DEVELOPMENT AND PERFORMANCE TESTING OF PROTOTYPE WINDSCREEN WIPER

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Abstract
This paper describes research work involved indevelopment and performance testing of prototype windscreen wiper. Nickel-titanium alloy having near equiatomic composition (Ni_{50} Ti_{50}) spring is used as an actuator for triggering of the relay. The expanded spring is heated by means of silicon heating coil to study effect of shape memory alloy. A relay circuit is designed and fabricated incorporating relay to trigger off the circuit. After heating the expanded shape memory alloy, nitinol spring is used to actuate the wiper motor. The prototype windscreen is incorporated with the humidity sensor for smart wiping action. Smart wiping and controlling action is performed by integrating shape memory alloy spring, humidity sensor and suitable electronics circuitry.
Keywords: Shape memory alloy, NiTinol, humidity sensor, windscreen Wiper.

I. INTRODUCTION

While technological advances have worked to increase the safety and convenience of modern vehicles, the fact remains that drivers today have more distraction than ever before. The prevalence of cell phones, MP3 players, and in-dash navigation system has lead to a multitude of potentially dangerous diversion literally at the drivers' fingertips. One feature designed to ease the burden on vehicle operators is the automatic rain-sensing wiper system, which detects rain on the windshield and turns on the automobile's wipers accordingly. In our country almost all automobiles are marketed with manually operated wipers. In some vehicles such as of three wheelers (either goods carrier or passenger carrying vehicles), are marketed with wipers having no motors to run the wiper. In these automobiles on a rainy day the auto driver periodically wipes manually by operating lever & makes the vision of the road ahead clear.

A wiper consists of an arm, pivoting at one end and a long rubber blade attached to the other. The blade is swung back and forth over the glass pushing water from its surface. The speed is normally adjustable with several continuous speeds and often one or more intermittent setting. Most automobile use two synchronized radial type arm, which many commercial vehicles use one more pantograph arms.

Traditional windshield wipers are actuated by a single constant speed motor related to the wiper by system of connecting rods, often called the wiper arm. The wiping movement may be parallel or in opposition and in each case the geometry of the arm is designed such that, first, the wiper movement are generated by almost constant speed rotation of the motor, and second, collision between the two blades are impossible. There are generally three speeds: fast, slow, and intermittent, whose selection is made by the driver as shown in fig.1. In this configuration, the motor control consists only of a proportional and integral (PI) regulator of the given constant speeds [1].

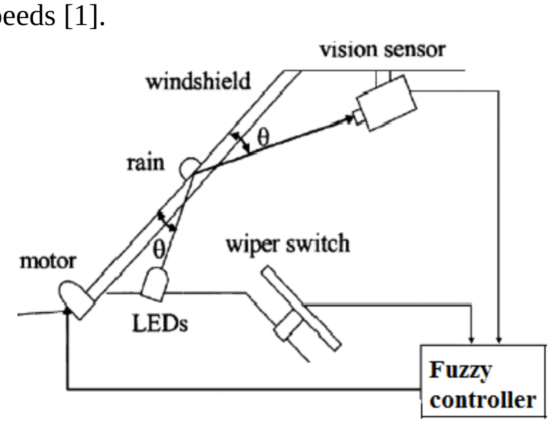

Fig. 1 Schematic diagram of vision-based smart wiper system

The field of smart material and structure is very broad and will ultimately include a variety of diverse disciplines including biotechnology, neural network, photonics, nanotechnology and artificial intelligence. However, at this time, significance developments have occurred in a somewhat limited area of this diverse field because teams of engineers and scientists have focused on employing a network of embedded sensors, microprocessors, and an array of dynamically-tunable actuators materials interfaced at a global level with traditional structural materials [2].

Material which exhibits the shape memory effect include the copper alloy system of Cu-Zn, Cu-Zn-Al, Cu-Zn-Ga, Cu-Zn-Sn, Cu-Zn-Si, Cu-Zn-Ni, Cu-Au-Zn, Cu-Sn and the alloys of Au-cd, Ni-Al, and Fe-pt, Nitinol , a nickel-titanium alloy, is the most common of the SMAs or transformation metal [2].

Nickel-titanium alloy (Nitinol, NiTi) acquire their name from Ni(Nickel)-Ti(Titanium)-NOL(Naval ordnance Laboratory). NiTi alloys, featuring a near equiatomic composition, can be plastically deformed in their low temperature martensitic phase and then be restored to the original shape by heating them above the characteristic transition temperature.

II. DEVELOPMENT OF PROTOTYPE WINDSCREEN WIPER

A prototype windscreen has been fabricated using used materials such as bus window glass and mild steel hardware items.

A windscreen wiper composed of only three components, namely a holder, a flexible wiper blade which is detachably secured at the holder and an element for securing the holder at the pivotable wiper arm of the windscreen wiper and which is articulated at the center of the holder. The holder and the securing element are fabricated of plastic and each is formed as a one-piece element. The holder possesses two adjacently arranged curved or arcuate elements which are interconnected with one another at different points or locations with the aid of connecting bridges. The height of such curved elements increases from the ends thereof towards the center and each such curved element is provided with at least one flange or vane along its lower edge, and each flange or vane fits into a lateral groove or recess of the wiper blade in order to retain the upper portion of such wiper blade in the space between the curved or arcuate elements.

Typical commercially available Cars windscreen dimensions are as follows

Front glass dimensions: length-137 cm ,
Width-77 cm

Rear glass dimensions: length-119 cm,
Width- 54 cm

The fabrication of prototype windscreen has been done by using used materials such as bus window glass and mild steel hardware items. The prototype windscreen having dimensions-

1. Length of windscreen frame is 1050 mm and width is 830 mm.
2. Length of windscreen glass is 990 mm and width is 780 mm.
3. Channel having height of 80 mm and width of 40 mm. Channel thickness is approximately 1mm.

A. Selection of smart actuators

Actuators materials are one of the principle ingredients of several important classes of smart material and structure. These actuator materials are typically employed to dynamically tune the global mechanical properties of the structure, or else to dynamically tailor the shape of the structure in an orchestrated manner. Shape memory materials Shape memory alloys have been employed as both actuators sensing in smart materials and structures application. Shape memory phenomena are not limited to the metals. Shape memory plastics have also been developed.

B. How Shape Memory Alloys Work

The two unique properties are made possible through a solid state phase change that is a molecular rearrangement, which occurs in the shape memory alloy. Typically when one thinks of a phase change a solid to liquid or liquid to gas change is the first idea that comes to mind. A solid state phase change is similar in that a molecular rearrangement is occurring, but the molecules remain closely packed so that the substance remains a solid. In most shape memory alloys, a temperature change of only about 10^{o}C is necessary to initiate this phase change. The two phases, which occur in shape memory alloys, are Martensite, and Austenite.

Martensite is the relatively soft and easily deformed phase of shape memory alloys, which exists at lower temperatures. The molecular structure in this phase is twinned which the configuration is shown in the of Figure 3. Upon deformation this phase takes on the second form shown in Figure. Austenite, the stronger phase of shape memory alloys, occurs at higher temperatures. The shape of the Austenite structure is cubic, the structure shown on the left side of Figure. The un-deformed Martensite phase is the same size and shape as the cubic Austenite phase on a macroscopic scale, so that no change in size or shape is visible in shape memory alloys until the martensitic is deformed as shown in fig.2.

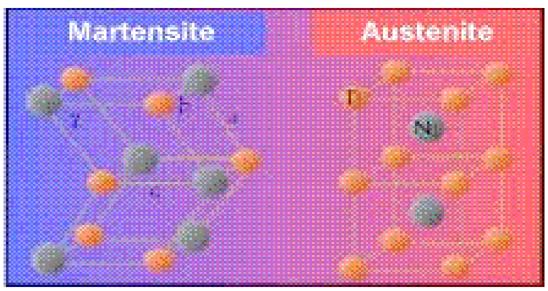

Fig. 2 The Martensite and Austenite phases

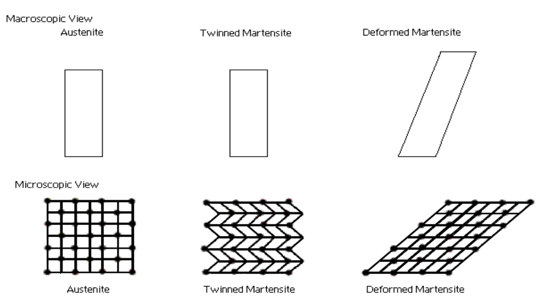

Fig. 3 Microscopic and Macroscopic Views of the Two Phases of Shape Memory Alloys

C. Circuit Diagram for Triggering off the motor

The transformation will step down the voltage from 230V to 5V and then it is given to the rectifier to remove the negative clipping of the sine wave. This rectified output is given to the filter circuit which is formed by the capacitor as shown in fig.4 . Now the output obtained is of rippled DC and to obtain. The pure DC we have to give it to the regulators. The details of touch switch for triggering off the motor and the power supply for the circuit is as shown in Fig. 5.

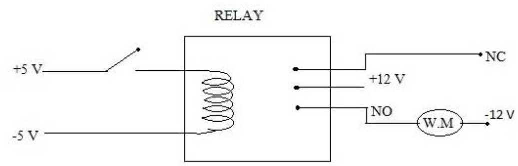

Fig. 4 Touch switch for Triggering off the motor

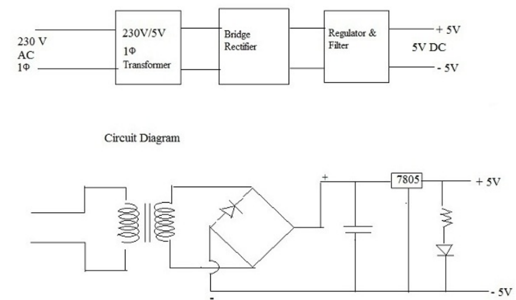

Fig. 5 Power supply for Triggering off the motor

D. Demonstration Nitinol SMA Spring

Nickel-Titanium alloy having near-equiatomic composition ($Ni_{\sim 50}.Ti_{\sim 50}$) spring has been used as an actuator for triggering off the relay. The Nitinol wire used in this prototype has 1mm to 1.5 mm diameter. This wire has been wound on suitable tool to get a shape of spring having diameter approximately 7mm and overall length 27mm in non-elongated condition. The spring has been stretched by about 20 % in length as shown in fig.6. The expanded length of Nitinol SMA Spring at room temperature has been measured to have a length of 30 to 33 mm as shown in fig.7 [2].

The expanded spring has been immersed in hot water maintained at temperature of 90˚ C. It has been observed the expanded Nitinol spring immediately regain its original dimensions. The spring has been removed from hot water, cooled to room temperature and dimensions were measured. The dimensions have been found to be the same as in the unstretched condition. In figure the SMA effect of Notinol spring are presented. Experiments are underway to incorporate the SMA spring in the wiper motor circuit to triggers off the motor by heating the expended SMA spring.

E. Humidity sensor

Humidity is a term for the amount of water vapor in air, and can refer to any one of several measurements of humidity. Formally, humid air is not "moist air" but a mixture of air and water vapor, and humidity is defined in terms of the water content of this mixture, called the Absolute humidity. In everyday usage, it commonly refers to relative humidity, expressed as a percent in weather forecasts and on household humidistats; it is so called because it measures the current absolute humidity relative to the maximum. Specific humidity is a ratio of the water vapor content of the mixture to the dry air content (on a mass basis). The water vapor content of the mixture can be measured either as mass per volume or as a partial pressure, depending on the usage.

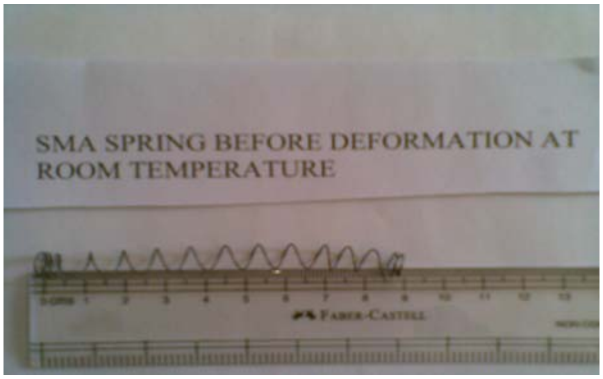

Fig. 6 Demonstration of Shape Memory Effect with Nitinol Spring

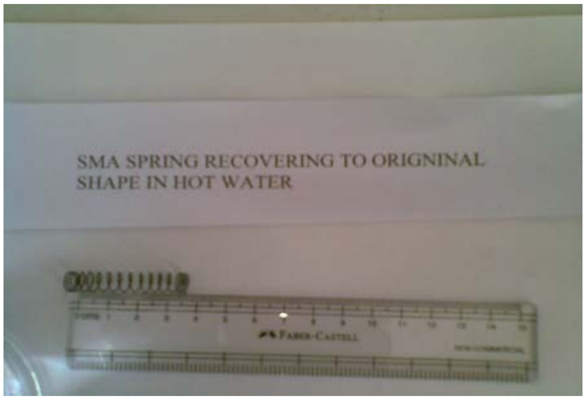

Fig. 7 Demonstration of Shape Memory Effect with Nitinol Spring

Humidity sensor works on the principle of ambient / proximate relative humidity and gives the output in the form of voltage. This analog voltage provides the information about the percentage relative humidity present in the environment. The relative humidity is defined as-the analog output of sensor is connected to ADC to get its corresponding digital value. For calibration of digital values, the reference voltage of ADC is set to 1.5 volts. The digital are received at port of microcontroller. These digital values are used to calculate percentage relative humidity of environment. The calculated data is sent to LCD to display the percentage relative humidity. The connection of ADC 0804 and LCD with the 8051 microcontroller.

To incorporate the humidity sensor in a suitable circuit for triggering the wiper motor, following components have been used-

1. Humidity sensor (The HIH-3610 Series).
2. P89V51RD2 development board with IC.
3. Relay single pole double through (5V).
4. Regulated DC power supply board 5V & 12V.
5. ADC 0804 board with IC.
6. Printed Circuit Board (PCB).

The HIH-3610 Series humidity sensor is designed specifically for high volume OEM (Original Equipment Manufacturer) users. Direct input to a controller or other device is made possible by this sensor's linear voltage output. With a typical current draw of only 200 mA, the HIH-3610 Series is ideally suited for low drain, battery operated systems. Tight sensor interchangeability reduces or eliminates OEM production calibration costs. Individual sensor calibration data is available. The Humidity sensor is as shown in figure 8.

The HIH-3610 Series delivers instrumentation-quality RH (Relative Humidity) sensing performance in a low cost, solderable SIP (Single In-line Package). Available in two lead spacing configurations, the RH sensor is a laser trimmed thermoset polymer capacitive sensing element with on-chip integrated signal conditioning. The sensing element's multilayer construction provides excellent resistance to application hazards such as wetting, dust, dirt, oils, and common environmental chemicals. The construction of Humidity sensor is as shown in figure.9

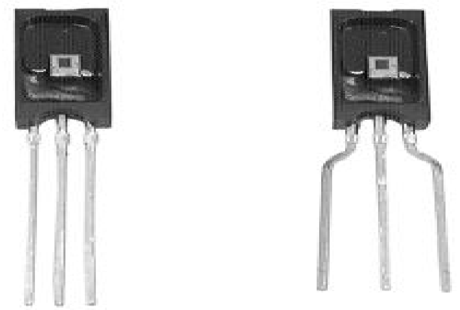

Fig. 8 HIH-3610 Series Humidity Sensor

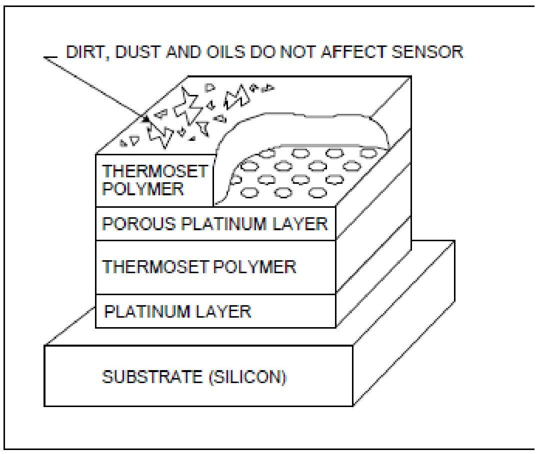

Fig. 9 Construction of Humidity sensor

F. P89V51RD2 development board with IC

P89V51RD2 Development Board is low cost development boards which have all the basic components needed for gaining a headstart on your first 8051 microcontroller projects. It is made from double sided PTH PCB board to provide extra strength to the connector joints for increased reliability. Board can work on 7 to 15V AC or DC supply. It has built-in reverse polarity protection. 7805 voltage regulator has heat sink for heat dissipation so that it can supply 1Amp current continuously without getting over heated. It has switches for reset and power. It also has RS232 interface with DB9 female connector based on MAX232. All the ports are connected to standard 10 pin FRC connectors. Open pads for connecting microcontroller's pins to external devices are also provided. It can be programmed using Flash Magic programming utility of NXP's own programming utility via serial port.

The features of the P89V51RD2 development board as shown in figure 10, are as follows-

I. 80C51 Central Processing Unit
II. 5 V Operating voltage from 0 to 40 MHz
III. 64 kB of on-chip Flash program memory with ISP (In-System Programming) and IAP (In-Application Programming)
IV. Supports 12-clock (default) or 6-clock mode selection via software or ISP
V. SPI (Serial Peripheral Interface) and enhanced UART
VI. PCA (Programmable Counter Array) with PWM and Capture/Compare functions
VII. Four 8-bit I/O ports with three high-current Port 1 pins (16 mA each)
VIII. Three 16-bit timers/counters
IX. Programmable Watchdog timer (WDT)
X. Eight interrupt sources with four priority levels
XI. Second DPTR register
XII. Low EMI mode (ALE inhibit).

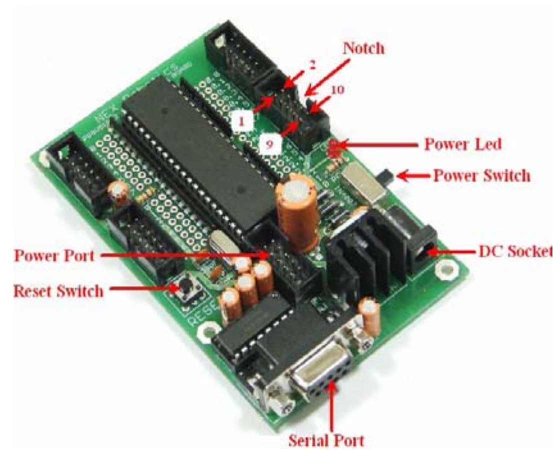

Fig. 10 P89V51RD2 Development Board

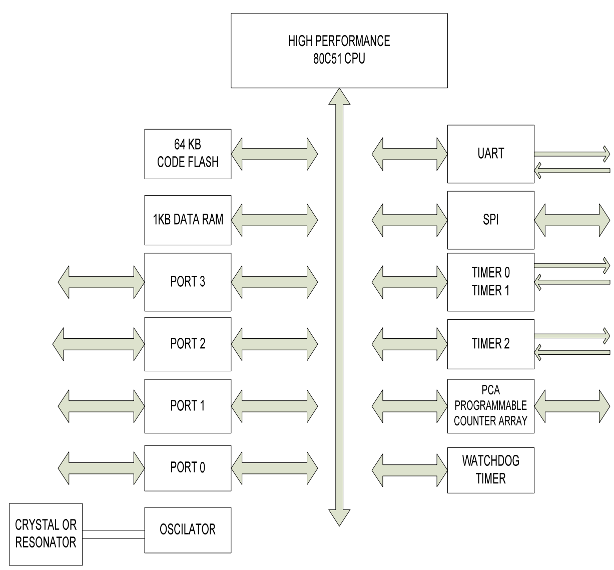

Fig. 11 Block diagram of P89V51RD2 development board

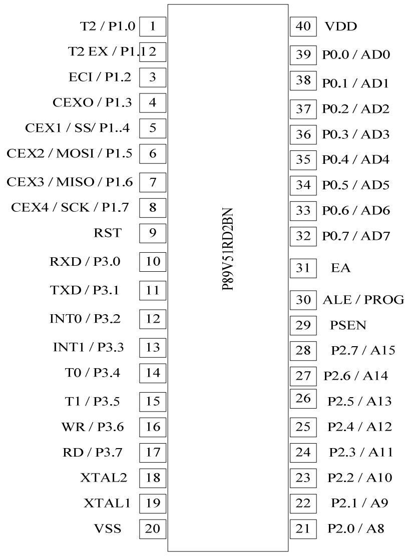

Fig. 12 Pin configuration of P89V51RD2 development board

G. Relay

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another. Relays were used extensively in telephone exchanges and early computers to perform logical operations. The Figure 13 indicates simple electromechanical relay.

A type of relay that can handle the high power required to directly control an electric motor is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

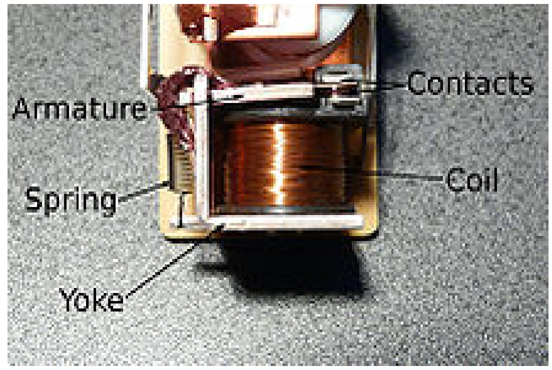

Fig. 13 Simple electromechanical relay

III. PERFORMANCE TESTING

A. Dry wiping

A 12 V DC battery has been incorporated in the electrical circuit of the wiper motor. Dry wiping action in two speeds has been successfully demonstrated. The details have been shown in figure 14.

Fig. 14 Dry wiping action

B. Wet wiping action

A water jet with a flow rate of 6 liter/min has been directed on to the windscreen while dry wiping action is been carried out there by simulating wet wiping action. This has been successfully demonstrated and ensured clear vision from the driver's of the windscreen. The details have been shown in figure.15.

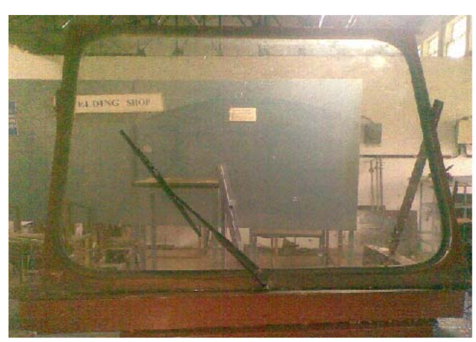

Fig. 15 Wet wiping action

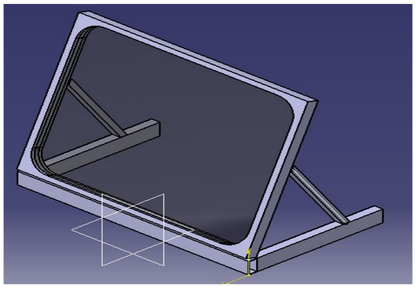

Fig. 16 Isometric View of the Prototype windscreen Wiper

IV. VALIDATION OF EXPERIMENTAL RESULTS

1. It has been possible to successfully demonstrate the triggering off, of wiper action by heating expanded shape memory alloy. The results have been validated by repeated trails.

2. It has been possible to successfully demonstrate the triggering off, of wiper action by sprinkling / moistening the Humidity sensor.

3. This smart wiping action has been validated by repeated successfully trials.

4. Based on the numerous successful trials from the two design, namely

    a) Design-1 – Incorporating Nitinol Shape Memory Alloy Spring and

    b) Design-2- Incorporating Humidity Sensor, in the suitable electronic circuitry.

    These two designs have been validated within the scope of present investigation.

V. CONCLUSION

A first prototype of the conceptual automobile windscreen has been fabricated. This windscreen has been fitted with the wiper blade and wiper motor. Dry wiping action of the prototype windscreen has been successfully demonstrated. Wet wiping action with water jet being directed on this prototype windscreen has been successfully demonstrated.

Simulation of dusty storm:

1. Has been done by sprinkling dry sand of 300 mesh.
2. The wiping action has been successfully demonstrated.

A very rare probability occurring conditioner wet mud getting struck on the windscreen also been simulated and wiping action successfully demonstrated. A conceptual electronics circuit to trigger off wiper motor has been fabricated and the wiping action has been successfully demonstrated by simple short circuiting. Shape memory effect has been successfully demonstrated. The prototype windscreen has been incorporated with the Humidity sensor for automatic wiping action. Incorporation of suitable circuit mechanism of Humidity sensor for triggering the wiper motor. Efforts are underway to incorporate suitable the nitinol shape memory spring in the circuit to act as a smart switch cum actuators to trigger off the wiping action.

REFERENCES

[1] Jean Lévine, On the Synchronization of a pair of Independent Windshield Wipers, IEEE Transactions On Control Systems Technology, Vol. 12, No.5, September 2004. PP-787-795.

[2] Paola Bassani , Andrea Mangioni , Luca Toia , Francesco Butera Fabrication Process and Characterization of NiTi Wires for Actuators, Ausonio Tuissi. 1-Natinal Research Council-Institute for Energetics and Interphases CNR-IENI Lecco, C.so P.Sposi 29, 23900, Italy. 2- Saes Getters S.P.A, Viale Italia 77, 20020 Lainate (Mi), Italy. 3- Centro Ricerche FIAT, CRF S.C.P.A, Strada Torino 50, 10043 Orbassano (To), Italy.

[3] Hideaki Kato and Tatsuhiro Matsuki, Raindrop sensor using electric double layers, R & D Department, Nippondenso Co., Ltd., 1-1, Syouwa-Chou, Kariya-Shi, Aichi 448 (Japan). Sensors and Actuators, BI (1990), pp- 308-311

[4] Joon Woo Son, Seon Bong Lee, Intelligent Rain Sensing and Fuzzy Wiper Control Algorithm for Vision-based Smart Windshield Wiper Syatem, Department of Mechatronics, Daegu Gyeongbuk Institute Science & Technology, Deagu 700-742, Korea. Journal of Mechanical Science and Technolgy (KSME Int.J), Vol.20, No.9, 2006, pp- 1418-1427.

[5] Mehmet Ucar, Huseyin M.Ertnc, Onder Turkoglu, The Design and Implementation of Rain Sensitive Triggering system for Windshield Wiper Motor, , 1-Kocaeli University, Technical Education Faculty, Izmit, Turkey. 2-Marmara University, Technical Education Faculty, Istanbul, Turkey. IEEE-2001, pp-329-336.

[6] J.chen , Z.Li , Y.Y.Zhao A high-working-temperature CuAlMnZr shape memory alloy. School of martensite science and Engineering, central south University, Lushan south Road, Chngsha 410083, China. Key Laboratory of Nonferrous Metal Material Science and Engineering, Ministry of Education, Changsha 410083, China. Department of Engineering, University of Liverpool, Liverpool L69, UK. Journal of Alloys and Compounds 480 (2009), pp-481–484.

[7] C.Urbina, S.De la Flor, F.ferrando , R-phase influence on different two-way shape memory training methods in NiTi shape memory alloys, Department of d'Enginyeria Mecanica, Universitat Rovira I Virgili, Avinguda dels paisos Catalans 26, 43007 Tarragona, Spain. Journal of Alloys and Compounds 490 (2010), pp- 499–507.

[8] M. Arciniegas, J. Casals, J.M. Manero, J. Pena, F.J. Gil, Study of hardness and wear behaviour of NiTi shape memory alloys, Biomaterials and Biomechanics Division, Department of Materials Science and Metallurgy, Technical University of Catalonia (UPC), Avda. Diagonal 647, 08028 Barcelona, Spain. Journal of Alloys and Compounds 460 (2008), pp- 213–219.

[9] Dr.Ing.habil.H.Janocha (Ed.), Adaptronics and Smart Structures, Basic, Material, Design, Application. Prof, Saarbrucken, Germany, may 1999.

[10] Tan wee choon, Abdul Saad Salleh, Saifulnizan Jamain and Mohd. Imran ghazali, Phase Transformation Temperatures for Shape Memory Alloy Wire, World Academy of Science, Engineering and Technology 25, 2007, pp-304-307.