. J. Eng. Applied Sci, 2, 407-415.

Barone, G., Buonomano, A., Forzano, C., & Palombo, A. (2016). WLHP systems in commercial buildings: A case study analysis based on a dynamic simulation approach. Am. J. Eng. Applied Sci, 9, 659-668.

Bedon, C. (2016). Review on the use of FRP composites for facades and building skins.

Bedon, C., & Amadio, C. (2016). A unified approach for the shear buckling design of structural glass walls with non-ideal restraints. Am. J. Eng. Applied Sci, 9, 64-78.

Bedon, C., & Louter, C. (2016). Finite-element numerical simulation of the bending performance of post-tensioned structural glass beams with adhesively bonded cfrp tendons.

Ben-Faress, M., Elouadi, A., & Gretete, D. (2019). Global Supply Chain Risk Management. Risk, 1(1), 2-2.

Bier, H. H., & Mostafavi, S. (2015). Structural optimization for materially informed design to robotic production processes. American Journal of Engineering and Applied Sciences 8 (4), 549-555.(2015).

Bolonkin, A. (2009a). Femtotechnology: Nuclear matter with fantastic properties. Am. J. Eng. Applied Sci, 2(2), 501-514.

Bolonkin, A. A. (2009b). Converting of matter to nuclear energy by ab-generator. Am. J. Eng. Applied Sci, 2, 683-693.

Boucetta, A. (2008). Vector control of a variable reluctance machine stator and rotor discs imbricates. American Journal of Engineering and Applied Sciences, 1(4).

Bourahla, N., & Blakeborough, A. (2015). Similitude distortion compensation for a small scale model of a knee braced steel frame. American Journal of Engineering and Applied Sciences, 8(4), 481.

Bucinell, R. B. (2016). Stochastic model for variable amplitude fatigue induced delamination growth in graphite/epoxy laminates. Am. J. Eng. Applied Sci, 9, 635-646.

Budak, S., Xiao, Z., Johnson, B., Cole, J., Drabo, M., Tramble, A., & Casselberry, C. (2016). High Efficient Advanced Thermoelectric Devices from Different Multilayer Thin Films.

Buonomano, A., Calise, F., & Vicidomini, M. (2016a). A novel prototype of a small-scale solar power plant: Dynamic simulation and thermoeconomic analysis. Am. J. Eng. Applied Sci, 9, 770-788.

Buonomano, A., Calise, F., d'Accadia, M. D., Vanoli, R., & Vicidomini, M. (2016b). Simulation and experimental analysis of a demonstrative solar heating and cooling plant installed in Naples (Italy). Am. J. Eng. Applied Sci, 9, 798-813.

Cao, W., Ding, H., Zi, B., & Chen, Z. (2013). New structural representation and digital-analysis platform for symmetrical parallel mechanisms. International Journal of Advanced Robotic Systems, 10(5), 243.

Calise, F., Dâ'Accadia, M. D., Libertini, L., Quiriti, E., & Vicidomini, M. (2016). Dynamic simulation and optimum operation strategy of a trigeneration system serving a hospital. Am. J. Eng. Applied Sci, 9, 854-867.

Campo, T., Cotto, M., Márquez, F., Elizalde, E., & Morant, C. (2016). Graphene Synthesis by Plasma-Enhanced CVD Growth with Ethanol. American Journal of Engineering and Applied Sciences, 9(3).

Cardu, M., Oreste, P., & Cicala, T. (2009). Analysis of the tunnel boring machine advancement on the Bologna-Florence railway link. Am. J. Eng. Applied Sci, 2, 416-420.

Casadei, D. (2015). Bayesian statistical inference for number counting experiments. American Journal of Engineering and Applied Sciences, 8(4), 730.

Comănescu, A., Comănescu, D., Dugăeşescu, I., & Boureci, A. (2010). Bazele modelării mecanismelor. Politehnica Press.

Darabi, A., Soleamani, S. A., & Hassannia, A. (2008). Fuzzy based digital automatic voltage regulator of a synchronous generator with unbalanced loads. American J. of Engineering and Applied Sciences, 1(4), 280-286.

Daud, H., Yahya, N., Aziz, A. A., & Jusoh, M. F. (2008). Development of wireless electric concept powering electrical appliances. Am. J. Eng. Applied Sci, 1, 12-15.

De León, J., Cotto, M., & Márquez, F. (2019). Toxicology of Nanomaterials on Zebrafish. Am. J. Eng. Applied Sci, 12, 193-203.

Demetriou, D., Nikitas, N., & Tsavdaridis, K. D. (2015). Semi active tuned mass dampers of buildings: A simple control option. American Journal of Engineering and Applied Sciences, 8(4), 620-632.

Dixit, S., & Pal, S. (2015). Synthesis and characterization of ink (Carbon)-perovskite/polyaniline ternary composite electrode for sodium chloride separation. American Journal of Engineering and Applied Sciences, 8(4), 527.

Djalel, D., Mourad, M., & Labar, H. (2013). New approach of electromagnetic fields of the lightning discharge. Am. J. Eng. Applied Sci, 6, 369-383.

Dong, H., Giakoumidis, N., Figueroa, N., & Mavridis, N. (2013). Approaching behaviour monitor and vibration indication in developing a General Moving Object Alarm System (GMOAS). International Journal of Advanced Robotic Systems, 10(7), 290.

El-Labban, H. F., Abdelaziz, M., & Mahmoud, E. R. (2013). Modification of carbon steel by laser surface melting: Part I: Effect of laser beam travelling speed on microstructural features and surface hardness. Am. J. Eng. Applied Sci, 6, 352-359.

Elliott, A., AlSalihi, S., Merriman, A. L., & Basti, M. M. (2016). Infiltration of nanoparticles into porous binder jet printed parts. American Journal of Engineering and Applied Sciences, 9(1).

Elmeddahi, Y., Mahmoudi, H., Issaadi, A., Goosen, M. F., & Ragab, R. (2016). Evaluating the effects of climate change and variability on water resources: A case study of the cheliff Basin in Algeria. American Journal of Engineering and Applied Sciences, 9(4), 835-845.

El-Tous, Y. (2008). Pitch angle control of variable speed wind turbine. American Journal of Engineering and Applied Sciences, 1(2), 118-120.

Faizal, A., Mulyono, S., Yendra, R., & Fudholi, A. (2016). Design Maximum Power Point Tracking (MPPT) on photovoltaic panels using fuzzy logic method. Am. J. Eng. Applied Sci, 9, 789-797.

Farahani, A. S., Adam, N. M., & Ariffin, M. K. A. (2010). Simulation of airflow and aerodynamic forces acting on a rotating turbine ventilator. Am. J. Eng. Applied Sci, 3, 159-170.

Farokhi, E., & Gordini, M. (2015). Investigating the parameters influencing the behavior of knee braced steel structures. American Journal of Engineering and Applied Sciences, 8(4), 567.

Fathallah, A. Z. M., & Bakar, R. A. (2009). Prediction studies for the performance of a single cylinder high speed spark ignition linier engine with spring mechanism as return cycle. American Journal of Engineering and Applied Sciences, 2(4).

Fen, Y. W., & Yunus, W. (2011). Optical properties of crosslinked chitosan thin film with glutaraldehyde using surface plasmon resonance technique. American Journal of Engineering and Applied Sciences, 4(1).

Feraga, C. E., Moussaoui, A., Bouldjedri, A., & Yousfi, A. (2009). Robust position controller for a permanent magnet synchronous actuator. American Journal of Engineering and Applied Sciences, 2(2).

Fontánez, K., García, A., del C Cotto-Maldonado, M., Duconge, J., Morant, C., Pinilla, S., & Márquez, F., 2019. Development of Ionizing Radiation Sensors Based on Carbon Nanotubes. Am. J. Eng. Applied Sci, 12(2), 185-192.

Franklin, D. J. (1930). Ingenious mechanisms for designers and inventors.

Fu, Y. F., Gong, J., Huang, H., Liu, Y. J., Zhu, D. M., & Zhao, P. F. (2015). Parameters optimization of adaptive cashew shelling cutter based on BP neural network and genetic algorithm. American Journal of Engineering and Applied Sciences, 8(4), 648.

Ge, L., & Xu, X. (2015). A scheme design of cloud+ end technology in demand side management. American Journal of Engineering and Applied Sciences, 8(4), 736.

Gupta, P., Gupta, A., & Asati, A. (2015). Ultra low power MUX based compressors for wallace and dadda multipliers in sub-threshold regime. American Journal of Engineering and Applied Sciences, 8(4), 702.

Gusti, A. P. Semin, 2016. The effect of vessel speed on fuel consumption and exhaust gas emissions. Am. J. Eng. Applied Sci, 9, 1046-1053.

Hassan, M., Mahjoub, H., & Obed, M. (2012). Voice-based control of a DC servo motor. American Journal of Engineering and Applied Sciences, 5(1).

Hasan, S., & El-Naas, M. H. (2016). Optimization of a combined approach for the treatment of carbide slurry and capture of CO2. Am. J. Eng. Applied Sci, 9, 449-457.

He, B., Wang, Z., Li, Q., Xie, H., & Shen, R. (2013). An analytic method for the kinematics and dynamics of a multiple-backbone continuum robot. International Journal of Advanced Robotic Systems, 10(1), 84.

Helmy, A. K., & El-Taweel, G. S. (2010). Neural network change detection model for satellite images using textural and spectral characteristics. American Journal of Engineering and Applied Sciences, 3(4).

Hirun, W. (2016). Evaluation of interregional freight generation modelling methods by using nationwide commodity flow survey data. Am. J. Eng. Applied Sci, 9, 625-634.

Ho, C. Y. F., Ling, B. W. K., Blasi, S. G., Chi, Z. W., & Siu, W. C. (2011). Single step optimal block matched motion estimation with motion vectors having arbitrary pixel precisions. Am. J. Eng. Applied Sci, 4, 448-460.

Huang, B., Masood, S. H., Nikzad, M., Venugopal, P. R., & Arivazhagan, A. (2016). Dynamic mechanical properties of fused deposition modelling processed polyphenylsulfone material. Am. J. Eng. Applied Sci, 9, 1-11.

Hypolite, B. P., Evariste, W. T., & Adolphe, M. I. (2019). A 10GHZ Low-Offset Dynamic Comparator for High-Speed and Lower-Power ADCS.

Idarwazeh, S., (2011). Inverse discrete Fourier transform-discrete Fourier transform techniques for generating and receiving spectrally efficient frequency division multiplexing signals. Am. J. Eng. Applied Sci, 4, 598-606.

Iqbal, M. (2016). An overview of Energy Loss Reduction (ELR) software used in Pakistan by WAPDA for calculating transformer overloading, line losses and energy losses. Am. J. Eng. Applied Sci, 9, 442-448.

Ismail, M. I. S., Okamoto, Y., Okada, A., & Uno, Y. (2011). Experimental investigation on micro-welding of thin stainless steel sheet by fiber laser. Am. J. Eng. Applied Sci, 4, 314-320.

Jaber, A. A., & Bicker, R. (2016). Industrial robot fault detection based on statistical control chart. Am. J. Eng. Applied Sci, 9, 251-263.

Jafari, N., Alsadoon, A., Withana, C. P., Beg, A., & Elchouemi, A. (2016). Designing a comprehensive security framework for smartphones and mobile devices. American Journal of Engineering and Applied Sciences, 9(3), 724-734.

Jarahi, H. (2016). Probabilistic seismic hazard deaggregation for Karaj City (Iran). Am. J. Eng. Applied Sci, 9, 520-529.

Jarahi, H., & Seifilaleh, S. (2016). Rock fall hazard zonation in Haraz Highway. Am. J. Eng. Applied Sci, 9, 371-379.

Jauhari, K., Widodo, A., & Haryanto, I. (2016). Identification of a machine tool spindle critical frequency through modal and imbalance response analysis. Am. J. Eng. Applied Sci, 9, 213-221.

Jiang, J., Chen, Q., & Nimbalkar, S. (2016). Field data based method for predicting long-term settlements.

Kaewnai, S., & Wongwises, S. (2011). Improvement of the runner design of francis turbine using computational fluid dynamics. Am. J. Eng. Applied Sci, 4, 540-547.

Khalifa, A. H. N., Jabbar, A. H., & Muhsin, J. A. (2015). Effect of Exhaust Gas Temperature on the Performance of Automobile Adsorption Air-Conditioner. American Journal of Engineering and Applied Sciences, 8(4), 575.

Khalil, R. (2015). Credibility of 3D volume computation using GIS for pit excavation and roadway constructions. American Journal of Engineering and Applied Sciences, 8(4), 434.

Kamble, V. G., & Kumar, N. (2016). Fabrication and tensile property analysis of polymer matrix composites of graphite and silicon carbide as fillers. Am. J. Eng. Applied Sci, 9, 17-30.

Kazakov, V. V., Pavlikov, A. I., Kamensky, V. A., Yusupov, V. I., & Bagratashvili, V. N. (2016). Control of bubble formation at the optical fiber tip by analyzing ultrasound acoustic waves. American Journal of Engineering and Applied Sciences, 9(4), 921-927.

Kechiche, O. B. H. B., Sethom, H. B. A., Sammoud, H., & Belkhodja, I. S. (2011). Optimized high frequency signal injection based permanent magnet synchronous motor rotor position estimation applied to washing machines. American Journal of Engineering and Applied Sciences, 4(3).

Kuli, I., Abu-Lebdeh, T. M., Fini, E. H., & Hamoush, S. A. (2016). The use of nano-silica for improving mechanical properties of hardened cement paste. Am. J. Eng. Applied Sci, 9, 146-154.

Kumar, N. D., Ravali, R. D., & Srirekha, P. R. (2015). Design and realization of pre-amplifier and filters for on-board radar system. American Journal of Engineering and Applied Sciences, 8(4), 689.

Kunanoppadon, J. (2010). Thermal efficiency of a combined turbocharger set with gasoline engine. Am. J. Eng. Applied Sci, 3, 342-349.

Kwon, S., Tani, Y., Okubo, H., & Shimomura, T. (2010). Fixed-star tracking attitude control of spacecraft using single-gimbal control moment gyros. Am. J. Eng. Applied Sci, 3, 49-55.

Lamarre, A., Fini, E. H., & Abu-Lebdeh, T. M. (2016). Investigating effects of water conditioning on the adhesion properties of crack sealant. Am. J. Eng. Applied Sci, 9, 178-186.

Lee, B. J. (2013). Geometrical derivation of differential kinematics to calibrate model parameters of flexible manipulator. International Journal of Advanced Robotic Systems, 10(2), 106.

Li, R., Zhang, B., Xiu, S., Wang, H., Wang, L., & Shahbazi, A. (2015). Characterization of solid residues obtained from supercritical ethanol liquefaction of swine manure. American Journal of Engineering and Applied Sciences, 8(4), 465.

Lin, W., Li, B., Yang, X., & Zhang, D. (2013). Modelling and control of inverse dynamics for a 5-DOF parallel kinematic polishing machine. International Journal of Advanced Robotic Systems, 10(8), 314.

Liu, H., Zhou, W., Lai, X., & Zhu, S. (2013). An efficient inverse kinematic algorithm for a PUMA560-structured robot manipulator. International Journal of Advanced Robotic Systems, 10(5), 236.

Lubis, Z., Abdalla, A. N., Mortaza, M., & Ghon, R. (2009). Mathematical Modeling of the Three Phase Induction Motor Couple to DC Motor in Hybrid Electric Vehicle. American Journal of Engineering and Applied Sciences, 2(4).

Madani, D. A., & Dababneh, A. (2016). Rapid entire body assessment: A literature review. American Journal of Engineering and Applied Sciences, 9(1), 107-118.

Malomar, G. E., Gueye, A., Mbow, C., Traore, V. B., & Beye, A. C. (2016). Numerical study of natural convection in a square porous cavity thermally modulated on both side walls. Am. J. Eng. Applied Sci, 9, 591-598.

Mansour, M. A. (2016). Developing an anthropometric database for Saudi students and comparing Saudi dimensions relative to Turkish and Iranian peoples. American Journal of Engineering and Applied Sciences, 9(3), 547-557.

Maraveas, C., Fasoulakis, Z. C., & Tsavdaridis, K. D. (2015). A review of human induced vibrations on footbridges. American Journal of Engineering and Applied Sciences, 8(4), 422-433.

Marghany, M., & Hashim, M. (2009). Robust of doppler centroid for mapping sea surface current by using radar satellite data. Am. J. Eng. Applied Sci, 2, 781-788.

Martins, F. R., Gonçalves, A. R., & Pereira, E. B. (2016). Observational study of wind shear in northeastern Brazil. Am. J. Eng. Applied Sci, 9, 484-504.

Marzuki, M. A. B., Abd Halim, M. H., & Mohamed, A. R. N. (2015). Determination of natural frequencies through modal and harmonic analysis of space frame race car chassis based on ANSYS. Am. J. Eng. Applied Sci, 8, 538-548.

Mavukkandy, M. O., Chakraborty, S., Abbasi, T., & Abbasi, S. A. (2016). A clean-green synthesis of platinum nanoparticles utilizing a pernicious weed lantana (Lantana Camara). Am. J. Eng. Applied Sci, 9, 84-90.

Minghini, F., Tullini, N., & Ascione, F. (2016). Updating Italian design guide CNR DT-205/2007 in view of recent research findings: Requirements for pultruded FRP profiles.

Moezi, N., Dideban, D., & Ketabi, A. (2008). A novel integrated SET based inverter for nano power electronic applications. Am. J. Eng. Applied Sci, 1, 219-222.

Mohamed, M. A., Tuama, A. Y., Makhtar, M., Awang, M. K., & Mamat, M. (2016). The effect of RSA exponential key growth on the multi-core computational resource. Am. J. Eng. Applied Sci, 9, 1054-1061.

Mohan, S. R. K., Jayabalan, P., & Rajaraman, A. (2012). Properties of fly ash based coconut fiber composite. American Journal of Engineering and Applied Sciences, 5(1).

Mohseni, E., & Tsavdaridis, K. D. (2016). Effect of nano-alumina on pore structure and durability of Class F Fly ash self-compacting mortar. American Journal of Engineering and Applied Sciences, 9(2), 323-333.

Momani, M. A., Al Smadi, T. A., Al Taweel, F. M., & Ghaidan, K. A. (2011). GPS ionospheric total electron content and scintillation measurements during the October 2003 magnetic storm. Am. J. Eng. Applied Sci, 4, 301-306.

Momta, P. S., Omoboh, J. O., & Odigi, M. I. (2015). Sedimentology and depositional environment of D2 sand in part of greater ughelli depobelt, onshore Niger Delta, Nigeria. American Journal of Engineering and Applied Sciences, 8(4), 556.

Mondal, R., Sahoo, S., & Rout, C. S. (2016). Mixed nickel cobalt manganese oxide nanorods for supercapacitor application.

Montgomery, J., Abu-Lebdeh, T. M., Hamoush, S. A., & Picornell, M. (2016). Effect of nano-silica on the compressive strength of harden cement paste at different stages of hydration. Am. J. Eng. Applied Sci, 9, 166-177.

Moretti, M. L. (2015). Seismic design of masonry and reinforced concrete infilled frames: a comprehensive overview. American Journal of Engineering and Applied Sciences, 8(4), 748.

Morse, A., Mansfield, M. M., Alley, R. M., Kerr, H. A., & Bucinell, R. B. (2016). Traction enhancing products affect maximum torque at the shoe-floor interface: A potential increased risk of ACL injury. Am. J. Eng. Applied Sci, 9, 889-893.

Moubarek, T., & Gharsallah, A. (2016). A six-port reflectometer calibration using Wilkinson power divider. Am. J. Eng. Applied Sci, 9, 274-280.

Nabilou, A. (2016a). Effect of parameters of selection and replacement drilling bits based on geo-mechanical factors:(Case study: Gas and oil reservoir in the Southwest of Iran). Am. J. Eng. Applied Sci, 9, 380-395.

Nabilou, A. (2016b). Study of the parameters of Steam Assisted Gravity Drainage (SAGD) method for enhanced oil recovery in a heavy oil fractured carbonate reservoir. Am. J. Eng. Applied Sci, 9, 647-658.

Nachiengtai, T., Chim-Oye, W., Teachavorasinskun, S., & Sa-Ngiamvibool, W. (2008). Identification of shear band using elastic shear wave propagation. American Journal of Engineering and Applied Sciences, 1(3).

Nahas, R., & Kozaitis, S. P. (2014). Metric for the fusion of synthetic and real imagery from multimodal sensors. American Journal of Engineering and Applied Sciences, 7(4), 355.

Nandhakumar, S., Selladurai, V., & Sekar, S. (2009). Numerical investigation of an industrial robot arm control problem using haar wavelet series. American Journal of Engineering and Applied Sciences, 2(4).

Ng, K. C., Yusoff, M. Z., Munisamy, K., Hasini, H., & Shuaib, N. H. (2008). Time-marching method for computations of high-speed compressible flow on structured and unstructured grid. Am. J. Eng. Applied Sci, 1(2), 89-94.

Obaiys, S. J., Abbas, Z., Long, N. N., Ahmad, A. F., Ahmedov, A., & Raad, H. K. (2016). On the general solution of first-kind hypersingular integral equations. Am. J. Eng. Applied Sci, 9, 195-201.

Odeh, S., Faqeh, R., Eid, L. A., & Shamasneh, N. (2009). Vision-based obstacle avoidance of mobile robot using quantized spatial model. Am. J. Eng. Applied Sci, 2, 611-619.

Ong, A. T., Mustapha, A., Ibrahim, Z. B., Ramli, S., & Eong, B. C. (2015). Real-time automatic inspection system for the classification of PCB flux defects. American Journal of Engineering and Applied Sciences, 8(4), 504.

Opafunso, Z. O., Ozigis, I. I., & Adetunde, I. A. (2009). Pneumatic and hydraulic systems in coal fluidized bed combustor. Am. J. Eng. Applied Sci, 2, 88-95.

Orlando, N., & Benvenuti, E. (2016). Advanced XFEM simulation of pull-out and debonding of steel bars and FRP-reinforcements in concrete beams. Am. J. Eng. Applied Sci, 9, 746-754.

Pannirselvam, N., Raghunath, P. N., & Suguna, K. (2008). Neural network for performance of glass fibre reinforced polymer plated RC beams. Am. J. Eng. Applied Sci, 1(1), 82-88.

Pattanasethanon, S. (2010). The solar tracking system by using digital solar position sensor. American Journal of Engineering and Applied Sciences, 3(4), 678-682.

Pérez-de León, G., Lamberti, V. E., Seals, R. D., Abu-Lebdeh, T. M., & Hamoush, S. A. (2016). Gas atomization of molten metal: Part I. Numerical modeling conception. American Journal of Engineering and Applied Sciences, 9(2).

Padula, F., & Perdereau, V. (2013). An on-line path planner for industrial manipulators. International Journal of Advanced Robotic Systems, 10(3), 156.

Perumaal, S. S., & Jawahar, N. (2013). Automated trajectory planner of industrial robot for pick-and-place task. International Journal of Advanced Robotic Systems, 10(2), 100.

Petrescu, F., & Petrescu, R. (1995a). Contributions to optimization of the polynomial motion laws of the stick from the internal combustion engine distribution mechanism. Bucharest, 1, 249-256.

Petrescu, F., & Petrescu, R. (1995b). Contributions to the synthesis of internal combustion engine distribution mechanisms. Bucharest, 1, 257-264.

Petrescu, F., & Petrescu, R. (1997a). Dynamics of cam mechanisms (exemplified on the classic distribution mechanism). Bucharest, 3, 353-358.

Petrescu, F., & Petrescu, R. (1997b). Contributions to the synthesis of the distribution mechanisms of internal combustion engines with a Cartesian coordinate method. Bucharest, 3, 359-364.

Petrescu, F., & Petrescu, R. (1997c). Contributions to maximizing polynomial laws for the active stroke of the distribution mechanism from internal combustion engines. Bucharest, 3, 365-370.

Petrescu, F., & Petrescu, R. (2000a). Synthesis of distribution mechanisms by the rectangular (Cartesian) coordinate method. University of Craiova, Craiova.

Petrescu, F., & Petrescu, R. (2000b). The design (synthesis) of cams using the polar coordinate method (triangle method). University of Craiova, Craiova.

Petrescu, F., & Petrescu, R. (2002a). Motion laws for cams. In Proceedings of the International Computer Assisted Design, National Symposium with Participation,(SNP'02), Braşov (pp. 321-326).

Petrescu, F., & Petrescu, R. (2002b). Camshaft dynamics elements. In Proceedings of the International Computer Assisted Design, National Participation Symposium,(SNP'02), Braşov (pp. 327-332).

Petrescu, F., & Petrescu, R. (2003). Some elements regarding the improvement of the engine design. In Proceedings of the National Symposium, Descriptive Geometry, Technical Graphics and Design,(GTD'03), Braşov (pp. 353-358).

Petrescu, F. I., & Petrescu, R. V. (2005a). The cam design for a better efficiency. Available at SSRN 3076805.

Petrescu, F. I., & Petrescu, R. V. (2005b, September). Contributions at the Dynamic of Cams. In The Ninth IFTOMM International Symposium on Theory of Machines and Mechanisms.

Petrescu, F. I., & Petrescu, R. V. (2005c). Determining the dynamic efficiency of cams. Available at SSRN 3076802.

Petrescu, F. I., & Petrescu, R. V. (2005d). An original internal combustion engine. In The Ninth IFTOMM International Symposium on Theory of Machines and Mechanisms.

Petrescu, R. V., & Petrescu, F. I. (2005e). Determining the mechanical efficiency of Otto engine's mechanism. Available at SSRN 3076804.

Petrescu, F., & Petrescu, R. (2011a). Mechanical Systems, Serial and Parallel. Lulu. com.

Petrescu, F. I. T., & Petrescu, R. V. (2011b). Trenuri planetare. Createspace Independent Pub, 104.

Petrescu, F. I., & Petrescu, R. V. (2012a). Kinematics of the planar quadrilateral mechanism.

Petrescu, F. I., & Petrescu, R. V. (2012b). Mecatronica-sisteme seriale si paralele.

Petrescu, F. I., & Petrescu, R. V. (2013a). Cinematics of the 3R Dyad.

Petrescu, F. I., & Petrescu, R. V. (2013b). Forces and efficiency of cams. Int. Rev. Mech. Eng, 7(3), 507-511.

Petrescu, F. I., & Petrescu, R. V. (2013c). Cams with high efficiency. Int. Rev. Mech. Eng, 7(4), 599-606.

Petrescu, F. I. T., & Petrescu, R. V. (2013d). An algorithm for setting the dynamic parameters of the classic distribution mechanism. Int. Rev. Modell. Simulat, 6, 1637-1641.

Petrescu, F. I., & Petrescu, R. V. (2013e). Dynamic synthesis of the rotary cam and translated tappet with roll. Engevista, 15(3).

Petrescu, F. I., & Petrescu, R. V. (2014a). Parallel moving mechanical systems. Independent Journal of Management and Production (IJMandP), 5(3).

Petrescu, F. I., & Petrescu, R. V. (2014b). Cam gears dynamics in the classic distribution. Independent Journal of Management and Production (IJMandP), 5(1).

Petrescu, F. I., & Petrescu, R. V. (2014c). High efficiency gears synthesis by avoid the interferences. Independent Journal of Management and Production (IJMandP), 5(2).

Petrescu, F. I., & Petrescu, R. V. (2014d). Gear design.

Petrescu, F. I., & Petrescu, R. V. (2014e). KINETOSTATIC OF THE 3R DYAD. Engevista, 16(3), 314-321.

Petrescu, F. I. T., & Petrescu, R. V. (2014f). Balancing otto engines. Int. Rev. Mech. Eng, 8, 473-480.

Petrescu, F. I. T., & Petrescu, R. V. (2014g). Machine equations to the classical distribution. Int. Rev. Mech. Eng, 8, 309-316.

Petrescu, F. I. T., & Petrescu, R. V. (2014h). Forces of internal combustion heat engines. Int. Rev. Modell. Simulat, 7, 206-212.

Petrescu, F. I. T., & Petrescu, R. V. (2014i). Determination of the yield of internal combustion thermal engines. Int. Rev. Mech. Eng, 8, 62-67.

Petrescu, F. I., & Petrescu, R. V. (2015a). Forces at the main mechanism of a railbound forging manipulator. Independent Journal of Management and Production, 6(4).

Petrescu, F. I., & Petrescu, R. V. (2015b). Kinematics at the main mechanism of a railbound forging manipulator. Independent Journal of Management and Production, 6(3).

Petrescu, F. I. T., & Petrescu, R. V. V. (2015c). Machine motion equations. Independent Journal of Management and Production, 6(3), 773-802.

Petrescu, F. I., & Petrescu, R. V. (2015d). Presenting a railbound forging manipulator. In Applied Mechanics and Materials (Vol. 762, pp. 219-224). Trans Tech Publications Ltd.

Petrescu, F. I. T., & Petrescu, R. V. (2015e). About the anthropomorphic robots. J. ENGEVISTA, 17: 1-15.

Petrescu, F. I., & Petrescu, R. V. (2016a). Parallel moving mechanical systems kinematics.

Petrescu, F. I., & Petrescu, R. V. (2016b). Direct and inverse kinematics to the anthropomorphic robots.

Petrescu, F. I., & Petrescu, R. V. (2016c). Dynamic cinematic to a structure 2R. GEINTEC Journal, 6(2).

Petrescu, F. I., & Petrescu, R. V. (2016d). An otto engine dynamic model. Independent Journal of Management and Production (IJMandP), 7(1).

Petrescu, N., & Petrescu, F. I. (2018a). Elementary structure of matter can be studied with new quantum computers. American Journal of Engineering and Applied Sciences, 11(2), 1062-1075.

Petrescu, N., & Petrescu, F. I. (2018b). Geometric-Cinematic Synthesis of Planetary Mechanisms. Nicolae Petrescu and Florian Ion Tiberiu Petrescu/American Journal of Engineering and Applied Sciences, 11(3), 1141-1153.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2016). Future medicine services robotics. American Journal of Engineering and Applied Sciences, 9(4), 1062-1087.

Petrescu, F. I., Grecu, B., Comanescu, A., & Petrescu, R. V. (2009, October). Some mechanical design elements. In The 3rd International Conference on Computational Mechanics and Virtual Engineering COMEC (pp. 29-30).

Petrescu, F. I. T. (2011). Teoria Mecanismelor si a Masinilor: Curs Si Aplicatii. CreateSpace Independent Publishing Platform. ISBN-10, 1468015826, 432.

Petrescu, F. I. (2015a). Geometrical synthesis of the distribution mechanisms. American Journal of Engineering and Applied Sciences, 8(1), 63-81.

Petrescu, F. I. T. (2015b). Machine motion equations at the internal combustion heat engines. American Journal of Engineering and Applied Sciences, 8(1), 127.

Petrescu, F. I. T. (2015c). Machine motion equations at the internal combustion heat engines. American Journal of Engineering and Applied Sciences, 8(1), 127.

Petrescu, F. I. (2018a). Dynamic Models of Rigid Memory Mechanisms. American Journal of Engineering and Applied Sciences, 11(4), 1242-1257.

Petrescu, F. I. (2018). About the triton structure. American Journal of Engineering and Applied Sciences, 11(4), 1293-1297.

Petrescu, F. I. T. A., Apicella, A., Aversa, R., Petrescu, R. V., Calautit, J. K., Mirsayar, M. M., & Riccio, A. (2016). Something about the mechanical moment of inertia.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Calautit, J. K., ..., & Petrescu, F. I. (2017a). Yield at thermal engines internal combustion. American Journal of Engineering and Applied Sciences, 10(1), 243-251.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017b). Velocities and accelerations at the 3R mechatronic systems. American Journal of Engineering and Applied Sciences, 10(1), 252-263.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017c). Anthropomorphic solid structures nr kinematics. American Journal of Engineering and Applied Sciences, 10(1), 279-291.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017d). Inverse kinematics at the anthropomorphic robots, by a trigonometric method. American Journal of Engineering and Applied Sciences, 10(2), 394-411.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Calautit, J. K., ..., & Petrescu, F. I. (2017e). Forces at internal combustion engines. American Journal of Engineering and Applied Sciences, 10(2).

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017f). Gears-part I. American Journal of Engineering and Applied Sciences, 10(2), 457-472.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017g). Gears-part II. American Journal of Engineering and Applied Sciences, 10(2), 473-483.

Aversa, R., Petrescu, R. V., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017h). Cam-gears forces, velocities, powers and efficiency. American Journal of Engineering and Applied Sciences, 10(2), 491-505.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Kozaitis, S., ..., & Petrescu, F. I. (2017i). Dynamics of mechanisms with cams illustrated in the classical distribution. American Journal of Engineering and Applied Sciences, 10(2), 551-567.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Kozaitis, S., ..., & Petrescu, F. I. (2017j). Testing by non-destructive control. American Journal of Engineering and Applied Sciences, 10(2), 568-583.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2017k). Transportation engineering. American Journal of Engineering and Applied Sciences, 10(3).

Petrescu, R. V., Aversa, R., Kozaitis, S., Apicella, A., & Petrescu, F. I. (2017l). The quality of transport and environmental protection, part I. American Journal of Engineering and Applied Sciences, 10(3), 738-755.

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017m). Modern propulsions for aerospace-a review. Journal of Aircraft and Spacecraft Technology, 1(1).

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017n). Modern propulsions for aerospace-part II. Journal of Aircraft and Spacecraft Technology, 1(1).

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017o). History of aviation-a short review. Journal of Aircraft and Spacecraft Technology, 1(1).

Petrescu, R. V., Aversa, R., Akash, B., Bucinell, R., Corchado, J., Apicella, A., & Petrescu, F. I. (2017p). Lockheed martin-a short review. Journal of Aircraft and Spacecraft Technology, 1(1).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Apicella, A., & Petrescu, F. I. (2017q). Our universe. Journal of Aircraft and Spacecraft Technology, 1(2).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Apicella, A., & Petrescu, F. I. (2017r). What is a UFO?. Journal of Aircraft and Spacecraft Technology, 1(2).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Berto, F., Mirsayar, M., ..., & Petrescu, F. I. T. (2017s). About bell helicopter FCX-001 concept aircraft-a short review. Journal of Aircraft and Spacecraft Technology, 1(2), 91-96.

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Apicella, A., & Petrescu, F. I. (2017t). Home at airbus. Journal of Aircraft and Spacecraft Technology, 1(2).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Kozaitis, S., Abu-Lebdeh, T., ..., & Petrescu, F. I. (2017u). Airlander. Journal of Aircraft and Spacecraft Technology, 1(2).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Berto, F., Apicella, A., & Petrescu, F. I. (2017v). When boeing is dreaming–a review. Journal of Aircraft and Spacecraft Technology, 1(3).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Berto, F., Apicella, A., & Petrescu, F. I. (2017w). About northrop grumman. Journal of Aircraft and Spacecraft Technology, 1(3).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Berto, F., Apicella, A., & Petrescu, F. I. (2017x). Some special aircraft. Journal of Aircraft and Spacecraft Technology, 1(3).

Petrescu, R. V., Aversa, R., Akash, B., Corchado, J., Berto, F., Apicella, A., & Petrescu, F. I. (2017y). About helicopters. Journal of Aircraft and Spacecraft Technology, 1(3), 204-223.

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017z). The modern flight. Journal of Aircraft and Spacecraft Technology, 1(4), 224-233.

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017aa). Sustainable energy for aerospace vessels. Journal of Aircraft and Spacecraft Technology, 1(4), 234-240.

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017ab). Unmanned helicopters. Journal of Aircraft and Spacecraft Technology, 1(4), 241-248.

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017ac). Project HARP. Journal of Aircraft and Spacecraft Technology, 1(4), 249-257.

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017ad). Presentation of Romanian Engineers who Contributed to the Development of Global Aeronautics–Part I. Journal of Aircraft and Spacecraft Technology, 1(4), 258-271.

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017ae). A first-class ticket to the planet mars, please. Journal of Aircraft and Spacecraft Technology, 1(4), 272-281.

Petrescu, R. V., Aversa, R., Kozaitis, S., Apicella, A., & Petrescu, F. I. (2017af). Some basic reactions in nuclear fusion. American Journal of Engineering and Applied Sciences, 10(3).

Petrescu, R. V., Aversa, R., Kozaitis, S., Apicella, A., & Petrescu, F. I. (2017ag). Deuteron dimensions. American Journal of Engineering and Applied Sciences, 10(3).

Petrescu, R. V., Aversa, R., Kozaitis, S., Apicella, A., & Petrescu, F. I. (2017ah). Some proposed solutions to achieve nuclear fusion. American Journal of Engineering and Applied Sciences, 10(3).

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017ai). Dynamic elements at MP3R. Journal of Mechatronics and Robotics, 1(2), 24-37.

Petrescu, R. V., Aversa, R., Akash, B., Berto, F., Apicella, A., & Petrescu, F. I. (2017aj). Nikola Tesla. American Journal of Engineering and Applied Sciences, 10(4),

Petrescu, R. V., Aversa, R., Apicella, A., Kozaitis, S., Abu-Lebdeh, T., & Petrescu, F. I. (2018a). NASA started a propeller set on board voyager 1 after 37 years of break. American Journal of Engineering and Applied Sciences, 11(1), 66-77.

Petrescu, R. V., Aversa, R., Apicella, A., Kozaitis, S., Abu-Lebdeh, T., & Petrescu, F. I. (2018b). There is Life on Mars?. American Journal of Engineering and Applied Sciences, 11(1), 78-91.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018c). Friendly environmental transport. American Journal of Engineering and Applied Sciences, 11(1), 154-165.

Petrescu, R. V., Aversa, R., Akash, B., Abu-Lebdeh, T., Apicella, A., & Petrescu, F. I. (2018d). Buses running on gas. American Journal of Engineering and Applied Sciences, 11(1), 186-201.

Petrescu, R. V., Aversa, R., Akash, B., Abu-Lebdeh, T., Apicella, A., & Petrescu, F. I. (2018e). Some aspects of the structure of planar mechanisms. American Journal of Engineering and Applied Sciences, 11(1), 245-259.

Petrescu, R. V., Aversa, R., Abu-Lebdeh, T. M., Apicella, A., & Petrescu, F. I. T. (2018f). The forces of a simple carrier manipulator. Am. J. Eng. Applied Sci, 11, 260-272.

Petrescu, R. V., Aversa, R., Abu-Lebdeh, T., Apicella, A., & Petrescu, F. I. (2018g). The dynamics of the otto engine. American Journal of Engineering and Applied Sciences, 11(1), 273-287.

Petrescu, R. V., Aversa, R., Abu-Lebdeh, T., Apicella, A., & Petrescu, F. I. (2018h). NASA satellites help us to quickly detect forest fires. American Journal of Engineering and Applied Sciences, 11(1), 288-296.

Petrescu, R. V., Aversa, R., Abu-Lebdeh, T., Apicella, A., & Petrescu, F. I. (2018i). Kinematics of a mechanism with a triad. American Journal of Engineering and Applied Sciences, 11(1), 297-308.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018j). Romanian Engineering'On the Wings of the Wind'. Journal of Aircraft and Spacecraft Technology, 2(1), 1-18.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018k). NASA Data used to discover eighth planet circling distant star. Journal of Aircraft and Spacecraft Technology, 2(1), 19-30.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018l). NASA has found the most distant black hole. Journal of Aircraft and Spacecraft Technology, 2(1), 31-39.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018m). Nasa selects concepts for a new mission to titan, the moon of saturn. Journal of Aircraft and Spacecraft Technology, 2(1), 40-52.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018n). NASA sees first in 2018 the direct proof of ozone hole recovery. Journal of Aircraft and Spacecraft Technology, 2(1), 53-64.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018o). Dynamic Synthesis of a Dual-Clutch Automatic Gearboxes. American Journal of Engineering and Applied Sciences, 11(2), 663-679.

Petrescu, R. V., Aversa, R., Apicella, A., & Petrescu, F. I. (2018p). Dynamic Synthesis of a Classic, Manual Gearbox. American Journal of Engineering and Applied Sciences, 11(2), 586-597.

Petrescu, R. V., Aversa, R., Abu-Lebdeh, T., Apicella, A., & Petrescu, F. I. (2018q). The dynamics of the otto engine. American Journal of Engineering and Applied Sciences, 11(1), 273-287.

Petrescu, R. V., Aversa, R., Abu-Lebdeh, T., Apicella, A., & Petrescu, F. I. (2018r). Kinematics of a mechanism with a triad. American Journal of Engineering and Applied Sciences, 11(1), 297-308.

Petrescu, F. I., Abu-Lebdeh, T., & Apicella, A. (2018s). Presentation of a Mechanism with a Maltese Cross (Geneva Driver). American Journal of Engineering and Applied Sciences, 11(2), 891-900.

Petrescu, F. I., Abu-Lebdeh, T., & Apicella, A. (2018t). An Analytical Method for Determining Forces within a Triad. American Journal of Engineering and Applied Sciences, 11(2), 901-913.

Petrescu, F. I., Abu-Lebdeh, T., & Apicella, A. (2018u). Study of an Oscillating Sliding Mechanism. American Journal of Engineering and Applied Sciences, 11(2), 870-880.

Petrescu, F. I., Abu-Lebdeh, T., & Apicella, A. (2018v). Presentation of the Mechanism in the Cross. American Journal of Engineering and Applied Sciences, 11(2), 881-890.

Pisello, A. L., Pignatta, G., Piselli, C., Castaldo, V. L., & Cotana, F. (2016). Investigating the dynamic thermal behavior of building envelope in summer conditions by means of in-field continuous monitoring. Am. J. Eng. Applied Sci, 9, 505-519.

Pourmahmoud, N. (2008). Rarefied gas flow modeling inside rotating circular cylinder. Am. J. Eng. Applied Sci, 1(1), 62-65.

Pravettoni, M., Polo Lopez, C. S., & Kenny, R. P. (2016). Impact of the edges of a backside diffusive reflector on the external quantum efficiency of luminescent solar concentrators: Experimental and computational approach. American Journal of Engineering and Applied Sciences, 9(1), 53-63.

Qutbodin, K. (2010). Merging autopilot/flight control and navigation-flight management systems. Am. J. Eng. Applied Sci, 3, 629-630.

Rajbhandari, S., Ghassemlooy, Z., & Angelova, M. (2011). The performance of a dual header pulse position modulation in the presence of artificial light interferences in an indoor optical wireless communications channel with wavelet denoising. American Journal of Engineering and Applied Sciences, 4(4), 513-519.

Rajput, R. S., Pandey, S., & Bhadauria, S. (2016). Correlation of biodiversity of algal genera with special reference to the waste water effluents from industries. Am. J. Eng. Applied Sci, 9, 1127-1133.

Rajupillai, K., Palaniammal, S., & Bommuraju, K. (2015). Computational intelligence and application of frame theory in communication systems. American Journal of Engineering and Applied Sciences, 8(4), 633.

Raptis, K. G., Papadopoulos, G. A., Costopoulos, T. N., & Tsolakis, A. D. (2011). Experimental study of load sharing in roller-bearing contact by caustics and photoelasticity. Am. J. Eng. Applied Sci, 4, 294-300.

Rama, G., Marinković, D., & Zehn, M. (2016). Efficient co-rotational 3-node shell element. American Journal of Engineering and Applied Sciences.

Rea, P., & Ottaviano, E. (2016). Analysis and mechanical design solutions for sit-to-stand assisting devices. Am. J. Eng. Applied Sci, 9, 1134-1143.

Rhode-Barbarigos, L., Charpentier, V., Adriaenssens, S., & Baverel, O. (2015). Dialectic form finding of structurally integrated adaptive structures. American Journal of Engineering and Applied Sciences, 8(4), 443-454.

Riccio, A., Caruso, U., Raimondo, A., & Sellitto, A. (2016a). Robustness of XFEM method for the simulation of cracks propagation in fracture mechanics problems.

Riccio, A., Cristiano, R., & Saputo, S. (2016b). A brief introduction to the bird strike numerical simulation.

Rich, F., & Badar, M. A. (2016). Statistical analysis of auto dilution Vs manual dilution process in inductively coupled plasma spectrometer tests. Am. J. Eng. Applied Sci, 9, 611-624.

Rohit, K., & Dixit, S. (2016). Mechanical properties of waste Biaxially Oriented Polypropylene metallized films (BOPP), LLDPE: LDPE films with sisal fibres. Am. J. Eng. Applied Sci, 9, 913-920.

Rulkov, N. F., Hunt, A. M., Rulkov, P. N., & Maksimov, A. G. (2016). Quantization of map-based neuronal model for embedded simulations of neurobiological networks in real-time. American Journal of Engineering and Applied Sciences, 9(4), 973-984.

Saikia, A., & Karak, N. (2016). Castor oil based epoxy/clay nanocomposite for advanced applications. Am. J. Eng. Applied Sci, 9, 31-40.

Sallami, A., Zanzouri, N., & Ksouri, M. (2016). Robust diagnosis of a DC motor by bond graph approach. Am. J. Eng. Applied Sci, 9, 432-438.

Samantaray, K. S., Sahoo, S., & Rout, C. S. (2016). Hydrothermal synthesis of CuWO4-reduced graphene oxide hybrids and supercapacitor application. Am. J. Eng. Applied Sci, 9, 584-590.

Santos, F. A., & Bedon, C. (2016). Preliminary experimental and finite-element numerical assessment of the structural performance of SMA-reinforced GFRP systems. American Journal of Engineering and Applied Sciences, 9(3), 692-701.

Semin, S., Ismail, A. R., & Bakar, R. A. (2009a). Combustion temperature effect of diesel engine convert to compressed natural gas engine. American Journal of Engineering and Applied Sciences, 2(1).

Semin Ismail, A. R., & Rosli, A. B. (2009b). Effect of diesel engine converted to sequential port injection compressed natural gas engine on the cylinder pressure vs crank angle in variation engine speeds. Am J Eng and Applied Sci, 2(1), 154-9.

Semin, S., Ismail, A. R., & Bakar, R. A. (2009c). Diesel engine convert to port injection CNG engine using gaseous injector nozzle multi holes geometries improvement: A review. American Journal of Engineering and Applied Sciences, 2(2).

Semin and Bakar, R. A. (2008). A technical review of compressed natural gas as an alternative fuel for internal combustion engines. Am. J. Eng. Appl. Sci, 1(4), 302-311.

Sepúlveda, J. A. M. (2016). Outlook of municipal solid waste in Bogota (Colombia). Am. J. Eng. Applied Sci, 9, 477-483.

Serebrennikov, A., Serebrennikov, D., & Hakimov, Z. (2016). Polyethylene pipeline bending stresses at an installation. Am. J. Eng. Applied Sci, 9, 350-355.

Shanmugam, K. (2016). Flow dynamic behavior of fish oil/silver nitrate solution in mini-channel, effect of alkane addition on flow pattern and interfacial tension. Am. J. Eng. Applied Sci, 9, 236-250.

Shruti, (2016). Comparison in cover media under stegnography: Digital media by hide and seek approach. Am. J. Eng. Applied Sci, 9, 297-302.

Stavridou, N., Efthymiou, E., & Baniotopoulos, C. C. (2015a). Welded connections of wind turbine towers under fatigue loading: Finite element analysis and comparative study. American Journal of Engineering and Applied Sciences, 8(4), 489.

Stavridou, N., Efthymiou, E., & Baniotopoulos, C. C. (2015b). Verification of anchoring in foundations of wind turbine towers. American Journal of Engineering and Applied Sciences, 8(4), 717.

Suarez, L., Abu-Lebdeh, T. M., Picornell, M., & Hamoush, S. A. (2016). Investigating the role of fly ash and silica fume in the cement hydration process. Am. J. Eng. Applied Sci, 9, 134-145.

Syahrullah, L. O. I., & Sinaga, N. (2016). Optimization and prediction of motorcycle injection system performance with feed-forward back-propagation method Artificial Neural Network (ANN). American Journal of Engineering and Applied Science, 9(2), 222-235.

Sylvester, O., Bibobra, I., & Ogbon, O. N. (2015a). Well test and PTA for reservoir characterization of key properties. American Journal of Engineering and Applied Sciences, 8(4), 638.

Sylvester, O., Bibobra, I., & Augustina, O. (2015b). Report on the evaluation of Ugua J2 and J3 reservoir performance. American Journal of Engineering and Applied Sciences, 8(4), 678.

Taher, S. A., Hematti, R., & Nemati, M. (2008). Comparison of different control strategies in GA-based optimized UPFC controller in electric power systems. Am. J. Eng. Applied Sci, 1(1), 45-52.

Takeuchi, T., Kinouchi, Y., Matsui, R., & Ogawa, T. (2015). Optimal arrangement of energy-dissipating members for seismic retrofitting of truss structures. American Journal of Engineering and Applied Sciences, 8(4), 455.

Theansuwan, W., & Triratanasirichai, K. (2011). The biodiesel production from roast Thai sausage oil by transesterification reaction. Am. J. Eng. Applied Sci, 4, 130-132.

Thongwan, T., Kangrang, A., & Homwuttiwong, S. (2011). An estimation of rainfall using fuzzy setgenetic algorithms model. Am. J. Eng. Applied Sci, 4, 77-81.

Tourab, W., Babouri, A., & Nemamcha, M. (2011). Experimental study of electromagnetic environment in the vicinity of high voltage lines. Am. J. Eng. Applied Sci, 4, 209-213.

Tsolakis, A. D., & Raptis, K. G. (2011). Comparison of maximum gear-tooth operating bending stresses derived from niemann's analytical procedure and the finite element method. Am. J. Eng. Applied Sci, 4, 350-354.

Vernardos, S. M., & Gantes, C. J. (2015). Cross-section optimization of sandwich-type cylindrical wind turbine towers. American Journal of Engineering and Applied Sciences, 8(4), 471.

Wang, L., Liu, T., Zhang, Y., & Yuan, X. (2016). A methodology for continuous evaluation of cloud resiliency. Am. J. Eng. Applied Sci, 9, 264-273.

Wang, L., Wang, G., & Alexander, C. A. (2015). Confluences among big data, finite element analysis and high-performance computing. Am. J. Eng. Applied Sci, 8, 767-774.

Wang, J., & Yagi, Y. (2016). Fragment-based visual tracking with multiple representations. Am. J. Eng. Applied Sci, 9, 187-194.

Waters, C., Ajinola, S., & Salih, M. (2016). Dissolution sintering technique to create porous copper with sodium chloride using polyvinyl alcohol solution through powder metallurgy. Am. J. Eng. Applied Sci, 9, 155-165.

Wessels, L., & Raad, H. (2016). Recent advances in point of care diagnostic tools: A review. Am. J. Eng. Applied Sci, 9, 1088-1095.

DOI: 10.3844/jmrsp.2020.156.190

Yang, M. F., & Lin, Y. (2015). Process is unreliable and quantity discounts supply chain integration inventory model. American Journal of Engineering and Applied Sciences, 8(4), 602.

Yeargin, R., Ramey, R., & Waters, C. (2016). Porosity analysis in porous brass using dual approaches. Am. J. Eng. Applied Sci, 9, 91-97.

You, M., Huang, X., Lin, M., Tong, Q., & Li, X. (2016). Preparation of LiCoMnO4 assisted by hydrothermal approach and its electrochemical performance. Am. J. Eng. Applied Sci, 9, 396-405.

Zeferino, R. S., Ramón, J. R., de Anda Reyes, E., Gónzalez, R. S., & Pal, U. (2016). Large scale synthesis of ZnO nanostructures of different morphologies through solvent-free mechanochemical synthesis and their application in photocatalytic dye degradation. Am. J. Eng. Applied Sci, 9, 41-52.

Zhao, B. (2013). Identification of multi-cracks in the gate rotor shaft based on the wavelet finite element method. Am. J. Eng. Applied Sci, 6, 309-319.

Zheng, H., & Li, S. (2016). Fast and robust maximum power point tracking for solar photovoltaic systems. Am. J. Eng. Applied Sci, 9, 755-769.

Zotos, I. S., & Costopoulos, T. N. (2009). On the use of rolling element bearings' models in precision maintenance. Am. J. Eng. Applied Sci, 2, 344-352.

Zulkifli, R., Sopian, K., Abdullah, S., & Takriff, M. S. (2008). Effect of pulsating circular hot air jet frequencies on local and average nusselt number. American Journal of Engineering and Applied Sciences, 1(1), 57-61.

Zulkifli, R., Sopian, K., Abdullah, S., & Takriff, M. S. (2009). Experimental study of flow structures of circular pulsating air jet. American Journal of Engineering and Applied Sciences, 2(1).

Zurfi, A., & Zhang, J. (2016a). Model identification and wall-plug efficiency measurement of white LED modules. Am. J. Eng. Applied Sci, 9, 412-419.

Zurfi, A., & Zhang, J. (2016b). Exploitation of battery energy storage in load frequency control-a literature survey. Am. J. Eng. Applied Sci, 9, 1173-1188.

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Fig. 3

https://2.bp.blogspot.com/-DwbUcVp1IHg/WYSoiPzOI2I/AAAAAAAAIXA/rwRqYH586Js74sKDtpf1rxE3o61YSHl1gCLcBGAs/s1600/anti-lock%2Bbraking%2Bsystem.jpg

Fig. 4

https://upload.wikimedia.org/wikipedia/commons/b/b4/O-2_electromagnetic-power-off-brake1.gif

Fig. 5

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Fig. 6

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