

Explicit Dynamic Analysis of Mechanical Motion Rectifier Used for Energy Harvesting

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Abstract - An energy regenerative shock absorber is able to harvest the kinetic energy from the vehicle suspension vibration. A Mechanical Motion Rectifier is a device that translates bi-directional rotational motion into unidirectional rotational motion. This rotational motion is used for generating electrical energy. This work details the innovative design of a compact mechanical motion rectifier with the improved output power and efficiency and this device will suitable for future research purposes. The design of a gear directly effect the efficiency of the system This will leads to appropriate design and testing of the gear system which is very costly. So simulation have wider acceptance. This work deals with explicit dynamic analysis of mechanical motion rectifier which represent the response of the system to the variation of rotational speed. For simulation ANSYS workbench is used. Appropriate boundary conditions and loadings are applied to the mechanical motion rectifier. Total Deformation and Von Mises stresses are evaluated through explicit dynamic analysis.

Key Words: Mechanical Motion Rectifier, Explicit Dynamic Analysis, Energy Harvesting, Vibration, etc

1. INTRODUCTION

The suspension system isolates the vehicle body from the disturbances coming from road. The suspension system consists of three main elements i.e. mass, spring and damper. The spring stores the kinetic energy into potential energy. The function of damper is to dissipate the vibrational energy. The energy dissipated by the vibration is important loss in the suspension system. Harvesting of vibration energy is possible from the suspension system; such suspension system is called regenerative suspension system.

There is relative linear motion in the suspension system of the vehicle. These linear vibrations can be converted into bidirectional oscillatory motion or unidirectional rotational motion by incorporating transmission mechanism called as mechanical motion rectifier (MMR). This MMR is connected to DC or AC generator, which can harvest waste energy. Such mechanical mechanism consists of rack and pinion, bevel gears. The electrical energy can be generated in rotary energy harvester by converting up and down vibrations into unidirectional rotary motion.

This MMR device consists of different gears. These gears are designed as per power generated in the system. Design of

gears consists of balance between cost and requirements. After design the gear is manufactured and tested in the laboratory. Testing of gears are too costly. So different simulation packages are used to simulate the dynamic nature of spur gears in motion. Ansys workbench is one of the good simulation package which provide explicit dynamic analysis.

1.1 Design Details of Mechanical Motion Rectifier

The maximum energy that is available for harvesting is the amount that is dissipates by the viscous damping. , The power dissipated by shock absorber is nearly equal to 25 to 100 Watt. Mechanical motion rectifier is designed for 150 W power.

Table -1: Specifications of Pinion

Material	45C8
Ultimate tensile strength (S_{ut})	660MPa
Number of teeth (N)	20
Pitch circle diameter (D)	25 mm

Table -2: Specifications of Shaft

Material	Plain Carbon Steel
Ultimate tensile strength (S_{ut})	770 MPa
Yield strength (S_{yt})	580 MPa
Diameter (d)	10 mm

Table -3: Specifications of Bevel Gear

Material	45C8
Ultimate tensile strength (S_{ut})	660MPa
Cone distance (A_0)	25.45 mm
Pitch circle diameter (D)	36 mm

1.1 3D CAD Model of Mechanical Motion Rectifier

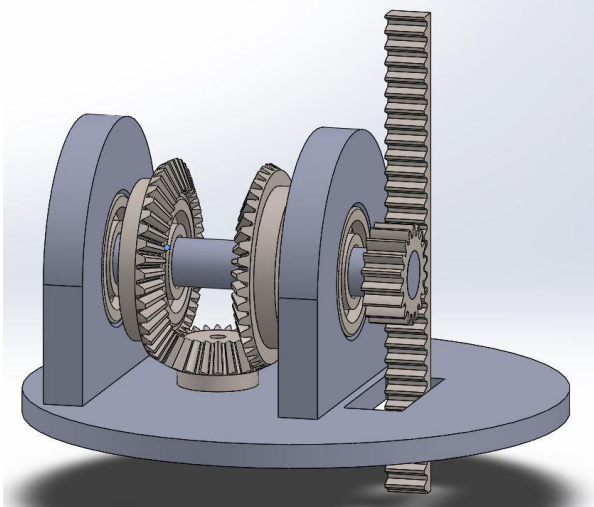


Fig -1: 3D CAD Model of Mechanical Motion Rectifier

2. PROCEDURE OF EXPLICIT DYNAMIC ANALYSIS

An explicit dynamic analysis is computationally efficient for the analysis of large models with relatively short dynamic response times and for the analysis of extremely discontinuous events or processes; allows for the definition of very general contact conditions.

Following steps are performed explicit dynamics analysis of different components;

- i) Open Ansys Workbench and drag explicit dynamics block in workspace.
- ii) Add material with its mechanical properties in library of the Ansys Workbench.
- iii) Import geometry to Ansys workbench and assign material as per product.
- iv) Apply the contacts between the all-mating parts.

In Contacts, the contacts are given between two mating parts. Several contact types are used in Explicit Analysis. These names might be called with different names according to software. In Ansys software, contact names are titled frictional, frictionless, rough, bonded and no separation.

Frictional Type Contact- The contact pair can slide and separate on the target surface. Friction coefficients affect tangential movements. Frictional contacts are given between two moving parts of MMR and the coefficient of friction is considered between two parts is 0.25. Frictional type contact between rack and pinion is shown in Figure-1.

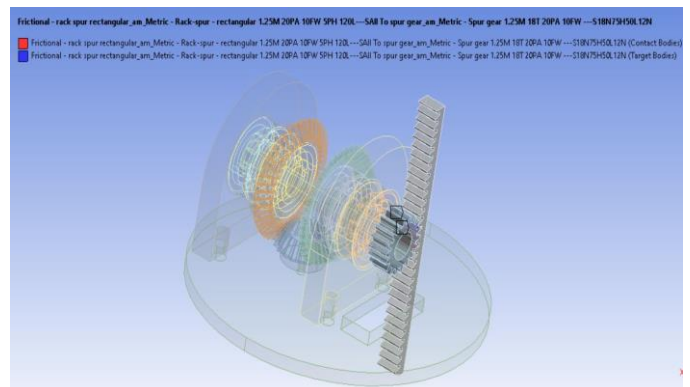


Fig -1: Frictional Type Contact between Rack and Pinion

Bonded type Contact- If contact regions are bonded, then no sliding or separation between faces or edges is allowed. In this contact, defined geometries act like one body. Bodies cannot move (no slide and no separate) and rotate between each other. This type of contact is given between two parts where no relative motion occurs. Figure -2 shows the contact details and bonded type contact between pinion and shaft respectively.

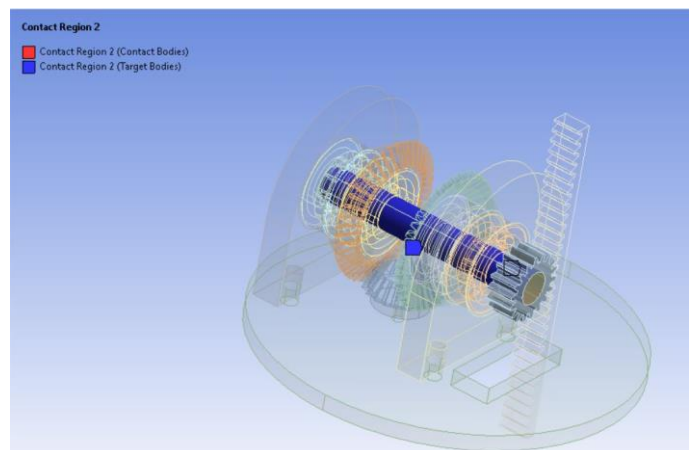


Fig -2: Bonded Type Contact between Pinion and Shaft

- v) Mesh the geometry and check whether proper mesh is generated or not.

In meshing, the physics preference, element order and element size are the main parameters considered. In this analysis, meshing is done by using Explicit physics preference, linear element order and default element size. Mesh model is shown in the Figure -3.

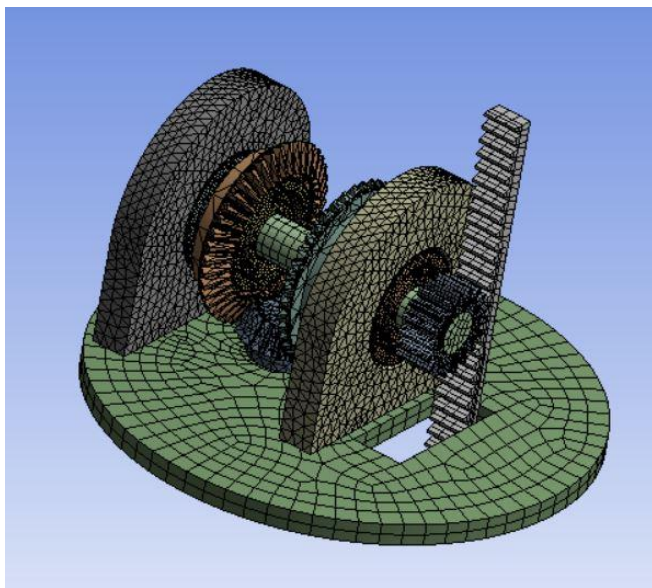


Fig -3: Mesh Model of MMR

vi) Provide value of end time in the analysis setting.

The maximum length of time (starting from time zero) to be simulated by the explicit analysis. End Time is calculated from the natural frequency of 257.42 Hz and is 3.1×10^{-4} sec.

vii) Apply boundary conditions like fixed support, velocity etc.

The velocity of rack is calculated from the natural frequencies of vibration. The velocity is given to the rack in the reverse Y-direction and fixed support is given to the base plate. Figure-4 shows the velocity details and velocity boundary condition.

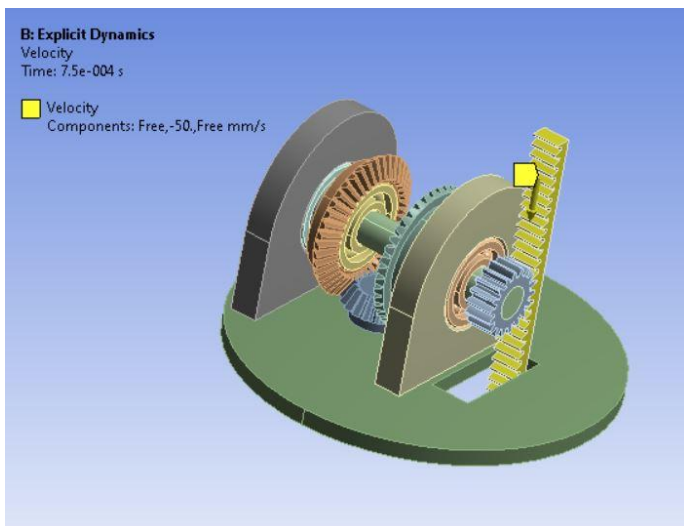


Fig -4: Velocity Boundary Condition

viii) Apply post processing Parameter to be evaluated like total deformation, equivalent stress, etc.

ix) Solve the model and record solutions.

3. RESULTS OF EXPLICIT DYNAMICS ANALYSIS

3.1 Calculation of Total Deformation

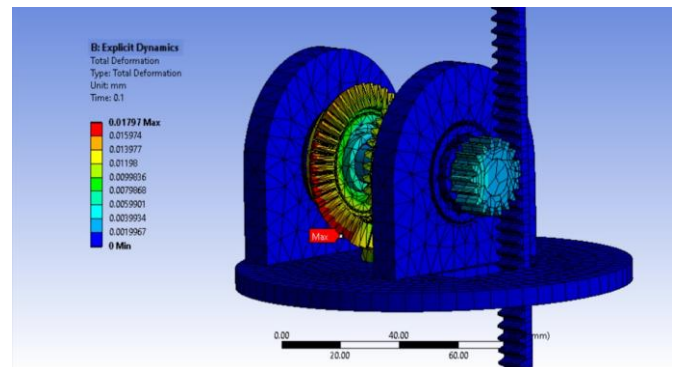


Fig -5: Total Deformation of MMR at 78.5 mm/s

Figure-5 shows total deformation of mechanical motion rectifier when the velocity is given to rack of 78.5 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total deformation is 0.01797 mm.

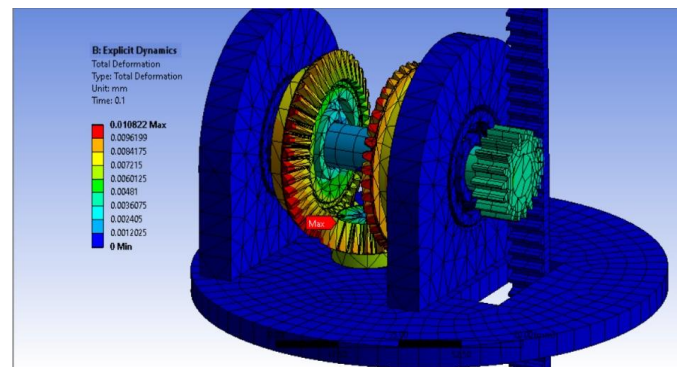


Fig -6: Total Deformation of MMR at 117.75 mm/s

Figure-6 shows total deformation of mechanical motion rectifier when the velocity is given to rack of 117.75 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total deformation is 0.010822 mm.

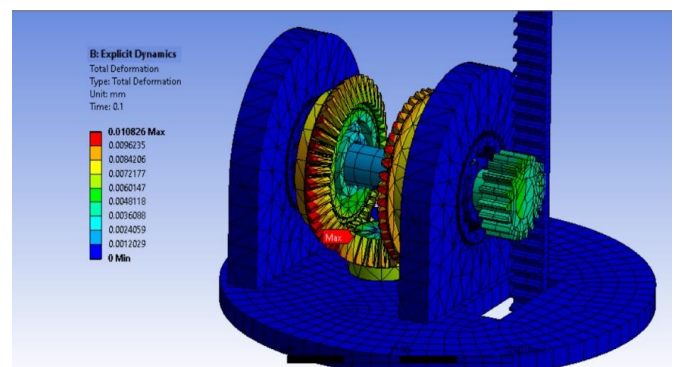


Fig -7: Total Deformation of MMR at 157 mm/s

Figure-7 shows total deformation of mechanical motion rectifier when the velocity is given to rack of 157 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total deformation is 0.010826 mm.

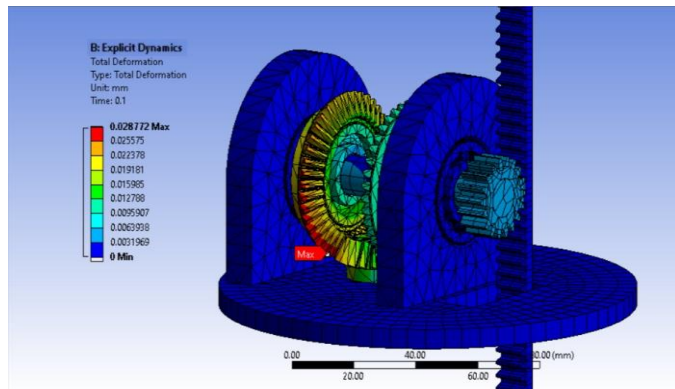


Fig -8: Total Deformation of MMR at 196.25 mm/sec

Figure-8 shows total deformation of mechanical motion rectifier when the velocity is given to rack of 196.25 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total deformation is 0.028772 mm.

3.2 Calculation of Von Misses Stresses

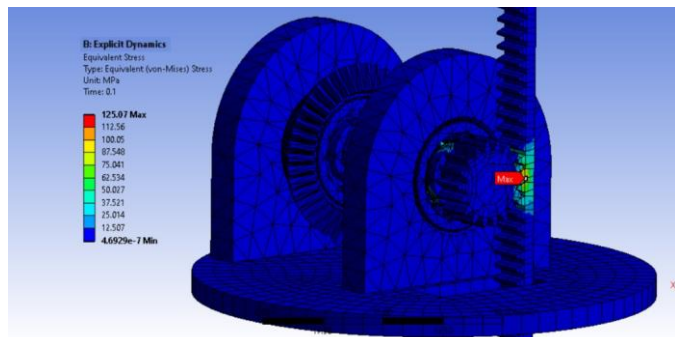


Fig -9: Von Mises Stresses of MMR at 78.5 mm/s

Figure-9 shows Von-Mises stress distribution of mechanical motion rectifier when the velocity is given to rack of 78.5 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total stress developed is 109.5 MPa.

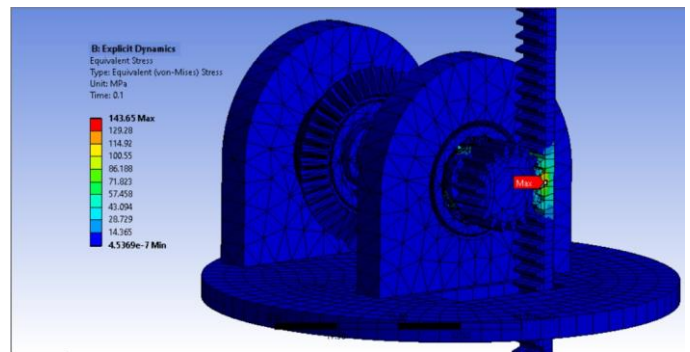


Fig -10: Von Mises Stresses of MMR at 117.75 mm/s

Figure-10 shows Von-Mises stress distribution of mechanical motion rectifier when the velocity is given to rack of 117.75 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total stress developed is 143.65 MPa.

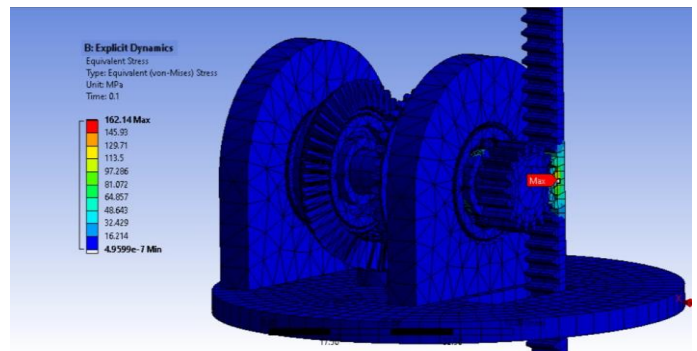


Fig -11: Von Mises Stresses of MMR at 157 mm/s

Figure-11 shows Von-Mises stress distribution of mechanical motion rectifier when the velocity is given to rack of 157 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total stress developed is 162.14 MPa.

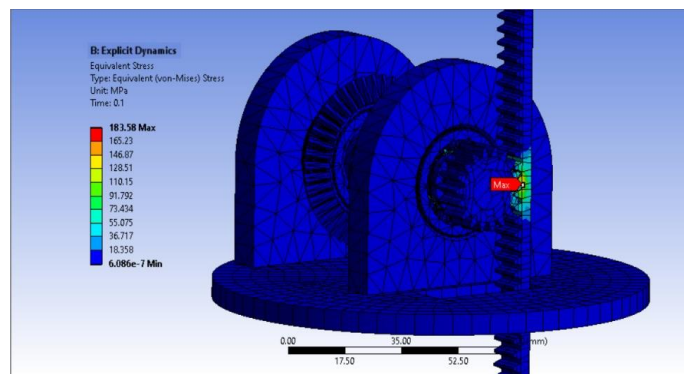


Fig -12: Von Mises Stresses of MMR at 196.25 mm/s

Figure-12 shows Von-Mises stress distribution of mechanical motion rectifier when the velocity is given to rack of 196.25 mm/s. The explicit dynamic analysis of mechanical motion rectifier shows that when boundary condition is applied, the maximum total stress developed is 183.58 MPa.

Table -4: Results of Explicit Dynamics

Boundary Condition (Velocity in mm/s)	Total Deformation (mm)	Von Misses Stress (MPa)
78.5	0.01797	109.5
117.75	0.010822	143.65
157	0.010826	162.14
196.25	0.028772	183.58

Result obtained are plotted on graph as follows.

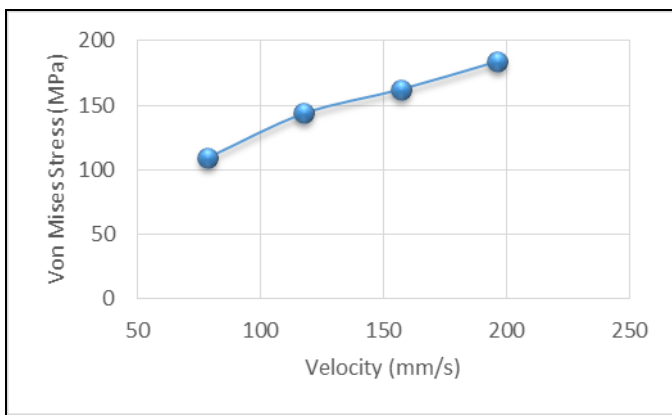


Chart -1: Von Mises Developed Vs Velocity

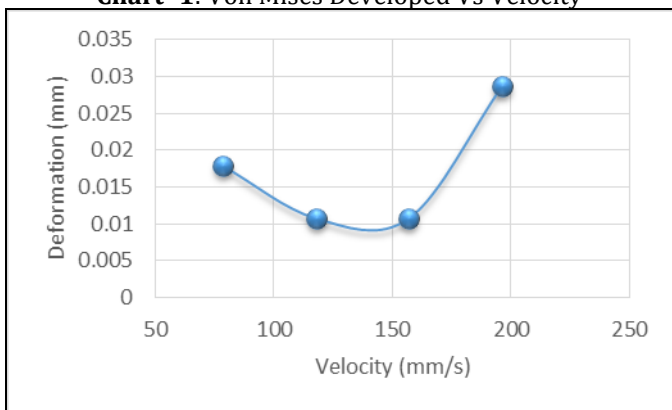


Chart -2: Deformation Developed Vs Velocity

4. CONCLUSIONS

The Mechanical Motion Rectifier is analyzed for the strength and dynamic simulation of the gear movements. It is proved that explicit dynamic analysis is great tool to study the time dependent behavior of the gears. The Von Mises stress values and Total deformations are calculated through simulation are said to be convinced with the desired values. Deformation during the action of the loads is limited hence leads to the smooth operation of gears. Stresses developed under dynamic condition are ultimate stress value. Therefore, design of mechanical motion rectifier is safe.

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