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METHODOLOGY FOR RESEARCH OF BASIC PARAMETERS FOR DOUBLE WISHBONE TYPE SUSPENSION USING CAD PROGRAMS

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Abstract: *Sports cars use mainly suspensions of the type double wishbone where shock absorbers are hidden in the body of the car so that they do not affect the air flow. The technology for designing such suspensions is extremely complex and requires specialized knowledge. Methodologies for research of parameters for suspension using CAD programs give opportunities to study the parameters of the car suspension during its design. The testing of the main parameters of the suspension is of extreme importance for the automobile industry, and their usage reduces the costs of modelling, prototyping, and possible mistakes in the production process.*

Keywords: *Design, CAD software, Suspension, Double wishbone, Caster, Camber, TOE, Bump Steering, Ackermann angle, Car design, Design of Vehicles*

INTRODUCTION

Sports cars use mainly suspensions of the type double wishbone where shock absorbers are hidden in the body of the car so that they do not affect the air flow, and a rod is used through which they operate. When the rod pushes the rocker, it’s pushrod suspension, and when the rod pulls the rocker, it’s pullrod suspension. There are also systems that do not use a rocker and a rod but the shock absorber is attached directly to the lower or upper wishbone. When the suspension is done this way, the possibility to adjust some of the parameters is lost.

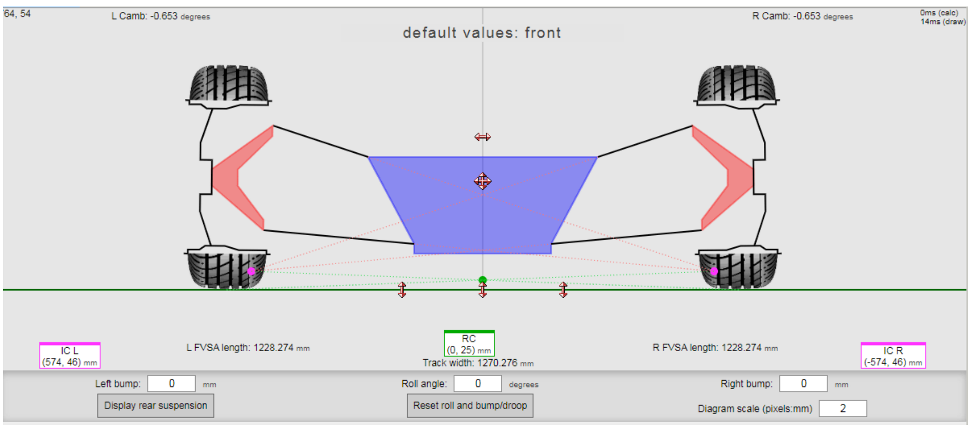


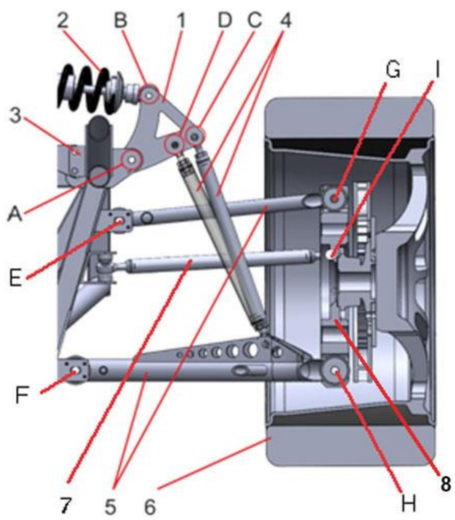
Fig. 1. Double wishbone suspension - dynamic test with http://www.vsusp.com

SUMMARY

1. Description of the double wishbone suspension.

Attaching an upper wishbone, a lower wishbone, and a shock absorber to the designated spots on the chassis. The other end of the shock absorber is fixed to one of the two wishbones (in this case, the lower one). The upright is fixed to the two wishbones with the help of joints or uniballs, and then a bearing of the wheels, a brake disk, a brake device, and a wheel rim with a wheel are added to the upright. The steering rack is attached to a selected (possible) spot on the chassis while the outer steering tips are fixed to the upright.

The suspension geometry (Fig. 2) is determined from the position and distance where the wishbones are attached to the chassis (points E and F), the length of the upper wishbone (points E and G), the length of the lower wishbone (points F and H), and the angle of the lower wishbone in relation to the ground.

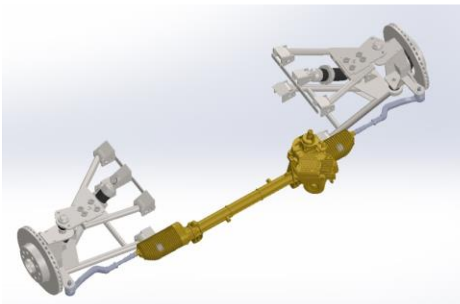


Suspension elements:

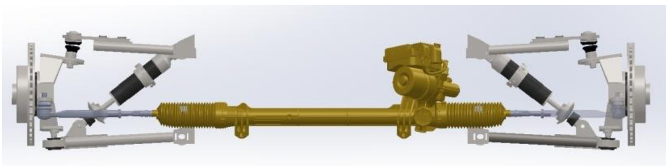
1 – Rocker;
2 – Shock absorber/spring;
3 – Chassis;
4 – Pushrod;
5 – Wishbones (upper and lower);
6 – Wheel;
7 – Steering tip (rod for adjusting TOE);
8 – Upright;

A, B, C, D, E, F, G, H, I – Openings for attaching a rocker, a shock absorber, wishbones, a steering tip, and a pushrod;

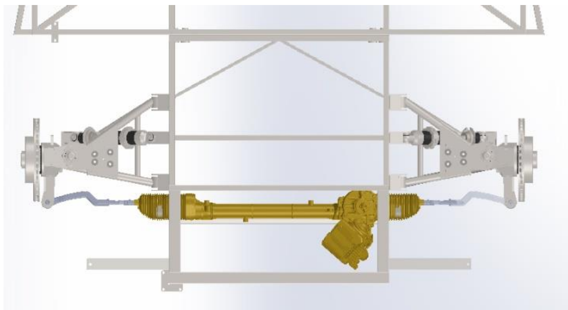
Fig. 2. Suspension of the type double wishbone with a pushrod and a rocker - schematic diagram



a) 3D view



b) Front view



c) Top view

Fig. 3. Front (controllable) suspension of the type double wishbone without using a pushrod and a rocker

2. Main parameters

Roll M Center - The roll center of a vehicle is a conditional point in which the rotating forces in the suspension react to the chassis of the vehicle. They are two types: geometrical (or cinematic) roll center whereas the Society of Automotive Engineers uses a method that's based on the applied forces. The following values are recommended for the geometrical method of determining the Roll M Center: front suspension 0-50 mm, rear suspension 50-100 mm above the ground.

The following algorithm is used for determining the Roll Center:

- Lines that intersect in point F are drawn through the connection points of the upper (A and B) and lower (C and D) wishbones;
- A line to the middle of the wheel (point E) is drawn from point F;
- The diagram is repeated for the left and right sides;
- The intersection of the lines EF with the vertical line in the center of the car determines point M (Roll M Center);

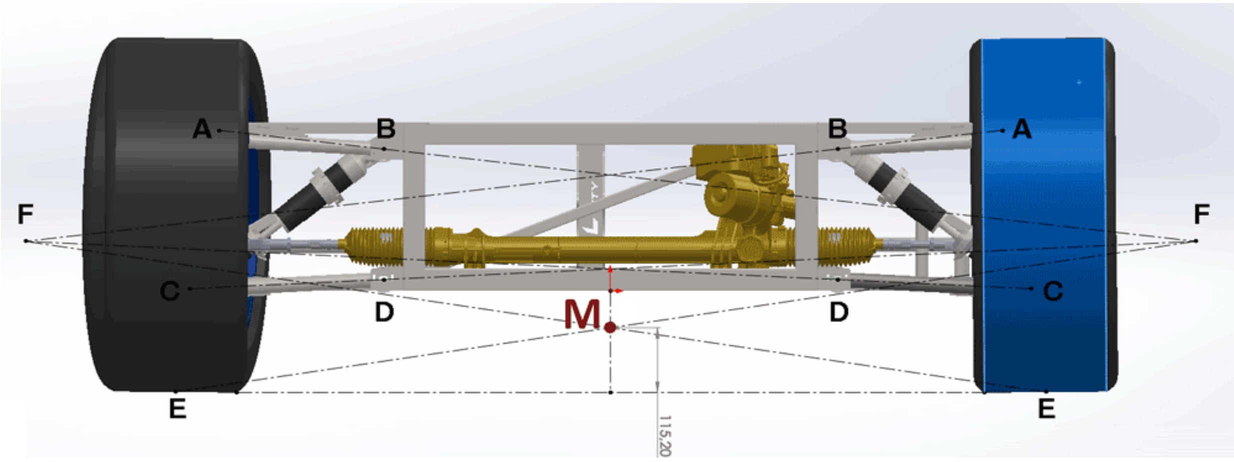


Fig. 4. How to determine the geometrical Roll M Center

Camber - inclination of the wheel in relation to the longitudinal plane of the car - static. The positive values for camber - the upper end OUTWARDS and the negative values for camber - the upper end INWARDS. Camber is neutral for standard cars but camber for sports cars is recommended to be in the range of -0,5^0 to -2^0 and maximum to -5,5^0 (negative), the benefit being better traction and stability at turns. The negative value of the angle creates a force called camber thrust. When turning, the car will try to straighten the steering wheel and that leads to increased stability but also to greater wearing out of the inside part of the tire.

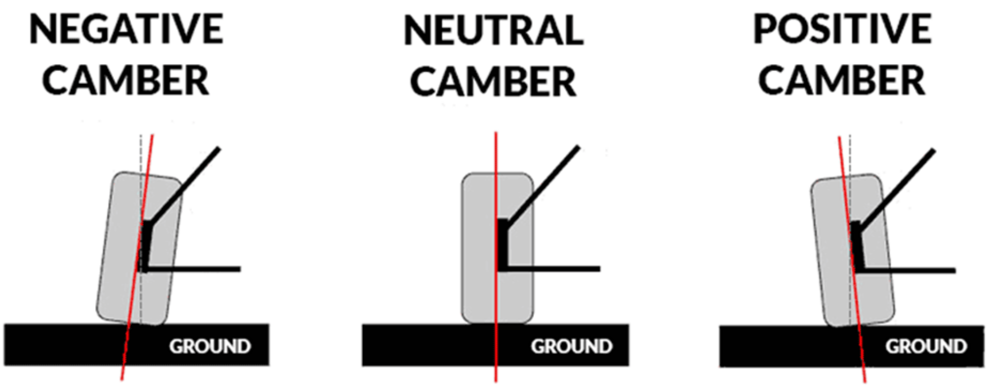


Fig. 5. Camber – static

During the movement of the wheel (up/down - mainly over bumps), the camber changes dynamically in the range of ±1,5° and more, and it can go from negative through neutral to positive values.

To test the Camber angle, a dynamic plane has to be created that is (always) parallel to the cross plane of the car and that passes through the roll center of the tire that is being tested (Fig. 6). A diagram of two lines is created in the resulted plane - one vertical line and one line that is tangential to the inner part of the wheel and passes through the roll center of the wheel (Fig. 7).

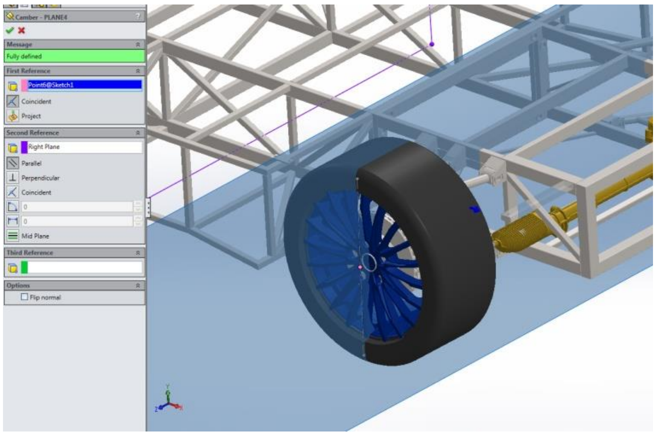


Fig. 6. Method for generating a plane for testing the camber angle

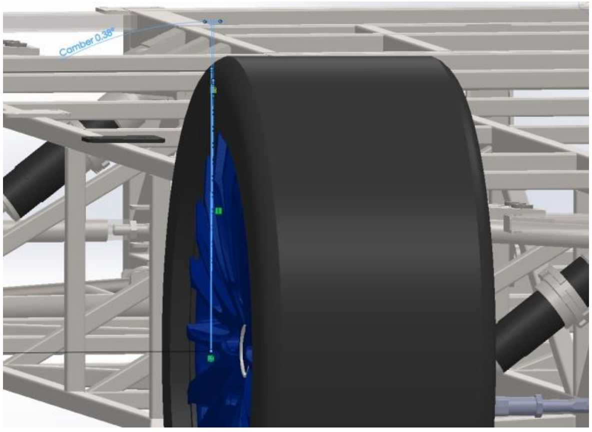


Fig. 7. Diagram for testing the camber

Caster - inclination of the roll axis of the upright in relation to the upper and lower wishbones and in relation to the vertical line Fig. 8 - static. The positive values are when the roll axis is backwards, and the negative values are when it is forwards.

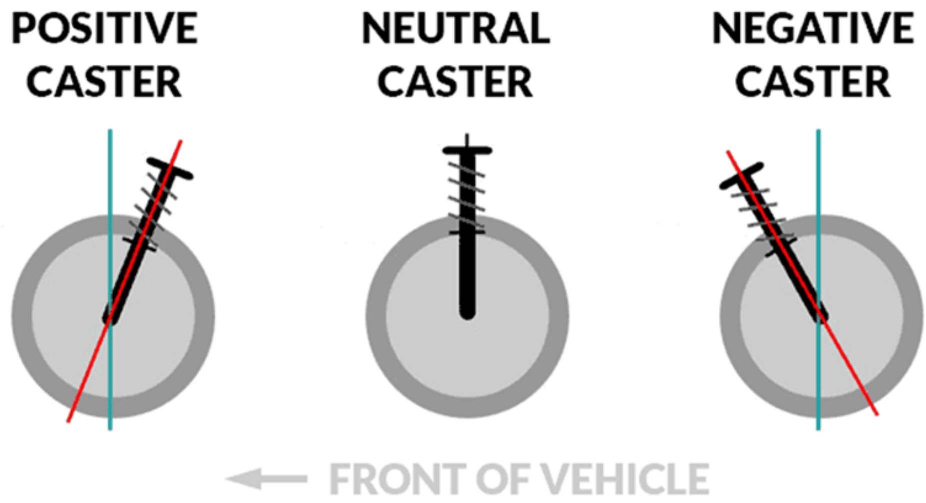


Fig. 8. Caster

Race cars are recommended to have caster in the range of 2° to 5° while street cars - from 3° to 12°. It is determined in advance and is achieved by turning the attachment points of the upright to the upper and lower wishbones. Additional strips can be used that allow the change of that angle by replacing them. A bigger caster means easier return of the steering wheel in neutral position but the effort when turning is increased, and vice versa.

To test the caster angle properly, a dynamic plane has to be created that is (always) parallel to the cross plane of the car and that passes through the roll center of the tire that is being tested (Fig. 9). A diagram of two lines is created in the resulted plane - one vertical line and one line that passes through the roll axis of the wheel when turning (Fig. 10).

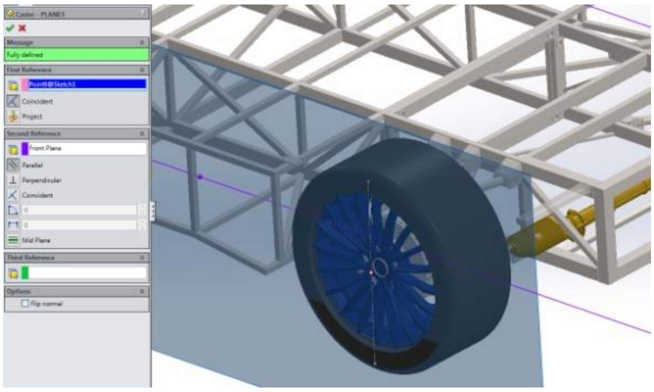


Fig. 9. Method for generating a plane for testing the caster angle

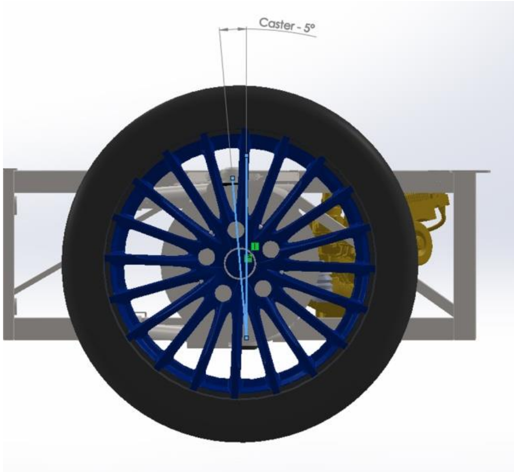


Fig. 10. Diagram for testing the caster

TOE – static. The positive values for TOE in - opening up (front), and the negative values for TOE out - closing in (front).

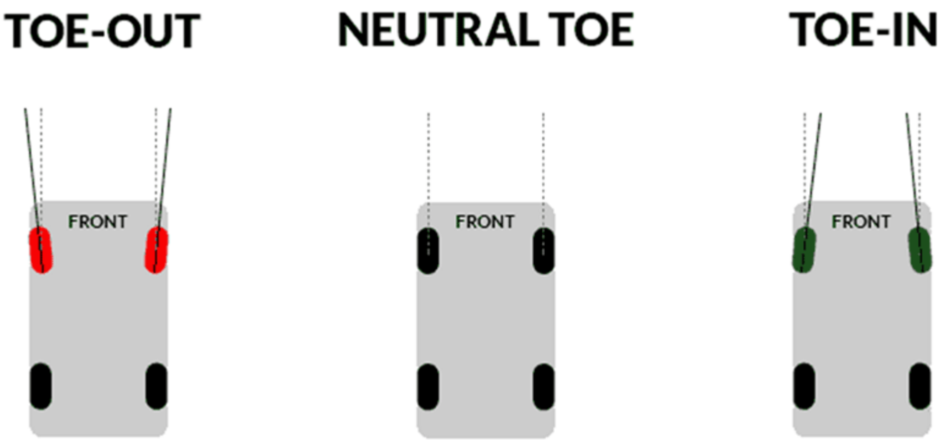


Figure 11. Different TOE angle cases

When used, the center of the wheel creates a dynamic plane that’s parallel to the top plane. A diagram is created in the resulted plane where a scheme is drawn as shown in fig. 13. A line should be drawn from the middle point of the wheel - we will call this line central axis. It should be 100 mm long and perpendicular to the longitudinal axis. A new line is drawn that’s parallel to the longitudinal axis and perpendicular to the central axis, and that new line will play the role of a rocker arm. Lines that are parallel to the central axis are drawn at the end of the wheel in the outermost possible (front and rear) flat part. At one end, it is attached to the rocker arm while at the other end it is fixed to one and the same circle of the wheel. We will call these lines levers of the rocker arm. Fig. 13 shows that the wheel is parallel to the longitudinal plane of the car and the two levers have the size of 100 mm, which means that TOE = 0 mm.

When the wheel is moving up/down, the values of the levers of the rocker arm will be changing, which in turn will lead to changes in TOE of the car when it goes over bumps (convex or concave).

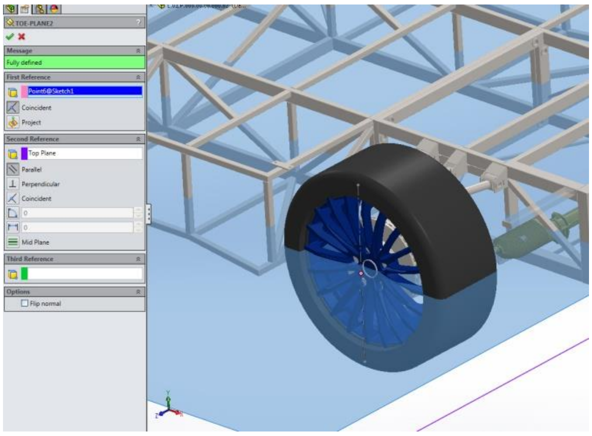


Fig. 12 Method for generating a plane for testing TOE

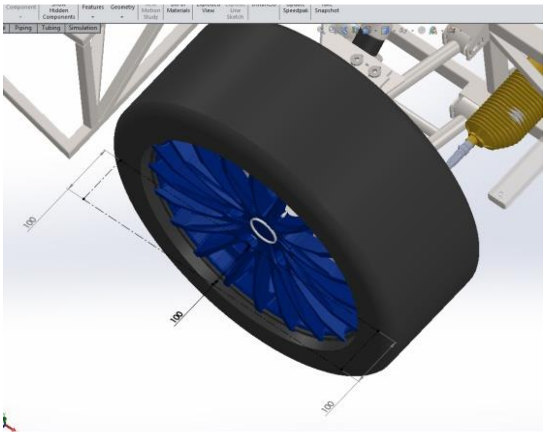


Fig. 13 Diagram for testing TOE

Motion Ratio - the ratio of the motion of the shock absorber/spring to the motion of the wheel. It is known by the term **Motion Ratio** (MR) and is described by the formula:

$$MR = \frac{SD}{WD} \tag{1}$$

where:

MR – Motion Ratio;
SD – Spring Displacement;
WD – Wheel Displacement;

There is the so-called hard suspension for sports cars (MR = 1.00 or 1/1) and soft suspension for cars for everyday use (MR ≤ 0.75). The measurement of MR is done by measuring the dimensions between the base plane of the car and the out plane and in plane surfaces for the wheel. When the wheel is moving up/down, there's contraction or extension of the shock absorber with 5 mm steps, and the difference from the measured dimensions in relation to the external and internal plane and their average value defines the value of the wheel motion [Table 1].

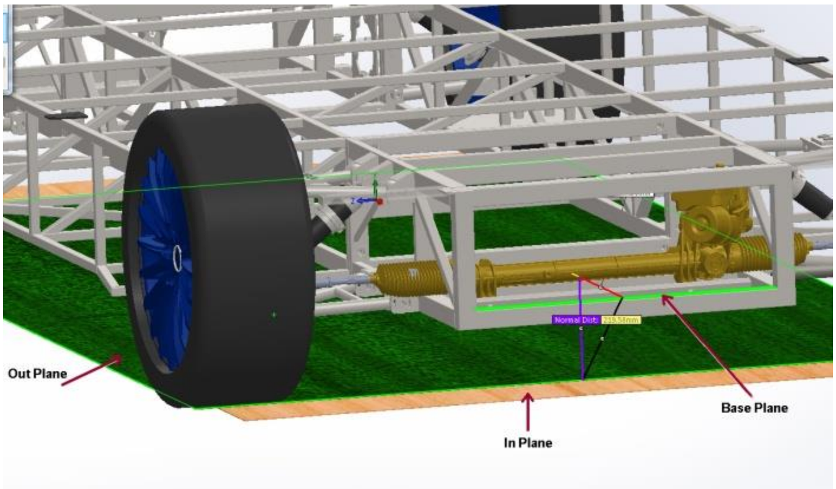


Fig. 14 Measurement of MR with the help of two planes.

Bump Steering. The total testing of all above-mentioned parameters: TOE, Caster, Camber and MR is done by changing the dimension of the shock absorber (contraction or extension) with 5 mm steps as the zero position (the state of equilibrium of the shock absorber in initial/balanced state) is connected with the adjustment of the clearance.

Table 1. Results when testing the base parameters of suspension of the type double wishbone of a specific car

Infos for Shock absorber	Стойност на натиск на амортисьора	Отпред	Отзад	Средна Стойност TOE 2 колела	Средна Стойност TOE 1 колело	Camber	Caster	MOTION WHELL				СРЕДНО	MR
	Shock absorber travel	front	rear	TOE 2 Wheels [mm]	TOE 1 Wheel [mm]	Camber [degree]	Caster [degree]	Whell OUT	Motion OUT	Whell IN	Motion IN	Δ (in/out)	MR=(Δ(in/out))/5
Closed (свит)	-40	103,19	96,81	-6,38	-3,19	1,20	5,83	181,97	8,69	185,62	8,29	8,49	1 : 1,698
	-35	102,67	97,33	-5,34	-2,67	1,06	-5,81	190,66	8,78	193,91	8,40	8,59	1 : 1,718
	-30	102,12	97,88	-4,24	-2,12	0,94	-5,80	199,44	8,88	202,31	8,51	8,69	1 : 1,739
	-25	101,73	98,27	-3,46	-1,73	0,82	-5,79	208,32	8,98	210,82	8,62	8,80	1 : 1,760
	-20	101,31	98,69	-2,62	-1,31	0,70	-5,78	217,30	9,07	219,44	8,74	8,91	1 : 1,781
	-15	100,93	99,07	-1,86	-0,93	0,59	-5,77	226,37	9,16	228,18	8,85	9,01	1 : 1,801
	-10	100,58	99,42	-1,16	-0,58	0,49	-5,76	235,53	9,27	237,03	8,96	9,12	1 : 1,823
	-5	100,27	99,73	-0,54	-0,27	0,39	-5,76	244,80	9,35	245,99	9,06	9,21	1 : 1,841
Ride height	0	100,00	100,00	0,00	0,00	0,30	-5,76	254,15	0,00	255,05	0,00	0,00	1 : 1,852
Stretched (разтьнат)	5	99,78	100,22	0,44	0,22	0,21	-5,76	263,59	9,44	264,23	9,18	9,31	1 : 1,862
	10	99,60	100,40	0,80	0,40	0,13	-5,77	273,13	9,54	273,51	9,28	9,41	1 : 1,882
	15	99,47	100,53	1,06	0,53	0,05	-5,78	282,76	9,63	282,91	9,40	9,52	1 : 1,903
	20	99,39	100,61	1,22	0,61	-0,02	-5,79	292,47	9,71	292,40	9,49	9,60	1 : 1,920
	25	99,37	100,63	1,26	0,63	-0,09	-5,80	302,27	9,80	302,01	9,61	9,70	1 : 1,941
	30	99,41	100,59	1,18	0,59	-0,15	-5,82	312,16	9,89	311,71	9,70	9,80	1 : 1,959
	35	99,51	100,49	0,98	0,49	-0,20	-5,85	322,12	9,96	321,52	9,81	9,88	1 : 1,977
	40	99,63	100,37	0,74	0,37	-0,24	-5,87	332,17	10,05	331,44	9,92	9,99	1 : 1,997

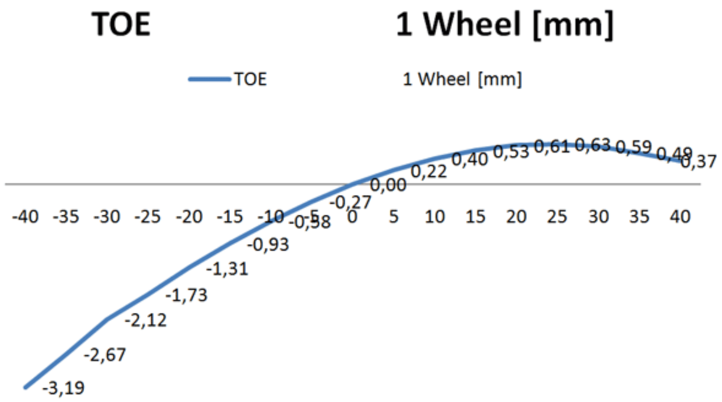


Fig. 15. Changing the values of TOE when the shock absorber is moving

Ackermann angle – the difference between the angles of the inside wheel and outside wheel of the driving axle of the car. The recommended values of the Ackermann angle are $\geq 3^0$.

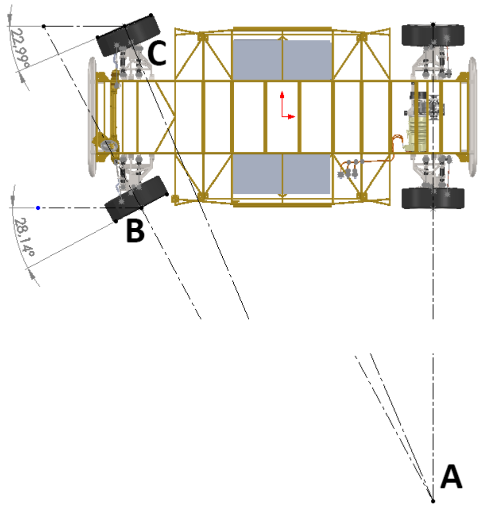


Fig. 16. Ackermann angle

CONCLUSION

The opportunity to use 3D CAD programs during the stages of designing the construction of a car (chassis, rollbar, suspension, exterior and interior panels, electrical, cooling, and combustion systems, doors and hinges, etc.) and the following testing of the main parameters of the suspension is of extreme importance for the automobile industry, and their usage reduces the costs of modelling, prototyping, and possible mistakes in the production process.

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