

# ANALIZA KONSTRUKCIONIH ZAHTJEVA NEOPHODNIH ZA STABILNO UPRAVLJANJE I KRETANJE AUTOBUSA

## ANALYSIS OF STRUCTURAL REQUIREMENTS NECESSARY FOR STABLE OPERATION OF BUSES

Mesud Ajanović<sup>1</sup>  
Zdravko Nunić<sup>1</sup>  
Fuad Klisura<sup>2</sup>  
Snežana Petković<sup>3</sup>

*Stručni rad*

<sup>1</sup>University of East Sarajevo  
Traffic Faculty Doboj  
<sup>2</sup>IPI Institute Zenica  
<sup>3</sup>University of Banja Luka,  
Mechanical Engineering Faculty

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### REZIME

*Današnja moderna vozila za masovni prevoz putnika, čiji su najzastupljeniji predstavnici autobusi, moraju udovoljavati zahtjevima udobnosti, široke upotrebe, ali i posebno mjerama sigurne vožnje. Kako bi se veliki zahtjevi mogli ispuniti i duž cijelog „vijeka trajanja vozila“, ili i nakon mogućih nezgoda, neophodno je ostvariti dobra i optimalna konstrukcijska rješenja i voznog postroja. Ovim radom se analiziraju i obrađuju neki od početnih, ali veoma bitnih konstrukcionih zahtjeva na voznom postroju autobusa, poput položaja motora i pogonskih točkova, broja osovina i njihovog rastojanja, sistema upravljanja koji omogućava adekvatne radijuse zaokretanja, kao i geometrija upravljivih točkova. Pored navedenog rad provocira i temu elektro mobilnosti kao konstrukcijski izazov.*

*Professional paper*

### SUMMARY

*Today's modern vehicles for mass transport of passengers, of which the most common representatives are the buses must comply with the requirements of comfort, wide usage, and in particular the measures of safe driving. In order to meet large requirements along the "life of the vehicle," or even after possible accidents, it is necessary to achieve good and optimum structural solutions of the running gear. This paper analyses and processes some of the initial but very important constructional requirements on the running gear of buses, such as the position of the motor and driving wheels, number of axles and their distance, the management system that provides adequate turning radius and the geometry of controllable wheels. Besides aforementioned this paper also provokes the topic of electric mobility as a structural challenge.*

### 1. UVOD

Vozni postroj je poveznica između vozila i ceste. I sile ovjesa točkova i pogonske sile kao i bočne sile koje nastaju tokom vožnje zavojima se preko točkova kroz vozni postroj prenose na cestu. Vozni postroj je time izložen mnoštvu djelujućih sila i momenata. Porast snage vozila kao i povećani zahtjevi za udobnošću i sigurnošću vozila dovode do stalnog porasta zahtjeva od svih elemenata voznog postroja.

Koliko je važno iznalaziti dobra konstrukciona rješenja, govori činjenica da vozilo tokom vožnje stalno mijenja svoje stanje, ono ubrzava, koči ili mijenja smjer vožnje. Ove fenomene uzrokuje veliki broj sila, čiji se zbir naziva dinamika vozila.

### 1. INTRODUCTION

The running gear is a link between the vehicle and the road. Both the forces of suspension of wheels and the driving forces as well as the lateral forces that occur during driving in curves are transferred through the running gear to the road. The running gear is thus exposed to many active forces and moments. The increase of strength of vehicle as well as increased requirements for comfort and safety of vehicle lead to the constant increment of requirements of all elements of running gear.

How important is to find good constructional solutions speaks the fact that the vehicle while driving constantly changes its state, it accelerates, brakes or changes the direction of travel. This phenomenon is caused by a large number of forces, whose summation is called the vehicle dynamics.

Prosto rečeno, kada je zbir svih ovih sila jednak "nuli", to znači da je vozilo u mirovanju, a kada nije jednak nuli tada se vozilo kreće.

Sve ove sile ipak variraju u zavisnosti o fizikalnoj veličini koja se naziva ubrzanje, koja utiče na brzinu i promjenu smjera kretanja svakog pojedinog predmeta. Tako primjerice povećanje brzine vožnje predstavlja pozitivno ubrzanje, dok kočenje predstavlja negativno ubrzanje.

Kod uobičajene vožnje vozilo se ponaša tako kako mu to vozač nalaže, i to stoga što ne dolazi do prekoračenja fizikalnih graničnih vrijednosti, koje ovise o svojstvima puta i konstrukcionim rješenjima samog vozila. Kada dođe do prekoračenja graničnih vrijednosti, što kod autobusa predstavlja poseban problem zbog njegove specifične namjene i oblika, vozilo se zanosí, dolazi do blokiranja točkova ili čak do izlijetanja sa puta i prevrtanja, uz skoro pa uvijek velike i tragične posljedice.

## 2. POLOŽAJ MOTORA

Postoje tri osnovne koncepcije postavljanja motora kod autobusa:

- **naprijed** (zastarjeli koncept), može da se sretne samo u nekim autobusima izrađenim na osnovi teretnog vozila (i sa nosećim ramom),
- **centralno**, ležeći položen motor, sreće se u gradskim i prigradskim autobusima; problem ove koncepcije predstavlja povećana visina poda zbog smještaja horizontalnog linijskog motora, i povećana buka i vibracije koje osjete putnici, dok je za vozača smanjena u odnosu na prvu koncepciju,
- **nazad**, uzdužno ili poprečno postavljen motor, može da bude i položen, danas najzastupljenija koncepcija (Slika 1 i 2).

Koncepcija autobusa sa smještajem pogonske grupe u zadnjem prepustu vozila je danas najšire zastupljena kod svih tipova autobusa, izuzev minibusa. Ovaj koncept omogućava najbolje iskorišćenje putničkog i prtljažnog prostora. Kod gradskih autobusa moguće je izvođenje niskopodne šasije, kao i mogućnost zadovoljenja strogih ekoloških zahtjeva u pogledu buke i vibracija. U slučaju međugradskih i turističkih autobusa prozračnost potpodne šasijske konstrukcije, omogućava pogodno smještanje, ležaja vozača, toalet-kabine i sl.

Simply, when the sum of all these forces is "zero", it means that the vehicle is stationary and when it is not equal to zero then the vehicle is moving. All of these forces still vary depending on the physical size which is called acceleration, which affects the speed and change of direction of each individual subject. For example, increasing the speed of drive represents positive acceleration, while the braking represents negative acceleration.

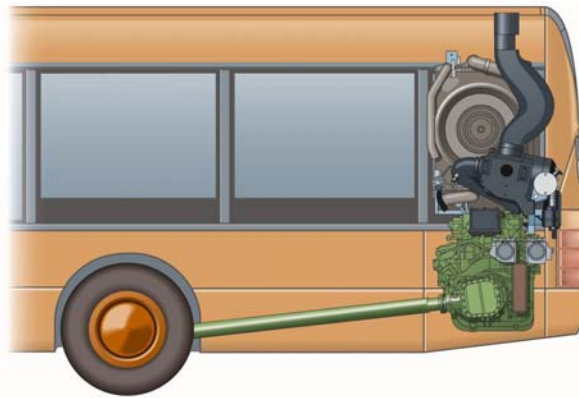
In normal driving the vehicle behaves in the way required by a driver, and this is because there is no physical exceeding the limit values, which depend on the road conditions and structural solutions of the vehicle itself. When it comes to the threshold limits, which is a special problem with buses because of its specific purpose and form, the vehicle slips, there is a blockage of the wheels or even skidding off the road and rolling over, with almost always great and tragic consequences.

## 2. THE ENGINE POSITION

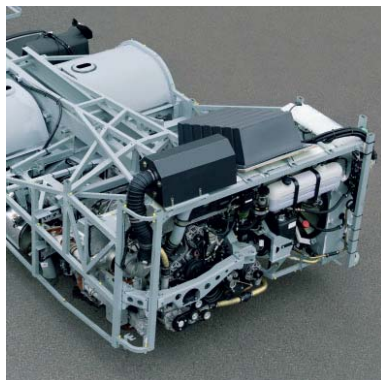
There are three basic concepts of placing the engine at bus:

- **frontally** (an outdated concept), can meet only in some buses made on the basis of the cargo vehicle (and with a carrying frame),
- **centrally**, laying placed engine, met in urban and suburban buses; the problem of this conception is the increased height of the floor because of placement of horizontal line engine, and increased noise and vibration sensed by passengers, while the noise is reduced with the driver in comparison to the first concept,
- **in the back**, longitudinally or transversely mounted engine, can be laid, today the most common conception (Pictures 1 and 2).

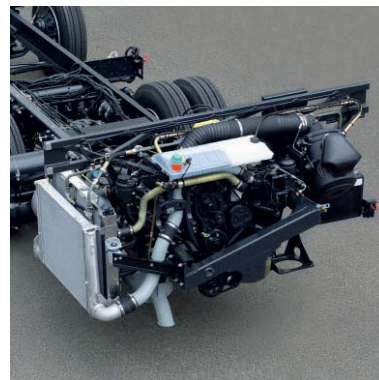
The concept of a bus with the placement of powertrain in the rear overhang of vehicle is now the most widely represented in all types of buses, except for minibuses. This concept allows the best utilization of passenger and cargo space. For urban buses it is possible to perform low-floor chassis, as well as the ability to meet strict environmental requirements in terms of noise and vibration. In case of suburban and touristic buses the ventilation under floor wheel chassis structure allows convenient placement, beds for drivers, toilet cabins and similar.



**Slika 1.** Autobus sa nazad poprečno postavljenim motorom.  
**Picture 1.** Bus with a back transverse engine



a) Horizontalno postavljen motor  
 a) Horizontally mounted engine  
 (D2066 LUH) (D2066 LUH)



b) vertikalno postavljen motor  
 b) Vertically mounted engine  
 (D0836 LOH)

**Slika 2.** Šasija MAN autobusa.  
**Picture 2.** The Chasis of MAN bus

Koncentracija pasivnog opterećenja kod ove koncepcije autobusa se nalazi u zadnjem prepustu, međutim izborom položaja ostalih teških komponenti vozila (kao što su rezervoari za gorivo, baterije i rezervni točak) u prednjem prepustu, kao i odgovarajućim rasporedom sjedišta, odnosno korisnog opterećenja, postižu se zadovoljavajući parametri stabilnosti kretanja. Dva su glavna razloga zbog kojih se minibus najčešće izvodi sa klasičnom koncepcijom smještaja pogonske grupe u prednjem prepustu:

- poboljšanje sigurnosti kod čeonog sudara, jer se ispred vozača nalazi znatna masa koja može da apsorbuje energiju eventualnog udara,
- mogućnost unifikacije šasije minibusa sa šasijama lakih dostavnih vozila, kod kojih je pogonska grupa, najčešće, smještena u prednji prepust.

The concentration of the passive load in this conception of a bus is located in the rear overhang, however, by the choice of the location of other heavy components of the vehicle (such as fuel tanks, battery and spare wheel) in the front overhang, as well as the corresponding arrangement of the seats, or payload, it is yielded satisfactory stability parameters of movement.

There are two main reasons why the minibus is usually performed with the classical concept of accommodation of powertrain in the front overhang:

- improving safety at frontal collision, because in front of the driver there is a considerable mass which can accordingly absorb the energy of possible collision,
- possibility of unification of minibus chassis to chassis of light commercial vehicle, in which the power unit is usually located in the front overhang

### 3. POLOŽAJ POGONSKIH TOČKOVA

Tokom razvoja nekog vozila prvo se definiše položaj konstrukcije. On se opisuje preko X-Y-Z osnog sistema. Pri tome Z i X osa prolaze sredinom prednje osovine, Y osa najčešće prolazi tačno kroz sredinu prednjih točkova. Ovdje treba napomenuti da položaj konstrukcije odgovara položaju vozila na zadanoj visini.

Kod standardnih solo autobusa, bez obzira na položaj ugradnje pogonske grupe, bilo da se radi o ugradnji u prednjem, zadnjem prepustu ili na sredini vozila, pogon vozila se vrši preko zadnjeg mosta. S obzirom na to da su prednji mostovi kod svih autobusa upravljivi i da stoga isključuju mogućnost ugradnje udvojenih pneumatika koji su neophodni za prenos odgovarajućih obrtnih momenata sa transmisije na tlo, logično je da se preostali neupravljivi most upotrijebi za funkciju pogona.

Postoje i specifična rješenja autobusa koji nisu izloženi velikim korisnim opterećenjima, npr. aerodromski i vanputni autobusi, gdje je prednji upravljivi most takođe i pogonski.

#### *Koncepcije pogona zglobnog autobusa*

Kod prvih zglobnih autobusa ustanovljena je koncepcija sa pogonom na srednjem mostu, tako da je, praktično, prednji vučni dio vozila imao potpunu pogonsku autonomiju, odnosno sve komponente pogona nalazile su se u prednjem dijelu autobusa (Slika 3). U početku je motor ugrađivan u prednjem prepustu vozila, a kasnije, razvojem ekoloških zahtjeva, u potpodni prostor između prednjeg i srednjeg mosta. Ova koncepcija je omogućavala izvođenje trećeg mosta, na drugom dijelu zglobnog vozila, kao upravljivog, što je omogućavalo eksploataciju u gradskim uslovima saobraćaja.

Daljim razvojem došlo je do premještanja pogonske grupe u zadnji prepust vozila, čime je i pogon prebačen na treći most (tip autobusa „pusher“). Samim tim, treći most je morao da bude neupravljiv, i do uvođenja automatske elektronske kontrole uglova zaokretanja okretnice ovi autobusi nisu imali zadovoljavajuću kinematiku upravljanja cijele kompozicije vozila (Slika 4).

Prelazno rješenje ka koncepciji „pusher“ bilo je rješenje fabrike MAN, sa smještajem pogonske grupe u zadnjem prepustu vozila i pogonom na drugom mostu (Slika 5). Prenos obrtnog momenta vrši se sa zadnjeg prepusta, kardanskim vratilima preko okretnice, na drugi most. Na taj način omogućeno je izvođenje trećeg mosta kao upravljivog.

### 3. THE DRIVING WHEELS POSITION

During the development of a vehicle we firstly define the position of the structure. This is described through the X-Y-Z axis system. Wherein Z and X axis crosses through the front axles, the Y axis usually passes right through the middle of the front wheels. It should be noted that the position of the structure corresponds to the position of the vehicle at a given height.

For standard single buses, regardless of the position of installation of the drive line, whether it's about fitting in the front, the rear overhang or on the middle of the vehicle, the vehicle propulsion is done over the last end. Given the fact that the anterior ends with all the buses are manoeuvrable and that, therefore, exclude the possibility of a tandem tires which are necessary for the transfer of appropriate moments from the transmission to the ground, it is logical that the remaining unmanaged end is used in a drive.

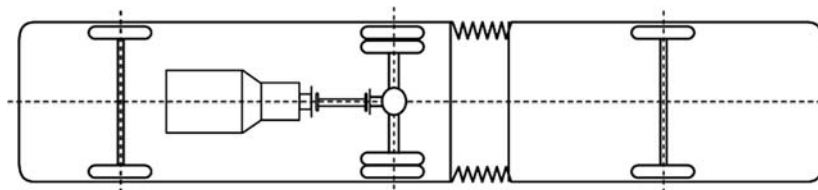
There are also specific solutions of buses that are not exposed to high useful loads, e.g. airfare and non road buses, where the front manageable end and is also a driving end.

#### *Concepts of driving of articulated bus*

In the first articulated buses there is established the concept of drive in the middle end, so, practically, the front towing part of the vehicle had full operational autonomy, i.e. all components of the drive were in front of the bus (Picture 3). At first, the motor was built into the front overhang of the vehicle, and later, by the development of environmental requirements, under the floor between the front and middle end. This concept has allowed the execution of the third end, at the second part of the articulated vehicle, as manageable, allowing for exploitation in urban traffic conditions.

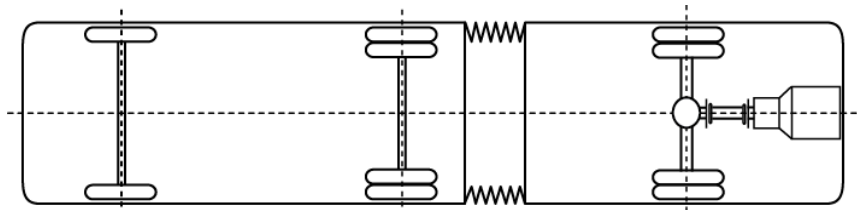
With further development there has been a displacement of powertrain in the rear overhang of the vehicle, whereas the drive was transferred to the third end (bus type "pusher"). Therefore, the third end had to be ungovernable, and to the introduction of automatic electronic control angles of swing these buses did not have satisfactory kinematics control of the entire composition of the vehicle (Picture 4).

An interim solution towards the concept of "pusher" was the solution of the factory MAN, with the placement of powertrain in the rear overhang of the vehicle and the drive to the second end (Picture 5). The transmission of moment is made from the rear overhang, through the cardan shafts over a turntable, to the second end. Thus, it is allowed for the execution of the third end as manageable.



*Slika 3. Zglobni autobus sa motorom u sredini prednjeg dijela i pogonom na srednjem mostu (Demić, 2003).*

*Picture 3. Articulated bus with the engine in the middle of front part and driving on the central end (Demić, 2003).*



*Slika 4. Zglobni autobus „pusher“ sa motorom u zadnjem prepustu i pogonom na trećem mostu (Demić, 2003).*

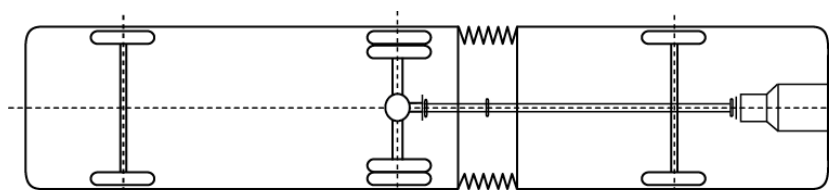
*Picture 4. Articulated bus “pusher” with the engine in the rear overhang and driving on the third end (Demić, 2003).*

Slabosti ove koncepcije su:

- komplikovan kardanski prenos,
- nedovoljna nosivost trećeg mosta sa jednostrukim pneumaticima, s obzirom na konstantno pasivno opterećenje koje potiče od mase pogonske grupe,
- pogonski most je izložen znatnim oscilacijama u zavisnosti od opterećenja (broja putnika) vozila. Time se dovode u pitanje bezbjednost kočenja i mogućnost propulzije neopterećenog vozila u uslovima vlažnog i klizavog kolovoza, jer se obje performanse definišu za nominalno puno opterećenje vozila.

The disadvantages of this concept are:

- complicated cardan transmission,
- insufficient capacity of the third end with single tires, due to the constant load of a passive mass originating from the drive train,
- driving end is exposed to significant oscillations depending on the load (number of passengers) of the vehicle. This brings into question the safety of braking and propulsion possibility of unloaded vehicle in conditions of wet and slippery road surface, for both performance are defined for the nominal full load of vehicle.



*Slika 5. Zglobni autobus sa motorom u zadnjem prepustu i pogonom na drugom mostu (Demić, 2003).*

*Figure 5. Articulated bus with the engine in the rear overhang and driving on the second end (Demić, 2003).*

#### 4. BROJ OSOVINA I OSOVINSKO RASTOJANJE

Potreban broj osovina može da se odredi na osnovu:

- dozvoljenih osovinskih opterećenja, i
- nosivosti pneumatika.

#### 4. NUMBER OF AXLES AND AXLE DISTANCE

The required number of axles can be determined on the basis of:

- permissible axle loads, and
- tire capacity.

Kod solo autobusa uzima se ukupna masa vozila (sopstvena masa + korisna nosivost), a kod zglobnih autobusa sopstvena masa + korisna nosivost + opterećenje, koje se sa drugog dijela preko okretnice prenosi na prednji dio vozila.

U toku analize mora da se vodi računa i o odnosu reakcija tla na upravljivim i neupravljivim točkovima vozila. Uobičajeno je da je statička reakcija tla na upravljivim točkovima, pri potpuno opterećenom vozilu, za 20-40% manja od statičke reakcije tla neupravljivih točkova (Demić 1999). Preraspodjela opterećenja se određuje kompromisno na osnovu zadovoljenja parametara upravljivosti vozilom i zamora vozača ili opterećenja sistema za upravljanje kod vozila sa servo upravljačem.

Pri izradi projekta najčešće nisu poznate dimenzije pneumatika. Zato se u toku izbora dimenzija naplatka preporučuje korišćenje analogije sa izvedenim vozilima, a potrebna širina pneumatika može da se orijentaciono izračuna na osnovu empirijske jednačine (Demić 1999):

$$cB^3 + cB^2 - G_1B - 0,508 G_1 = 0 \quad (1)$$

gdje je:

- $G_1$ , N opterećenje pneumatika,
- $c$  koeficijent koji se kreće u granicama 23-27 (za pneumatike bez regulacije pritiska),
- $B$ , cm širina pneumatika.

Osovinsko rastojanje je veoma značajan parametar koji se određuje pri projektovanju autobusa, a prilikom njegovog definisanja uobičajeno se uzimaju u obzir sljedeći parametri:

- funkcionalni parametri autobusa, odnosno posebni zahtjevi vezani za tip autobusa (prednji i zadnji prepust s obzirom na potrebu ugradnje vrata autobusa, jednokrlna, dvokrlna ili četvorokrlna),
- manevarske sposobnosti autobusa u saglasnosti sa važećim standardima i preporukama,
- raspoloživi prtljažni prostor,
- vibraciona udobnost, koja direktno zavisi od geometrijskih i masenih parametara vozila.

Prilikom definisanja osovinskog rastojanja trebalo bi da se ima u vidu i subjektivni osjećaj vozača.

Talking about a single buses, we calculate the total vehicle weight (net weight + payload), and at articulated buses we calculate the net weight + payload + load, which from the second part via a turntable it is transferred to the front of the vehicle.

During the analysis we have to take into account the ratio of ground reaction to the controllable and unmanageable wheels. Normally the static ground reaction is on the controllable wheels, with fully loaded vehicle, for 20-40% less than the static ground reaction of unmanaged wheels (Demić 1999). Redistribution of load is determined by a compromise on the basis of meeting the parameters of handling the vehicle and driver fatigue or load of steering wheel system for vehicles with power steering.

In making the project we usually do not know dimensions of the tires. Therefore, during the selection of dimensions of rim it is recommended the usage of analogies with derived vehicles, and the required width of the tire may be approximate calculation based on empirical equations (Demić 1999):

$$cB^3 + cB^2 - G_1B - 0,508 G_1 = 0(1)$$

where in:

- $G_1$ , N load tire
- $c$  coefficient which ranges from 23 to 27 (for the tires without air-pressure regulation),
- $B$ , cm tire width.

Wheelbase is a very important parameter that is determined at the design of buses, and when its defining there is usually taken into account the following parameters:

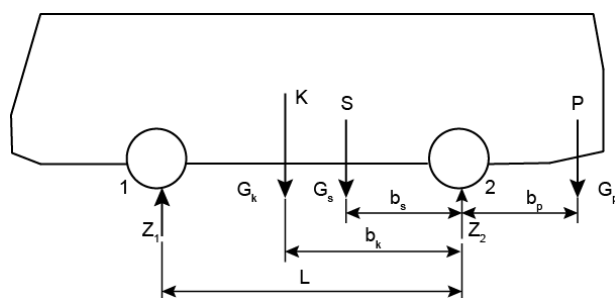
- bus operation parameters, or specific requirements for the type of bus (front and rear overhang with the respect to the need of installation of the door stops, single, double or quadruple),
- manoeuvrability of buses in accordance with the applicable standards and recommendations,
- available luggage space,
- vibrational comfort, which directly depends on the geometrical parameters and the weight of the vehicle.

In defining the axle distance we should also have in mind the subjective feeling of the driver.

Pri izboru osovinskog rastojanja kod višeosovinskih autobusa mora da se vodi računa i o rastojanjima između susjednih osovina. One moraju da obezbijede i u najtežim uslovima normalno kotrljanje točkova (bez međusobnog kontakta), računajući pritom i na mogućnost ugradnje lanaca za zimske uslove eksploatacije. Za izračunavanje osovinskog rastojanja može da posluži Slika 6.

In selecting axle distance at the multi-axle buses we must take into account the distance between adjacent axles. They must ensure in the most severe conditions normally rolling of the wheels (no contact with each other), and counting on the possibility of installing chains for winter conditions.

For the calculation of the axle distance we may use the Picture 6.



**Slika 6.** Raspored sila bitnih za određivanje osovinskog rastojanja.  
**Picture 6.** Distribution of forces important for determining the axle distance

Statičke reakcije tla na prednjoj osovini za stanje kad je opterećen i kad je rasterećen autobus se određuju prema jednačinama:

$$Z_{1opt} = \frac{G_s b_s + G_k b_k - G_p b_p}{L} \quad (2)$$

$$Z_{1rast} = \frac{G_s b_s - G_{prast} b_p}{L} \quad (3)$$

$$\begin{aligned} & Z_{1opt} - Z_{1rast} \\ &= \frac{G_k b_k - (G_p - G_{prast}) b_p}{L} \\ L &= \frac{G_k b_k - (G_p - G_{prast}) b_p}{Z_{1opt} - Z_{1rast}} \end{aligned}$$

gdje je:

$Z_1, Z_2$  reakcije tla na prednjoj i zadnjoj osovini (opt – opterećeno i rast – rasterećeno stanje),

$b_s, b_k, b_p$  koordinate težišta sopstvene mase, mase putnika i zgloba okretnice kod zglobnog autobusa,

$G_s, G_k, G_p$  sopstvena težina, težina putnika, težina koja se prenosi na okretnicu sa drugog odjeljka.

Promjena normalne reakcije tla kod opterećenog i rasterećenog vozila ( $Z_{1opt} - Z_{1rast}$ ) iznosi u granicama 35-40%, zbog subjektivnog osjećaja nesigurnosti vozača.

Static ground reactions on the front axle, for the situation when the bus is loaded and when unloaded, are determined by the equations:

$$Z_{1opt} = \frac{G_s b_s + G_k b_k - G_p b_p}{L} \quad (2)$$

$$Z_{1rast} = \frac{G_s b_s - G_{prast} b_p}{L} \quad (3)$$

$$\begin{aligned} & Z_{1opt} - Z_{1rast} \\ &= \frac{G_k b_k - (G_p - G_{prast}) b_p}{L} \\ L &= \frac{G_k b_k - (G_p - G_{prast}) b_p}{Z_{1opt} - Z_{1rast}} \end{aligned}$$

wherein:

$Z_1, Z_2$  ground reaction on the front and rear axle (opt = loaded and rast = unloaded condition),

$b_s, b_k, b_p$  coordinates of the centre of net weight, the weight of passengers and joint swing of an articulated bus,

$G_s, G_k, G_p$  net weight, the weight of passengers, the weight which is transferred to the turntable from the second compartment.

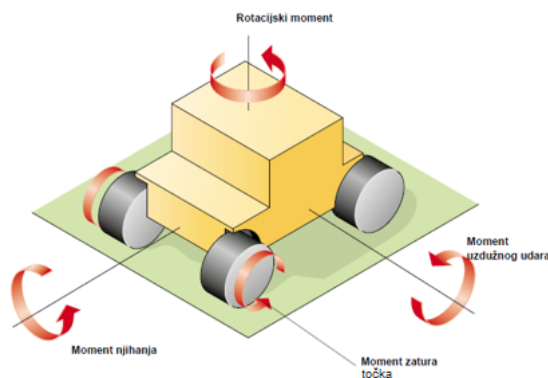
Change of normal ground reactions with loaded and unloaded vehicles ( $Z_{1opt} - Z_{1rast}$ ) is within the limits of 35-40%, due to the subjective feelings of insecurity of driver.



## 5. RADIJUSI ZAOKRETANJA AUTOBUSA

Tokom vožnje na sve točkove djeluje ista vrsta sila, ali različitog intenziteta, što je povezano sa stalnom izmjenom putanje vozila. Opšte je poznato, da je prilikom kočenja na prednjoj osovini intenzitet opterećenja veći (moment uzdužnog udara), ili da su u zavojima vanjski točkovi opterećeni više od unutrašnjih (moment njihanja). Osim već poznatih sila koje djeluju na točkove, postoje i neke druge sile koje djeluju na vozilo, kao primjerice zračni otpor: Vjetar sprijeda koči vozilo, a bočni ga vjetar potiskuje iz putanje.

Zbir svih sila koje uzrokuju zakretanje vozila oko vlastite okomite ose naziva se rotacijski moment. Pod momentom se podrazumijeva fenomen do koga dolazi prilikom djelovanja neke sile na krak poluge oko njene okretne tačke. Okretna se tačka naziva još i geometrijska osa. To između ostalog predstavlja i koncept zakretnog momenta vijka. Poznati rotacijski moment kod vozila je onaj, koji se uspostavlja prilikom blokiranja jednog od stražnjih točkova u zavoju; na taj se način uspostavlja rotacijski moment koji uzrokuje zanošenje. To se isto događa i na autocestama pod uticajem bočnog vjetra; ovaj je fenomen posebno izražen kod autobusa i teretnih vozila.



Moment njihanja = The moment of oscillations

Moment uzdužnog udara = The moment of longitudinal force

Moment zatura točka = The moment of wheel caster

**Slika 7.** Momenti koji utiču na vozilo kao cjelinu.  
**Picture 7.** The moments affecting the vehicle as a whole.

Sistem za upravljanje trebalo bi da omogućava održavanje željenog pravca kretanja autobusa. Konceptcija autobusa (šema pogona, broj i raspored upravljivih osovina, opterećenja po osovinama, dimenzija točkova, osno rastojanje, tragovi točkova, parametri sistema oslanjanja) određuje i izbor parametara upravljanja.

## 5. TURNING RADIUS OF BUSES

During the for wheel drive the same type of force operates to all wheels, but of varying intensity, which is related to constantly change of the direction of the vehicle. It is generally known that when applying the brakes, greater intensity is on the front axle load (moments of longitudinal impact), or that the outer wheels are burdened more in turns from the inner wheels (oscillation moment). Besides already known forces acting on the wheels, there are also other forces acting on the vehicle, such as air resistance: Wind hampers vehicle from the front, and lateral wind pushes it out of orbit.

The sum of all forces that cause the rotation of the vehicle around its vertical axis is called a rotary moment. Under the moment it is meant the phenomenon that occurs when there is action of some force on the lever arm around its swivel point. Swivelling point is also called a geometrical axis. This among other represents the concept of moment screw. The known rotary moment at vehicle is the one which is established during blocking one of the rear wheels in curves; in this way there is established a rotational moment which causes a drift. The same happens on the highways under the influence of crosswinds; this phenomenon is particularly expressed in buses and trucks.

The steering wheel system should be able to maintain the desired direction of movement of a bus. The concept of a bus (drive scheme, number and arrangement of steering axles, axle load, wheels dimensions, axial distance, a rut, and the supporting system parameters) determines the selection of the steering wheel parameters.



Osim nabrojanih faktora, za određivanje osnovnog kinematskog zahtjeva koji sistem za upravljanje mora da zadovolji, polazi se od minimalnog i maksimalnog poluprečnika zaokretanja autobusa koji je definisan ECE pravilnicima. Na Slici 8. su prikazani poluprečnici zaokretanja zahtjevani prema ECE standardima, a na Slici 9. prema Američkim standardima, kao i osnovne dimenzije autobusa. Radijus okretanja kod zglobnih autobusa sa fiksnom zadnjom osovinom i upravljanom zadnjom osovinom je prikazan na Slici 10.

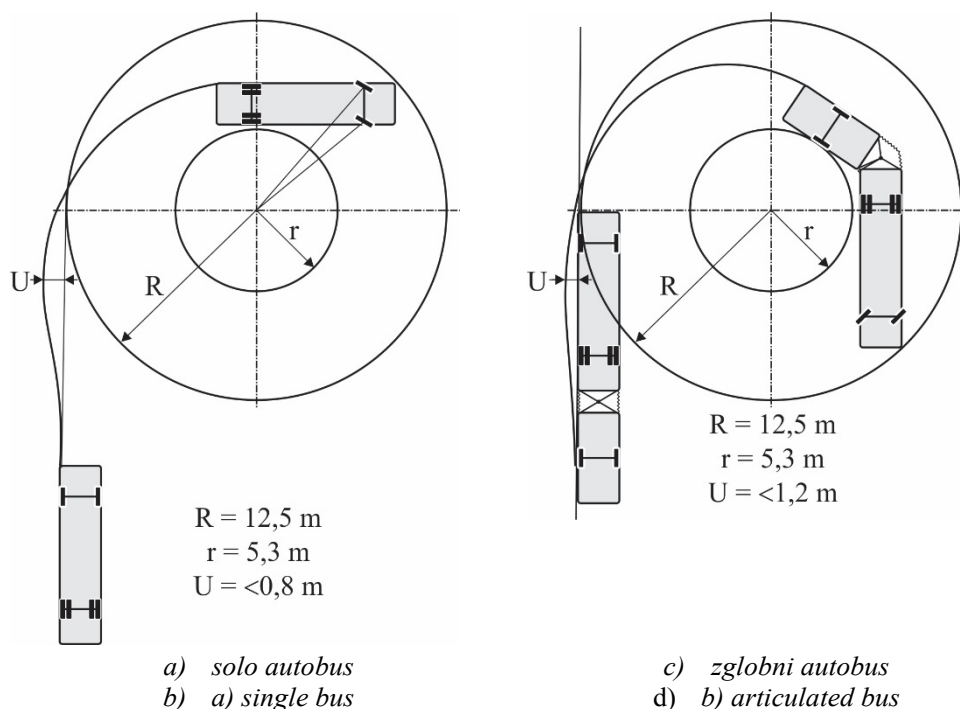
Prema ECE R 36 i Slici 8. definisano je da se vozilom mora da omogući upravljanje unutar kruga poluprečnika 12,5 m, a da nijedna njegova krajnja tačka ne strši izvan tog kruga. Kada se krajnje tačke vozila kreću po kružnici poluprečnika 12,5 m, vozilo mora da se kreće u granicama kružnog pojasa širine 7,2 m.

Od radijusa zaokretanja će da zavisi i prohodnost autobusa i njegova namjena. Na Slici 11. prikazano je zaokretanje zadnje ivice solo i zglobnog autobusa u putnim uslovima.

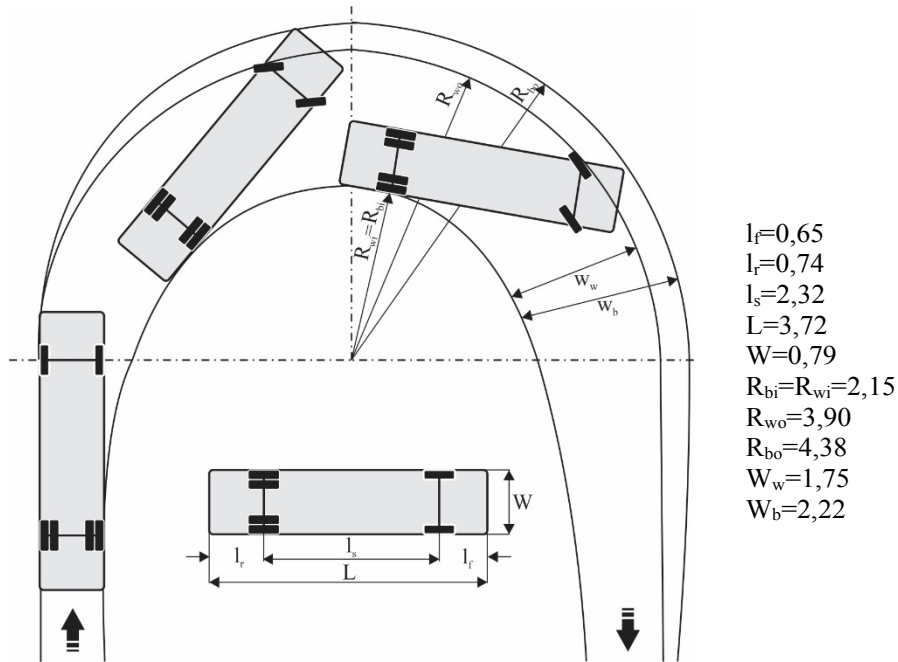
Besides the above mentioned factors, to determine the basic kinematic requirements that steering wheel system must satisfy, we have to start from the minimum and maximum radius of turning the buses which is defined by the ECE regulations. In Picture 8 it is shown the radiuses of turns required by the ECE standards, and in Picture 9 according to the American standard, as well as the basic dimensions of the bus. The turning radius with the articulated bus with a fixed rear axle and the rear axle controlled is shown in Picture 10.

According to ECE R 36 and Picture 8 it is defined that the vehicle must enable steering within a circle radius of 12.5 m, without any of its end point does not protrude outside of the circle. When the endpoints of vehicles move around the circle radius of 12.5 m, the vehicle must be moving in the limits of a circular area with a radius of 7.2 m.

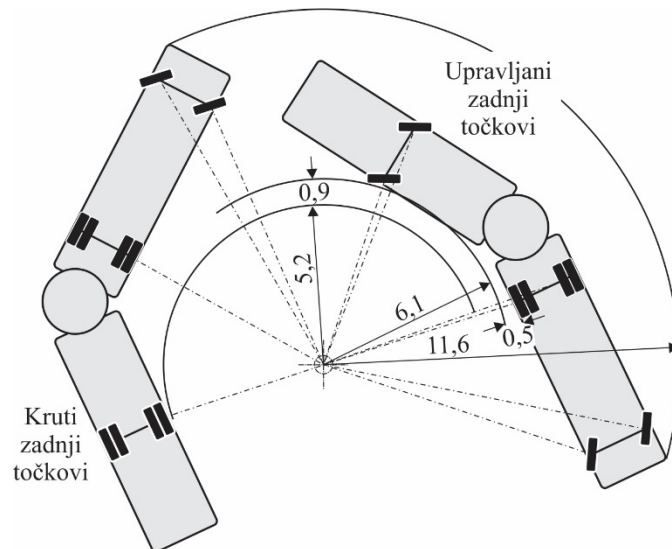
The turning radius affects the mobility of bus and its purpose. Picture 11 shows the swing of the back edge of single and articulated bus on road conditions.



**Slika 8.** Radijusi zaokretanja autobusa prema ECE R 36.  
**Picture 8.** Turning radius of the bus according to ECE R 36.

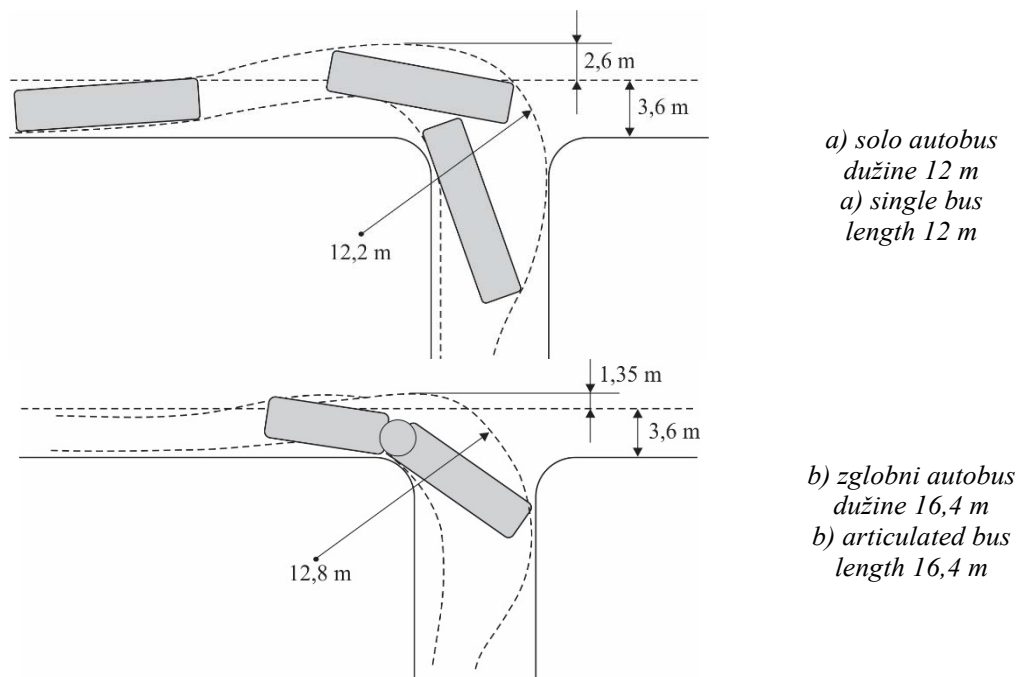


**Slika 9.** Minimalni radijus zaokretanja standardnog američkog autobusa (vrijednosti u metrima).  
**Picture 9.** The minimum turning radius of the standard American bus (values in metres).



Upravljeni zadnji točkovi = Controlled rear wheels  
 Kruti zadnji točkovi = Rigid rear wheels

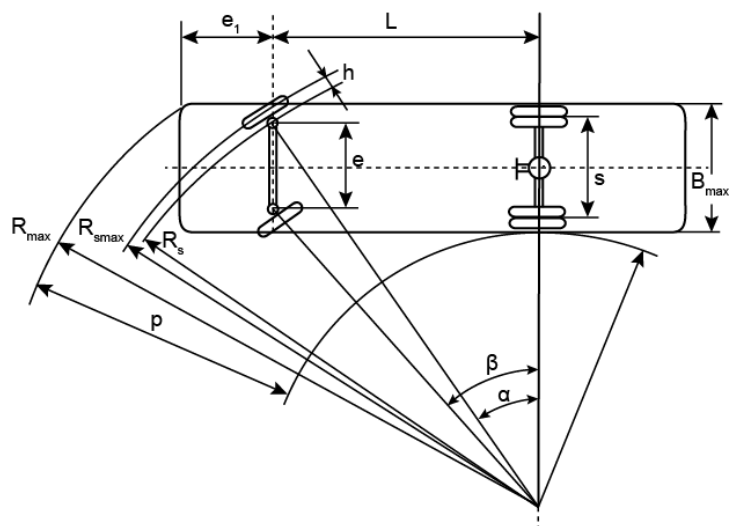
**Slika 10.** Radijus zaokretanja kod zglobnih autobusa sa fiksnom zadnjom osovinom i upravljanom zadnjom osovinom (vrijednosti u metrima).  
**Picture 10.** Turning radius of articulated bus with a fixed rear axle and driven rear axle (values in metres).



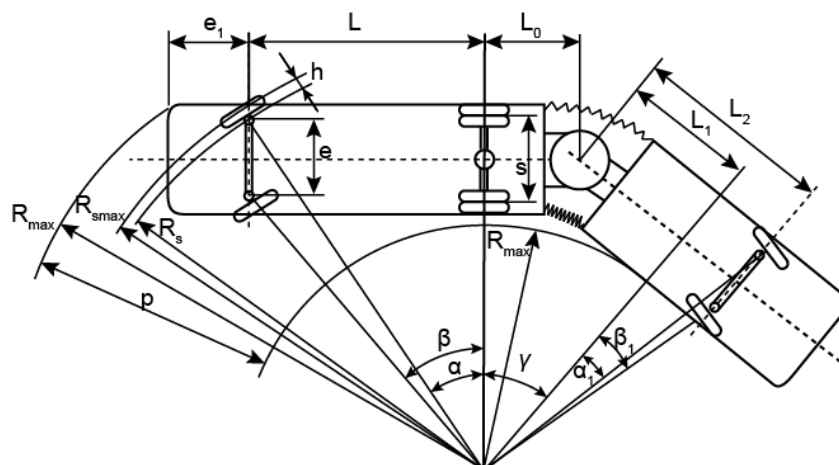
**Slika 11.** Zaokretanje zadnje ivice solo i zglobnog autobusa.  
**Picture 11.** Rotating the rear edge of a single and an articulated bus.

Za analizu kinematskih zahtjeva za zaokretanje dvosovinskih i troosovinskih autobusa može da posluži Slika 12., na kojoj je prikazano zaokretanje točkova vozila sa jednom upravljajućom osovinom, dok je na Slici 13. prikazano zaokretanje troosovinskog zglobnog autobusa.

For the analysis of the kinematic requirements for pivoting the two-axle and three-axle buses we can use Picture 12, showing the pivoting of the wheels of the vehicle with one managing shaft, while Picture 13 shows three-axle pivoting of articulated bus.



**Slika 12:** Zaokretanje dvoosovinskog autobusa  
**Chart 12:** Rotating of the two-axle bus.



**Slika 13:** Zaokretanje troosovinskog zglobnog autobusa sa upravljivim pratećim mostom.  
**Chart 13:** Rotating of the three-axle articulated bus with controllable supporting end.

Kinematski zahtjev zaokretanja dvoosovinskog i troosovinskog autobusa dat je jednačinom:

$$ctg \alpha - ctg \beta = \frac{e}{L} \quad (4)$$

Minimalni i maksimalni radijusi zaokretanja, kao i širina koridora, imajući u vidu kinematiku zaokretanja autobusa, uz pretpostavku da su točkovi bočno kruti, dati su jednačinom (Simić, 1980):

$$R_{min} = \frac{L}{tg \alpha} - \frac{e}{2} - \frac{B_{max}}{2} \quad (5)$$

$$R_{max} = \sqrt{((L + e_1)^2 + (R_{min} + B_{max})^2)} \quad (6)$$

$$p = R_{max} - R_{min} \quad (7)$$

Iterativnim ili grafičkim postupcima mogu da se izračunaju uglovi zaokretanja spoljnjih upravljivih točkova, čije su vrijednosti, iz konstruktivnih razloga, ograničene na  $45^\circ$ , zbog potrebe da unutrašnji uglovi imaju vrijednost i do  $55^\circ$ .

Koncepcija sistema za upravljanje usvaja se u zavisnosti od koncepcije autobusa, pri čemu mora da se vodi računa o zadovoljenju kinematskih zahtjeva zaokretanja. Do potrebnih dimenzija elemenata sistema za upravljanje, u početnoj fazi izrade projekta, obično se dolazi izvođenjem proračuna njihovog opterećenja pri zaokretanju točkova u mjestu, pri čemu se moment izračunava empirijski (Demić, 1994):

$$M_z = \frac{G_u^{1,5}}{k \cdot p^{0,5}} \quad (8)$$

The kinematic requirement of pivoting two-axle and three-axle buses is given by the equation:

$$ctg \alpha - ctg \beta = \frac{e}{L} \quad (4)$$

The minimum and maximum turning radius, as well as the width of the corridor, bearing in mind the kinematics of the bus pivoting, assuming that the lateral wheels are rigid, are given by equation (Simić, 1980):

$$R_{min} = \frac{L}{tg \alpha} - \frac{e}{2} - \frac{B_{max}}{2} \quad (5)$$

$$R_{max} = \sqrt{((L + e_1)^2 + (R_{min} + B_{max})^2)} \quad (6)$$

$$p = R_{max} - R_{min} \quad (7)$$

Using iterative or graphical methods we can calculate turning angle of external controllable wheels, whose values, for structural reasons, are limited to  $45^\circ$ , due to the need to have internal angles of a value up to  $55^\circ$ .

The concept of steering wheel system is adopted depending on the concept of a bus, in which must be taken into account to satisfy the requirements of cinematic swing. To the required dimensions of elements of steering system, in the initial phase of the project, we usually come by the execution of the calculation of its load in turning the wheels in one spot, whereby the moment is calculated empirically (Demić, 1994):

$$M_z = \frac{G_u^{1,5}}{k \cdot p^{0,5}} \quad (8)$$

gdje je:

$M_z$ : moment zaokretanja autobusa u mjestu;

$k$  koeficijent koji se obično usvaja 2,1;

$p$  pritisak vazduha u pneumaticima upravljivih točkova;

$G_u$  opterećenje upravljivih točkova.

Na osnovu izabranih parametara sistema za upravljanje može da se definiše moment na točku upravljača, koji zbog zamora vozača ne bi smio biti veći 100-200 N (Mitschke 1992, Minić 1992). Ovo često nije ispunjeno kod autobusa, pa je neophodno korištenje servo upravljača i radnih cilindara. U Tabeli 1 su dati osnovni podaci za servo upravljače firme „ZF“.

wherein:

$M_z$ : the turning moment of a bus in one spot;

$k$  coefficient, usually adopted 2,1;

$p$  air pressure in tires of controllable wheels;

$G_u$  the load of controllable wheels;

On the basis of selected parameters of the steering wheel system we can define the moment on the steering wheel point, which due to the fatigue of drivers should not exceed 100-200 N (Mitschke 1992, Minić 1992). This often is not met with buses, so it is necessary to use the power steering wheel and working cylinders. Table 1 presents data for power steering of the company "ZF".

**Tabela 1:** Osnovni tehnički podaci za servo upravljače „ZF“ (<http://www.ppt-servo.co.rs>).

Tip servoupravljača	ZF 8042	ZF 8045	ZF 8045*
Hidraulički moment (Nm)	3.570	4.800	4.800
Prenosni odnos	20,7:1	22,7:1	22,7:1
Ugao poluge upravljača (°)	96	96	96
Broj obrtaja točka upravljača	5,5	6,1	6,1
Puž	lijevi	lijevi	lijevi
Povratno dejstvo (Ncm)	1.560 (6 MPa)	28,5 (100 MPa)	
Opterećenje prednjeg mosta (daN)	4.000-6.000	6.500-7.500	

\*Mogućnost priključenja dodatnih cilindara.

**Table 1:** Basic technical data for power steering “ZF” (<http://www.ppt-servo.co.rs>).

Type of power steering	ZF 8042	ZF 8045	ZF 8045*
Hydraulic moment (Nm)	3.570	4.800	4.800
Gear ratio	20,7:1	22,7:1	22,7:1
Steering angle of lever (°)	96	96	96
RPM of the steering wheel	5,5	6,1	6,1
Snail	left	left	left
Retroaction (Ncm)	1.560 (6 MPa)	28,5 (100 MPa)	
The load of front end (daN)	4.000-6.000	6.500-7.500	

\*The possibility of connecting additional cylinders

## 6. GEOMETRIJA UPRAVLJIVIH TOČKOVA I OSOVINICA RUKAVACA

Odlika kolovoza o kojoj zavisi pojava manje ili više izraženog efekta proklizavanja naziva se **koeficijent trenja**. Visoka vrijednost ukazuje na grubu površinu koja gotovo uopšte nije klizava, dok niska vrijednost znači da je površina glatka, odnosno klizava. Koeficijent trenja utiče na kočionu silu i kočioni put. Kao primjer navodimo samo razliku između kočenja po suhom, odnosno mokrom kolovozu.

## 6. THE GEOMETRY OF CONTROLLABLE WHEELS AND AXLES OF BEARING

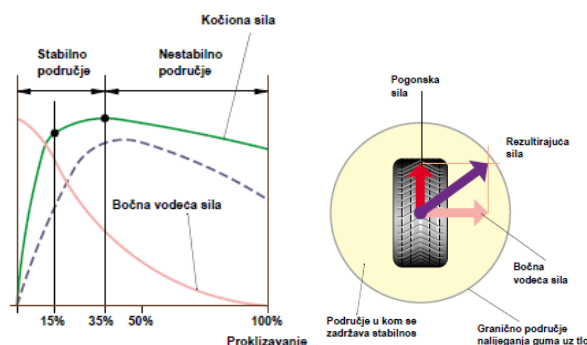
Quality of the road surface of which the occurrence of more or less pronounced traction effect depends is called **the coefficient of friction**. A high value indicates a rough surface that certainly is not slippery, while a low value indicates that the surface is smooth or slippery. The coefficient of friction affects the braking force and braking time. As an example we underline only the difference between braking on dry or wet roads.

Pored toga niski koeficijent trenja pridonosi blokiranju točkova prilikom kočenja, primjerice na snijegu ili ledu. U takvim slučajevima točak klizi preko kolovoza, događa se **proklizavanje** vozila. Proklizavanje varira po skali od 0-100 %. Kada je veličina 0% točak se slobodno okreće, dok je pri veličini od 100% potpuno blokiran.

Proklizavanje tokom nekog manevra uvijek predstavlja kritičnu situaciju, pošto je time ugrožena stabilnost vozila; kao primjer se može navesti kretanje u krivini, kao i kočenje ili ubrzavanje na kolovozu prekrivenim ledom ili šljunkom. Kako bi se održala stabilnost vozila potrebno je osigurati to, da zbir pogonske i vodeće sile (rezultirajuće sile) nikada ne premaši graničnu vrijednost prijanjanja guma uz tlo. Ova se granična vrijednost prikazuje pomoću Kamm-ovog kruga (Slika 14.). U slučaju da neka od sila "probije" Kamm-ov" krug, ponašanje vozila poprima nestabilna svojstva. Elektronski sistemi, kao što su ABS, EDS ili ESP sistem ne povećavaju vrijednost sile prijanjanja guma uz tlo. Oni pomažu vozaču u kritičnim situacijama, i na taj način sprečavaju prekoračenje navedene granične vrijednosti.

In addition to this, a low coefficient of friction contributes to the lock of wheels when braking, for example on snow or ice. In such cases, the wheel slides over the road, **the vehicle is slipping**. The slipping varies from 0-100%. When the value is 0% the wheel rotates freely, while at the value of 100% it is completely blocked.

The slipping during a manoeuvre is always a critical situation, and thus the stability of the vehicle is compromised; as an example we can indicate movement in a curve, as well as braking or accelerating on roads covered with ice or gravel. To maintain vehicle stability it is necessary to ensure that the sum of the driving and the leading force (resulting force) never exceeds the limit of adhesion of tires to the ground. This limit value is displayed with the Kamm's circle (Picture 14). In case that some of the forces "breaks" Kamm's circle, the vehicle's behaviour takes unstable properties. The electronic systems such as ABS, EDS or ESP system do not increase the value of the force of adhesion of tires to the ground. They assist the driver in critical situations, and thus prevent exceeding the threshold value.



Stabilno područje = Stable area  
 Nestabilno područje = Unstable area  
 Koćiona sila = Braking force  
 Boćna vodeća sila = Lateral leading force  
 Pogonska sila = Driving force  
 Rezultujuća sila = Resulting force

Proklizavanje = Slipping  
 Područje u kojem se zadržava stabilnost = The area in which it retains stability  
 Granićno područje nalijeganja guma uz tlo = The border area of seating the tires to the ground

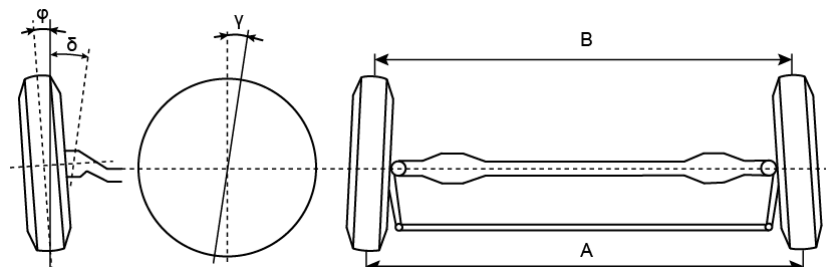
**Slika 14.** Kamm-ov krug sile.  
**Figure.** The Kamm's circle of forces.

U cilju stabilizacije autobusa upravljivi točkovi i osovinice rukavaca postavljaju se pod određenim uglovima (boćni nagib toćka  $\varphi$ ), konvergencija  $\omega$ ), ugao uzdućnog zatura  $\gamma$ ) i boćni nagib osovinice rukavca  $\delta$ ), u odnosu na horizontalnu i vertikalnu ravan autobusa, kako je prikazano na Slici 15.

In order to stabilize the bus the manoeuvring wheels and bearing axles are placed at certain angles (lateral deviation of wheel  $\varphi$ / convergence  $\omega$ / angle of longitudinal caster  $\gamma$ / and lateral deviation of the bearing axles  $\delta$ ), in relation to the horizontal and vertical plane of buses, as shown in Picture 15.

Prilikom projektovanja autobusa veličine se obično usvajaju po analogiji sa već izvedenim vozilima slične kategorije. U Tabeli 2 prikazane su približne veličine parametara geometrije upravljivih točkova i rukavaca kod autobusa (Minić, 1992).

When designing the bus the values are usually adopted by analogy with already constructed vehicles of similar categories. Table 2 shows the approximate values of the parameters of controllable geometry of wheels and bearing axles in buses (Minić- 1992).



**Slika 15.** Geometrija upravljivih točkova i osovina rukavaca (Demić, 2003).  
**Picture 15.** The geometry of driving wheels and axles of bearing (Demić, 2003).

**Tabela 2.** Osnovni kinematski parametri upravljivog mosta.

Osnovni parametri geometrije točkova	Vrijednost
Bočni nagib točka ( $\varphi$ ) ( $^{\circ}$ )	1-1,5
Konvergencija (A-B) (mm)	3-10
Bočni nagib osovina rukavca ( $\delta$ ) ( $^{\circ}$ )	0-6
Uzdužni zatur ( $\gamma$ ) ( $^{\circ}$ )	0-3,5

**Table 2.** The basic kinematic parameters of controllable end.

Basic parameters of the wheels geometry	Value
Lateral deflection of a wheel ( $\varphi$ ) ( $^{\circ}$ )	1-1,5
Convergence (A-B) (mm)	3-10
Lateral deflection of the axles of bearing ( $\delta$ ) ( $^{\circ}$ )	0-6
Longitudinal caster ( $\gamma$ ) ( $^{\circ}$ )	0-3,5

## 7. ZAŠTO JE ELEKTRO MOBILNOST ZANIMLJIVA?

Prema aktuelnim procjenama će 2050. biti zadnja godina eksploatacije nafte, kakvu čovjek poznaje do sada. Dobivanje nafte će osim toga biti moguće samo uz velike tehničke izdatke. Stoga je neophodno da konstruktori autobusa, kao i svih drugih vozila, kroz svoja rješenja koriste resurse savjesno i učinkovito. Sensibilizacija i postizanje te svijesti mora da bude glavni zadatak! Upotreba energije i sirovina stalno mora optimalna. Zagađenje okoline u istoj mjeri mora stalno opadati.

Cilj je da globalni porast temperature do 2050. ne raste za više od  $2^{\circ}\text{C}$ . Kako bi se postigao taj cilj, konstrukcijska rješenja moraju voditi ka smanjenju emisije stakleničkih plinova, kao npr. ugljičnog dioksida ( $\text{CO}_2$ ).

## 7. WHY IS THE ELECTRIC MOBILITY INTERESTING?

According to current estimates, the year 2050 will be the last years of oil exploitation, which man knows so far. Getting the oil will moreover be possible only with great technical expenditure. It is therefore essential that the designers of buses and all other vehicles, through its solutions, use resources conscientiously and effectively. The sensitization and achievement of that awareness must be the main task! The use of energy and raw materials must constantly be optimal. Pollution of the environment to the same degree must steadily decline.

The goal is that the global increase of temperatures by 2050 does not grow by more than  $2^{\circ}\text{C}$ . To achieve this goal, the structural solutions must lead to a reduction of greenhouse gas emissions, for example Carbon dioxide ( $\text{CO}_2$ ).



U usporedbi s vozilima s motorima s unutrašnjim sagorijevanjem, vozila s elektro pogonom tokom vožnje ne stvaraju ispušne plinove. Samo to svojstvo čini elektro vozila prihvatljivijima za okoliš od vozila uobičajene tehnike. To pretpostavlja da električna energija za punjenje vozila potiče iz obnovljivih izvora energije, npr. iz vjetroelektrane, solarne elektrane, elektrane na pogon vodom ili bio plina.

Potvrdu značaja ovog poglavlja, bez obzira što ne nudi nikakva konstrukcijska rješenja, ili primjere istih, pokazuje činjenica da bi do 2020. njemačkim cestama trebalo saobraćati minimalno milion elektro vozila. Donošenjem nacionalnog plana razvoja elektro mobilnosti (NEPE) u avgustu 2009. Savezna vlada naglašava značenje ove teme u Njemačkoj. Elektrifikacija vozila će dakle stalno rasti. Uz gore navedene konstrukcije zahvate, elektro mobilnost autobusa predstavlja zasigurno najveći konstrukcijski izazov, kako današnji, tako i budući. Prvi korak su svakako hibridna vozila, koja povezuju prednosti oba sistema elektro i motora s unutrašnjim sagorijevanjem. Ovakvom kombinacijom pogona poboljšava se ukupni stepen učinka vozila te se smanjuje potrošnja goriva.

Elektro mobilnost je vječna tema, koja je ubrzala razvoj motornih vozila. Ako je njezino značenje privremeno ustuknulo pred prividom nepresušnih nalazišta nafte, tada joj sa sviješću o prolaznosti tih nalazišta i porastom zahtjeva globalne zaštite okoline i klime vrijednost raste. Konstrukcijski gledano, kako bismo promotrili osnovne aspekte elektro mobilnosti, moramo uvažiti područja ekologije, politike, industrije, društva, infrastrukture i svakako tehnike. Sadržajno razdvajanje tih područja nije moguće u potpunosti, jer među njima postoji složen socijalni odnos. Klimatske promjene i uslovi kod upotrebe fosilnih resursa (ograničena raspoloživost, cijena) dovode do promjene klimatske i energetske politike država i do promjena nacionalnih društava. Politika kao odgovor na te promjene daje nacionalno utvrđene, a ipak međunarodno međusobno odstupajuće granične vrijednosti za emisije. Te granične vrijednosti u pravilu opisuju direktne emisije ILI-ILI druge plinove koji utiču na okolinu.

Elektro vozilo nema direktnu emisiju u obliku CO<sub>2</sub>, predstavlja ključni odgovor na postavljeno pitanje!

Compared to vehicles with internal combustion engines, the vehicles with electric drive during the drive do not generate exhaust gases. This characteristic makes electric vehicles more environmentally friendly for environment than conventional techniques. This assumes that electricity to charge the vehicles comes from renewable energy sources, e.g. from wind farms, solar power plants, hydropower plants or biogas plants.

The confirmation of importance of this section, no matter that it does not offer structural solutions, and examples thereof, is shown by the fact that until 2020 German roads should operate a minimum of one million electric vehicles. By adoption of a national plan for the development of electro mobility (NEPE) in August 2009 The Federal Government emphasizes the importance of this topic in Germany. Electrification of vehicles will therefore continue to grow. With the above structural interventions, the electric mobility of buses represents surely the greatest structural challenge, as today, as in the future. The first step is certainly the hybrid vehicles, which combine the advantages of both systems electric and internal combustion engines. This combination improves the drive performance of the vehicle overall efficiency and reduces fuel consumption.

Electric mobility is the eternal theme, which has accelerated the development of motor vehicles. If its meaning temporarily retreated from the illusion of inexhaustible resources of oil, then, with the awareness of the transience of these sites and with the increase of requirements for the global environmental and climate the value of electric mobility grows.

Speaking of construction, in order to observe the basic aspects of electric mobility, we have to take into account the field of ecology, politics, industry, society, infrastructure and certainly techniques. Substantially separating these areas cannot be fully, because among them there is a complex social relationship. The climate changes and conditions with the use of fossil resources (limited availability, price) lead to changes in climate and energy policy of the country and to the change of national societies. The policy as a response to these changes gives nationally determined, yet internationally mutually deviating limit values for emissions. These limits typically describe the direct emissions of ILI-ILI other gases that affect the environment.

Electric vehicle has no direct emissions in the form of CO<sub>2</sub>, and is a key answer to posed question!

## 8. ZAKLJUČAK

Eksploatacioni uslovi autobusa su u direktnoj vezi sa njegovom namjenom. Namjeni autobusa treba posvetiti posebnu pažnju u toku projektovanja autobusa i iznalaženju najboljih konstrukcijskih rješenja. Na primjer, specifičnost eksploatacije gradskih autobusa se ogleda u često promjeni korisnog opterećenja (broja putnika), velikoj razlici ukupne mase opterećenog i neopterećenog vozila, čestim slučajevima preopterećenja, kao i često promjeni režima vožnje (ubrzanja i usporjenja), što za turističke autobuse nije karakteristično.

Turistički autobusi se eksploatišu na dugim relacijama, sa većim putnim brzinama kretanja, znatno manjim brojem promjena stepena prenosa, sa malim promjenama opterećenja vozila (samo se prevoze putnici u sjedećem položaju).

Takođe, propisi za gradnju autobusa nameću sve strože zahtjeve u pogledu bezbjednosti putnika. Stoga se kod konstrukcionih izvođenja autobusa poklanja posebna pažnja ovom problemu, pa je u skladu sa tim, što treba posebno naglasiti, Evropska unija donjela niz propisa kojima su definisani osnovni konstrukcioni zahtjevi za autobuse, kao i metode ispitivanja čvrstoće nadogradnje.

U cilju povećanja bezbjednosti saobraćaja savremeni autobusi doživljavaju vrlo brz razvoj i po svojim karakteristikama veoma malo zaostaju za putničkim motornim vozilima, gdje se primjenjuju najsavremeniji elektronski sistemi (ABS, ASR, ASC, poluaktivno oslanjanje, klimatizacija putničkog prostora, servoupravljač, automatska transmisija i sl.).

Sa aspekta iznalaženja dobrih konstrukcijskih rješenja poseban značaj imaju autobusi u gradskom prevozu. Pogotovo kada se zna da se oko dvije trećine svih putovanja javnim prevozom u svijetu obavlja autobusom. Karakteristike gradskog autobusa su mogućnost postizanja većeg ubrzanja, manje maksimalne brzine, laka i česta promjena stepena prenosa, nizak pod sa olakšanim ulaskom i izlaskom putnika, većim brojem vrata i većim brojem mjesta za stajanje.

Zbog savremenih zahtjeva za gradnju gradskih autobusa, kao što su: povećanje kapaciteta prevezenih putnika, ekonomičnost, tj. mala potrošnja goriva, ekološkičnost, tj. smanjena emisija izduvnih gasova, došlo se do novih konstrukcionih rješenja autobusa. Osim, već dobro poznatih standardnih rješenja, kao što su: dvospratni, zglobovi autobus ili niskopodni autobus, u različitim dijelovima svijeta pojavila su se sasvim nova rješenja.

## 8. CONCLUSION

Exploitation conditions of a bus are directly related to its purpose. Use of the bus should be given special attention during the design of bus and finding the best design solutions. For example, the specific operation of city bus is reflected in the frequent change of useful load (number of passengers), the great difference of the total weight of loaded and unloaded vehicle, frequent cases of overloading, as well as frequent changing driving modes (accelerations and decelerations), which for touristic buses is not typical.

Touristic buses are exploited over long routes, with higher travel speeds, significantly smaller number of gear changes, with small changes in load vehicles (passengers in a sitting position).

Also, the regulations for the construction of buses impose increasingly stringent requirements regarding the safety of passengers. Therefore, at the structural performance of buses we have to pay special attention to this problem, however, in line with this, which is necessary to emphasize, the European Union brought a number of regulations which define the basic structural requirements for buses, as well as methods of testing the strength of upgrades.

In order to increase traffic safety the modern buses are experiencing a very fast development and in their characteristics they are very little behind the passenger's motor vehicles, where there is applied the most advanced electronic systems (ABS, ASR, ASC, Semi active suspension, air conditioning of passenger's compartment, power steering, automatic transmission and similar).

From the point of finding good structural solutions the buses in urban transport have special significance. Especially when you know that about two thirds of all public transport transports in the world is done by buses. Characteristics of the city bus have the ability to achieve a higher acceleration, lower maximum speed, easy and frequent change of gear, low floor to facilitate the entry and exit of passengers, greater number of doors and greater number of places for standing.

Due to modern requirements for the construction of city buses, such as: increasing the capacity of transported passengers, economy, i.e. low fuel consumption, environmental protection, i.e. reduced carbon emissions, there are new structural solutions of buses. Besides the well-known standard solutions, such as: double-decker bus, articulated bus or low-floor bus, in different parts of the world there have appeared completely new solutions.

Ova rješenja obično su prilagođena novim tehnologijama prevoza putnika u gradovima.

Posljednjih nekoliko decenija automobilska industrija posebnu pažnju posvećuje ekološkim kvalitetima svojih proizvoda. Da bi proizvodi mogli definisati kao ekološki prihvatljiv, još u fazi projektovanja definišu se ekološke smjernice: oslanjanje na nove materijale, mogućnost recikliranja, lake konstrukcije, manje zapremine motora, uvođenje električnih pogona, odnosno elektro mobilnost.

Uvođenje zona sa smanjenom, ili bez emisije u gradovima kao i promijenjeni politički okvirni uslovi ubrzo će proširenje elektro mobilnosti. Civilizacijski odgovor je da državne ili komunalno finansijske mjere poticanja potiču industriju i podržavaju proces razvoja u nauci i istraživanju. Sve više preduzeća ulaže u elektro mobilnost, te tako u kombinaciji s istraživanjem poboljšavaju daljnji razvoj postojećih koncepata, tehnoloških inovacija i njihovih trenutnih mogućnosti upotrebe.

These solutions are usually adjusted to the new technologies of passenger transport in cities.

In the last few decades, the automotive industry pays special attention to the environmental qualities of their products. To be able to define products as environmentally friendly, still in the design phase, there are defined environmental guidelines: relying on new materials, recyclability, light constructions, less engine volume, the introduction of electric drives, and electric mobility.

The introduction of zones with reduced or no emissions in cities as well as the changed political framework conditions will accelerate the expansion of electric mobility. Civilizational response is that the state or municipal financial measures encourage industry and support the process of development in science and research. More and more companies are investing in electric mobility, so in combination with research they enhance the further development of existing concepts, technological innovations and their current usage possibilities.

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**Corresponding author:**

**Mesud Ajanović**

**University of East Sarajevo**

**Traffic Faculty Doboj**

**Email: ajanovicmesud@gmail.com**

**Phone: +387 61 482 143**