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Dynamic Analysis of Cardan Joints for Improving Its Performance and Life Expectancy

S. Hariharan
P.G. Student, Department of Mechanical Engineering
Mahendra Engineering College, Namakkal, Tamil Nadu, India
S. Yuvaraj
Assistant Professor, Department of Mechanical Engineering
Mahendra Engineering College, Namakkal, Tamil Nadu, India

Abstract:
Cardan joint is commonly used in shafts that transmit rotary motion. The Cardan joint may appear as a simple component within a machine. It is no longer in use for many modern day automobiles. However, almost all semi heavy and heavy trucks and automobiles with engine power of more than 250 Hp have rear driving wheels and have to be equipped with Cardan joints. On the other hand, a Cardan joint is fairly cheap and very easy to be replaced. This can be performed during the routine maintenance services. It consists of a pair of hinges located close together, oriented at 90o to each other, connected by a cross shaft. The Cardan joint suffers from one major problem even when the input drive shaft rotates at a constant speed, the output drive shaft rotates at a variable speed, thus causing vibration and wear. The variation in the speed of the driven shaft depends on the configuration of the joint. Such configuration can be specified by three variables. The universal (Cardan) joints are associated with power transmission systems.

1. Introduction

The idea of a mechanism that can provide slight inclination to the direction of the rotating shafts has long been thought of by the engineers. Artobolevsky introduced a handful of such mechanisms. Some of such mechanisms with their corresponding characteristic curves are presented in. Failure of the universal joints can end up with serious consequences and it can be very costly. It causes sudden disruptor in the supply of power between its source and the consumer device. Therefore, many studies are performed in order to recognize the nature of the corresponding forces and the failure within these mechanisms. For example, Hajirezaei & Ahmadi have reported their research results on the effect of cracks in fragile failure of Cardan joints . Bayrakceken, et al. reported research results on two cases of failure in the power transmission system on vehicles equipped with the universal joints. All such studies concentrated on the failure in the universal joints or its connecting rods, in a general sense. There is hardly any research report specifically concerned with the failure of the bearings in the universal joints. However, in practice there have been many cases of failure associated with the malfunctioning universal joint bearings.

2. The Universal Joint Mechanism

In 1904, Clarence Spicer, a young engineering graduate from Cornell University, registered his invention of a mechanism. Since then, the mechanism that was called the Cardan joint has found widespread industrial applications. The Cardan joint is amongst the most popular universal joints. It is widely used in the mechanical couplings and joints with the pre-condition that the input drive shaft and the output drive shaft are not aligned. It may also be desired to permit some angular deviations along the axis of rotation. The Cardan joint comprises of the three main parts includ-malfunction and need to be replaced in comparatively short intervals of time. Naturally, it means that such parts have limited life span.

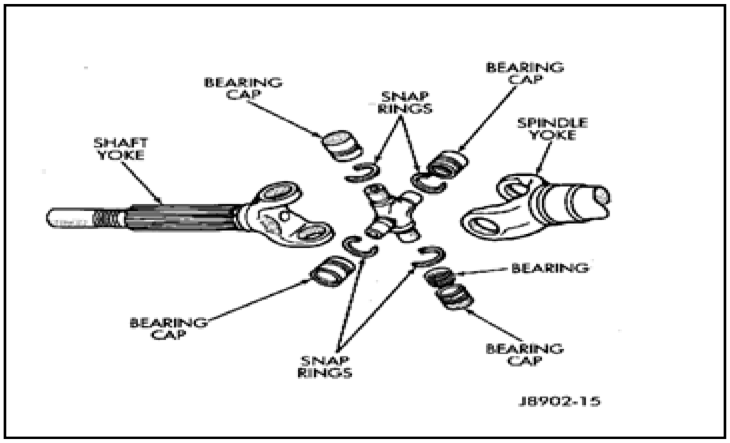

Figure 1: Detailed view of cardan joints

The universal joints and the corresponding characteristic curves that were introduced by Artobolevsky, the dashed lines indicate angular velocity of the input drive shaft and the heavy lines indicate angular velocity of the output drive shaft.

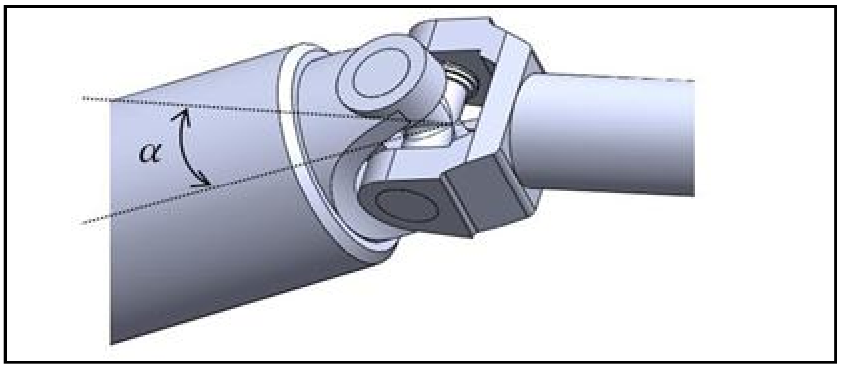

Figure 2: Schematic of the Cardan joint.

Two points of the cross piece connect to the input drive shaft and two other points connect to the output drive shaft. Connections are provided by the needle bearings. It is an important aspect of these bearings that while in action they never go through complete cycles. In other words, each of these bearings revolves only a few degrees around its axis before returning to its original position. Therefore, there are only a group of balls in these bearings that take the bearing load. On the other hand, even if the angular speed of the input drive shaft is constant, the angular speed of the output drive shaft oscillates. The size of such oscillation depends on the amount of the angular deviation of the output drive shaft. These couplings are widely used in the automobile power transmission systems. However, they are prone to wear and Numerous mechanisms are used to transmit power between traversing shafts. Amongst them Hooke's joints are the most commonly used. Hooke's joint is categorized as the Cardan joint and the spherical joint. These joints have relative intersecting angles of 15 and 45 degrees, respectively. These types of joints are used in the equipments that are capable of high power transmission. However, the angular velocity of the driven shaft is not constant. This means that the ratio of the output velocity to the input velocity is not the same at all angular positions. Bayrakceken, et al. carried out the fracture analysis of a universal joint yoke and a drive shaft of an automobile power transmission system.

Figure 3: Sample of a failed Cardan joint

Hummel and Chassapis investigated a systematic approach to the design and optimization of the ideal universal joint. It was shown that extremely high internal forces develop if contact occurs between the various components of the mechanism. The high internal forces can cause failure; therefore, interference must be avoided at all times. Untimely joint failures were attributed to the rocking torque that was investigated by Dodge and Evernden. General universal joint design and dynamics guidelines have been written by Wagner and Cooney, Lee, Lingaiah, and Shigley and Mischke. The need for advancing the power transmission mechanisms is endless. Engineers are restless in their attempts to explore more sophisticated systems that can do the job more efficiently. The need to transmit the power co-exists with the aspiration for reducing the levels of undesirable vibrations in the machineries. An example for such attempts can be found in the work reported by Chen, et al. They proposed a method for vibration isolation of a vertical axis through small amplitude of the suspension rod's axial force. By combing the geometric constraints and the governing dynamic equations they achieved a general governing equation for vibration isolation of the system. In order to improve the quality of the power transmission systems, a second path is the improvement in the material content of the bearing surfaces.

3. Design Process

The design solution steps used by the students to accomplish the tasks in completing a design project are shown in the following block diagram. Note that refinement is always occurred in between the steps.

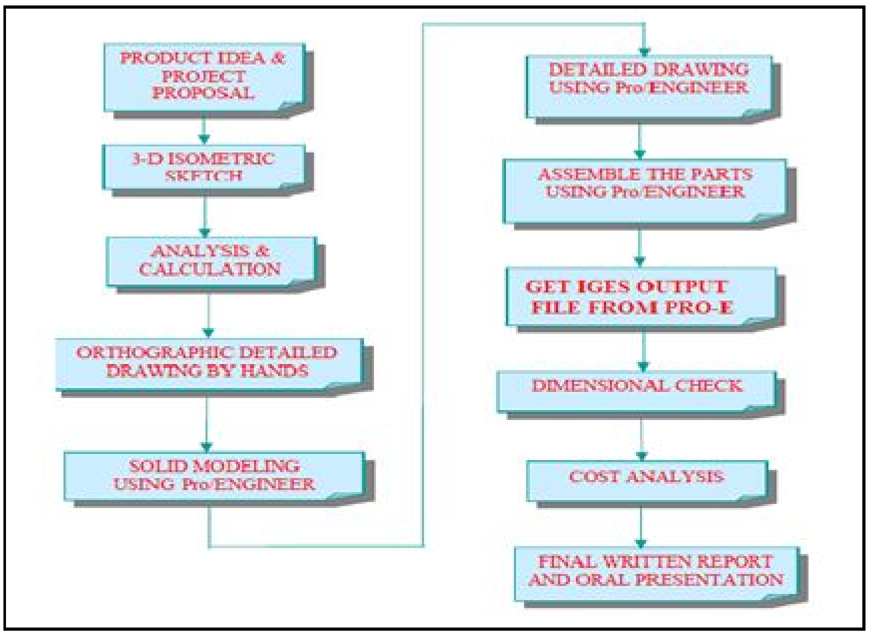

Figure 4: Design Process

The universal crusher is a machine of simple design, but its many uses are essential to daily living. People spend hundreds of dollars buying innumerable little gadgets to do small jobs in their house. Integrating these machines into one multipurpose unit can easily solve this problem. The multipurpose, universal crusher resolves this dilemma. The crusher employs a simple design that is expanded upon to create the functionality included in this device. The basic design is that of a four bar linkage. This linkage is laid out in an in-line slider crank fashion. The bar attached to the slider is extended so that when pressure is applied in a downward motion, the slider moves in a forward motion.

A tongue on the slider inserts into a tongue groove on the base. This controls the motion of the entire four-bar linkage. The slider moves into a box at the end of the base that contains the material to be crushed. The material is pushed up against the back wall of box causing it to be crushed. The back end of this box is removable adding multiple functions to the crusher. It allows for easy insertion and removal of the material being crushed. It can also be replaced with different blades to increase the functionality of the crusher. This is the basic design of the universal crusher. The universal crusher consists of five basic parts. The first is a base. The base has a connection for on of the arms of the four bar linkage, a tongue groove to hold and 27 direct the movement of the slider, and a box where the material is crushed. The back end of this box is made of the second part, which is the blade. This part can be a flat piece of material to be used for simple crushing, or R can be redesigned to add functions to the crusher.

The third part is the crusher. This is the slider in the four bar linkage. This has a tongue on it that fits into the tongue groove on the base. It also has a protrusion designed to attach to handle. The fourth part is handle. This attaches to the crusher and is where the user drives the entire apparatus. It is rounded and cut to fit comfortably in the user's hand. The fifth part is the arm. This attaches to the base and to the handle. It completes the four bar linkage that drives the crusher. These five parts are the main construction of the universal crusher. The materials used in the crusher are simple. The product will mainly be constructed of steel. The crusher is being used for many high stress operators and must be as sturdy as possible. Steel is the best material to handle the functions included in the crusher.

A rubber coating could also be placed over the steel-based handle. The steel would supply the necessary strength for the handle and the rubber coating would supply additional comfort for the user. The universal crusher can be used in the kitchen to prepare mashed potatoes or crushed garlic, or it can be used in the garage to crush soda cans. Its functions are countless, This is the basic design and idea behind the universal crusher.

- SPEED (N): 500rpm.
- TORQUE TRANSMITTED (T): 100N-m.
- POWER TRANSMITTED(P):

$$P= 2\prod NT/60$$

$$P=5233.33\text{Watts}.$$

The designs of cardan joint diagrams are shown in bellow.

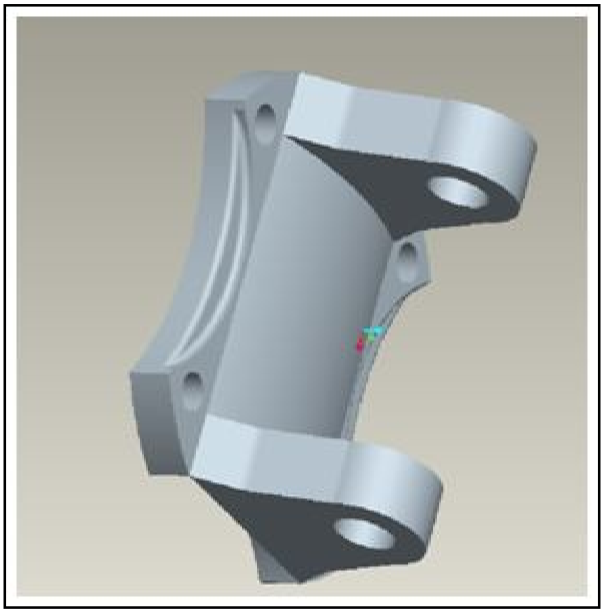

Figure 5: Flange

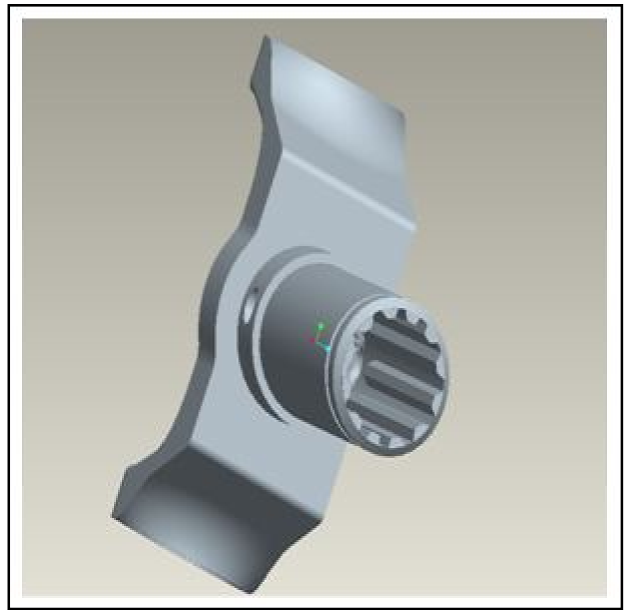

Figure 6: Yoke

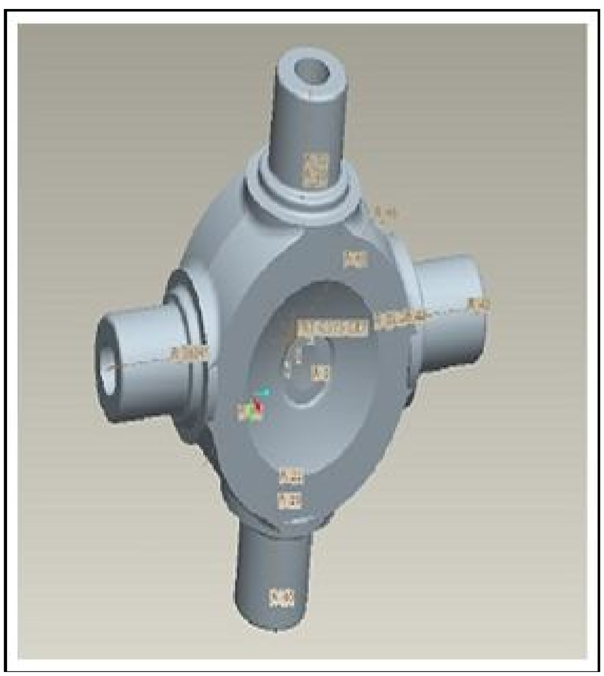

Figure 7: Spider

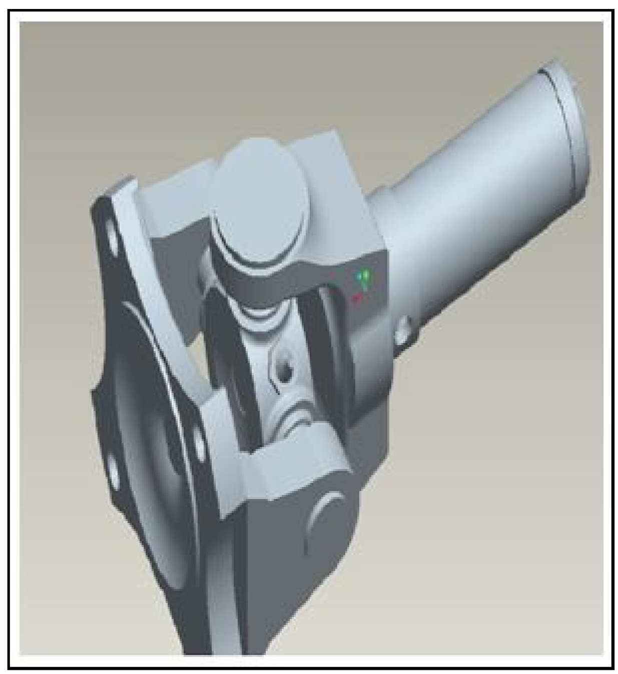

Figure 8: Assembled view of Cardan Joint.

4. Results and Discussions

The results for Equivalent (Von- Mises) Stress, Equivalent (Von- Mises) Elastic Strain and Total Deformation at different loading conditions are shown bellow.

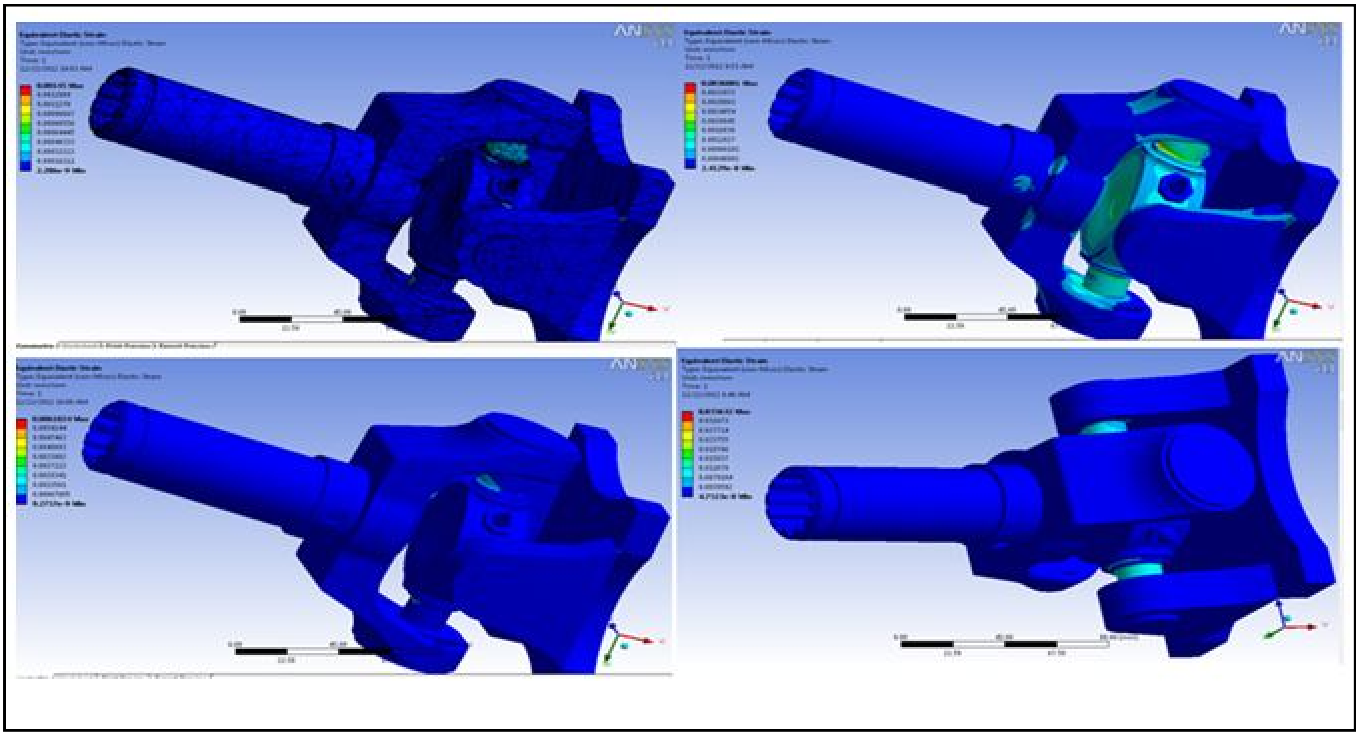

Figure 9: Equivalent (Von- Mises) Elastic Strain for Different Loading Conditions (100n, 250n, 500n & 1000n)

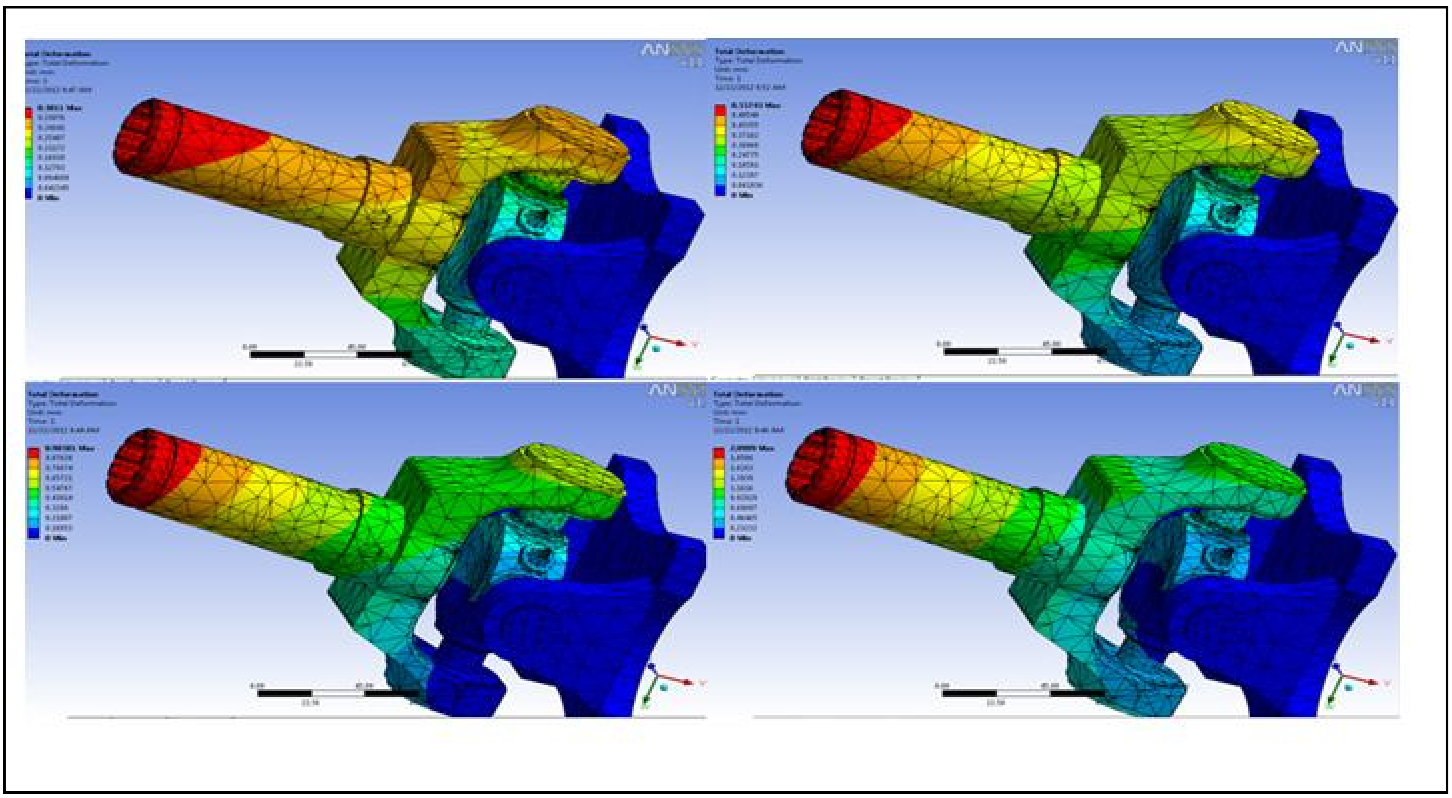

Figure 10: Total Deformation for Different Loading Conditions (100n, 250n, 500n & 1000n)

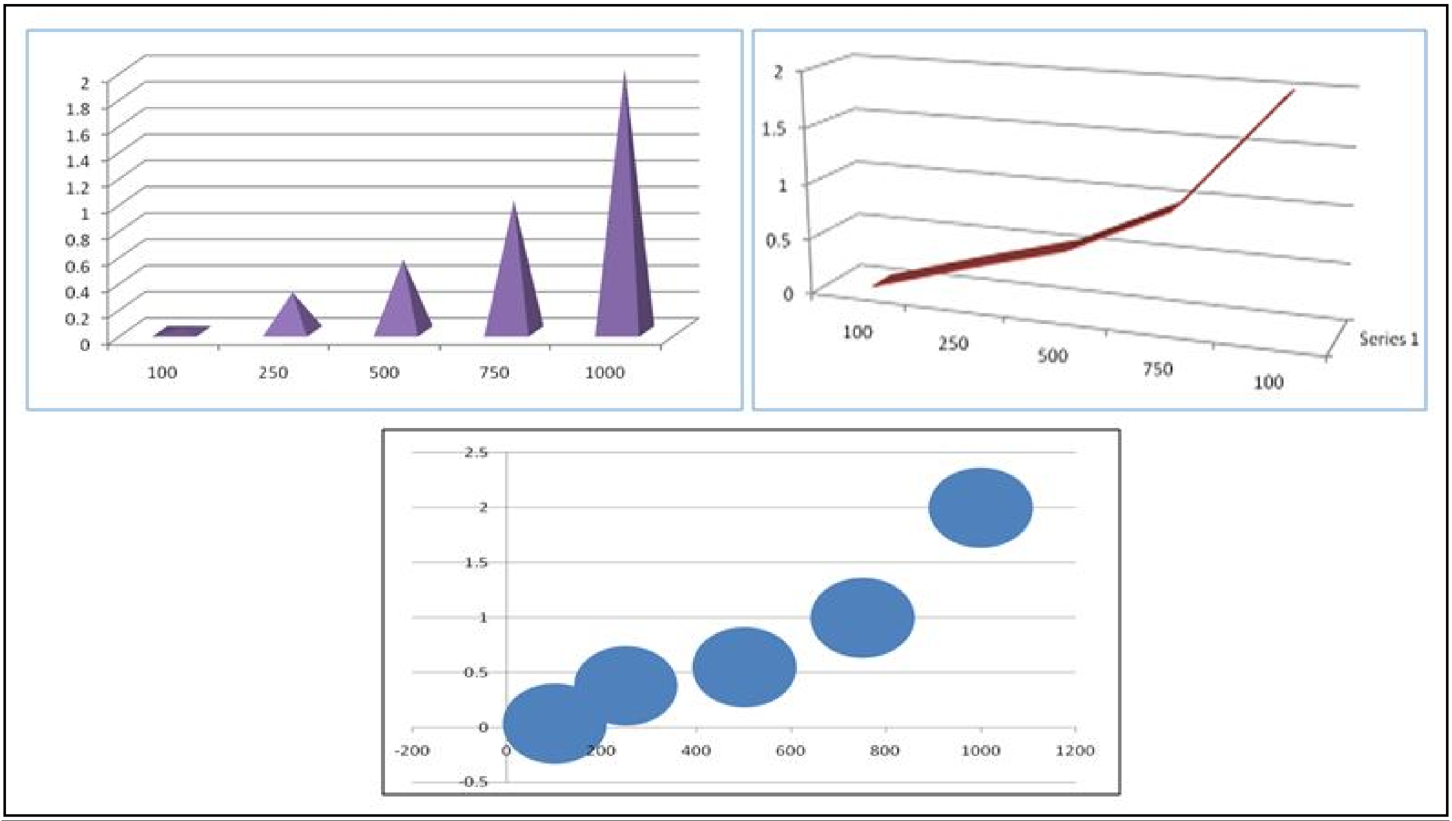

Figure 11: Total Deformation for Different Loading Conditions

In present synoria using of cardan joint may occur impact load that affect in failure. In case this defect can be prevented by implementing the spring which observes the loads and it increase the life of the cardan joint.

5. Comparing the Three Models

Different loads In n	Existing model Deformation In mm	Previous research model deformation in mm	New model deformation In mm
100	0.29	0.2	0.14
250	0.56	0.45	0.32
500	0.91	0.67	0.5
1000	2.03	1.33	0.94

Table 1: Comparing the Three Models

6. Conclusion

The Cardan joint may appear as a simple component with in a machine. It is no longer in use for many modern day automobiles. However, almost all semi heavy and heavy trucks and automobiles with engine power of more than 250 Hp have rear driving wheels and have to be equipped with Cardan joints. A parallel task was the assessment of the Cardan joint behavior under loaded conditions through some numerical simulations. Many damaged samples of the Cardan joints were also collected. The damaged sections of such joints were carefully examined. The analytical and the numerical simulated results were verified by comparing them with the outcome of the investigations about some damaged samples.After careful examinations of the damaged bearings and by resorting to the analytical and the numerical simulated results some remedies are proposed. It is anticipated that such proposals can increase the performance and improve the life expectancy of the Cardan joints. These include:

- The use of the intermediate spring to reduce the size of the impact loads and deformation in 46%.
- Reducing the load on the bearings that are viable to damage by increasing the torque arm.
- Increasing the degrees of freedom in order to remove the regularity in the impact load.

7. References

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