Optimum Sprocket Ratio for vehicle based on Modelling and Simulation

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***Abstract*— Now a days in world, best performance of vehicle depends on one of the factor that is Optimum Sprocket ratio. The optimum Sprocket ratio for Vehicle (Formula student car) can be find out from the tire data analysis and simulation. The desirable sprocket ratio will give the maximum speed and maximum torque .In this paper, range of longitudinal force has been chosen as objective function to be maximized and for that purpose the tire data simulation has been made also Simscape (Simulink) is used for the simulation of sprocket ratio. From that simulation we have fitted curve to the data points of sprocket ratio and Velocity to have function of it. Simulation is the imitation of the operation of a real-world process.**

***Keywords*— Sprocket ratio (SR) , Slip ratio (S_r) Longitudinal force (F_x), Simulation (simscape), Curve fitting.**

I. Introduction

Sprockets are most widely used in automobile sector and in machinery. A sprocket or sprocket-wheel is a profiled wheel with teeth that meshes with a chain .To have high horse power , torque and less lap time the Optimum sprocket ratio is designed from the variable parameters that are longitudinal force (F_x), engine torque (T),gear position(1^{st} ,2^{nd} ,3^{rd} …). **.** The gears in transmission are torque multipliers, and the final-drive ratio of countershaft and rear sprockets also have an effect on torque. Changing the final-drive ratio is one of the easiest ways to achieve top speed of vehicle. In this paper the analysis of sprocket ratio is done on zero inclination angles. The way of getting the sprocket ratio is to balance the torque available at rear sprocket and at the tire (traction) **.**If the sprocket ratio is oversized then initially the torque(pick up) will be more but speed gain is less and vice versa .Sprocket ratio is calculated for different 4 gear ratios with same value of longitudinal force (F_x) and engine torque(T).The number of data points are collected by changing the longitudinal force (F_x) and torque and this all data points of sprocket ratio are simulated on matlab software by using simscape .

Several research works have been done on optimization, but out of this very few literatures available on optimization of sprocket ratio. Milliken[1] described optimization procedure for longitudinal force (F_x) and slip ratio (S_r) by using non dimensional method. Chapra[2] described numerical method to fit the curve.

TABLE I
TRANSMISSION DATA

Gear Position	Gear Ratio
First Gear(1^{st})	12:32
Second Gear(2^{nd})	14:26
Third Gear(3^{rd})	19:27
Fourth Gear(4^{th})	21:24
Primary Reduction(P_r)	12:32

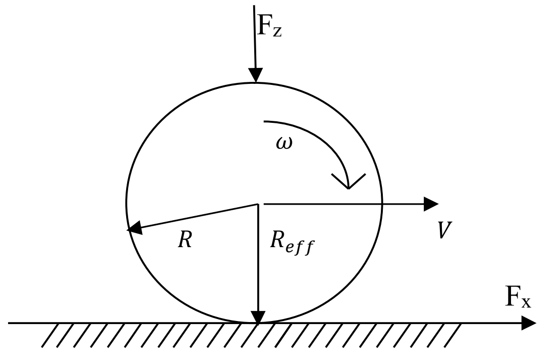

Fig. 1 Rolling tire

The tire is rolling on a good traction surface which is shown in Figure 1, tire is not a rigid body because it is made up of rubber material (polymer) which is deformable hence at the point of contact radius of tire is different due to the normal load on tire. The longitudinal force is in the direction of motion of tire because of driven wheel (tire).

F_z = Normal Load on driven wheel (weight distribution on front wheel and rear wheel).
F_x = Longitudinal Force on tire.
V = Centre point Velocity of tire (Vehicle Velocity) .
SR = Sprocket Ratio
ω = Angular Velocity.
R = Radius of tire (natural radius without deformation).
R_{eff} = Effective radius of tire.
S_r = Slip ratio

$$S_r = \left(R_{eff} \times \omega - V\right)/V \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

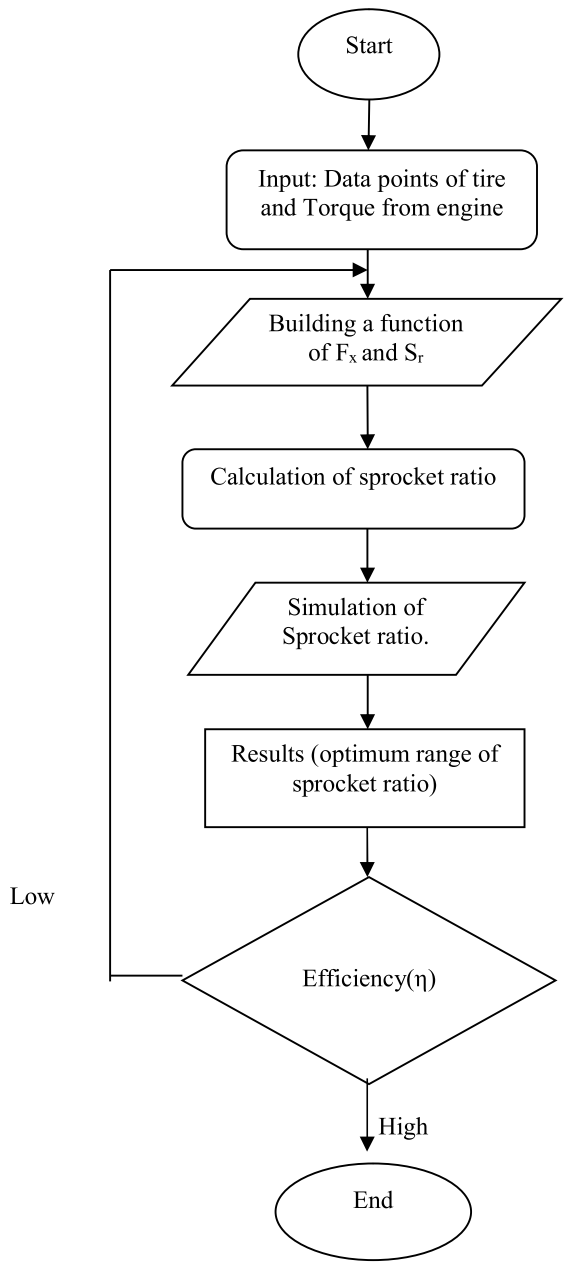

Fig. 2 Flow chart of designing of sprocket ratio

II. RESULT ANALYSIS

A. Longitudinal Force Vs Slip ratio

The tire is tested on machine from that testing, we have 65000 tested tire data points sheet consist of normal load (F_z), longitudinal Force(F_x),lateral force (F_y), inclination angle(IA) ,pressure of tire(P), velocity(v),slip ratio(S_r) and Slip angle etc. From this we have sorted out the data points of longitudinal force and slip ratio for normal load (F_z)=150 N and Inclination angle (IA) =0 for this data points we have fitted the curve with the polynomial equation in matlab. Figure (3) shows the curve fitted to sorted data points from 0 to 0.05 slip ratio. This will give the function of longitudinal force (F_x)and slip ratio(S_r).

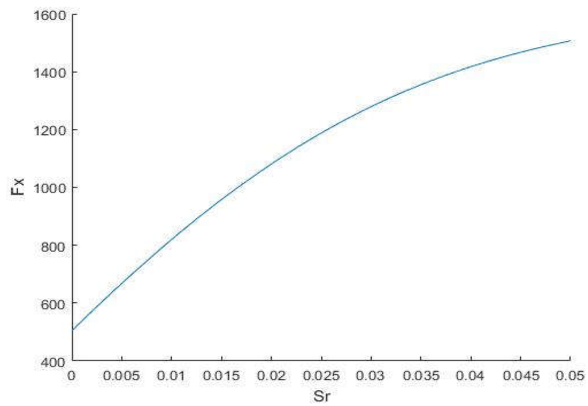

Fig. 3 Function of F_x and S_r

B. Sprocket Ratio Vs Longitudinal force

We calculated the sprocket ratio with the help of equation (2)

$T_{engine} \times T_{gear} \times P_r \times SR = F_x \times R_{eff}$……………………..(2)

Sprocket ratio (SR) is calculated for the variable parameters T_{engine} ,T_{gear} and F_x in matlab. We have T_{engine}, for 2000 to 10000 range of rpm from the software , P_r is the primary reduction having a constant value, sprocket ratio is calculated for 4 different gear ratio ref table (1) and we have the function of F_x and S_r as discussed above

TABLE II: ENGINE DATA

T_{engine}(N/m)	Engine speed (RPM)
37	2000
35	2500
36	3000
34	3500
33.5	4000
33	4500
33	5000
32	5500
31	6000
31	6500
29	7000
25	7500
23	8000
20	8500
18	9000
15	9500
13	10000

On the basis of above equation we are plotted the graph of SR vs F_x. In this figure (4) the four different curves are for four different gears as shown in table no.II

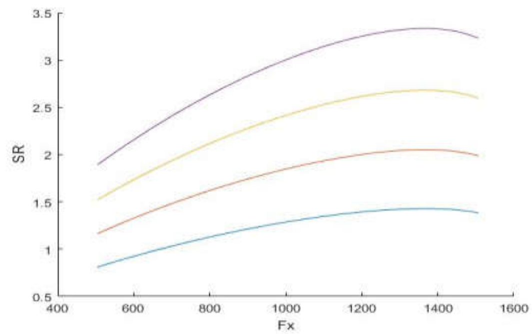

Fig. 4 Function of F_x and SR

C. Simulation Process

The power train model (Transmission) which is built in Matlab simscape(simulink). From this model the different range of sprocket ratios are being simulated to get optimum sprocket ratio .Simulation time for all sprocket ratios range is 5 sec .In this model all physical component are used like Engine block, torque convertor, gear, clutch, Vehicle body and tire model etc. First we have to provide input to the engine block i.e driver input like throttle , gear position etc. The power is transmitted to the gear box through torque convertor. Manual Gear box is designed with the help of dog clutch and gear. The torque is transmitted to the tire model through sprocket ratio, then depending on torque transmitted the velocity of vehicle can be estimated from the vehicle body block and that can be seen in scope block which is connected to vehicle body.

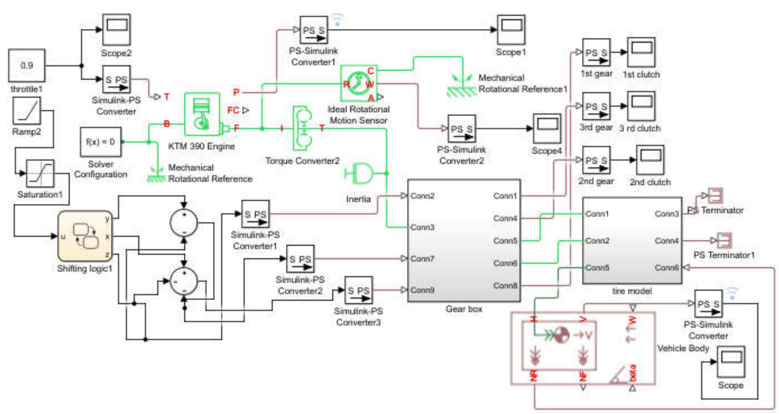

Fig. 5 Simscape model

TABLE III:TESTED DATA POINTS

Sr. No.	Sprocket Ratio(SR)	Velocity(V)	Sr. No	Sprocket Ratio(SR)	Velocity(V)
1	1.15	7.83	7	2.05	8.88
2	1.24	8.05	8	2.26	8.85
3	1.34	8.31	9	2.41	8.83
4	1.42	8.44	10	2.66	8.66
5	1.5	8.56	11	2.91	8.55
6	1.7	8.6	12	3.02	8.51

From tested data points (table no.III) the graph is plotted as shown in figure(6) ,from that nature of graph it shows that as sprocket ratio increases the velocity increases but as long as sprocket ratio increases the velocity starts decreasing. From the graph 2 to 2.5 range of sprocket ratio is optimum range of sprocket ratio which will give nearly same velocity.To get velocity at any sprocket ratio the curve is fitted to data points by using least square method. By using this method the curve is fitted .

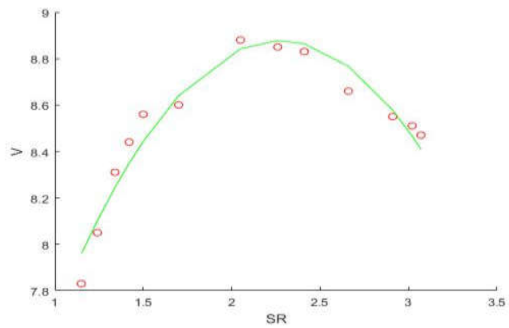

Fig. 6 Curve fit

$V = C_1 + C_2 \times SR + C_3 \times SR^2$…………...(3)
C_1= 5.1045 ,C_2= 3.3242 and C_3= -0.7321 these are the coefficient of curve fitted equation (3)

III. Conclusions

In present paper, procedure for optimum design of sprocket ratio has been proposed. The Intermediate range of longitudinal force and slip ratio has been taken the objective function. The sprocket ratio design has been optimized using modeling and simulation. For each sprocket ratio the velocities are obtained from the simulation. For high velocity i.e less lap time can help in efficient designs of sprocket ratio to have both better pickup and velocity.

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