TOOL TO DETERMINE VEHICLE GROUND LINES

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ABSTRACT

Before completing the design of a car, the ground lines position must be determined to determine the other position and design of part of a car. The ground lines consist of three lines which is the curb line, design line and the Gross Vehicle Weight line (GVW). The ground lines position is essential to be determined at the beginning of a project due to the influence on design and styling. The first method of determining the position of the ground lines is to identify and research on the factors that need to be analyze first before the position of the ground lines is obtained. These factors are used to calculate the ground lines position. The existing of program will assist the design engineers' team to calculate the ground lines position faster and save time to calculate the ground lines position. The formulation is then modelled in Microsoft Visual Studio.net to build a program that will function as a tool to calculate the vehicle ground lines position. The data to test the formulation for this project was taken from the Proton Persona 1.6. The result obtained was then compared with the real published data to check the accuracy of the ground lines calculation program. Then the obtained ground clearance from this program is compared with the data from the Proton Persona 1.6 brochure. After the comparison, the program is proved to be sufficient to estimate the ground lines position.

ABSTRAK

Sebelum sesebuah lakaran kenderaan siap sepenuhnya, kedudukan garisan tanah daripada kenderaan perlu ditentukan untuk menentukan kedudukan dan spesifikasi bahagian lain kenderaan. Garisan tanah ini terdiri daripada tiga garisan iaitu pada keadaan berat asas tanpa penumpang, berat lakaran dan berat maksimum dengan penumpang. Kedudukan ini penting untuk ditentukan pada awal projek lakaran kerana ia member impak kepada lakaran dan pengayaan kenderaan. Langkah pertama bagi menentukan kedudukan ini adalah dengan mengenal pasti dan mengkaji fakor-faktor yg digunakan dalam menentukan kedudukan garisan tanah. Faktor-faktor tersebut ditentukan menggunakan formula yang sedia ada. Dengan adanya alat bagi membantu jurutera menentukan kedudukan garisan tanah kenderaan, proses rekaan kenderaan akan menjadi lebih cepat. Formula-formula bagi menentukan garisan tanah ini kemudian diprogramkan ke dalam perisian Microsoft Visual Studio.net bagi menghasilkan program yang akan menjadi alat bagi mengira kedudukan garisan-garisan tanah kenderaan. Data-data yang digunakan sebagai contoh pengiraan dalam program ini ialah data daripada kereta Proton Persona 1.6. Program ini kemudiannya dibandingkan dengan data sebenar yang menggunakan pengiraan manual untuk menentukan ketepatan program yang dibina. Jarak antara tanah dengan bahagian bawah kenderaan yang diperolehi daripada kedudukan garisan-garisan tanah dari program ini kemudiannya dibandingkan dengan jarak yang dicetak pada risalah Proton Persona 1.6 tersebut. Setelah dibandingkan, program yang dibina terbukti boleh digunakan bagi menentukan kedudukan garisan-garisan tanah kenderaan.

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 METHODOLOGY

LIST OF FIGURES

LIST OF SYMBOL

%	Percentage
$\emptyset_{rim}$	Rim diameter

LIST OF ABBREVIATION

GVW	Gross Vehicle Weight
FR	Front wheel
RR	Rear wheel
SLR	Static loaded radius
d	Design overall diameter
M_{cf}	Front curb weight
M_{cr}	Rear curb weight
M_{df}	Front design weight
M_{dr}	Rear design weight
M_{vf}	Front GVW weight
M_{vr}`	Rear GVW weight
Rs	Theoretical static loaded radius

CHAPTER 1

INTRODUCTION

1.0 PROJECT BACKGROUND

In vehicle design, there are several stages or procedures that are followed by car designer. First stage is the sketching. This stage is to determine the design of vehicle to be selected for production. After the approval from the car manufacturer, the design is proceed to next stage which is to produce the detail drawing for the model. The detail drawing consists of two types of drawing which are layout drawings and part drawings.

Part drawing is a drawing of a single part with larger design. Part drawings tell the detail for component such as the specification of the parts. It usually has an assigned number called part number. The part drawing should have completely sufficient to have someone to manufacture the part. Using the car analogy, the button one would press to open the door on a car would be a single part. This button will have a drawing of its own, and the button will have a part number and be manufactured as discreet item.

Layout drawing is a special drawing that often is a master of the released drawing. Layout drawings determined the location and general layout of that component. This is where all the components are shown in the context of the entire design to basically figure how things fit. In general layout drawing, ground lines are included to estimate the ground clearance. With accurate ground lines, delay and technical error related to ground clearance can be reduced.

The ground lines consist of three lines (see Fig. 1) which is curb line that shows the position of the vehicle from ground with no passenger and driver and with full fuel tank and no luggage. Second line is the design line for two people which are the driver and one passenger with full fuel tank and no luggage. The third line is the GVW line for a driver and four passengers with full fuel tank and maximum luggage. The weight of luggage, people in the car and the weight distribution of the car are determined by the manufacturer according to their sales planning.

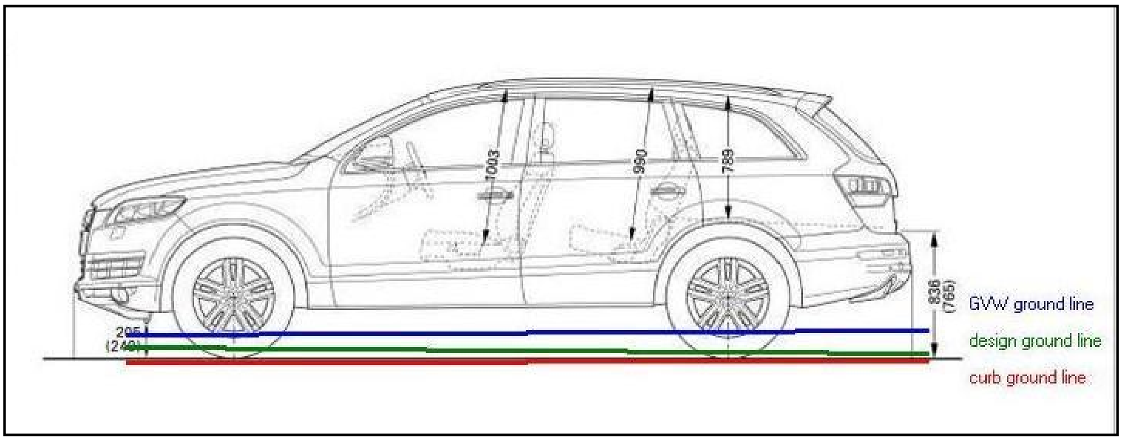

Figure 1.1: Locations of ground lines

1.1 PROBLEM STATEMENT

The ground lines are determined to estimate the ground clearance of the car. The inaccurate ground lines will result an error occur in design stage. Complication in design stage related to inaccurate ground lines are such as unsuitable clearance from under floor components to the ground. For example, if the ground clearance is too low, the under floor components such as the muffler will be too close to the ground and will hit the ground if the car hit a bump. This will caused damage on the component.

The problem can be rectifying just by simply making an adjustment to the suspension. But in reality of the mass production of a car, this problem will cause more problems to the company. Adjustment to suspension will cause delay on launching due to need for discussing with vendor to change the specification of the suspension and testing the suspension again before changing or alteration is made.

The delay in launching will caused the company to suffer financial loss. For example if two models from two different companies were to launch on a same date, the one that can launch their product in time will attract more customer. The marketing strategy of the model that is delayed needed to be change and the company still suffers financial loss.

Thus, the good design of ground lines will minimize the problems after design stage. With accurate ground lines will produce good ground clearance and the above problem can be avoided. In industry, there is still no tool in calculating the ground lines position. The engineer only calculated by hand. The existing of a tool to calculate the position will reduce the production time.

1.2 OBJECTIVE

The objective of this project is to determine the position of ground lines for new vehicle development. Next is to analyze the method and formulas to calculate the position. The factors that involve in determining the positions such as wheelbase, weight distribution of car, centre of gravity and tyre size needs to be analyzed. The formulation is then developed to be a tool for calculating the ground lines. For this project, it is very hard to find the information regarding the ground lines calculation. There are no specific formulas or research on determining the ground lines position. The positions are determined by the car manufacturer design engineer and the formulas are kept in the company only.

1.3 SCOPE

The scope of this project is to study the parameters that determine the ground lines position. All the parameters that involve in determining the ground lines position will be study. Next is to study the formulation used to determine the ground lines position. The formulations that are used in determining all the parameters to calculate the ground lines position will be studied.

CHAPTER 2

LITERATURE REVIEW

2.1 THE WEIGHT

The data that is needed for creating ground clearance layout are weight on front and rear axle, given at Curb, Design and Gross Vehicle Weight. If the curb weight is unknown, one has to estimate the weight and the weight distribution. The curb weight can be difficult to estimate, but initial vehicle concept should provide information of target vehicle weight. When the curb weight is establish, the design weight and the GVW can be calculated. (Tim Gilles, 2005)

The gross vehicle weight rating (GVWR) is the single most important information that the truck manufacturer provides its’ customer. It is the maximum design weight of the vehicle. This includes its’ payload, the occupants, and the weight of the vehicle itself. This weight should not be exceeded. Note that for many trucks the GVWR is less than the sum of its’ individual Gross Axle Weight Ratings (GAWR). Be careful! In these cases you can be within the limits of the GAWRs but exceed the load capacity of the vehicle. This is because the weight ratings take into account the load capacity of a variety of components, including the tires, suspension and frame. Any one of these, or other factors, may limit the weight rating. (Sheatev, 1998)

2.2 THE WEIGHT DISTRIBUTION

The weight distribution is also necessary to continue. A rule of thumb is that a front wheel driven car will have 60-63% of the curb weight on the front axle. Taking an estimation of the weight distribution of 60/40, 60% of the weight on front axle and 40% on rear axle are acceptable. (Chilton Class Journal Co, 1972)

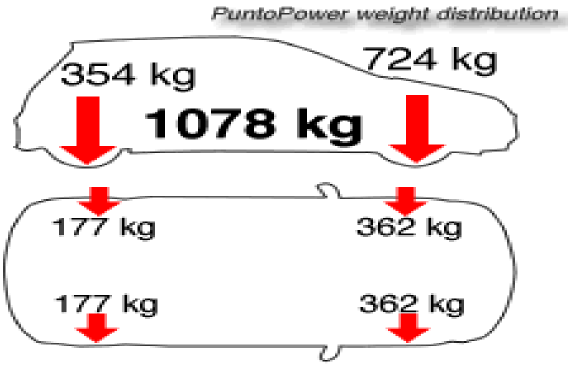

Figure 2.1: The weight distribution of Fiat Punto

2.3 CENTRE OF GRAVITY

To calculate the centre of gravity of a car, there are three parameters that need to be determined. First is the longitudinal distance from the centre line of front axle. Second is the transverse distance from the vertical symmetry plane of the vehicle (±***e***).This eccentricity (***e***) is positive, if CG is closer to the service door side and negative if it is farther. The third parameters are vertical distance (height) above the horizontal ground level (***h***) when the tyres are inflated as specified for the vehicle.(Ciotti, 2000). The CG position shall be determined by measurements which are the longitudinal (***l1***) and transverse (***e***) parameters with a measurement on flat, horizontal ground.

There are two options to determine the CG'-s height (h) which are lifting method and lilting method.

To determination of the longitudinal and transverse position of CG. Using the measured and calculated load parameters, as wall as the given geometrical values of the vehicle.

Calculate CG's longitudinal position accordingly:

$$I_1 = L_{23}\left(\frac{A_3}{M_k}\right) + L_{12}\left(1 - \frac{A_1}{M_k}\right)$$

Calculate CG's transverse position accordingly:

$$e = b\left(\frac{1}{2} - \frac{S_L}{M_k}\right)$$

Where b is the average track of the axles, if b1, b2 and b3 is track of the first, second and third axle

$$b = \frac{1}{3}(b_1 + b_2 + b_3)$$

2.3.1 Lifting test to determine CG's height

Lifting shall be done by both sides, both wheels of the second axle (e.g. by crane) in vertical direction. The spring system of the lifted axle should be sustained and the wheels of the first axle should be chocked. The lifting height (m) have to result a lifting angle (β) between 15^o-20^o. To ensure this lifting angle either a ditch should be used, or the front axle should be in an elevated position to overcome the limitation of the front angle of approach

Reaching the required lifting height the vehicle shall be held constantly in this position and the following values have to be measured:

- exact lifting height (*m*) measured at the centre of the lifted axle wheels
- vertical lifting load (*A*2*)
- vertical supporting axle load at the front axle (*A*1*)

Control the measured loads, the sum of them shall be equal to the unladen, kerb mass:

$$A*_1 + A*_2 = M_k$$

Calculate the exact lifting angle accordingly:

$$\beta = \arcsin\left(\frac{m}{L_{12}}\right)$$

Calculate CG’s height accordingly:

$$h = r + h_1 = r + \left(I_1 - L_{12}\frac{A*_2}{M_k}\right)\frac{1}{tg\beta}$$

Where r is the static rolling radius of the front wheels when they are inflated as specified.

2.3.2 Tilting test to determine CG’s height

The vehicle shall be placed parallel to the tilting axis on the tilting platform. The wheels should be supported against side slip. Three side supporting frames with padded heads should be applied to avoid rollover. The distances between the padded heads and the side wall of the vehicle should be equal and in the range of 60-100 when the vehicle stands on the horizontal tilting platform. All axles of the vehicle should be fixed, the spring system blocked

The tilting shall be done very slowly, until the unstable position of the vehicle. This position is reached, when the wheels on one side do not touch the tilting platform anymore, the side supporting load on that side is zero, the side wall of the vehicle touches the padded heads of the side supporting frames and measure precisely the tilting angle ($\boldsymbol{\alpha}$) of the unstable position. Three measurements have to be carried out independently and the average value of the three tilting angle should be used for the calculation of CG's height.

Tilting test shall be made on both directions determining two tilting angles: left side αl and right side αr. Calculate heights accordingly to both directions:

$$h_i = \frac{b \pm 2e}{2tg\alpha_i}$$

Where αi and hi mean the appropriate values of the left and right side tilting test. Calculate the CG'-s height:

$$h = \frac{h_I + h_r}{2}$$

2.4 TYRE SELECTION

To choose a tire program for a new car is usually difficult due to the number of parties involved such as market, styling and engineering. The only requirement that needs to be taken in consideration is that the tyre is not to be loaded more than 85% of its tyre load capacity. The tyre manufacturer will not allow their product to be used if they know the load is exceeding the 85%. The tyre chose must fulfill the legal requirement and fit inside wheel house.

Selecting the proper tire size, load range and design is very important to insure satisfactory performance. The best guide is to follow past experience and use the advice of professionals who are familiar with the types of tires used in service conditions similar to yours. Goodyear representatives are trained to aid you in this important decision. The following will provide basic guidelines for proper tire selection. The process of determining which tire to select for a particular job or operation may sometimes seem difficult or complex. Indeed, the proper selection involves a myriad of decisions concerning the size, the type, and the tread design of the tire based upon the intended application. Other considerations are the manufacturer of the tire, the tire dealer, price, availability, and the warranty coverage which comes with the product. However, there is a logical method for selecting which kind of tire would be most appropriate depending upon an assessment of the many considerations surrounding the fleet operation.

2.5 SUSPENSION DESIGN

2.5.1 Rear Suspension Systems

Designers have traditionally invested a great deal of effort in front suspension design. Often, the rear axle was simply hung in place and the driving was left to the front. Things have changed in the last couple of decades. Rear suspension design has become just as sophisticated as the front. In fact, the design variations are probably greater at the rear. Rear suspension systems can be divided into three basic categories.

2.5.1.1 Dead Rear Axle

The dead rear axle comes in a variety of configurations. Every layout of the powered rear suspension system becomes a dead axle layout when power is not transferred to the wheels. The rear wheels are not considered as steering wheels. As a result, even the beam axle is a more docile layout when the axle is used at the rear in an unpowered configuration. The most popular dead rear axles include the beam axle and the trailing arm and semi-trailing arm suspensions.

2.5.1.2 One-Piece Live Axle

The live rear axle is similar to the beam front axle or the dead rear axle, except that it is subjected to the torsional loads involved in transmitting power to the road. The design is rugged, simple, and relatively inexpensive, but its high unsprung weight results in a poor ride. The rear axle is not involved in steering so the disadvantages are somewhat less troublesome than those experienced with the beam front axle. However, unsprung weight is very high and as a result the design produces a rougher ride and is very susceptible to wheel hop and tramp.

The traditional live axle of older American cars is the Hotchkiss drive. The Hotchkiss drive is distinguished by its semi-elliptical leaf springs that also serve as the suspension links. Difficulties with the Hotchkiss drive have to do with its limited ability to transfer torque, its high interleaf friction and high unsprung weight, and the imprecise location of the rear axle assembly. Consequently, it is difficult to achieve a good ride and to appropriately manage the torsional loads of braking and power transfer. Braking and acceleration transfer high torsional loads to the axle, which can rotate off plane due to the flexibility of the springs.

2.5.1.3 The Swing Axle

Ride and handling are greatly improved when the wheels can respond independently to disturbances. The swing axle design is the simplest way of achieving an independent rear suspension. Its simple design utilizing the drive axle as the transverse link and the inboard universal joints as the suspension axis was responsible for its early attractiveness. With swing axles a disturbance on one side is not transferred to the opposite wheel as it is with a solid axle. Ride and handling are therefore improved. The first swing-axle design to gain wide popularity in the U.S. was the immortal VW Beetle. When the Beetle was introduced into the U.S., its fully independent suspension system represented a significant step forward in suspension design. However, swing axles do suffer from characteristic limitations and as a result the design is rarely used on modern cars.

Swing-axles produce large changes in camber and tread during bounce, and the design can become unstable in turns due to the "jacking" effect. Setting the wheels at a negative camber can reduce the tendency to jack. However, too much negative camber can also produce a vehicle with a vague, mushy feel of directional instability. Slings under the axles or zee brackets can be designed to limit downward travel and thereby avoid wheel tuck-under. A correctly designed swing axle suspension works reasonably well, but its undesirable characteristics can never be fully overcome.

2.5.2 Front Suspension Systems

The two types of front suspension systems that account for nearly all vehicles in production today are the double A-arm and the MacPherson strut. There are also a few variations that have not worked well in large-car applications, but may offer new possibilities with low mass vehicles.

2.5.2.1 The Double A-Arm Suspension System

The upper and lower A-arm suspension has been the predominate system of U.S. cars for nearly half a century. Early versions had two parallel A-arms of equal length which resulted in wheels that leaned outboard in turns. The design also caused excessive tire scrubbing because of the large variation in tread-width as the wheel moved off the neural position. When the concept of unequal length A-arms was developed, designers were given a new design tool that provided almost infinite control over the movements of the wheels. Today, handling characteristics are limited only by the limits of tire performance and the basic weight and balance of the vehicle, not by the mechanical limitations of the suspension system.

2.5.2.2 The MacPherson Strut

The advantages of the MacPherson strut include its simple design of fewer components, widely spaced anchor points that reduce loads, and efficient packaging. From a designer's viewpoint, its disadvantages include a relatively high overall height which tends encourage a higher hood and fender line, and its relatively limited camber change during jounce. A disadvantage on the consumer level is the comparatively high cost of servicing the shock absorber.

2.6 THE RATIO OF SPRUNG TO UNSPRUNG WEIGHT

Unsprung weight includes the mass of the tires, brakes, suspension linkages and other components that move in unison with the wheels. These components are on the roadway side of the springs and therefore react to roadway irregularities with no damping, other than the pneumatic resilience of the tires. The rest of the mass is on the vehicle side of the springs and therefore comprises the sprung weight. Disturbances from the road are filtered by the suspension system and as a result are not fully experienced by the sprung weight. The ratio between sprung and unsprung weight is one of the most important components of vehicle ride and handling characteristics.

Unsprung weight represents a significant portion of the total weight of the vehicle. In today's standard-size automobile, the weight of unsprung components is normally in the range of 13 to 15 percent of the vehicle curb weight. In the case of a 3,500 pound vehicle, unsprung weight may be as high as 500 pounds. A 500 pound mass reacting directly to roadway irregularities at highway speeds can generate significant vertical acceleration forces. These forces degrade the ride, and they also have a detrimental effect on handling.

The forces generated by roadway irregularities (bumps) must be overcome by the springs in order to keep tires in contact with the road. The force of the springs comes from the compressive load imposed by the weight of the vehicle. The lighter the vehicle, the less compressive force is available, and the easier it is for the vertical motion of the wheels to overcome the inertia of the sprung mass and transfer motion to it as well. The ideal combination occurs when the ground pressure is maximized and inertial forces are minimized by a high sprung-to-unsprung weight ratio. A high ratio keeps the tires more firmly in contact with the road, and it also produces the best ride.

2.7 IMPLICATIONS OF HIGH PAYLOAD-TO-VEHICLE WEIGHT RATIO

As vehicle mass is reduced, the payload-to-vehicle weight ratio naturally increases, which has trickle-down effects throughout the vehicle. An extremely low mass automobile, in the order of 1,000 pounds or less, for example, will have an unusually high payload-to-vehicle weight ratio.

Variations in payload affect the natural frequency of the suspension. The critical damping force also varies with load. Over-damping (above 100 percent) dramatically reduces ride quality. In order to avoid over-damping at light loads, some degree of under damping is usually accepted at the fully-laden weight. Also, a passive suspension in combination with a high payload-to-vehicle weight ratio requires a relatively high static deflection rate (a stiff suspension) in order to avoid undesirable effects on vehicle ride height. Ride height refers to the height of the body at a given load. It is important to keep ride height variations within predetermined limits in order to maintain headlight dip angle, provide adequate suspension stroke, and to provide an appropriate ground clearance. Load naturally affects the standing height of the vehicle. As load increases, the vehicle rests lower on its suspension, and at lighter loads it rests higher. Heavy loads in the luggage compartment can affect the pitch of the vehicle.

The importance of a high payload-to-vehicle weight ratio becomes more apparent when the effect of payload on a standard sedan is compared to the effect of the same payload on a hypothetical ultralight vehicle. For example, a standard sedan of 3,500 pounds curb weight and a natural frequency of 1.2 Hz will rest 0.7 inch lower with the weight of two, 175 pound occupants aboard. The same static deflection rate in a