DESIGN AND FABRICATION OF VARIABLE RACK AND PINION STEERING GEOMETRY

R. Rajasekar*, T. Kathireshan, Rohit G Prasad, M. Pradhyumnan
Department of Automobile Engineering, Sathyabama University, Chennai, Tamilnadu, India;
***Corresponding author: Email: sekarauto@gmail.com**

ABSTRACT

This paper analyzes the feasibility of improving the steering behavior in traffic situations using variable steering geometry. The design and fabrication of rack and pinion has been done by using soildworks software. The objective of this paper is basically to design and manufacturing a variable rack and pinion with higher to lower ratio in order to sensitize the steering for better manoeuvrability for Indian road condition or urban road condition. A variable-ratio steering, is a system that uses different ratios on the rack, in a steering system. At the centre of the rack, the space between the teeth is smaller and the space becomes larger as the pinion moves down the rack. In the middle of the rack, you will have a sensitive ratio and the response becomes a-base as you turn the steering wheel towards lock. This makes the steering more sensitive, when the steering wheel is close to its centre position and makes it easier for the driver to steer at low speeds.

Keywords: Rack and Pinion, soildworks, steering geometry, sensitive ratio.

INTRODUCTION

A rack and pinion is commonly found in the steering mechanism of cars or other wheeled, steered vehicles. Rack and pinion provides a less efficient mechanical than other mechanisms such as recirculation, but less backlash and greater feedback, or steering "feel". Arthur Ernest Bishop invented the use of a variable rack (still using a normal pinion) in the 1970s, to improve vehicle response and steering "feel," especially at high speeds. He also created a low cost press forging process to manufacture the racks, eliminating the need to machine the gear teeth.

Generally, a steering system in modern vehicle either commercial or owned consists of a Rack and Pinion gear combination. Where the pinion is connected to the steering wheel through steering column and while rotation the steering the pinion is rotated which is in mesh with the rack which converts the rotational motion into linear motions which moves the wheels with various geometry and positioning of the steering unit. In India the cars are mostly found to be front wheel drive and with the arrangement with drive shafts it made the turning of the wheels limited.

Rack-and-pinion steering is quickly becoming the most common type of steering on cars, small trucks and SUVs. It is actually a simple mechanism. A rack-and-pinion gear set is enclosed in a metal tube, with each end of the rack protruding from the tube. A rod, called a tie rod, connects to each end of the rack.

Anatomy of Steering System: Conventional Rack and Pinion System in Modern cars use rack and pinion steering mechanisms, where the steering wheel turns the pinion gear; the pinion moves the rack, which is a linear gear that meshes with the pinion, converting circular motion into linear motion along the transverse axis of the car (side to side motion). This motion applies steering torque to the swivel pin ball joints that replaced previously used kingpins of the stub axle of the steered wheels via tie rods and a short lever arm called the steering arm. The rack and pinion design has the advantages of a large degree of feedback and direct steering "feel". A disadvantage is that it is not adjustable, so that when it does wear and develop lash, the only cure is replacement.

Design Process and Software: The engineering design process is the formulation of a plan to help an engineer build a product with a specified performance goal. This process involves a number of steps, and parts of the process may need to be repeated many times before production of a final product can begin. It is the component, or process to meet desired needs. It is a decision-making problem (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation. The engineering design process is a multi-step process including the research, conceptualization, feasibility assessment, establishing design requirements, preliminary design, detailed design, production planning and tool design, and finally production. The sections to follow are not necessarily steps in the engineering design process, for some tasks are completed at the same time as other tasks. This is just a general summary of each part of the engineering design process. Once an engineering issue is clearly defined, solutions must be identified. These solutions can be found by using ideation, or the mental process by which ideas are generated. The following are the most widely used techniques:

- Trigger word - a word or phrase run, swim, roll, etc. associated with the issue at hand is stated, and subsequent words and phrases are evoked. For example, to move something from one place to another may evoke.
- Morphological chart - independent design characteristics are listed in a chart, and different engineering solutions are proposed for each solution. Normally, a preliminary sketch and short report accompany the morphological chart.
- Synectics - the engineer imagines him or herself as the item and asks, "What would I do if I were the system?" This unconventional method of thinking may find a solution to the problem at hand.
- brainstorming - this popular method involves thinking of different ideas and adopting these ideas in some form as a solution to the problem

Parameter	Rack	Pinion
No. Of Teeth	24	06.
Length	140mm	26mm.
Diameter	20mm	19mm
Pressure Angle	30 deg.	Helix 70 deg.
Travel	147mm	504 Deg. OWC

Table.1.Data calculated for variable Rack and Pinion

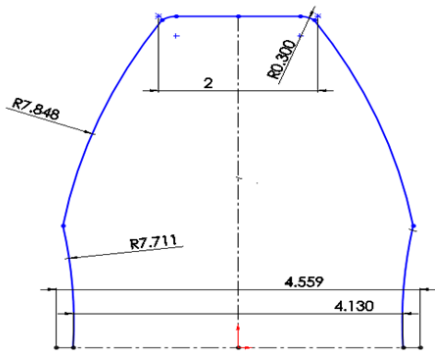


Figure.1.Gear front profile for Pinion drawn in Solid Works 2010. And Lewis curve was given for minimum hindrance and to withstand the force.

Rack Design: Table below presents the method for calculating the mesh of a rack and spur gear. Figure a, shows the pitch circle of a standard gear and the pitch line of the rack.

Table.2.Meshing of standard spur gear and Pinion

No.	Item	Symbol	Formula	Spur Gear	Rack
1	Module	m	----	3	3
2	Pressure Angle	α	----	30	30
3	Number of Teeth	z	---	12	24
4	Coefficient of Profile Shift	x	---	.6	--
5	Height of Pitch Line	H	---	--	32
6	Working Pressure Angle	αw	---		30
7	Center Distance	ax	Zm/2 + H + xm	51.800	51.800
8	Pitch Diameter	d	zm	36.00	--
9	Base Diameter	db	d cos α	33.829	--

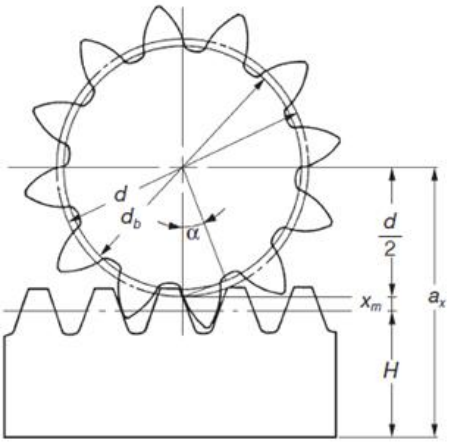
One rotation of the spur gear will displace the rack l one circumferential length of the gear's pitch circle, per the formula:

$$l = \pi mz$$

Figure 1, shows a profile shifted spur gear, with positive correction xm, meshed with a rack. The spur gear has a larger pitch radius than standard, by the amount xm. Also, the pitch line of the rack has shifted outward by the amount xm. Table presents the calculation of a meshed profile shifted spur gear and rack. If the correction factor x1 is 0, then it is the case of a standard gear meshed with the rack. The rack displacement, l, is not changed in any way by the profile shifting. Equation remains applicable for any amount of profile shift.

Rack Design Data:

Addendum, aw	234cm	Module	12
Dedendum, dw	195cm	T1 (Pinion)	6
Face Width, b	1.25cm	T2(Rack)	24
Thickness face	5mm	Dp1	20mm
Pressure angle	30 degrees	Dp2	80mm
		Phase shift	6



(N1/Dp1)=(N2/Dp2) = Pd.

Pd.=0.3

Gear Interference

$$T1 >= \frac{(2aw(1/T2)Pd)}{(\text{Sq. Root}\{1+(1/T2)((1/T2)+2)\sin^2(o)\}-1)}$$

T1>5.85 (T1=6)
Condition Satisfied

Figure.2.Meshing of Profile Shift Rack and Pinion.

RESULT AND DISCUSSION

Our project is basically to design and manufacturing a variable rack and pinion with higher to lower ratio in order to sensitize the steering for better maneuverability for Indian road condition or urban road condition. A variable-ratio steering, is a system that uses different ratios on the rack, in a rack and pinion steering system. At the center of the rack, the space between the teeth is smaller and the space becomes larger as the pinion moves down the rack. In the middle of the rack you'll have a higher ratio and the ratio becomes lower as you turn the steering wheel towards lock. This makes the steering less sensitive, when the steering wheel is close to its center position and makes it harder for the driver to over-steer at high speeds. As you turn the steering wheel towards lock, the wheels begins to react more to your steering input. A variable ratio steering mechanism for a vehicle having an axially movable rack meshing with a helical pinion the axis thereof making an angle with the axis of the said rack, the rack having a group of teeth at its center of varying form and varying inclinations with respect to the axis of the rack, the inclination of the teeth of said group becoming less closely aligned with the pinion axis as the teeth are more remote from the center of said rack, said teeth thereby meshing with the teeth of the pinion at varying effective pitch radii in a predetermined manner.

A general situation which could possibly explain the need for a more sensitive steering is as, in a hypothetical situation a person drive a car suddenly take a stop against a traffic signal and as a metro city traffic the vehicles are mostly drive very close to each other a.k.a bumper to bumper. And in this situation the vehicle in front has a sudden break down or he was supposed to go other way and now he is stop in between the traffic and the person behind is now out of any choice, he cannot go reverse or has the space to take a cut. The reason behind is the wheel track i.e width and the steering sensitivity which doesn't allow him to take measures in so close situation and mostly a public car has a standard turning radius around 3.8 to 4.5 meters depending upon the TW and WB of the vehicle. Hence, we arrive at a conclusion that there is a need of more responsive and low turning radius in the vehicle which would help escape from the close parking the traffic situations as provided in the situation above.

CONCLUSION

The objective of designing and manufacturing a variable rack and pinion steering system was performed successfully and various Ackermann's Geometry adjustments were also verified with the mostly possible steering sensitivity and minimized turning radius. And the different dynamic changes were incorporated and camber gain and stability was improved.

REFERENCES

Alexandru P, The design of the pinion-rack steering gear with variable ratio. 10th International Conference TMT 2006, University Politehnica Catalanya, 2006, 753-756.
Alexandru, P., Ceausescu, B., Diaconescu, D. - Important aspects of geometry of the pinion-rack gear with variable ratio: 8th Symposium IFToMM-SYROM'01, University Politehnica Bucharest, vol. III, pg. 12-18, 2001, Bucharest.
ASTM E-1316, Standard Terminology for Non-destructive Examinations, The American Society for Testing and Materials, in Volume 03.03 NDT, 1997.
Aurthor Bishor, US Patent (US 3753378 A), 1971.
Dean Karnopp, Vehicle Dynamics and Stability Dordrecht: ISBN 978-94-017-8532-7, 65-235, Handling, Braking, and Ride of Road, Race Cars.