



Research Development on Wiper Mechanism in Automotive Application: A Critical Review

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Authors' contributions

This work was carried out in collaboration between both authors. Author AS performed a comprehensive review on the development of wiper mechanism in automotive application. Author UN supervised the work and designed the contents in this article. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

In this generation, usage of transportation vehicles is drastically increased. It is very important to improve the safety facility in an automobile vehicles. Due to this, many researchers have contributed to research and development on smart wind shield wiper mechanism in automotive. Considering that, the current work compiles a compilation of articles reviewed on smart wind shield wiper mechanism from year 1903 to 2015. Further than that, this work also provides information relating to the varying designs and specifications of smart windshield wiper mechanism. At the same time, the writers also propose potential future research that could be undertaken in relation to the development in wiper mechanism in automotive application, which in turn may allow for new research pathways in this area of interest. Finally, taking into consideration the design and safety factors of the current market trend wiper mechanism, the writes also propose possible windshield washing system for various application.

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1. INTRODUCTION

Wiper is an essential component that used to wipe the raindrops or any water from the windshield. Wipers are designed and made to clear the water from a windshield. Most of cars have two wipers on the windshield, one on the rear window and the other on each headlight. The wiper parts visible from outside the car are the rubber blade, the wiper arm holding the blade, a spring linkage, and parts of the wiper pivots. The wiper itself has about six parts called pressure points or claws that are small arms under the wiper [1]. Existing system manually used control stalk to activate wiper and the process of pulling up wiper is difficult to be handled. The driver needs to switch on and off the control stalk and it will reduce the driver's concentration during the driving [2,3]. Moreover, it creates a temporary blindness for the driver when handling the vehicle. Thus, this system is proposed to solve all these problems. The concept of this wipers system is similar with other conventional wiper, yet this system will be upgraded to an automatic control system by using a sensor. Whenever the water hit a dedicated sensor that located on windshield, it will send a signal to move on the wiper motor. Once water is not detected by sensor, the wiper will automatically stop. Not only water, when there's any particles such as debris/dirt hit the windshield, it will automatically turn on the wiper system. Therefore, this will overcome the temporary blindness of the driver and the driver will have more concentration and reduce the car accident probability [4–6].

Fig.1 illustrates the number of articles published on research of smart wiper washing system for automotive car wind screen cleaning application over the last few years. It indicates the increasing interest of worldwide research on the topic.

2. HISTORICAL BACKGROUND

Numerous modifications and adjustments have been implemented since then when the first car was manufactured and available in the market in the early 1900's. About ten years after the first automobile was made the first windshield wiper was invented [7,8]. Part of the trouble with the earliest variations of windshield cleansing tools was the absence of home windows on the vehicles of the day. For numerous vehicles,

windcreens were a choice. In 1929, wrap around home windows, offered as a choice, ended up being a standing icon. But the trouble of needing to connect the home window with a squeegee sufficed to stimulate on developers long prior to confined cabin cars ended up being common. The idea for wind shield wiper was born when Mary Anderson when to visit New York City in the winter of 1903, in a trolley car on a frosty day. Anderson observed that a trolley car driver was struggling to see past the windows because of the falling fleet. When she returned to Alabama, she hired a designer for a hand-operated device to keep a windshield clear and had a local company produce a working model. It is operated via a lever from inside a vehicle, her version of windshield wipers closely resembles the windshield wiper found in on many early car models [9].

These days various associations from various countries mutually puts in efforts to maximize efficiency by continuing intensive research and by increasing the enforcement of rules and regulation pertaining to the safety of the driver and also the passenger.

As a result, there has been substantial interest and a large number of researches conducted over a last decade on development of a smart wiper washing system for automotive car windshield cleaning application. The number shows an increasing trend. Following this, this paper focuses on a review of car wiper system comprising of the design and specification, advantages and is advantages of an existing product. This paper also reviews the design patent from the years 1903 to 2015. Further, some state of art designs are proposed and discussed in this review such as improvement of existing wiper system, adding new feature to improve the wiper system, and to overcome the blind spot of the driver while operating the wiper system.

3. PATENT REVIEWS

3.1 Year 1903

The complete design as seen in Fig. 2 is invented by Mary Anderson, with the patent number (US 743 801) and was published in 1903. The inventor claimed that her invention is called as a "window cleaning device" for electric cars and other vehicles. The main objective of

this invention is to remove rain, snow, ice, water, and/ or debris from a vehicle's front window so the vehicle's operator can better see what's ahead of them. It is operated via a lever from inside a vehicle. The blade rested on the outside glass, connected to the inside via a hole and spindle through the windshield as shown in Fig. 2. However, the design of the first windshield wiper invention is operated manually without taking into consideration the comfort of the driver to operate it as shown in Fig. 2.c [10].

However, on the same year there were two more inventions were patented 3 months prior to Anderson's patent. A man named Robert A Douglass registered a patent with the patent number (US 762 889 A) in March, on the 12th 1903. What is more, the invention was closely resembling an upside down version of Anderson's but intended for locomotive cabs which is shown in Fig. 3 [11,12].

Another inventor named James Henry Apjohn designed an "Apparatus for Cleaning Carriage, Motor Car and other Windows" and registered it with patent number (US 743 801) on 18 June 1903 and later was issued to him by the US Patent Office on 10 November 1903. As shown in Fig. 4 the inventor claims that the invention cleans either both up and down or in just one direction on a vertical window using two brushes or wipers. Needless to say, the invention did not make it into cars.

3.2 Year 1917

The design as seen in Figure 5 was invented by Charlotte Bridgwood with patent number (US 1,274,983 A) and published in 1917. The inventor claimed that her invention was the improvisation of Mary Anderson's manually operated wipers. However, the inventor improvised Mary Anderson's invention into the first electrically powered windshield wiper. It uses roller blades rather than blades. To be honest, roller blades did not catch up with the technology because the cleaning efficiency of rollerblades was not as expected since the other inventions after this were way better and updated [13].

3.3 Year 1919

The design as seen in Fig. 6 is invented by William M. Folberth and Fred Folberth with patent number (US 1,420,538) and was published after it was granted on June 20, 1922. The inventor claimed that the blade design is more desirable to consumers than the rollers. Apart from that, the method of using air from the engine manifold would cause the wipers to speed up or slow down with the vehicle. However, a more consistent wiping speed is required in order for the wiper system to operate consistently to allow the driver to have a better view without any blind-spot or eye delay when focusing the road [14–16].

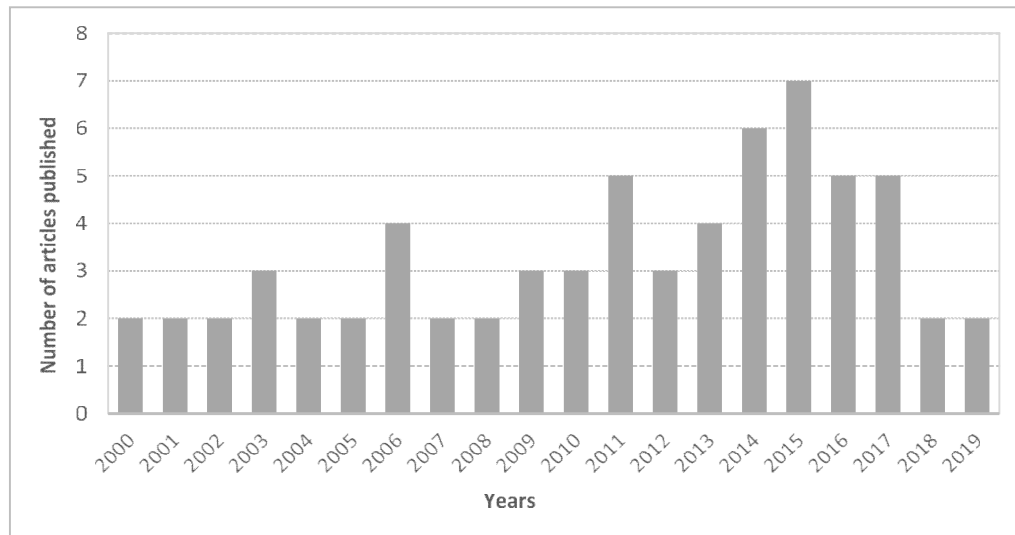
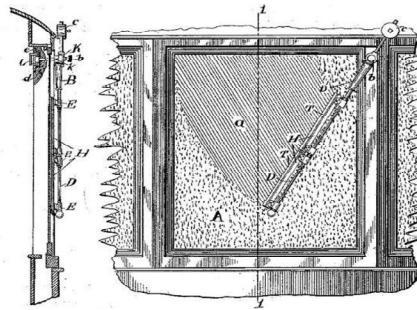


Fig. 1. Research progress on wiper washing mechanism used in the automotive sector

Search Engine: <http://www.ScienceDirect.com>.

Keywords used: Wiper; automotive, smart wiper washing system, windshiled wiper



a) The typical setup



b) Real time application



c) Manual operating system

Fig. 2. Invention of first windscreen wiper and its application

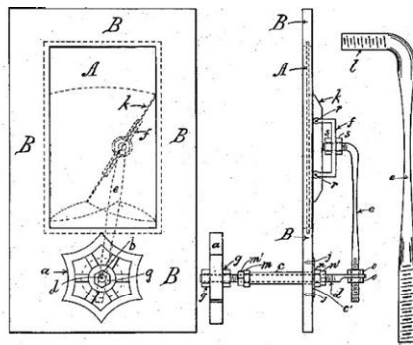


Fig. 3. Windscreen wiper invented by Robert A Douglass

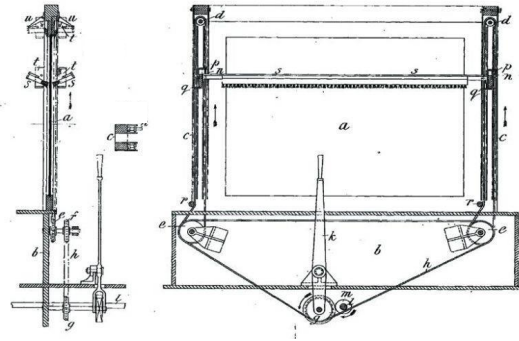


Fig. 4. Windscreen wiper invented by James Henry Apjohn

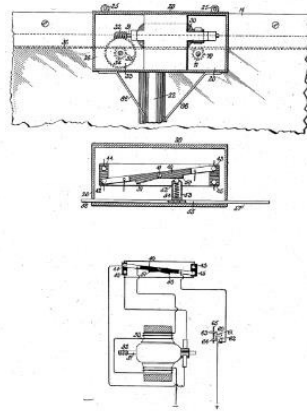


Fig. 5. Windscreen wiper invented by Charlotte Bridgwood

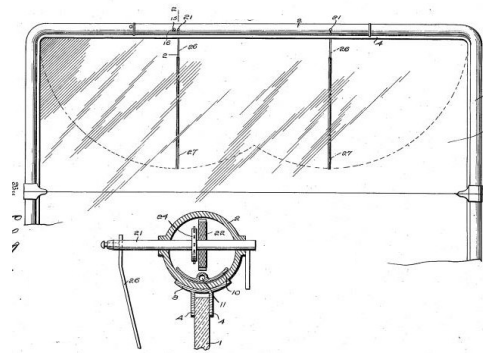


Fig. 6. Windscreen wiper invented by William M. Folberth and Fred Folberth

3.4 Year 1920

The design as seen in Fig. 7 is invented by John R. Oishei with patent number (US 1,362,175) and was published on 14 December 1920. John R. Oishei is the founder of Tri-

Continental Corporation also known as Trico. The inspiration to create an improvised wiper mechanism occurred when the inventor got into an accident with a bicyclist due to the lack of visibility. The inventor claimed that this invention relates more particularly to swinging cleaners of the kind

which are pivotally mounted on the windshields of automobiles so that the cleaner can be swung in an arc of a circle over the face of the windshield glass for cleaning or wiping the same. The operating arm is spring pressured to ensure that the wiper maintains a consistent force against the glass. Trico and other companies like Bosch introduced a rear- window wiping system in 1926 which shows the practical nature of windshield wiper systems was becoming much more widely accepted all around the world [17-19].

3.5 Year 1926

The design as seen in Fig. 8 is invented by Raymond Anderson with patent number

(US 1,588,399) and was published on June 15 1926. The inventor claimed that the windshield wiper system should be operating on electro-mechanical system. Then the inventor came up with an idea of operating the windshield cleaner with a motor which uses the power from the automobile. In the motor driven windshield cleaner most commonly used, the cleaner is oscillated continuously by a motor, but the continuous oscillating movement is objectionable because the cleaner is too frequently in front of the driver and obstructs his vision, and furthermore, the weight of the motor with the mechanism connecting it to the cleaner is excessive [20,21].

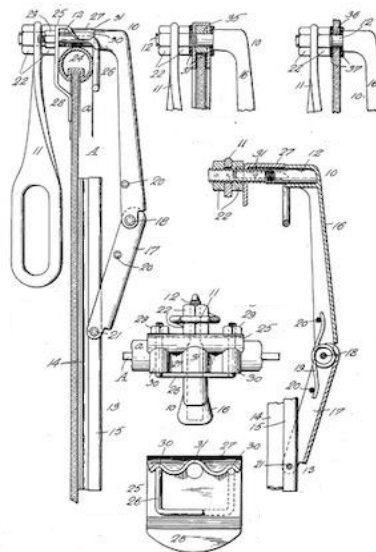


Fig. 7. Windscreen Wiper Invented by John R. Oishei

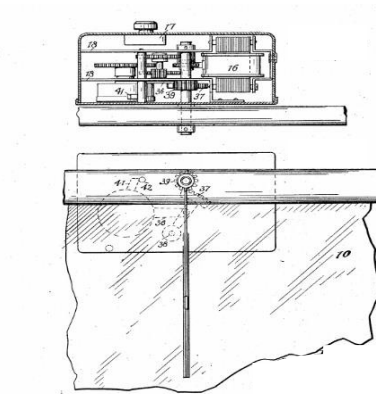


Fig. 8. Windscreen wiper invented by Raymond Anderson

3.6 Year 1961

The design as seen in Fig. 9 is invented by John R. Oishei et al, with patent number (US2,987,747) and was published in June 13 1961. The inventor claimed that not only electro-mechanical system design should be implemented in automobiles but also thermal and hydraulic designs. The objective of this invention is to provide a windshield cleaner system having timed interruptions in its operations so as to confine the movement of the wiper to a predetermined cycling, with intervening rest intervals of the blade or wiper preferably in the parked position and out of the line of vision [22].

3.7 Year 1966

The design as seen in Fig. 10 is invented by John Amos with patent number (US 3,262,042) and was published in July 19 1966. The inventor is an engineer for the UK automotive engineering company "Lucas Industries" who invented a solid-state electronic design. This invention relates to electrical operating circuits for vehicle wind screen wipers, and has for its object to provide such a circuit in a convenient form particularly suitable for use in light rain or mist. An operation circuit in accordance with the invention includes means for effecting a delay between the termination of one cycle of operation of the wipers and the commencement of the next cycle of operation [23–26].

Fig. 11. portrays the invention from the inventor known as Robert E Mcdevitt with patent number (US3230564A) and was published in January 25, 1966. The inventor claimed that wind shield washers of the type where in a nozzle is is

positioned exteriorly of the body of the vehicle is arranged to direct a stream of cleaning liquid upon the wind shield. The simplest type of wind shield was her used in the past comprises a closed tubular element fixedly positioned to project upwardly a short distance from the vehicle body adjacent the lower edge of the wind shield. A nozzle is provided for directing the cleaning fluid upwardly onto the wind shield by drilling a small opening at one side of the tubular element. However, since there are long periods of time when the Washer is not used, for most of the time the interior of the conduit is dry and the nozzle opening is unprotected, with the result that dust particles and the oily residues common to highways tend to settle in the nozzle and so clog it that when its use is necessary, it often is inoperative [27].

3.8 Year 1967

The design as seen in Fig. 12 is invented by Robert William Kearns with patent number (US 3,351,836) and was published in 7 November 1967. The present invention relates to windshield wiper systems and more particularly to a windshield wiper system of the intermittent type in which the wiper dwells for a time interval during a portion of each cycle of wiper operation. The inventor claims that under certain condition such as light rain or splash back produced by other vehicles on wet roads, the condition of the windshield is often in what may be termed a wet-dry condition. Continuous windshield wiper operation With Such a windshield condition may cause smearing to obscure the vision of the driver. The wiper element also may be inadequately lubricated, causing undue wear on the wiper blade.

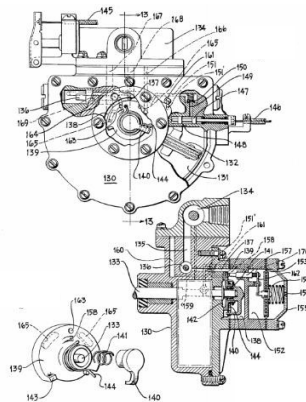


Fig. 9. Windscreen wiper system invented by John R. Oishei et al.

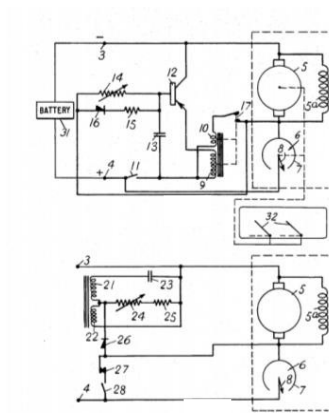


Fig. 10. Windscreen wiper system invented by John Amos

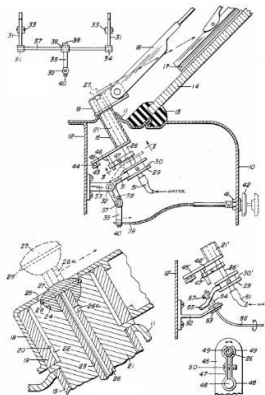


Fig. 11. Windscreen wiper system invented by Robert E Mcdevitt

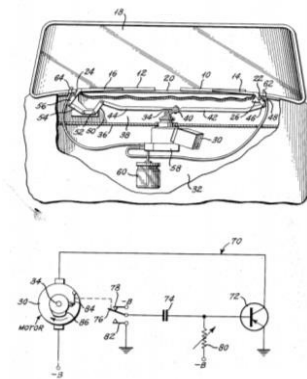


Fig. 12. Windscreen wiper system invented by Robert William Kearns

To overcome these problems, it is desirable to provide an intermittent operation in which the wiper dwells for an interval of time after a wiping operation and then automatically begins another cycle of operation [28–30].

However, in March 1970 a French automotive manufacturer called Citroën introduced more advanced rain-sensitive intermittent windscreen wipers on its SM model. The invention works as in when the intermittent

function was selected, the wiper would make one sweep. If the windscreen was relatively dry, the wiper motor drew high current, which would set the control circuit timer to a long delay for the next wipe. If the motor drew little current, it indicated that the glass was still wet, and would set the timer to minimize the delay [31].

3.9 Year 1969

The complete design as seen in Fig. 13 is invented by James W Tibbet with patent number (US 3 440 678 A) and was published in April 29, 1969. The inventor claims that the vehicle wind shield wiper blade is fitted with a jet type washer for directing cleaning fluid under pressure against the wind shield ahead of the blade. It is the common experience of all motorists using conventional windshield wipers and washers that the flow of cleaning fluid from the washer is directed inaccurately and inefficiently in that, depending in part upon the Speed of the vehicle,

the fluid impinges upon the windshield either above, below or behind the wiper blade. In extreme instances it may miss the windshield altogether. This inefficiency obviously causes inconvenience to the motorist and creates a hazardous driving situation [32,33].

3.10 Year 1973

The complete design as seen in Figure 14 is invented by Philippe Rouvre with patent number (US 3,750,080) and published in July 31, 1973. The inventor claims that the device is of the timing type and permits selection of, by means of a single control lever the desired mode of operation of the windscreen wiper by adjusting it. The desired timing under inter mitten operation conditions, that is the inoperative period between two successive wiping cycle, and the actuation of the electric pump operating the wind screen washer. The wind screen washer may be designed for delivering only the volume of fluid necessary for one cleaning operation [34,35].

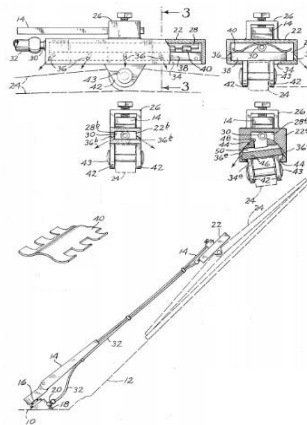


Fig. 13. Windscreen wiper system invented by James W Tibbet

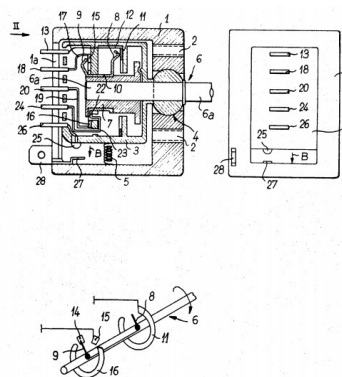


Fig. 14. Windscreen wiper system invented by Philippe Rouvre

3.11 Year 1986

The design as seen in Fig. 15 was invented by McCumber et al. with patent number (US4620141) and was published in October 28, 1986. The inventor claims that the invention relates generally to an electronic control circuit for controlling the operation of a motor vehicle's windshield wiper blades, and more particularly to an electronic control circuit responsive to the presence of rain to automatically activate the vehicle's windshield wiper at a rate dictated by the level of precipitation being encountered. Motor vehicles having wind shields have been equipped with motor-driven wind shield wiper sand associated with the wiper motor is a manually operated multi-position switch whereby the driver can turn on and select the speed at which the wiper blades will be driven [36–38].

3.12 Year 1989

The complete design as seen in Figure 16 is invented by Mark L. Larson with patent number (US 4,859,867) and published in August 22, 1989. The inventor claims that the invention relates to moisture detectors for automotive vehicle windshields, and more particularly to control systems incorporating such sensors to operate vehicle accessories such as windshield wipers. A wide variety of windshield moisture sensors have been developed for controlling the actuation of an auto motive vehicle windshield wiper and/or washer.

Generally speaking, the sensors are of three types-optical, capacitive, or resistive. In optical

systems, a light beam is directed into the windshield at an angle; and the refracted/ reflected portion of the beam is monitored to evaluate whether moisture is present [39]. In capacitive sensors, two electrodes are mounted on the windshield surface; and the capacitance between the electrodes is monitored to determine the presence of moisture. In resistive systems, the resistance encountered by the wiper motor in driving the wipers across the windshield is monitored; and the wipers are stopped when the resistance reaches a preselected drag level indicating that the windshield is dry [40–42].

3.13 Year 1991

The design as seen in Fig. 17 was invented by Rein S. Teder with patent number (US 5 059 877) and was published in October 22, 1991. The inventor claims that the invention generally relates to a control circuit for use with the windshield wiper motor on a vehicle, and more particularly to a circuit which senses the presence of moisture droplets on the wind shield to activate the wiper motor and adjust its speed in relation to the intensity of the precipitation encountered. Motor vehicles embodying wind shield wipers utilize a wiper system in which the wiper motor is controlled to operate intermittently or at slow or fast rates depending upon the setting of a manual switch lever by the driver. Such wiper control systems also now often include a variable delay feature, whereby the time period between successive strokes, when operating in the intermittent mode, can be adjusted [43,44].

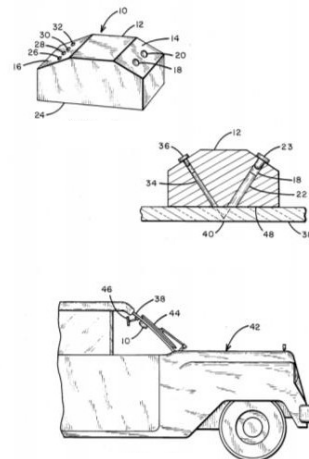


Fig. 15. Windscreen wiper system invented by McCumber et al.

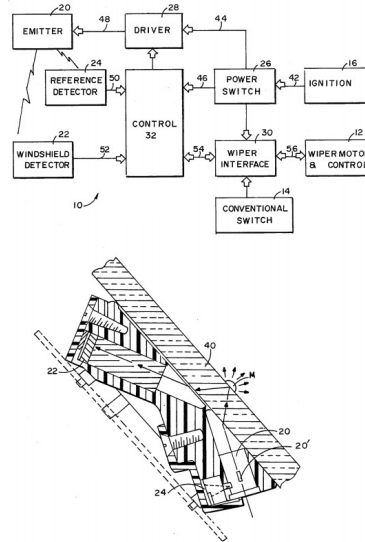


Fig. 16. Windscreen wiper system invented by Mark L. Larson

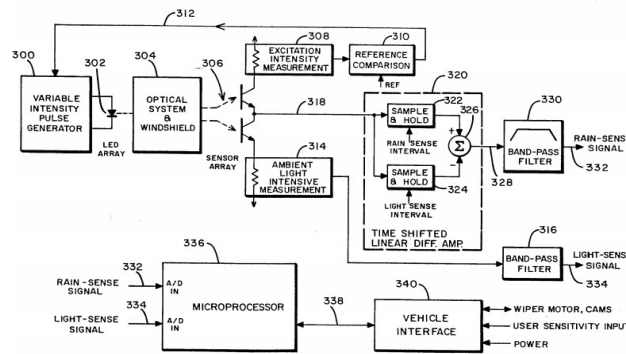


Fig. 17. Windscreen wiper system invented by Rein S. Teder

3.14 Year 2000

The complete design seen in Fig. 18 was invented by Takayama et al. with patent number (US 6 163 921) and was published in December 26, 2000. The inventor claimed that the wiper system for wiping a windshield of a motor vehicle is desired to be able to wipe as large a surface area of the windshield as possible. However, conventional wiper systems relied on angular motions of wiper arms, and it has not been possible to wipe all the corners of the windshield. Therefore, the wiper blade carried by the wiper arm can cover the substantially entire surface of the substantially rectangular windshield. However, when the wiper system is not operating or when the wiper arm stays stationary for a period of time in an intermittent mode, the wiper arm and the wiper-blade inevitably occupies a

position near one of the Side edges of the windshield in such a manner that the view of the vehicle operator is blocked to a certain extent [45–47].

It may be conceivable to provide a stowing capability to the wiper System to put the wiper arm and the wiper blade out of the view of the vehicle operator when the wiper system is not in use. However, it will require a series of steps which require so much time that the capability of the wiper system to meet the need to quickly respond to the need to wipe the windshield may be impaired. Also, the wiper system with translational motion should be capable of various modes of operation including an intermittent mode and a mist mode for the wiper system to be acceptable for general use [48, 49].

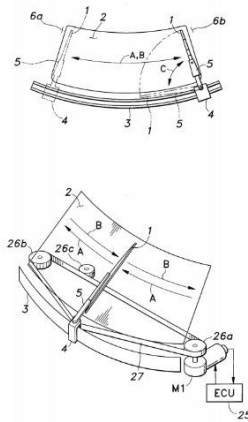


Fig. 18. Windscreen Wiper System Invented by Takayama et al.

3.15 Year 2013

The design as seen in Fig. 19 was invented by Ming-Yi Kuo with patent number (US 8 555 457 B1) and was published in October 15, 2013. The inventor claims that a conventional windshield wiper assembly for a car in accordance with the prior art shown in Fig. 21 comprises a support arm having a connecting portion, and wiper unit connected with the connecting portion of the support arm. The connecting portion of the support arm has a bottom provided with a snap-fit recess. The wiper unit includes a blade having a central portion provided with a hollow mounting seat, a resilient wiper connected with the blade, and a connecting member secured in the mounting seat and connected with the connecting portion of the support arm. The connecting member is snapped into snap-fit recess of the connecting portion. In operation, the connecting member is connected with the connecting portion of the support arm so that the wiper unit is connected with the support arm. Thus, when the support arm is driven by a drive motor and is pivoted on the wind shield of a car. The wiper unit is driven by the support arm to move on the windshield so as to rub and clean the windshield by the wiper [50,51].

However, when the wiper is moved on the windshield to clear the grease, dirt, dust or contaminant deposited on the wind shield, a drag is produced due to friction between the wiper and the windshield, so that the wiper easily produces vibration and noise during movement of the wiper unit [52,53]. In addition, when the car is move

data high speed, the air flow impacts the wiper of the unit and passes under the blade to produce a vibration during movement of the wiper unit and to increase the frictional resistance of the wiper unit due to an excessive force so that the wiper unit is easily worn out and easily produce noise, thereby decreasing the lifetime of the wiper unit, and easily causing an uncomfortable sensation to the driver in the car [54–56].

3.16 Year 2014

The design as seen in Figure 20 was invented by Norbert Wegner et al, with patent number (US 8 800 097 B2) and was published in August 12, 2014. The invention relates to a wind shield wiper drive for a motor. The inventor claims that wind shield wiper uses an electric driving motor and it is connected to the wiper shaft via a crank assembly. A continuous rotational movement of the driving motor is converted by the crank assembly into an oscillating movement of the wiper drives include the complex construction and the number of components required. “Windshield wiper direct drives” have therefore been developed, in which the provision of a crank assembly is omitted. In wind shield wiper direct drives, either the motor shaft of a reverse-operable driving motor is connected in a rotationally fixed manner to the wiper shaft, or a toothed gear mechanism is arranged between the motor shaft and the wiper shaft. A disadvantage of windshield wiper direct drives is the wiper shaft is theoretically rotatable through 360° when large external displacement forces are applied. During journeys at a high speed, this may result in the wiper arm which is fixed to the

wiper shaft being provided due to the forces in effect into a region outside the vehicle window, which constitutes a considerable safety risk [57–59].

Fig. 21 portrays the invention from the inventor known as Christopher A. Weber with patent number (US8819889B2) and was published in September 2, 2014. The inventor claimed that a conventional windshield wiper assemblies known in the related design include some type of blade assembly mounted to arm which, in turn, is mounted adjacent the wind shield and pivotally driven to impart reciprocal motion to the wiper blade assembly across the windshield. A rubber wiping element is supported by the blade assembly and contacts the windshield across the surface to be wiped. The wiper element often incorporates one or more metal strips which act to reinforce the wiper element across what is typically a curved glass surface [60]. In the context, the wiper arm delivers a downward force

to the blade assembly that is distributed there across pressing the blade assembly into a contact with the windshield [61]. However, there is an ongoing effort to lower the cost of manufacture and improve the operation of these assemblies in ways which have here to fore not been obvious to persons having ordinary skill in the art [62–64].

3.17 Year 2015

The design seen in Fig 22 was invented by Jere Lansinger et al, with patent number (US 8 925 620 B2) and was published on January 6, 2015. The inventor claims that the defrosting and deicing of automotive vehicles' front wind shields has been typically performed by conventional warm air defrosters. These warm air defrosters are heated by the heat from the coolant system which flows through a defroster core. Air fans then circulate air across the core and up to the inside surface of the wind shield. A primary

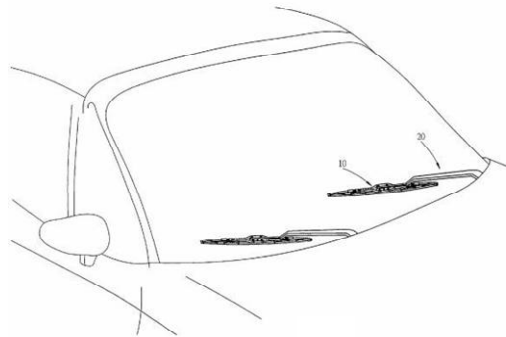


Fig. 19. Windscreen wiper system invented by Ming-Yi Kuo

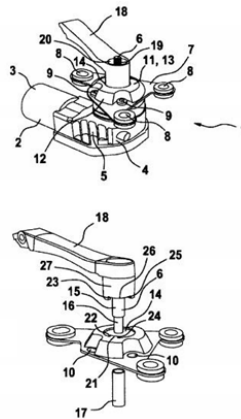


Fig. 20. Windscreen wiper system invented by Nobert Wegner et al.

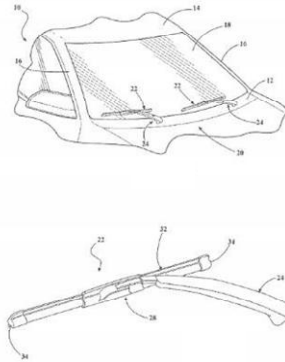


Fig. 21. Windscreen wiper system invented by Christopher A. Weber

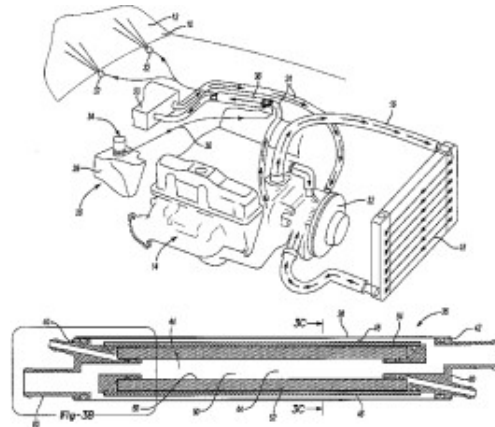


Fig. 22. Windscreen wiper system invented by Jere Lansinger et al.

disadvantage of these previously known warm air windshield defroster systems is that the overall time required to completely defrost and/or deice a front windshield is very lengthy [65]. This relatively long time required to completely defrost and deice the front windshield results from two factors. First, the engine coolant for the internal combustion engine in the automotive vehicle must become sufficiently heated to heat the air used to defrost the front windshield. Depending upon the weather conditions, it may require a minute or two for the engine coolant to become sufficiently heated to heat the air used to defrost the front windshield. The second, and more important, factor impacting upon the time required to defrost the front windshield using a hot air defrost system is that the heat transfer between the air and the front wind shield, as well as the heat conductance through the windshield and to the ice on the front windshield, is very inefficient. Such a long time delay to defrost/deice the front wind shield not only wastes time, but also engine fuel [66– 68].

Fig. 23 portrays the invention from the inventor known as Gaurav Bazaz with patent number (US 2015/0367819 A1) and was published in December 24, 2015. The inventor claimed that an alternative model where in high speed airflow is utilized to clear the windshield. This model cannot only clear the elements deposited on the wind shield, but also prevent them from contacting the Surface in the first place. The air jet windshield wiper system consists of a high speed air outlet mounted on the car near the bottom of the windshield through which a high speed mass of air, hence forth an air-beam, is released over the windshield. The air beam is characterized by velocity of its flow, its direction of motion and its shape. Similarly, the direction of the air-beam is the direction in which the majority of the air particles in the air- beam are travelling. Finally, the shape of the air-beam is the shape that would be observed close to the outlet, within the proximity of the windshield, if the particles in the air-beam had a colour distinct from the surroundings. An air fan, placed separately,

draws air from the surrounding regions, routes it through a channel and drives it at a very high speed over the surface of the windshield through the air outlet forming an air-beam emerging from the said outlet. As the air-beam blows over the surface of the windshield, it carries away elements deposited on the wind shield with it [69]. In addition, if the device is activated during rainfall, it can carry droplets of rain away from the wind shield even before the droplets hit the wind shield. With appropriate air speed and air volume, the device can ensure a completely dry windshield even during rainfall. This can allow a tremendous increase in visibility for the driver and occupants of the vehicle. The device can be used alone, or in conjunction with a standard mechanical wiper. The standard mechanical wiper in this configuration could be used to remove Sticky debris from the surface of the windshield, when the device wind flow is not effective to remove it [70–72].

4. WINDSHIELD WIPER GEOMETRY ASSESSMENT

The windshield wiper mechanisms are vehicle-specific systems in which the wiping motion is

transferred from the wiper motor to the pivot-shaft assemblies via linkages. A compact wiper system consists of the following components: wiper motor with thermo-switch, wiper gearing, motor crank, steel base-plate, crank linkage, pivot-shaft assembly with oscillating crank, and second pivot-shaft assembly with plate (for parallel wipe pattern). The linkage forces are supported by the sheet metal of the vehicle's bodywork. For the modern vehicles, the following systems are frequently used which is shown in Fig. 24 respectfully [73].

The modern design process of the products (in this case, the wiper mechanisms) involves conceptual and functional design, command & control, digital mock-up, virtual prototyping and testing [74]. The conceptual design has as main objective to establish the best product concept, by using data picked by the science, technology, economy or market, while the functional design involves identifying, modelling and evaluating the operational performances of the wiper systems, and the deviations from the imposed characteristics, with other words the mode in which the mechanism responds to the design parameters [75–80].

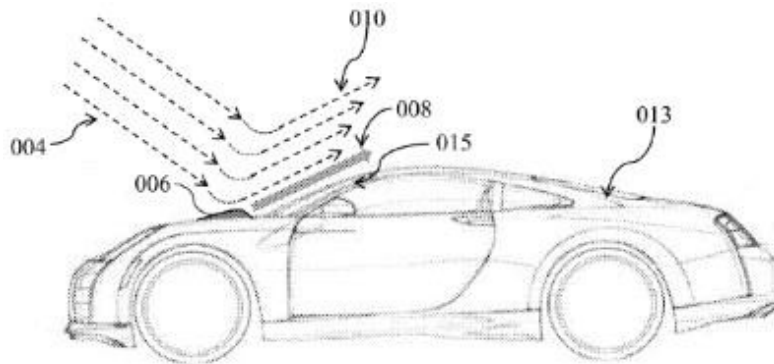
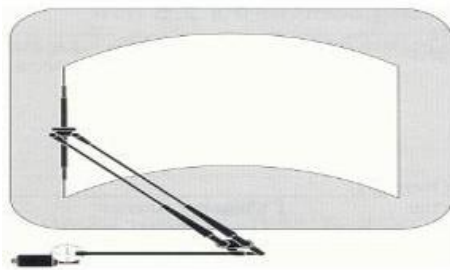
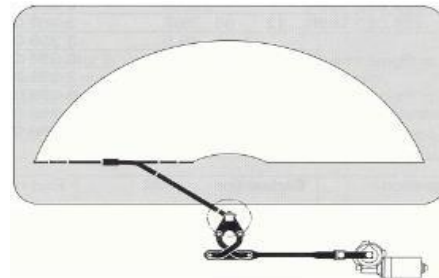


Fig. 23. Windscreen wiper system invented by Gaurav Bazaz



a) Single-lever systems with parallel wipe patterns



b) Single-lever system with sector wipe patterns

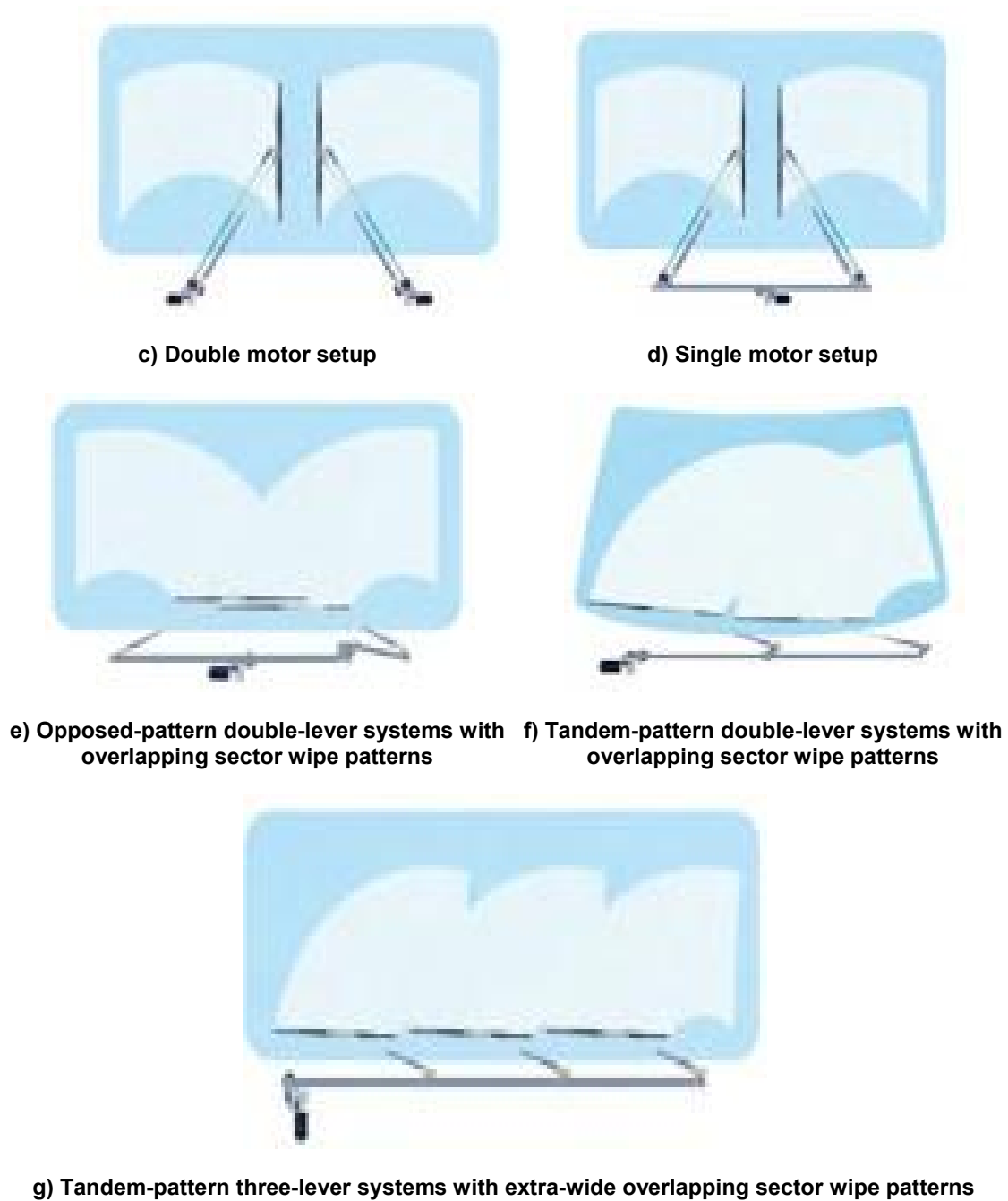


Fig. 24. Windshield wiper geometry assessment schematic diagrams

5. SUMMARY OF WINDSHIELD WIPER WASHING SYSTEM

From the critical review done, a summary can be highlighted which is presented in Table 1 respectively. The table shows the development of patent over the years namely from 1903 to 2015 by the respective inventors.

From the table it can be seen that the development of patents is converging from a manual windshield cleaner to an automated windshield cleaner. However, throughout the years many designs have been implemented on windshield cleaner such as washing system, sensors, and many more as shown in Table 1.

Table 1. Summary of windshield wiper washing system (1903 – 2015)

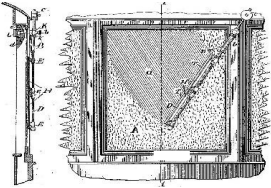
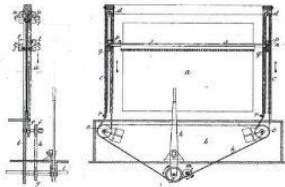
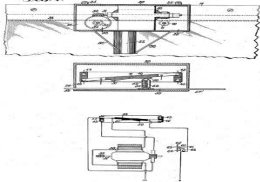
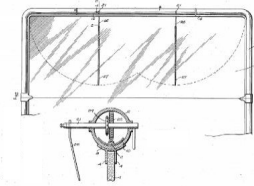
No	Application	Patent	Year	Inventor	Remarks	Ref
1	Function: Clean windshield manually		1903	Mary Anderson	An optional for cleaning the windshield when the windshield is not clear. Operated manually from inside of the vehicle.	[81]
2	Function: Clean windshield manually		1903	James Henry Apjohn	An optional for cleaning the windshield manually in both directions with two wipers or brushes	[81]
3	Function: Electrically powered windshield wiper		1917	Charlotte Bridgwood	Uses roller blades but the cleaning efficiency is not as expected	[82]
4	Function: Engine air powered windshield wiper		1919	William M. Folberth and Fred Folberth	Inconsistency of wiping speed due to the inconsistent air from the engine	[83]

Table 1 (cont'd). Summary of windshield wiper washing system (1903 – 2015)

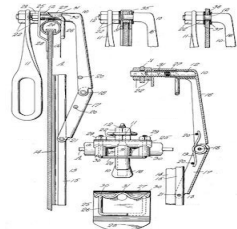
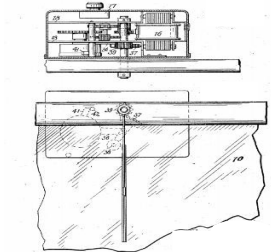
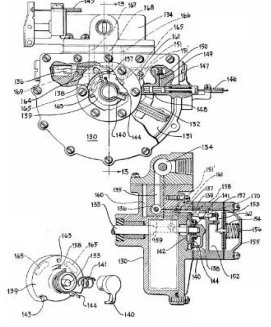
No	Application	Patent	Year	Inventor	Remarks	Ref
5	Function: Spring pressured operating arm windshield wiper		1920	John R. Oishei	Maintains a consistent force against the glass. Widely accepted around the world.	[84]
6	Function: Electro- mechanical windshield wiper system		1926	Raymond Anderson	Uses the power from the automobile. Continuous oscillating obstructs the drivers vision and the weight of the mechanism is excessive	[85]
7	Function: Thermal and hydraulic windshield wiper system		1961	John R. Oishei	To have a timed interruptions in the movement of the wiper.	[86]

Table 1 (cont'd). Summary of windshield wiper washing system (1903 – 2015)

8	Function: Solid-state electronic windshield wiper		1966	John Amos	Electrical operating circuits for windshield wiper. A delay is occurred between one complete cycle of operation to the next cycle of operation.	[87]
9	Function: Nozzle typed windshield washer system		1966	Robert E Mcdevitt	Direct a stream of cleaning liquid to the windshield. Nozzle opening is unprotected which tend to clog. System often inoperative.	[88]
10	Function: Intermittent windshield wiper system		1967	Robert William Kearns	The wiper dwells for a time interval during a portion of each cycle. May cause smearing to obscure the vision of the driver.	[89]

Table 1 (cont'd). Summary of windshield wiper washing system (1903 – 2015)

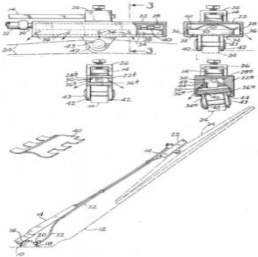
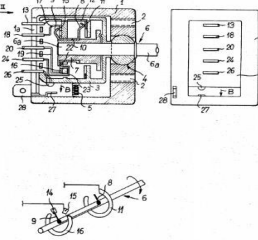
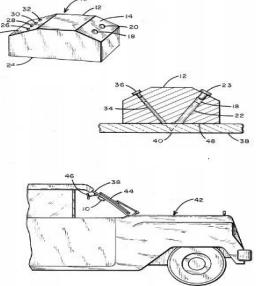
11	<p>Function: Combination of windshield wiper blade with washer assembly</p>		1969	James W Tibbet	<p>Inaccurate and Inefficient [90] washer system. Part of system depends on the speed of vehicle. Causes inconvenience and cause hazardous Driving situation.</p>
12	<p>Function: Timed and selection of desired mode operation of windshield wiping system</p>		1973	Philippe Rouvre	<p>Designed to deliver the [91] required volume of fluid for one cleaning operation.</p>
13	<p>Function: Automatically activate the windshield wiper system when there is presence of rain</p>		1986	McCumber et al	<p>Drivers can manually operate [92] the multi-position switch to turn on and control the speed of the wiper blades.</p>

Table 1 (cont'd). Summary of windshield wiper washing system (1903 – 2015)

14	Function: Moisture detectors for windshield wiper system		1989	Mark L. Larson	Developed for controlling the [93] actuation of vehicle windshield wiper or washer.
15	Function: Detect presence of moisture droplets on windshield to activate wiper motor and adjust its speed		1991	Rein S. Teder	Developed to operate intermittently depending on presence of moisture droplets and drivers setting on the manual switch lever by the driver. [94]
16	Function: To wipe a large surface area of the windshield		2000	Takayama et al	Conventional wiper systems depends on angular motions of wiper arms. The wiper arm and wiper-blade occupies a position at the edge of windshield blocking the view of the vehicle operator at certain extend [95]

Table 1 (cont'd). Summary of windshield wiper washing system (1903 – 2015)


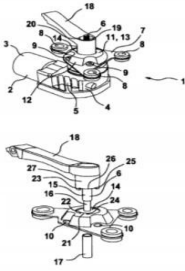
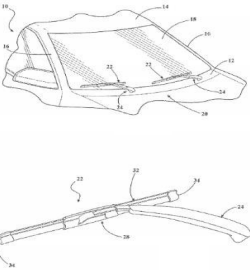
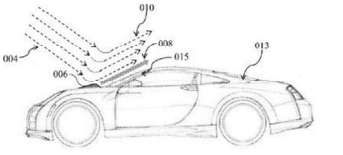
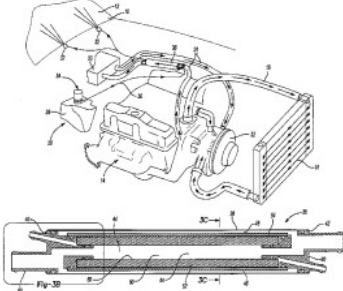
17	Function: Conventional windshield wiper assembly		2013	Ming-Yi Kuo	A drag produced due to friction between the wiper and the windshield causing the wiper to produce vibration and noise during the operation. The wiper is easily worn out therefore decreasing lifespan of the wiper.	[96]
18	Function: An electric driving motor connected to the wiper shaft via a crank assembly		2014	Norbert Wegner et al	Theoretically rotatable through 360° when large external displacement forces is applied. The wiper arm may comprise a considerable safety risk when the vehicle is at high speed.	[97]
19	Function: Conventional windshield wiper blade assembly mounted to arm		2014	Christopher A. Weber	Wiper arm delivers downward force to the blade assembly which distributed across pressing the blade assembly with contact with the windshield. Lowering the cost of manufacture and improve the system of these assemblies	[98]

Table 1 (cont'd). Summary of windshield wiper washing system (1903 – 2015)

20	Function: High speed airflow is utilized to clear the windshield		2015	Gaurav Bazaz	Air jet windshield wiper [99] consists of high speed air outlet. Able to carry droplets of rain away before it hits the windshield. Can be used together with standard mechanical wiper. Air jet wiper not effective to remove sticky debris
21	Function: Defrosting and deicing of windshields performed by conventional warm air defrosters		2015	Jere Lansinger et al	Very inefficient. More time [100] delay to defrost/deice the front windshield which leads to time waste and waste of engine fuel.

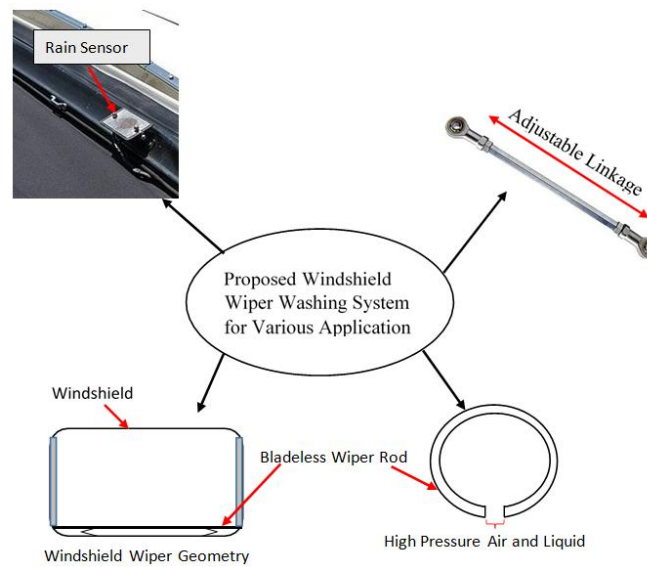


Fig. 25. Proposed windshield wiper washing system for various application

From the critical review analysed from year 1903 to year 2015, a few important points can be highlighted on the design and development of windshield wiper washing system. They are as follows:

- Windshield wiper system is implemented since 1903.
- Earlier designs focus more on just the ability to clean the windshield manually.
- Windshield wiper operation system is improved with electrical powered system.
- Features that maintain a consistent cleaning force such as spring pressured operating arm windshield wiper.
- Windshield wiper operation system is then modified into a solid-state electronic windshield wiper system.
- Windshield washing system is added on together with windshield wiper.
- Multiple mode of operation for windshield wiper system to control the volume of liquid.
- Sensors to detect presence of rain and presence of moisture to automatically activate the windshield wiper system.
- Life span of the wiper decreases as the wiper worn out due to friction between the wiper and the windshield.
- Electric motor is connected to the wiper shaft with a crank assembly which may reduce the safety risk and it is mounted to an arm to reduce the cost of manufacture and improve the assemblies.

- Air jet windshield wiper system is inadequate to detach sticky detritus.

6. CONCLUSION AND FUTURE WORK

As observed earlier, the existing designs of smart wiper washing system is far from quintessential. The function offered in any automobiles' wiper washing system does not accommodate the desire and needs of every driver entirely. Anyhow, there are some potential ways to enhance and upgrade the design of the existing smart wiper washing system to overcome the blind spot, temporary blindness of the driver during wiper washing operation and to identify the elements on ergonomic design principle. Fig. 25 summarises the proposed windshield wiper washing system for various applications.

The geometry of windshield wiper system plays an important role for the driver to overcome the blind spot. When the windshield wiper system operates and finishes the complete cycle, it leaves a blind spot for the driver. Many factors can contribute to this problem, including when the driver wouldn't be able to focus the view of the road because the driver would be busy finding away to overcome the blind spot. Therefore, a straight horizontal wiper should be used to clean the windshield vertically which moves up and down as same speed as the normal wiper system. This will allow the windshield to be clean and clear in every section.

Additionally, ergonomics is essential to any design and development of smart wiper

windshield washing system. This invention delivers a bladeless wiper washing system which cleans the windshield without a wiper blade. It uses high pressure air to clean the windshield as the horizontal wiper moves up and down. The high pressured air comes out from the horizontal wiper in a straight line continuously without any delay. This inventions reduces the cost of changing wiper blades when it is worn out because wiper blades has less lifespan since it is used in critical heavy duty situation.

The existing windshield wiper washing system creates a temporary blindness when it is operated. The operation of the washing system is a working combination of the wiper and washer. Two different operations working simultaneously may affect the view of the driver creating temporary blindness and lead to safety issue of the driver. To overcome the problem, in this invention, only one horizontal wiper will be used to clean the entire wind shield plus the washer system will be operated through the horizontal wiper itself. When the wiper moves up and down, the cleaning fluid will be directed out from the wiper at high pressure. Generally, both wiper and washer system will be operating in a single horizontal wiper rod. When it moves up, the cleaning fluid will be directed out from the wiper rod with high pressure to ensure the debris/dirt to clear from the windshield. When it moves down, the high pressure air will be directed out from the wiper rod to ensure a full clean wind shield.

This invention also offers a rain sensors. The systems is much more complex than the traditional system but is has few advantages such as, the driver does not need to worry about the rain intensity and can focus on the driving due to automatic speed control of the wipers and when rain keeps varying for skyscrapers then the wind shield can be cleaned without using any additional water. This will partially ease the life of driver from operating the windshield wiper system all the time.

Furthermore, this invention uses a an adjustable two bar linkage mechanism to hold the wiper rod and move up and down to complete one cycle of operation. The number of linkage can be adjusted depending on the size of the wind shield. The linkage expands out allowing the wiper rod to move up the wind shield and contracts in allowing the wiper rod to move down the wind shield. That's a brief idea on how the whole mechanism works.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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