

Perceptible Roll

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ABSTRACT

In case of design of passenger vehicles, one of the priorities is how the dynamics behavior shall be perceived by the vehicle occupants. One of many such handling parameters is the vehicle body roll, which is usually quantified by the vehicle's Steady State Roll Gradient. This number gives an indication of the rotation of the vehicle body in response to unit lateral force acting on the vehicle, as in the case of cornering. However it does not necessarily indicate the roll as sensed by a person seated inside it.

A study showed that the subjective feel is not entirely dependent on roll gradient. In some cases the occupant may feel more confident and comfortable in a vehicle with a relatively higher roll gradient, or vice versa. In such cases, designing for roll gradient alone may not serve the purpose of secure and comfortable feel. To account for this discrepancy, a study was carried out to quantify the motion felt by the occupant.

It was found that the seating position is a vital element influencing the sensation generated by the rolling motion. Incorporating the same, the already established roll gradient was augmented and the term "Perceptible Roll" was defined. The results were compared to subjective ratings for the same vehicles and were found to have a much better correlation. The parameter gives an accurate index for the magnitude of motion felt by the occupant, thereby giving a better quantification for the discomfort generated as a result of body roll. The same has been detailed in the following work.

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INTRODUCTION

Vehicle body roll denotes how much the vehicle rotates about its VCS X-axis in response to a lateral force acting upon its center of gravity, as in the case while going about a turn. To account for this degree of freedom, a parameter "Steady State Roll Gradient" is defined. In simple terms it is the roll angle acquired by the vehicle before attaining steady state while acted upon by a lateral force of 1 g, and hence usually has the unit deg/g. This number is a generally established means to quantify vehicle roll behavior.

The roll gradient aptly objectifies the roll motion of the vehicle body as a whole. The vehicles are designed and tuned as per targeted roll gradient values that are decided as per the market trend and competition, as well as safety in mind. However, in spite of achieving these targets, the general feedback received from evaluators as well as customers was that Tata Motors vehicles were felt to have more body roll than other vehicles in the same segment. This was in spite of having the roll gradient figures in line with benchmarks. To investigate this issue, a study was carried out wherein the perceived body roll of a number of vehicles was asked to be subjectively evaluated. This subjective evaluation was then compared to the measured roll gradient of those vehicles. Though the general trend was as expected, there were certain cases which deviated from the norm. For example, in some cases, cars with higher roll gradient could score better in subjective assessment than those with a lower

roll gradient. This indicated that roll gradient alone is not enough to predict the subjective feel of the body roll of a vehicle. A metric that could better quantify this subjective roll feel was required.

A study was carried out to find the reason behind the discrepancy. A theory was proposed that apart from the roll gradient, seating position of the occupant could play an important role in the perception of the roll motion, since the motion of the person would be more of an arc of a circle, the length of which would depend on the radius of rotation. It is obvious that a person undergoing more movement would be more unnerved than a person having lesser movement. Hence, a calculation was carried out theoretically to quantify the amount of motion that the seating point, and consequently the seated person, would undergo for the given body roll. It was speculated that the subjective feel would depend on this quantity. The quantity was tentatively named the "Perceptible Roll Index". To verify the theory, the perceptible roll indices of each of the tested vehicles were calculated using their driver H-point co-ordinates and the measured roll gradient values. This was compared against the respective subjective ratings to observe the trend just like it was done in the previous analysis. The perceptible roll index values were found to match the subjective ratings of the tested vehicles. This augmentation of roll gradient value corrected the deviations from the trend observed using roll gradient alone and the theory was thus verified.

NEED AND INITIAL STUDY

Cases were observed where the subjective roll behavior feedback would not agree with the measured roll gradient of the same vehicle. To find out the reason, a study was carried out wherein 14 vehicles were taken across segments. The roll gradients of these cars were measured and their roll behaviors were subjectively evaluated. The figures were then compared to find whether the subjective ratings matched with the roll gradient values. The measurement techniques used were as follows -

For roll gradient, the constant radius (33 m) Steady State Circular Test [1] was carried out on the test vehicles. The roll angle of the body along with lateral acceleration is recorded and plotted. The slope of the plot gives the roll gradient of the vehicle in unit deg/g. The subjective rating is given as an average of the ratings given by the evaluation jury on a scale of 1-10 as per SAE standard for subjective handling evaluation.[2] Note that the evaluation carried out in this case is for the intensity of roll perceived, not the roll damping or after-roll stability.

Table 1. Subjective evaluation scale

1-2	not acceptable
3-4	poor
5	borderline
6	acceptable
7	fair
8	good
9	very good
10	excellent

Observations

Table 2 shows the consolidation of the test results for the test vehicles. To see the trend, the roll gradient is plotted against subjective rating for the given vehicles in figure 1.

It is observed that even though the line has a negative slope as expected, there are certain aberrations that disturb the trend of the line. For example, vehicles C, D, E having markedly different roll gradients have the same subjective rating. Vehicle H has high roll gradient, yet the subjective rating allotted is also high. Vehicles I and J having much lesser roll gradient have the same rating. In short, just roll gradient is not enough information to predict the subjective perception of the vehicle.

Due to these discrepancies, it was clear that designing for roll gradient alone cannot guarantee a good roll perception. It was required to get a better quantification of the roll feel by developing better correlation with subjective perception of the body roll. An analytical study was carried out to find the missing element.

Table 2. Vehicles in increasing order of allotted subjective ratings and the respective measured roll gradient values.

Vehicle	Subjective rating	Roll Gradient (deg/g)
A	4	8.95
B	6	6.37
C	7	5.87
D	7	6.02
E	7	6.53
F	7.5	5.26
G	7.5	5.33
H	8	6.92
I	8	5.99
J	8	4.92
K	8.5	4.8
L	9	4.99
M	9	5.03
N	9	4.18

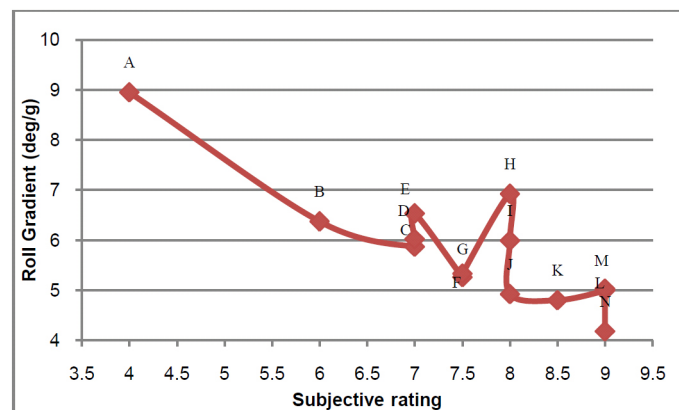


Figure 1. Plot of measured roll gradient against subjective rating of the tested vehicles.

THEORY

It was theorized that the seating position may play a crucial role in the perception of the rotational motion, as the motion felt by the occupant is more like an arc of a circle. The length of the arc is directly proportional to the radius of rotation. So, the idea is to incorporate the seating location in the roll gradient, thereby finding the rotational arm of the point and calculate the translational motion covered by that point using basic trigonometry. It was speculated that the roll experience would be dependent on the length of this arc of movement.

The simple principle is that as a point goes farther away from the axis of rotation, it will have to cover more distance for the same rotational angle, as given by the trigonometric equation below -