VIRTUAL DESIGN VERIFICATION OF MODULAR SPIKE SHAFT THROUGH SEMI-AUTOMATIC DIFFERENTIAL LOCKING FOR SUV

Jeevan Jathar[1] | Rahul Joshi[2]
[1](M.Tech Scholar, Mechanical Engineering Department, Swami Vivekanand College of Engineering, Indore)
[2](Asst Prof, Mechanical Engineering Department, Swami Vivekanand College of Engineering, Indore)

Abstract— *This paper presents theoretical calculation, CAE analysis and experiment validation on rig test of diff lock mechanism for easy shift select and positive locking. Bench test experiment has been carried out to correlate theoretical calculations and also virtual analysis which contents two cases one is with bench test 12 volt DC motors and second with actually off road vehicle torque data i.e. 60HP (Torque 80N-m) engine with five speed manual transmission and spiral design of crown wheel rear axle mechanism . This experiment has been done in order to achieve good performance in terms of smooth shifting and positive locking without failure of spike shaft. The diff lock concept refinement is done using theoretical iteration with spike shaft design. The performance prediction sheet has been developed. A range of performance analysis is done accordingly different road maps and gear application. The shear stress values are recorded; compared and plotted on the graph.. Thus the selected parameters are input into actual design to make it more realistic and safe spike shaft design.*

Keywords— SUV; CAE; FEA etc.,

1. INTRODUCTION

The differential is an important member of the automobile transmission system. The function of the differential is to distribute power equally to the driven wheels. The slip of differential which will prevent the vehicle from moving forward. In such cases an external assistance is required in form of pushing the vehicle or towing the vehicle. This becomes in convenient for the driver hence the need of differential locking arrangement is needed. Present solutions available in market are either too primitive where in the driver has to get down from the vehicle and then lock the differential or they are very sophisticated in the form of E-locker which is very costly to implement in commercial truck vehicles. So the objective of project is to design develop analysis , manufacturing and testing of a semi-automatic differential locking system which will be easy to install , low in cost and simple to operate . Testing will be done on the device by use of a test rig which will enable to find the performance of modular spike shaft locking mechanism in open condition and comparison will be done accordingly. This paper presents spike shaft locking mechanism and their design, FEA analysis and also experimental validation of differential lock in rear axle assembly for off-road vehicles. Experiment analysis was done to correlate theoretical calculations vs. CAE.

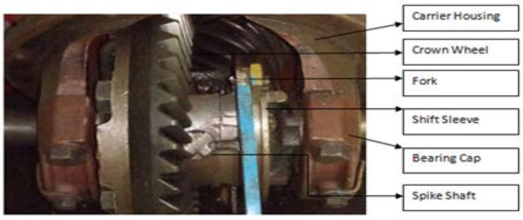


Figure 1: Shows diff lock mechanism with “SPIKE SHAFT “

A vehicle's wheels rotate at different speeds, mainly when turning corners. The differential is designed to drive a pair of wheels while allowing them to rotate at different speeds. In vehicles without a differential, both driving wheels are forced to rotate at the same speed, usually on a common axle driven by a simple chain-drive mechanism. When cornering, the inner wheel needs to travel a shorter distance than the outer wheel, so with no differential, the result is the inner wheel spinning and/or the outer wheel dragging, and this results in difficult and unpredictable handling, damage to tires and roads, and strain on the entire drive train.

Input torque is applied to the ring gear which turns the entire carrier. The carrier is connected to both the side gears only through the planet gear .Torque is transmitted to the side gears through the planet gear. The planet gear revolves around the axis of the carrier, driving the side gears. If the resistance at both wheels is equal, the planet gear revolves without spinning about its own axis, and both wheels turn at the same rate.

If the left side gear encounters resistance, the planet gear spins as well as revolving, allowing the left side gear to slow down, with an equal speeding up of the right side gear.

2. CAE VERIFICATION

Here, we did the design verification through CAE computation analysis. And used ANSYS R18.1 version for actual stress prediction at lower cross section as against demanded torqueing after locking the differential. We are completed 100% surface meshing by tetra, hexa or other tool parameter as shown in figure .Regards to boundary condition shaft having six degree of freedom but accordingly as our application we locked the rotational moment of shaft as shown in figure. Then we applied design overload torque on same shaft and observe what would be changes in that cross section. We found actual stress values on minimum cross section area but not crossing to permissible limit of considered material EN19 as shown in figures 7.

Case 1: CAE verification with torque of 12 volt DC motors.

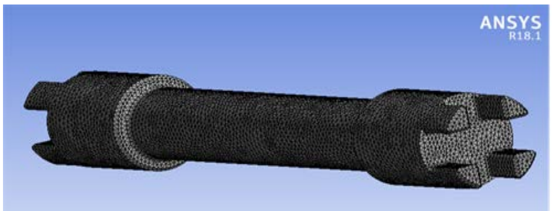


Figure 4: Shows meshing model of spike shaft

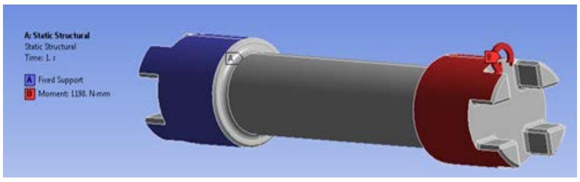


Figure 5: Shows applied boundary condition

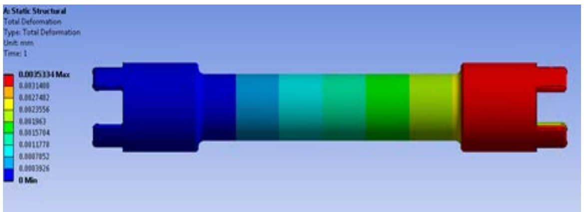


Figure 6: Shows total deflection

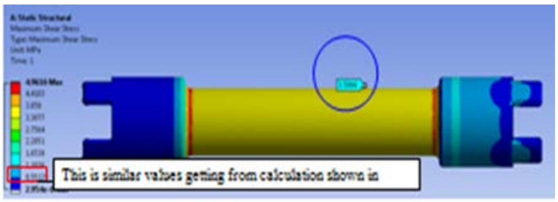


Figure 7: Shows shear stress

Case 2: CAE verification with actual torque values of off road vehicle (80Nm@2000rpm)

The duty cycle provided by customer is very severe, with maximum engine torque and speed.

The percentage of engine torque utilization considered for gears are as follows:

TABLE 1: SHOWS ACTUAL DUTY CYCLE OF OFF-ROAD VEHICLE.

Gear Mode	Max Engine torque N-m	Engine Torque Utilization N-m	Gear Ratios	Transmission Efficiency	100 % Torque Values N m	Max Engine Speed rpm	Speed in Gears rpm	% Utilization	Life Cycle in hrs	Hrs 100 %
1st	80	40	4.14	0.92	152	2000	483	0.1	10	0.01
2nd	80	48	3.52	0.92	155	2000	568	10	10	1.00
3rd	80	56	2.44	0.92	126	2000	820	20	10	2.00
4th	80	56	2.12	0.92	109	2000	943	30	10	3.00
5th	80	56	1.00	0.92	52	2000	2000	40	10	4.00
Rev	80	56	4.14	0.92	213	2000	483	0.1	10	0.01
								100		10.02

Here in CAE analysis we are applied the 100 % torque values and getting the results in shear stress values as shown in Figure 8, Table 2 and Graph 1.

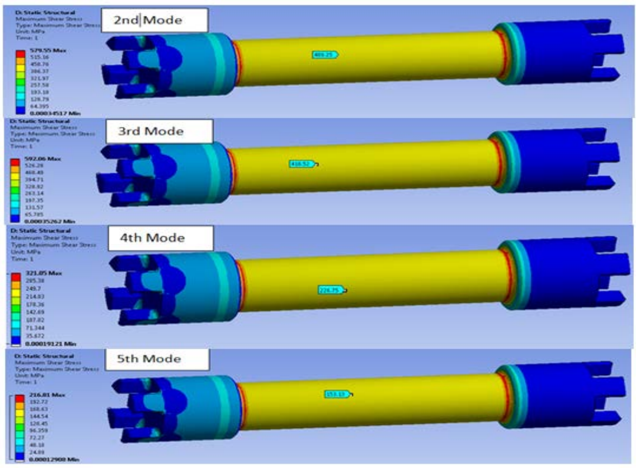
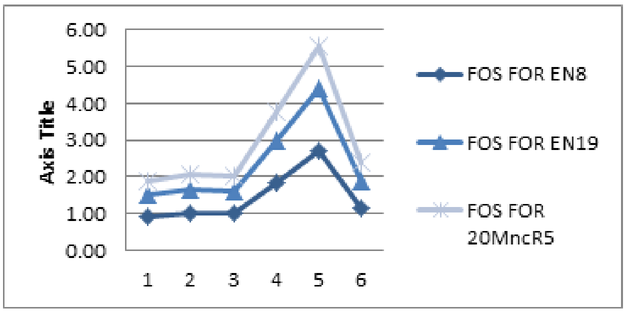


Figure 8: Shows CAE analysis report as per applied duty cycle torque

3. COMPARATIVE ANALYSIS

TABLE: 2 SHOWS SHEAR STRESS AND FOS DATA AS PER DIFFERENT MARTIAL AND APPLIED GEAR TORQUE

Sr. Nos.	Gear	100 % Torque values	Shear Stress N/mm^2 for EN8d	FOS	Shear Stress N/mm^2 for EN19	FOS	Shear Stress N/mm^2 for 20 Mncr 5	FOS
		Nm						
	Yield Strength		***415***		***675***		***850***	
1	Gear _ 1	152	448	0.93	448	1.51	448	1.90
2	Gear _ 2	155	409	1.01	409	1.65	409	2.08
3	Gear _ 3	126	418	0.99	418	1.61	418	2.03
4	Gear _ 4	109	226	1.84	226	2.99	226	3.76
5	Gear _ 5	52	153	2.71	153	4.41	153	5.56



Graph 1: Shows spike shaft FOS as per materials.

4. CONCLUSION

This simulation of spike shaft design getting similar results to CAE verification and theoretical calculation shows that shear stresses lowering from first mode (1st gear) to 5th mode (5th gear) and also changing the behavior of fatigue life for various mode and application .The minimum shear stress was occurs at high speed torque. First time by this methodology we are defined and verified virtual validation of torsional shear stress and suggest best suitability by this paper.

REFERENCE

[1] Giordani, G. and Fratta, C., "Light Commercial Vehicle with Locking Differential," SAE Technical Paper 2013-36-0467, 2013.

[2] Pinho, A. and Franco, C., "Studies on a Usage of a Limited Slip Differential Without Full Locking Features Compared to Open Type Differential and Traction Control in Mid-Size Truck - Drivers for Strategic Decision Balancing Technical Performance and Customer Perception," SAE Technical Paper 2015-36-0164, 2015.

[3] Hopkins, P. and Metz, L., "Oversteer/Understeer Characteristics of a Locked Differential," SAE Technical Paper 942485.

[4] Russo, R., Strano, S., and Terzo, M., "Yaw Moment Control of the Vehicle by Means of a Magneto rheological Semi-Active Differential," SAE Technical Paper 2015-24-2529, 2015

[5] Automotive transmission – G. lechner and H. Naunheim.