Experimental Analysis of Magneto- Rheological based Automotive Semi Active Suspension System

Mrityunjay Badhe[1], Prof. R.A. Kapgate[2]

[1]P.G. Student, M.E. Mechanical Engineering, SRE's, COE, Kopargaon, Ahmednagar, Maharashtra, India
[2]Professor, Mechanical Engineering Department, SRE's, COE, Kopargaon, Ahmednagar, Maharashtra, India

---

Abstract - *A system of mechanical linkages, springs, damper that is used to connect the wheels to the chassis is known as suspension system. It has usually done two works-controlling the vehicle's handling and braking for safety and keeping the passengers comfortable from bumps, vibrations etc. Magneto rheological (MR) damper is plays very important role to reduce the vibration. MR fluid has been attracting great research attention because it can change its characteristics very rapidly and controlled easily in the presence of an applied magnetic field. These fluids have the ability to transmit force in a controlled manner with the help of magnetic field, thus improving their performance especially in areas controlled fluid motion is required. If there is a fault in the system, the MR damper can still operate as a passive damping system within certain performance parameters depending on the off-state characteristics of the MR fluid inside. This work includes, design and development of adaptive Magneto-rheological (MR) based semi-active suspension system for specific automobile application. Its analysis is to be carried out experimentally and comparison of results with passive suspension system.*

Key Words: **Suspension, vibration, Magneto Rheological (MR) Fluid, semi- active damper, passive damper.**

1. INTRODUCTION

1.1. Need For Suspension System

A Mechanical system made by many parts which are having motion and vibration. Sometimes motions and vibrations can be useful but excessive vibration causes discomfort to human beings, damage to machines and buildings and wear of machine parts such as bearings and gears. The drivers of vehicles during are exposed to vibration due the unbalanced rotating parts of the machines or by the road surface unevenness. The biggest problem to passenger is that they are exposed to vibrations in a frequency range from almost 0 to 20 Hz. This kind of discomfort causes that the driver and passengers to lose concentration, get tired early and after several years it can have dramatic effects on their health Magneto-rheological Fluid Damper is plays very important role to reduce the vibration and gives ride comfort. MR dampers are not only advantageous in their ability to provide variable damping forces to the suspension; they are inherently fail-safe devices from an electronic point of view. If there was a fault in the system, the MR damper can still operate as a passive damping system within certain performance parameters depending on the off-state characteristics of the MR fluid inside

1.2 Scope

MR Dampers are mostly used in high end automotive vehicles. So try to design MR dampers for low end vehicles also. Design of MR Damper by prepares various types of MR fluid using different material and size of particles in various different Passive Dampers. Design of automatic on-off circuit to operate current or magnetic field

2. LITERATURE REVIEW

BannaKasemi[01], et. al., have explained in the paper entitled "Fuzzy-PID Controller for Semi-Active Vibration Control Using Magneto-rheological Fluid Damper'' in this paper explained that a mainly three types of control devices passive devices, active devices and semi-active devices. In this paper author explains the semi active control devices. Magneto-rheological (MR) dampers, variable orifice dampers and tuned liquid dampers are examples of semi-active devices. In this paper author conducted experiments to establish the behavior of the MR damper also the behavior of MR damper is studied and used in implementing vibration control. The relations between force -displacement and force-velocity have been established for the MR damper with varying current.

R.Sundarrajan[02]et. al., have explained in the paper entitled "Implementation of Magneto-rheological dampers in bumpers of Automobiles for reducing impacts during accidents'' that the paper contains the idea of implementing the magneto Rheological bumper in the front wheels of the four wheeler, which results into the reduction of the loss and deformation of vehicle during accident. This paper also consist the basic characters and properties of the magneto rheological fluids (MR). In this paper author analyzed the research results of the past decades in Magneto Rheological fluids and their applications are also reviewed. It is one of the important materials used by major engineers in designing components like brakes, dampers, clutches. Also the author explained Magneto-rheological techniques which are used to reduce the impacts during collision of vehicles.

Martin Orecny[03]et. al., have explained in the paper entitled "Application of a magneto-rheological damper and a dynamic absorber for a suspension of a working machine seat'' that the paper author explained two alternatives of semi active suspensions of a seat of working machine. The first one is magneto-rheological damper and the second one is the combination of magneto-rheological damper and dynamic absorber. In this paper the affectivity of a DA on seat suspended by a MR damper was studied. The change in the seat spring stiffness changed about for 3x, but the effect of the applied DA helped to reduce the effective values of displacements only for 5%.

Sadak Ali Khan[04], et. al., have explained in the paper entitled "Principles, Characteristics and Applications of Magneto-Rheological Fluid Damper in Flow and Shear Mode" that the various modes of usage and characteristics of MR fluids are discussed. Mathematical modeling of the MR fluid dampers based on Bingham plastic model and Herschel Bulkley model are presented. In this paper author explained Magneto-rheological (MR) fluids as their material properties can be modulated through an applied electro- magnetic field. Specially, they are capable of reversibly changing from a linear Newtonian fluid to a semi solid with in a fraction of the milli seconds and the yield strength of this semisolid is controllable.

Bhau K. Kumbhar[05], et. al., have explained in the paper entitled "Synthesis and characterization of magneto-rheological (MR) fluids for MR brake application'' that the Magneto-rheological (MR) fluid technology can be used in various industrial applications like shock absorbers, actuators, etc. MR fluid is a smart material whose rheological characteristics change rapidly and can be controlled easily in presence of an applied magnetic field. MR brake is a device to transmit torque by the shear stress of MR fluid. In this paper author explained the synthesization of MR fluid samples which will typically meet the requirements of MR brake applications. Many MR fluid applications operate under different modes like valve mode, shear mode and squeeze mode.

Suryawanshi Ravishankar[06], et. al., have explained in the paper entitled "A Study on Magneto-Rheological Fluids and There Applications" that the characteristics, composition, and rheological principle of magneto-rheological fluids. Also author gives the details of working principle of magneto-rheological fluid devices, and their applications in other engineering areas. This paper presents the current status of MR devices and their applications in mechanical engineering. Magneto rheological fluids commonly known as MR fluids are suspensions of solid in liquid whose properties changes drastically when exposed to magnetic field. It is this property which makes it desirable to use in different vibration controlling systems.

3. SEMI-ACTIVE SUSPENSION SYSTEM

3.1 Magneto-Rheological (MR) Damper

A magneto-rheological damper (MRD) is not very different from a conventional viscous damper. The key difference is the magneto-rheological (MR) oil and the presence of a solenoid embedded inside the damper which produces a magnetic field.

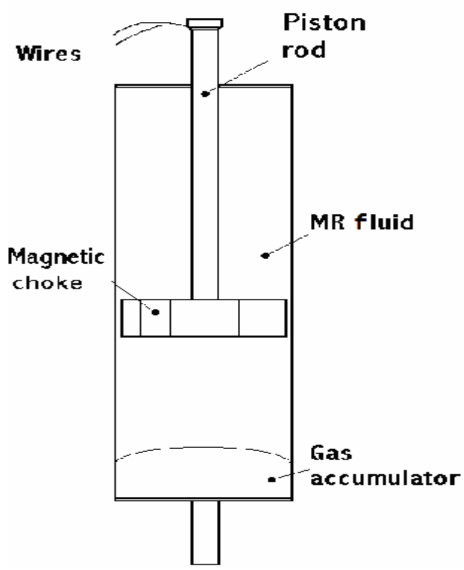

Fig -1 : Magneto-Rheological Damper (MRD)

MR oil is a particular type of fluid which contains micron-sized ferromagnetic particles in suspension. As a consequence of the polarising magnetic field, particles tend to form chains, which modify the value of the oil yield stress. In such a state rheological properties of oil change and the fluid passes from the liquid state to the semi-solid state. Hence by controlling the solenoid current, continuously variable damping can be produced without employing moving parts such as valves or variable orifices. The energy requirements are extremely low. For control, it is only necessary to supply the solenoid with a conventional battery.

Likewise it is important to remark that MR fluid rheological properties are virtually temperature and contamination independent. Therefore MRDs are rugged and reliable devices, capable of providing excellent performance over a wide variety of operating conditions. It is clear that appropriate control logic is crucial to take full advantage of the potential offered by an MRD. The main domains of application are automotive and structural. In the latter, they are employed for earthquake protection and for damping wind-induced Semi active Suspension Control oscillations of bridges and flexible structures. In the automotive field they are employed in semi-active suspensions. They are currently present on a number of high-segment market cars.

3.2 MAGNETO-RHEOLOGICAL (MR) FLUID

Magneto- rheological fluids commonly known as MR fluids are suspensions of solid in liquid whose properties changes drastically when exposed to magnetic field. It is this property which makes it desirable to use in different vibration controlling systems.

3.2.1 Working

Major constituents of MR fluid are oil (Mineral and Synthetic oil, Silicone Oil) and iron particles which vary in percentages according to the specifications. The size of magnetic particles is approximate of the order of 1μm to 10μm [6]. Iron particles are coated with anti-coagulant materials. When this combination of fluid is in inactive state, it acts as typical natural oil. When magnetic field is applied in the vicinity areas of fluids, micro-sized iron particles that are distributed throughout the fluid make themselves align according to the applied magnetic flux lines. It occurs when iron particles moves from one magnetic pole to the other and perpendicular to each paramagnetic pole surface.MR fluid is a non-colloidal suspension of polarisable particles While MR fluid usually contain carbonyl iron on the order of a few microns in size, Ferro fluids use nanometre-sized iron oxide particles. Ferro fluid particles are too small to demonstrate any yield strength; instead they tend to be only attracted to and flow toward a magnetic field. MR fluids, on the other hand, demonstrate very high yield strengths when a field is induced, usually on the order of 20 to 50 times the strength of ER fluids. With absence of applied magnetic field (off state), MR fluids behave as a Newtonian-fluid. Applying an external magnetic field through the fluid activates MR fluids, causing the micron-sized particles to form magnetic dipoles along the magnetic lines of force.

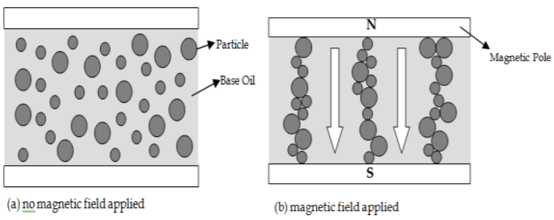

Fig-2: off State Magnetic Fluid particles and (b) Aligned in Applied Magnetic Field

3.2.2 Principle of Operation

Applying a magnetic field to magneto-Rheological Fluids causes particles in the fluid to align into chains. Micro particles are magnetized to produce orderly movement when an external magnetic field is applied, this movement generating at the beginning of micro particles are magnetized and finishing until reaching a relatively stable state, forming a fixed structure.

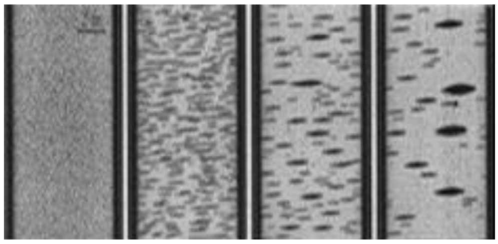

Fig-3 : Behavior of MR fluid under Alternating Magnetic Field

The structure of particles in an MR fluid gradually changes when an alternating magnetic field is applied. The leftmost picture shows an MR fluid after 1 second of exposure to a fast-changing magnetic field. The suspended particles form a strong, fibrous network. The pictures to the right show the fluid after 3 minutes, 15 minutes and 1 hour of exposure. The particles have formed clumps that offer little structural support [6].

3.2.3 Properties of Magneto Rheological Fluid

Properties	Values
Initial viscosity	0.2 – 0.3 [Pa.s] (at 25°C)
Density	3 – 4 [g/cm³]
Magnetic field strength	150 – 250 [kA/m]
Yield point	50 – 100 [k.Pa]
Reaction time	Few milliseconds
Current intensity	2 – 25 V, 1–2 A
Work temperature	-50 to 150 [°C]

Table 1 : Properties of MR fluids

3.2 Modes of operation for MR fluid devices

3.2.1 Valve mode

In this mode of MRF operation, fluid flow through the two fixed surfaces and magnetic field is applied perpendicular to the direction of flow. The resistance of the fluid can be controlled by controlling the intensity of magnetic field. Working of the Valve mode is shown in the fig

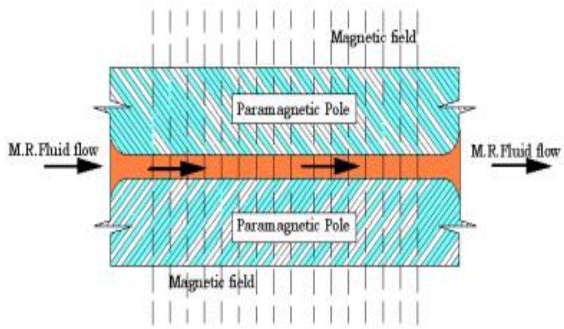

Fig 3 – Valve mode of MRF operation

Flow mode is the most widely used mode of operation in which the viscosity of the MR fluid flowing between stationary plates is changed by varying the applied magnetic field. In this mode, the activation regions are defined as those areas where MR fluid is exposed to the magnetic flux lines. This mode of MRF technology is used in various types of dampers, shock absorbers, servo valves, actuators and has vast application in automobile industry [4].

3.2.2 Shear mode

In this mode, the fluid flows between surfaces having relative motion and a magnetic field is applied perpendicular to the direction of flow.

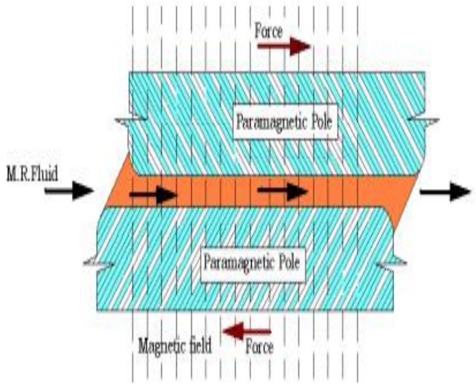

Fig 4 : Shear mode of MRF operation

In case of shear mode, MR fluid is present between sliding plates and related with magnetic field which is perpendicular to the direction of motion of these shear surfaces. Examples of shear mode devices include brakes, clutches, dampers, locking devices and structural composites [4].

3.2.3 Squeeze mode

This mode is used for low motion and high force applications. This mode is a recent development as compare to the other two. In this mode of MRF technology externally applied force is absorbed with the help of MR fluid. The yield stress developed through this mode is approximately ten times of the stress developed in either valve or shear mode. Working of the squeeze mode is clearly shown in the figure 5

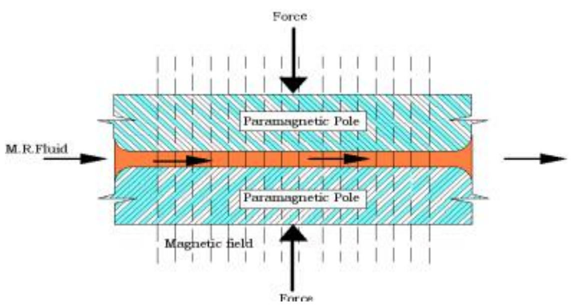

Fig 5 : Squeeze mode of MRF

Operation

The distance between parallel plates is changed when they are operated in squeeze mode. In this mode relatively very high forces can be achieved. It is especially suitable for the vibrating dampers with low amplitudes and high dynamic forces. So the devices using MR fluid like brakes, clutches, human prosthetics, robotics and automobile suspension made of MR dampers, etc., have a great promising future. Magneto-rheological (MR) devices are semi active control devices that use MR fluids to suppress the vibrations [4].

4. DESIGN OF MAGNETO-RHEOLOGICAL DAMPER

The damper has used for project to modify Yamaha FZ back shock absorber single-tube configuration. The piston, which is fixed onto the piston rod, moves up (rebound) and down (compression) along the inside of the inner tube. The piston divides the damper into two parts, namely: the rebound chamber, which is the space above the piston, and the compression chamber, which is the space below the piston. Holes at the bottom of the inner tube allow the compression chamber to be a continuous part of the outer tube. A magnetic circuit that is driven by an electromagnet located in the piston head. The resistance to the flow of the MR fluid which flows between the rebound and compression chambers through an annular gap can be controlled by varying the strength of the magnetic field generated by the coils.

4.1 DESIGN

Computer-aided design (CAD) is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations. The term CADD (for Computer Aided Design and Drafting) is also used. These 3D models are drawn in CATIA V5 R20. Different components drawn in CATIA V5 are: Base frame, Pneumatic cylinder, piston, disc & Assembly of all components. CAD model is made by the commands in CATIA V5 R20 of pad, pocket, fillet, sketcher, circular etc. Computer-aided design (CAD), also known as computer aided design and drafting (CADD), is the use of computer technology for the process of design. Computer Aided drafting describes the process of drafting with a computer. CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products.

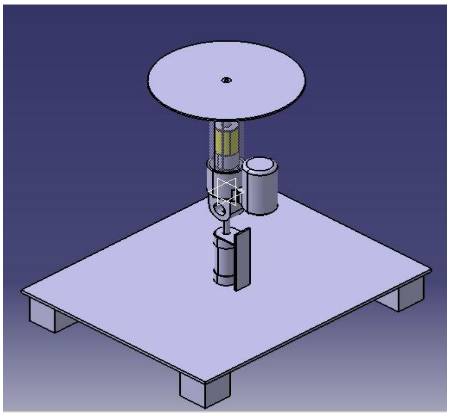

Fig 6 : 3D Model of MR damping Setup

4.2 Selection And Preparation of MR Fluid

A typical Magneto-Rheological fluid consists of 20-40 percent by volume of pure, 1-10 micron diameter iron particles that are suspended in a carrier liquid such as synthetic oil, water or glycol. A multiple of proprietary additives are added in commercial lubricants to hinder gravitational setting and promote particle suspension. Magneto-Rheological fluid are contains iron particles which exhibit the maximum yield strengths of 50-100 kPa for the applied magnetic fields of 150-250 kA/m. Magneto-Rheological fluid is not sensitive to moisture or other contaminants that might be encountered during its usage. Since viscosity of fluid can be changed accordingly it makes Magneto-Rheological fluid insensitive to temperature, to which passive suspension are sensitive.

4.3 Experimental Procedure

- After completion of MR damper setup testing reading was taken.
- First we had applied constant pressure of 2 Bar to pneumatic cylinder of dimension 25*50 on which damper was mounted.
- For applying constant force on MR damper Solenoid valve and Arduino Uno circuit was used.
- Then accelerometer was placed at output section plate of pneumatic cylinder on which MR damper was mounted and then reading of acceleration was taken.
- After that accelerometer shifted to the output section of MR damper plate having weight 315 grams and reading of acceleration was taken.
- Final step we had applied constant current and voltage (12 volt and 2 Amp) to input coil of electromagnet and above mentioned procedure was repeated.

5. RESULTS INTERPRETATIONS

5.1 Output of performance of damper vibration read by FFT analyzer:

5.1.1 Reading at output of pneumatic cylinder

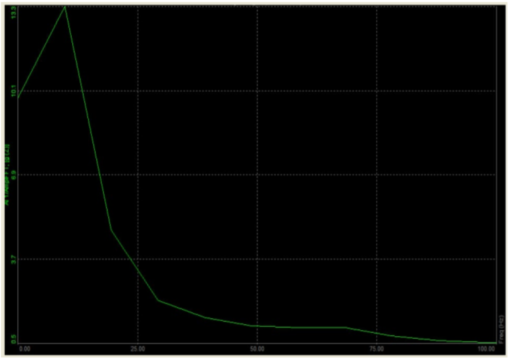

Chart 1 : Acceleration plot at output of pneumatic cylinder

Acceleration without electromagnet at MR damper input section was 13.3 g

5.1.2 Reading at output section of passive damper plate

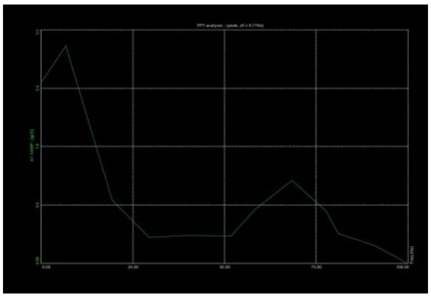

Chart 2 : Acceleration plot at output of passive damper

Acceleration of passive damper at output section was 2.9g

5.1.3 Reading at output section of MR damper plate without electromagnet

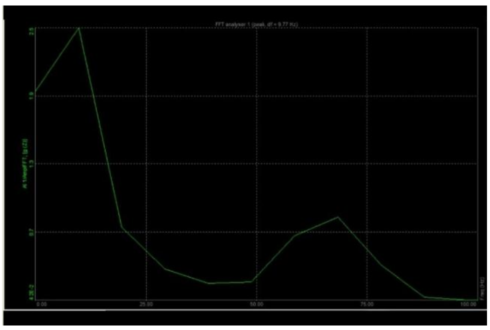

Chart 3 : Acceleration plot at output plate of MR damper without electromagnet

Acceleration without electromagnet at damper output was 2.5g

5.1.4 Reading at output section of MR damper plate with electromagnet

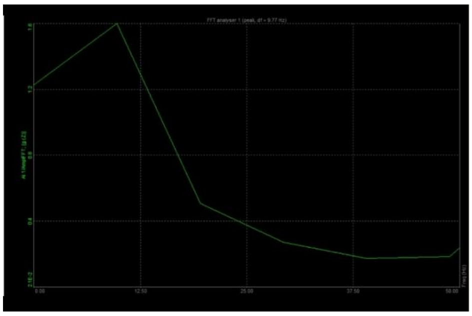

Chart 4 : Acceleration plot at output plate of MR damper with electromagnet

Acceleration with electromagnet at damper output was 1.6g

5.2 Results

Serial number	Condition	Acceleration	% of total damping performance
1	Acceleration with electromagnet at damper input	13.3g	
2	Acceleration of passive damper at output	2.9g	78.20%
3	Acceleration without electromagnet at damper output	2.5g	81.20%
4	Acceleration with electromagnet at damper output	1.6g	87.97%

Table 2 : Performance Results

6. Conclusions

1. MR Damper is mainly depended on MR Fluid and magnetic flux intensity.

2. Due to use of MR fluid with electromagnet acceleration at output of damper is 1.6g less than acceleration without electromagnet at damper output 2.5g.

3. As compare to conventional damper use of MR damper plays an important role in reducing the vibrations because, for every load condition the behavior of MR damper is change positively.

4. Dynamic analysis of modified MR based semi-active damper for Yamaha FZ bike is to be carried out and performances of this system over passive damper is to improve by 9.77%.

5. Also the performance of off stage of MR Damper over the Passive pamper is improve by 3%. That means MR damper perform good in off stage also.

6. MR Damper is the fail-safe suspension system from an electronic point of view.

7. If there was a fault in the system, the MR damper can still operate as a passive damping system within certain performance parameters depending on the off-state characteristics of the MR fluid inside it.

REFERENCES

1. Banna Kasemi, Asan G. A. Muthalif, "Fuzzy-PID Controller for Semi-Active Vibration Control Using Magnetorheological Fluid Damper", Department of Mectronics Engineering, International Islamic University Malaysia, Gombak, Kuala Lumpur, 53100, Malaysia.
2. T.Imthiyaz Ahamed, R. Sundarrajan, "Implementation of Magneto-rheological dampers in bumpers of Automobiles for reducing impacts during accidents", Department of Mechanical Engineering, Sri Sairam Engineering College, West Tambaram, Chennai 600 044, India, vol. 97, 2014, pp. 1220 – 1226.
3. Martin Oreny, Sefan Segl, "Application of a magneto-rheological damper and a dynamic absorber for a suspension of a working machine seat", Modelling of Mechanical and Mechatronic Systems, vol. 96, 2014, pp. 338 – 344.
4. Sadak Ali Khan, A.Suresh and N.Seetha Ramaiah, "Principles, Characteristics and Applications of Magneto RheologicalFluid Damper in Flow and Shear Mode", 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014), vol. 6, 2014,pp. 1547 – 1556.
5. Bhau K. Kumbhar, Satyajit R. Patil, "Synthesis and characterization of magneto-rheological (MR) fluids for MR brake application", Engineering Science and Technology, an International Journal, vol. 18, 2015, pp. 432-438.
6. Suryawanshi Ravishankar, Rayappa Mahale, "A Study on Magneto Rheological Fluids and Their Applications", International Research Journal of Engineering and Technology (IRJET), vol. 02, 2015, pp.2395-0072.