

Simulator vožnje vozila pri mejnem zdrsu

A Vehicle Skidding Simulator

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Usposabljanje poklicnih voznikov zahteva njihovo pripravo na kritične vremenske razmere v prometu (dež, sneg ali poledenelo cestišče). V teh razmerah je koeficient trenja med plaščem vozila in podlago bistveno manjši kakor v običajnih razmerah. Silo sojemanja je mogoče nadzorovano spreminjati z uporabo simulatorja zdrsa vozila. Ta deluje po načelu zmanjševanja pravokotne sile z dvigom kolesa vozila in s tem posledično zmanjševanja sile sojemanja pri nespremenjenem koeficientu trenja. Krmilni sistem na podlagi merjenja pravokotne sile na kolesu omogoča nadzorovano simuliranje zdrsa vozila. Prispevek predstavlja konstrukcijske rešitve posameznih sklopov simulatorja.

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(Ključne besede: simulatorji vožnje, zdrsanje vozil, krmiljenje zdrsa, rešitve konstrukcijske)

To qualify professional drivers for critical driving conditions, like rain, snow, and slippery ice, a skidding simulation is required. Using a skidding simulator it is possible to control the traction force of a vehicle. The traction force can be reduced by decreasing the normal force between the vehicle's wheels and the ground by lifting the vehicle's wheels, while the friction coefficient remains unchanged. In order to control the skidding simulator a new control system for the simulator was introduced. The system is based on measuring the normal force. This paper presents the design solutions for the individual parts of the simulator.

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(Keywords: vehicle simulator, skidding, slip control systems design solutions)

0 UVOD

Usposabljanje poklicnih voznikov terja tudi pripravo na kritične vremenske razmere v prometu (dež, sneg ali poledenelo cestišče) z uporabo simuliranih razmer zdrsa vozila. Neprilagojena hitrost vožnje in napačno ravnanje v takšnih razmerah lahko vodita do izgube nadzora nad vozilom. Kritične vozne razmere je mogoče poustvariti z umetnim zmanjševanjem koeficienta trenja z uporabo izrabljenih plaščev na posebni drsni prevleki vozišča in s polivanjem podlage z vodo [1]. Ta način simuliranja skrajnih razmer pri vožnji je nevaren. Nimamo nadzora nad zdrsom vozila, potrebne so velike hitrosti in ni mogoče ustaviti poskusa v primeru nevarnosti.

Drug način zmanjševanja sile sojemanja med plaščem in podlago je mogoč z uporabo simulatorja zdrsa vozila [2]. Simulator zdrsa deluje po načelu zmanjševanja pravokotne sile med plaščem in podlago in s tem posledično sile sojemanja pri nespremenjenem koeficientu trenja. To dosežemo z dvigom s kolesa vozila skupaj z obeso.

Glavni namen raziskovalnega dela je razvoj naprave in nadzornega sistema, ki omogoča nadzorovan zdrs vozila. S takšnim simulatorjem želimo doseči slabši prenos vzdolžnih in prečnih sil s plašča na podlago, kar vodi do hitrejšega zdrsa plašča v zavoj ali pri zaviranju.

0 INTRODUCTION

To qualify professional drivers for critical driving conditions, like rain, snow, and slippery ice, a skidding simulation is required. The high speeds and the mistakes made by the driver under these conditions can result in a loss of control over the vehicle. Critical traffic conditions can be simulated by deliberately decreasing the friction coefficient with a special skidding coating or by watering the driving area [1]. These methods are dangerous, however, because we do not have control over the simulation, high speeds are needed for the test and it is impossible to abort the test in the case of unexpected danger.

An alternative way to control the skidding simulation is by using a vehicle skidding simulator. The traction force can be reduced by decreasing the normal force [2]. This is achieved by lifting the wheels of the vehicle, while the friction coefficient remains unchanged.

Our goal is to develop a device that enables the vehicle to slip in a controlled fashion. With this device a weaker transfer of the longitudinal forces (acceleration, braking) and the transversal

Tako lahko simuliramo razmere pri vožnji po mokrem ali poledenelem vozišču, oljnih madežih ali lužah (akvaplaning), oziroma ko z delom vozila zapeljemo na podlago z drugačnim koeficientom sojemanja [3]. Tako lahko simuliramo pojav prekrmljenja ali podkrmiljenja vozila. Hitrosti vožnje pri simulaciji so manjše od običajnih, pri katerih prihaja do zdrsa na testnih poligonih [1]. Namen simulatorja je nadzorovano simuliranje skrajnih voznih razmer za testiranje različnih delov vozila (varnostni sistemi, pogonska veriga). Znane rešitve sistema za nadzor zdrsa uporabljajo kot nadzorno veličino višine dviga kolesa vozila. V našem primeru smo uvedli nadzor z merjenjem pravokotne sile med pnevmatiko in podlago.

Prispevek v prvem delu predstavlja poglavitno načelo delovanja simulatorja zdrsa, v nadaljevanju opisuje nov način nadzora zdrsa vozila, nato pa podaja konstrukcijske rešitve zaznavnega dela krmilnega sistema, nosilnega okvira in načina vpetja simulatorja na obese vozila. Na koncu so podani sklepi in predlogi za nadaljnje delo.

1 NAČELO DELOVANJA SIMULATORJA ZDRSA

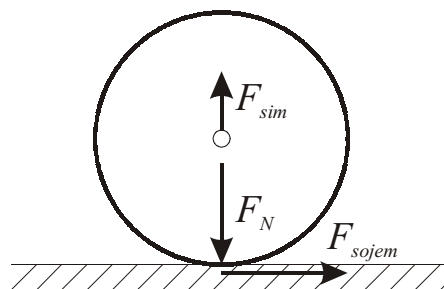
Pri vožnji sila sojemanja med plašči vozila in voziščem zagotavlja prenos vzdolžnih sil (pospeševanje, zaviranje) in prečnih sil (vztrajnostna sila pri vožnji v ovinku) z vozila na podlago. Velikost sile sojemanja med plaščem in podlago F_{sojem} je odvisna od koeficienta trenja μ [4] in pravokotne sile na podlago F_N (1):

$$F_{sojem} = \mu \cdot F_N \quad (1)$$

Silo sojemanja lahko zmanjšamo tako, da zmanjšamo koeficient trenja med plaščem in podlago ([5] do [7]). To lahko dosežemo s posebno drsno prevleko vozišča z manjšim koeficientom trenja in z dodatnim polivanjem podlage z vodo.

Druga možnost zmanjšanja sile sojemanja med plaščem in podlago, je zmanjšanje pravokotne sile na podlago (2). Z dvigom posameznega kolesa vozila ali pa celotne karoserije vozila se del normalne sile prenese na prosto gibljiv voziček simulatorja F_{sim} (sl. 1):

$$F_{sojem} = \mu \cdot (F_N - F_{sim}) \quad (2)$$



Sl. 1. Zmanjšanje sile sojemnja z zmanjšanjem pravokotne sile na kolesu vozila
 Fig. 1. The reduction of the normal force the result of a reduction of the traction force

forces (grip when cornering) between the tyre and the surface is achieved. Almost all critical traffic conditions can be reproduced (rain, snow, slippery ice, oil spills and aquaplaning) [3]. Understeering and oversteering can also be simulated. The required vehicle speeds for the simulation are lower than normal skidding speeds, and known solutions for the skidding conditions' control system use vertical displacements as the controlled quantity. In our case, the skidding conditions are controlled by the normal force between the tyre and the driving terrain.

This paper begins with a presentation of the basic working principle of the skidding simulator, which is followed by a description of the new control system. After the introduction of the control system, proposals for the design of individual parts of the skidding simulator are given in an illustrated form. Finally, some conclusions are drawn and there are some suggestions for future work.

1 THE BASIC WORKING PRINCIPLE

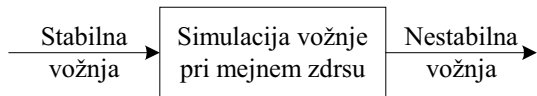
Longitudinal forces (acceleration, braking) and transversal forces (grip when cornering) are transferred from the vehicle to the ground by the traction forces between the tyre and the driving surface. The magnitude of the traction force F_{sojem} depends on the friction coefficient μ [4] and the normal force F_N (1):

The traction-force reduction can be achieved by decreasing the friction between the tyre and the driving surface by means of a special skidding coating on the surface ([5] to [7]). Additional watering is also required.

The second option is a reduction of the traction force by decreasing the normal force F_N (2). One part of the normal force is transmitted to the skidding simulator by lifting the vehicle's wheels or the entire chassis F_{sim} (Fig. 1):

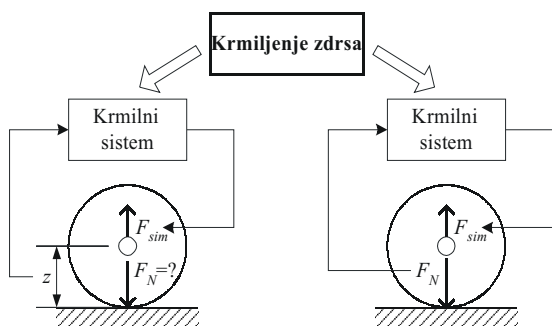
2 KRMILJENJE ZDRSA VOZILA

S simulatorjem zdrs želimo stabilno vozilo nadzorovano spraviti v stanje nestabilne vožnje (sl.2).



Sl. 2. Simulacija vožnje vozila pri mejnem zdrs

Zdrs kolesa vozila je mogoče krmiliti na podlagi višine dviga kolesa ali na podlagi merjenja normalne sile med kolesom in podlago (sl. 3).



Sl. 3. Dva načina krmiljenja zdrs kolesa ([2] in [9])

Zaradi neznane prenosne funkcije med plaščem in pravokotno silo (sl. 4) ni smotno meriti višino dviga kolesa [2]. Razvili smo postopek z merjenjem pravokotne sile med plaščem in podlago na samem nosilnem okviru simulatorja zdrs. Konstrukcijska rešitev zaznavnega dela merjenja pravokotne sile je predstavljena v naslednjem poglavju prispevka.

3 KONSTRUKCIJA SIMULATORJA ZDRSA VOZILA

3.1 Nosilni okvir

Pri zasnovi simulatorja zdrs je predvidena uporaba testnega vozila Renault safrane 2.2 RT. Nosilni okvir je glavna komponenta simulatorja

2 SLIP CONTROL

The smooth motion of the vehicle can be destabilized by the controllable vehicle skidding simulator (Fig. 2.).

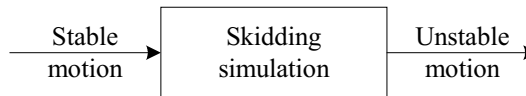


Fig. 2. The skidding simulation

Wheel slip can be controlled by the lift height or by the normal force between wheel and the driving terrain as a controlled quantity (fig. 3):

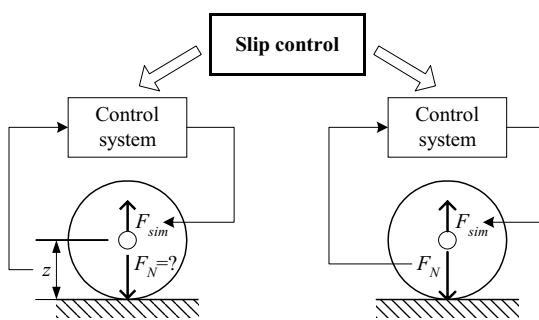


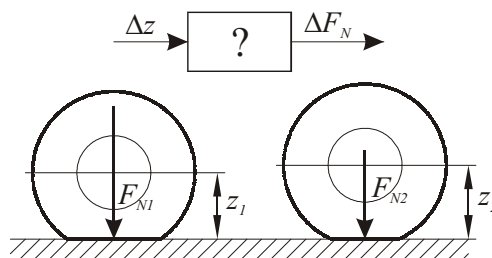
Fig. 3. Wheel slip control ([2] and [9])

Because of an unknown transfer function between the tyre and the normal force (Fig. 4) it is not appropriate to measure the lift height [2]. A measuring system for the normal force on a supporting frame was developed as a part of a new approach to control vehicle slip. The design of the load cell is presented in the next section.

3 DESIGN OF THE VEHICLE SKIDDING SIMULATOR

3.1 Supporting frame

A Renault Safrane 2.2 RT was used as the test vehicle. The supporting frame is the basis of the vehicle skidding simulator. The normal force F_N is



Sl. 4. Prenosna funkcija med višino dviga kolesa in pravokotno silo
Fig. 4. Transfer function between the wheel lift height and the normal force

zdrsa vozila. Prek okvira se del pravokotne sile F_{sim} na kolesu vozila prenese na prosto vrtljivo tekalno kolo simulatorja. Okvir povezuje glavne sklope simulatorja, kakor so tekalna kolesa z dvižnim mehanizmom in vpenjala na obesah vozila. Na podlagi zahtev je izbrana konstrukcija okvira simulatorja iz profilov kvadratnega prereza 90×90 mm in debeline stene 4 mm (sl. 5). Izbrana oblika nosilnega okvira ne ovira vstopanja v vozilo, ponuja manjšo težo (170 kg) in s tem manjši vpliv simulatorja na vozne lastnosti vozila. Konstrukcija nosilnega okvira simulatorja je razstavljiva na posamezne sklope, kar omogoča preprosto montažo in transport. Izvedba ima značilnosti modularne konstrukcije, kar omogoča dobro prilagodljivost različnim tipom osebnih vozil. Ponuja tudi večje možnosti prilagajanja različnim načinom vpetja vozila na simulator in možnost izvedbe mesta merjenja pravokotne sile. Pomanjkljivost tega osnutka je, da so tekalna kolesa nameščena zunaj osi koles vozila (sl. 5).

Pri trdnostnem nadzoru konstrukcije okvira ([9] in [10]) smo obravnavali obremenitveni primer, ko so kolesa simulatorja obrnjena navzven in je okvir obremenjen z največjo predvideno silo 6600 N na vseh štirih pritrdiščih. Največji povos 22 mm se pojavi na skrajnih koncih glavnih prečnih nosil, pri tem je deformacija okvira podana relativno na vozilo (sl. 6). Povos okvira ne vpliva na funkcijo simulatorja, ker je izravnava s krmilnim sistemom na podlagi merjenja pravokotne sile na kolesu vozila.

3.2 Konstrukcija zaznavala pravokotne sile na kolesu vozila

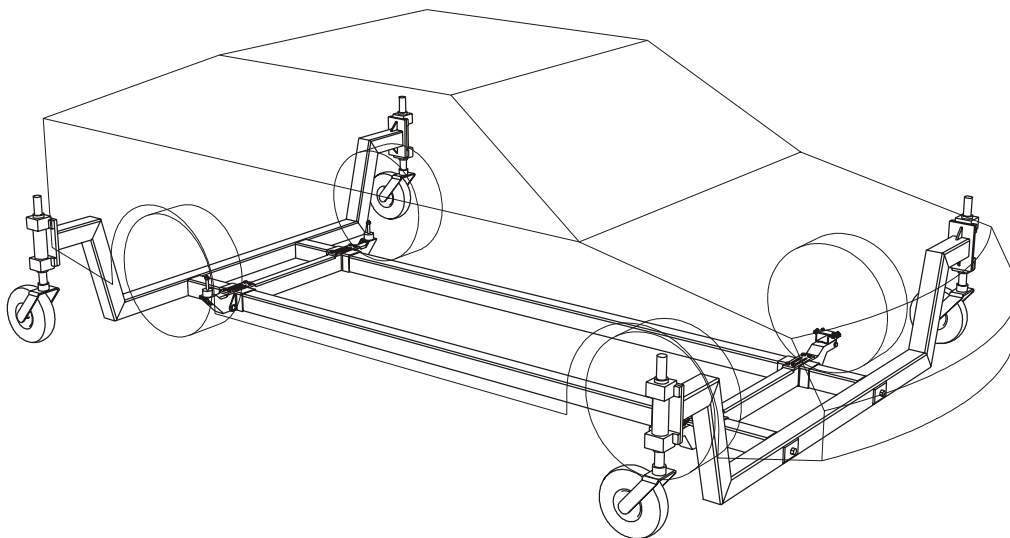
Lega tekalnih koles simulatorja ima zanemarljiv vpliv na obremenitev konzolnega dela nosila preme. Zaradi pomanjkanja prostora pod

transmitted from the vehicle wheel over the supporting frame to the auxiliary wheels on the skidding simulator. The supporting frame links together all the major parts of the simulator: the auxiliary swinging wheels, a lifting mechanism and the connection joints on the vehicle suspension. The frame is made from tubular steel profiles with a square-shaped cross-section $90 \times 90 \times 4$ mm (Fig. 5). The selected shape of the supporting frame must not make it difficult to get in or out of the car. The frame is lightweight (170 kg) and has only a small influence on the driving characteristics of the test vehicle. The frame can also be dismantled into its individual parts. This makes it easy to assemble and transport the simulator to other locations. Because of the simulator's design the skidding simulator and the connecting joints can be adjusted for different vehicle models. It is also possible to instal a load cell for measuring the normal force on the supporting frame. A negative aspect of this concept is the position of the simulator's auxiliary wheels, because they are not on the same axis as the vehicle's wheels (Fig. 5).

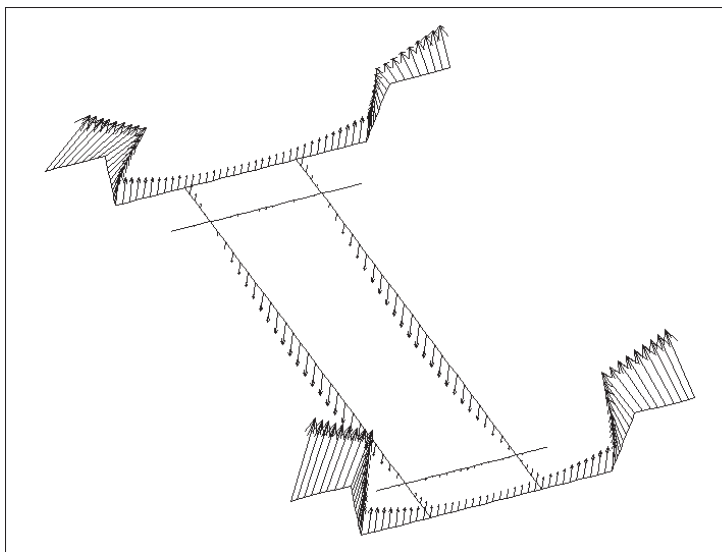
The strength of the frame was checked for the load case when all the auxiliary wheels of the skidding simulator are turned outwards ([9] and [10]). The frame was loaded with a force of 6600 N on all four connecting joints. This results in a maximum deformation of 22 mm on the end parts of the transversal beams (Fig. 6). This deformation is relative to the vehicle, so it does not have any influence on the key simulator function because the deformation is compensated by the control system that measures the normal force on the vehicle wheel.

3.2 Design of the load cell

The auxiliary wheel positions have a negligible effect on the load distribution on the console part of the frame. However, the available space under the



Sl. 5. Konstrukcija nosilnega okvira simulatorja vožnje vozila pri mejnem zdrs
Fig. 5. Supporting frame design



Sl. 6. Vektorski prikaz povesa nosilnega okvira v mm
 Fig. 6. Vectorial representation of the supporting frame deformation in mm

vozilom je najprimernejše merilno mesto na povezavi vzdolžnega nosila z nosilom preme (sl. 7). Silo merimo z merilno sondo za silo.

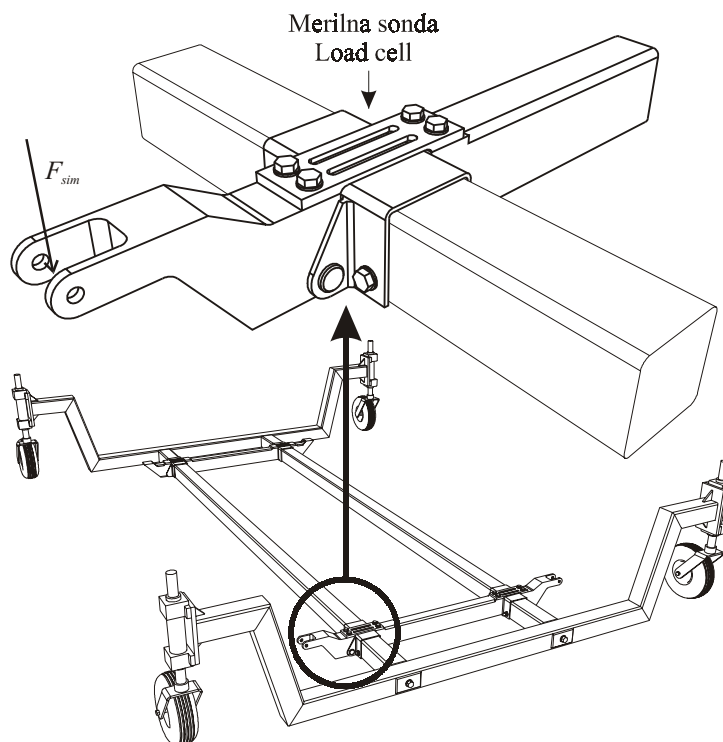
Pravokotno silo merimo z merilno sondo, izdelano iz pločevine, ki ima nalepljene merilne lističe proizvajalca HBM 3/120 XY 11, s katerimi merimo deformacijo enoosnega napetostnega stanja (nateg), ki je na daljši dolžini nespremenljivo po prerezu (sl. 8).

Na merilno pločevino poleg glavne natezne obremenitve deluje tudi upogibni moment zaradi vzdolžnih sil na simulatorju (pospeševanje,

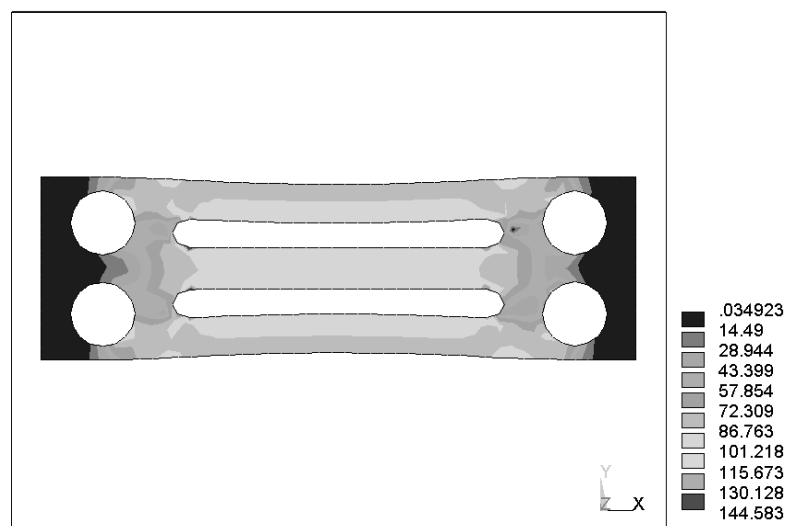
vehicle is limited. For this reason an appropriate place for measuring the normal force is the intersection of the longitudinal beam with a suspension holder (Fig. 7.). The force is measured with a tensometric load cell.

The load cell is made from a steel plate. The deformation of the plate is measured with strain gauges HBM 3/120 XY 11. The tensile stress is constant over the entire middle section of the load cell (Fig. 8.).

The load cell is also loaded with bending forces (xy plane) because of the longitudinal forces (acceleration, braking). There is also the bending



Sl. 7. Merilno mesto merjenja pravokotne sile kolesa F_{sim}
 Fig. 7. Load cell for measuring the normal force F_{sim}



Sl. 8. Napetosti na merilni pločevini v MPa [9]

Fig. 8. Stress of the load cell in MPa [9]

zaviranje). Pojavi se tudi upogibna obremenitev zaradi togega vpetja merilne sonde na nosilni okvir. Vpliv upogibne deformacije je nadomeščen z ustrezno povezavo merilnih lističev. Konstrukcija merilne sonde ne odpravi vseh stranskih vplivov na merilno mesto. Vpliv trenja med sornikom in pušo ter med nosilnim rebrom in steno konzolnega dela profila zmanjšamo z mazanjem in distančnimi podložkami. Okoli merilnega mesta je veliko virov toplote, ki lahko vplivajo na meritev. Glavni vir toplote je topel zrak iz motorja, izpušni sistem in pljuski vode iz luž. Temperaturni vpliv na meritev nadomestimo s primerno vezavo uporovnih merilnih lističev. Merilna sonda je izpostavljena tudi poškodbam zaradi tujkov na vozišču (pesek) in poškodbam pri nepazljivi montaži. Zato merilne lističe zaščitimo z gumastim premazom.

3.3 Pritrditev simulatorja na obese vozila

Simulator vožnje avtomobila pri mejnem zdrsu je tako zasnovan, da omogoča neodvisno spreminjanje pravokotne sile med plaščem in podlago za vsako kolo posebej. To dosežemo s pritrditvijo simulatorja zdrsa na obese vozila in z izbiro ustrezne oblike veznega člena. Vezni členi morajo izravnati pomike med nosilnim okvirom simulatorja in podvozjem nosila (sl. 9).

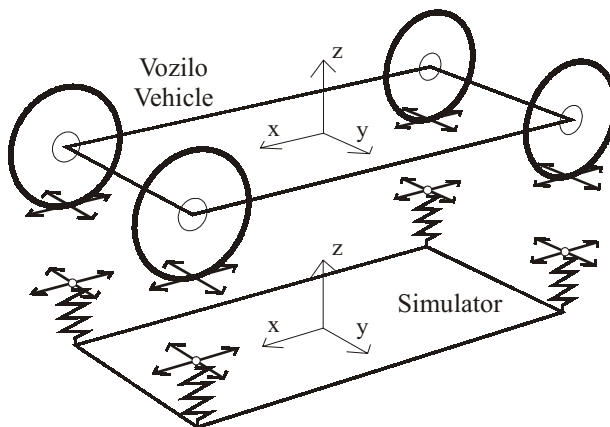
Glavni izziv je pritrditev togega okvira simulatorja na štiri neodvisne gibljive točke na podvozju vozila. Konstrukcija vpetja simulatorja na obese vozila je izvedena z elastičnim vpetjem (gumijeve vzmeti), ki izravnava pomike obes, prevzame normalno silo, določi lego simulatorja glede na vozilo in prenaša vzdolžne ter prečne sile iz simulatorja na vozilo. Guma je dober vibroizolator za nihanja simulatorja, ki so vzbujana z vožnjo prek neravnega cestišča in z dinamiko vožnje.

deformation in xz plane as a result of the rigid fixing of the load cell to the supporting frame. The influence of the bending is compensated for by a suitable connection of the strain gauges. All the side effects on the load cell are not eliminated with this design. In a joint between the console holder and the supporting frame some friction still exists, which can be reduced by lubrication and brushings. There are different causes for temperature changes close to the load cell, like the hot air from the engine or exhaust, or cold water from a puddle. The temperature influence is also compensated for by an appropriate connection of the strain gauges. The strain gauges are protected with a rubber coating against damage from small stones, from contact with the vehicle and from a careless assembly process.

3.3 Connecting joints between the frame and the suspension

The vehicle skidding simulator enables independent control of the normal force for each wheel. This goal is achieved by the shape of the connecting joint between the supporting frame and the vehicle suspension. These joints must be able to compensate for movements between the frame and the suspension (Fig. 9).

The major design challenge is to connect the rigid supporting frame with four independently moving points on the vehicle suspension. Elastic rubber brushes were used for the fixture joints. They were able to compensate for the suspension movements, to take over the wheel's normal force, to hold the frame position regardless of the vehicle motion, to transfer the longitudinal and transversal forces from the simulator back to the vehicle. The rubber is a good vibroisolator for vibrations that are excited by dynamic forces from rough terrain and driving dynamics.



Sl. 9. Pomiki koles vozila glede na elastično vpet simulator

Fig 9. Suspension movements and an elastic connecting joint of the supporting frame

3.3.1 Sprednje vpetje

Mesto vpetja simulatorja na roko sprednje obese ima velik vpliv na dejanskost simuliranja zdrsra vozila. Zaradi nagibanja vozila pri vožnji se spreminja nagib roke. Učinek gugalnice se pojavi v primeru, če pritrdišče simulatorja ni pod členkom roke. V tem primeru je dvig plašča odvisen od trenutnega nagiba vozila (sl. 10). Vpliv gugalnice pri sprednjem vpetju želimo čimbolj zmanjšati, zato smo prisiljeni izdelati pritrdišče v obodu platišča (točka B). Tu smo s prostorom zelo omejeni, ta je še dodatno omejen z obračanjem koles pri krmiljenju vozila (sl. 11).

Vozilo je na simulator pritrjeno z vpenjalom na roki sprednje obese. Na okrovu vpenjala je ležišče gumaste vzmeti, prek katere je z vijakom M12 povezano vozilo z vilicami konzolnega nosila simulatorja (sl. 12).

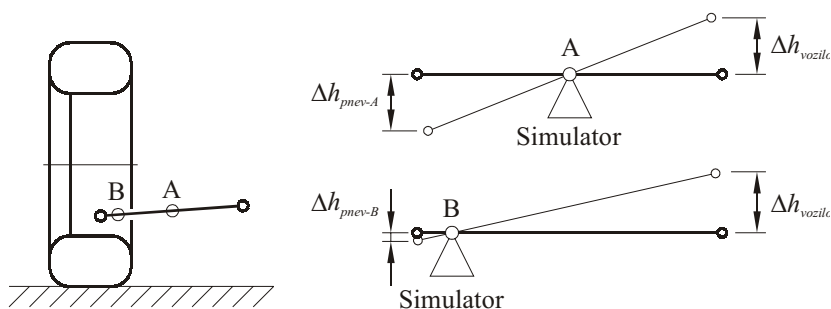
S pritrditvijo simulatorja v neposredno bližino členka je roka obese bolj ugodno obremenjena in obnašanje vozila v razmerah zmanjšane sojemanja stvarnejše. Vpenjalo za sprednjo roko omogoča preprosto montažo simulatorja na vozilo.

3.3.1 Front connecting joint

The position of the fixing point on the front suspension has a major influence on the simulation of the vehicle's slip. When the fixing point of the frame is not under the suspension joint, a swing effect occurs. The vehicle tilting causes changes to the inclination of the suspension arm. When this is the case, the height of the wheel lift is dependent on the arm inclination (Fig. 10). To avoid this effect the fixing point is placed near the suspension arm pivot (point B). The space is however, very limited because of the movement of the front wheels when steering the vehicle (Fig. 11).

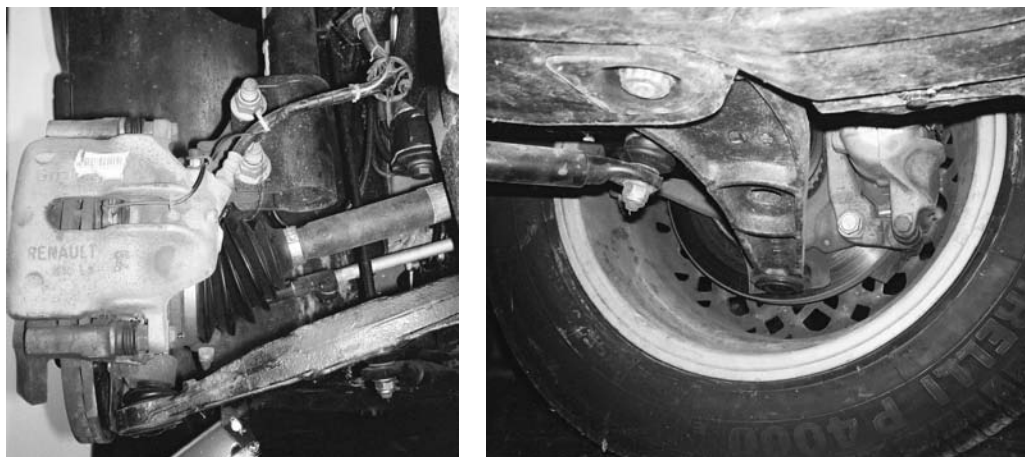
The vehicle and the simulator are connected together by a joint that is assembled from a supporting fork console, a steel casing for the suspension arm, a rubber brush and an M12 screw (Fig. 12.).

With the fixing point near the arm pivot the a load on the front suspension arm is smaller, so the vehicle behaves more realistically during skidding manoeuvres. The design of the front connecting joint enables a simple and quick mounting on the front

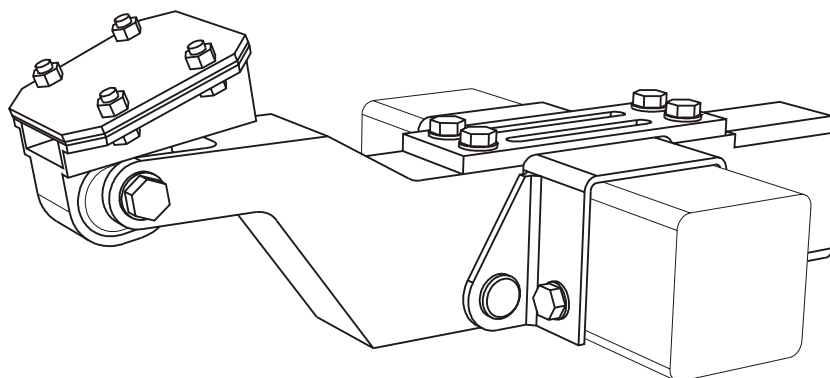


Sl. 10. Vpliv mesta vpetja na dvig kolesa vozila (učinek gugalnice)

Fig. 10. Influence of the connecting joint's position on the lift height (swing effect)



Sl. 11. Sprednja obesa vozila Renault safrane 2.2 RT
Fig. 11. Front suspension of the Renault Safrane 2.2 RT



Sl. 12. Izvedba sprednjega vpetja z gumasto pušo [9]
Fig. 12. Front connecting joint with the rubber brush [9]

Konstruksijska izvedba sprednjega vpetja z gumasto pušo je preprosta in ne potrebuje dodatnega varovanja v primeru izrednih obremenitev.

suspension arm and there is no requirement for any additional protection against extreme loading conditions.

3.3.2 Zadnje vpetje

3.3.2 Back connecting joint

Pri vpetju na zadnji obesi vozila pritrdimo simulator na prečno vodilo zadnjega kolesa (sl. 13). Osnovno vodilo ima majhno upogibno nosilnost (odprt profil U, debelina stene 2 mm), zato izdelamo novo prečno vodilo zadnjega kolesa. Poseg v vozilo zahteva le razstavitev dela zadnjega podvozja in zamenjavo prvotnega vodila z novim. Glavni del zadnjega vpetja je gumast blok, ki ima zalita vijaka sidra za pritržitev nosilnega okvira simulatorja na prečno vodilo zadnje obese vozila (sl. 14).

The fixture of the supporting frame to the back suspension is placed on the transversal guidance rod of the wheel (Fig. 13). The original guidance rod has a low bending strength (open U-profile, wall thickness of 2 mm). For this reason a new rod was made from a standard closed profile, and the mounting of the simulator required the disassembly of the back suspension. An elastic element in the joint was a rubber block with anchor screws for connecting the frame on the suspension (Fig. 14).

3.4 Nadzorni sistem

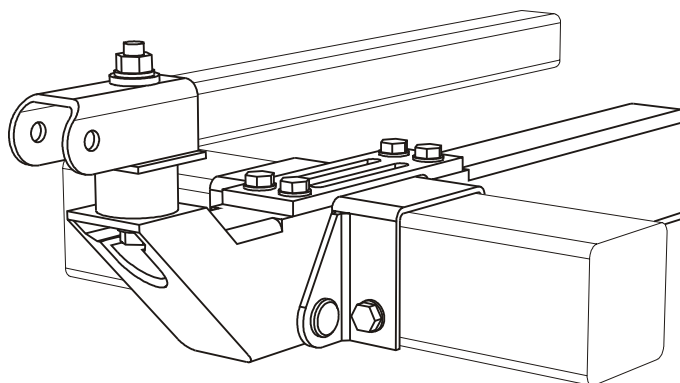
3.4 Control system

Hidravlični sistem za dviganje simulatorja vožnje vozila pri mejnem zdrsu ([8] in [9]) upravljamo s krmilnim sistemom (sl. 15.).

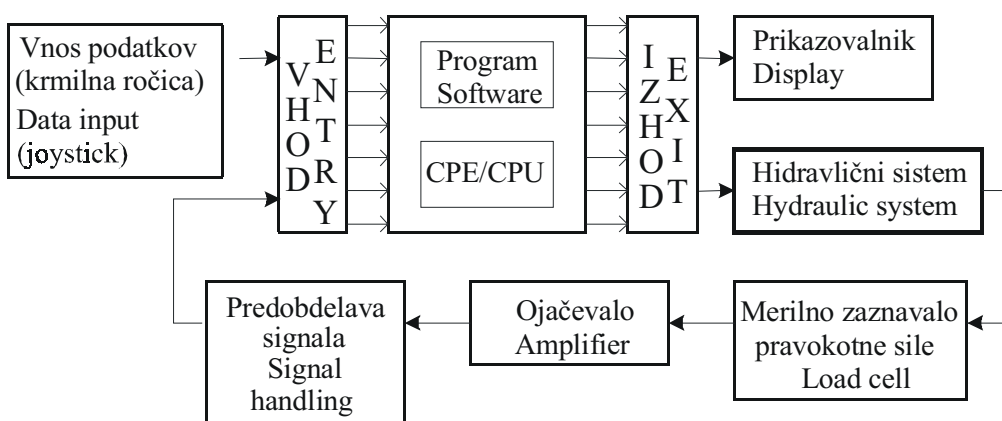
A hydraulic system for hoisting the skidding simulator ([8] and [9]) is operated with a control system (Fig. 15.).



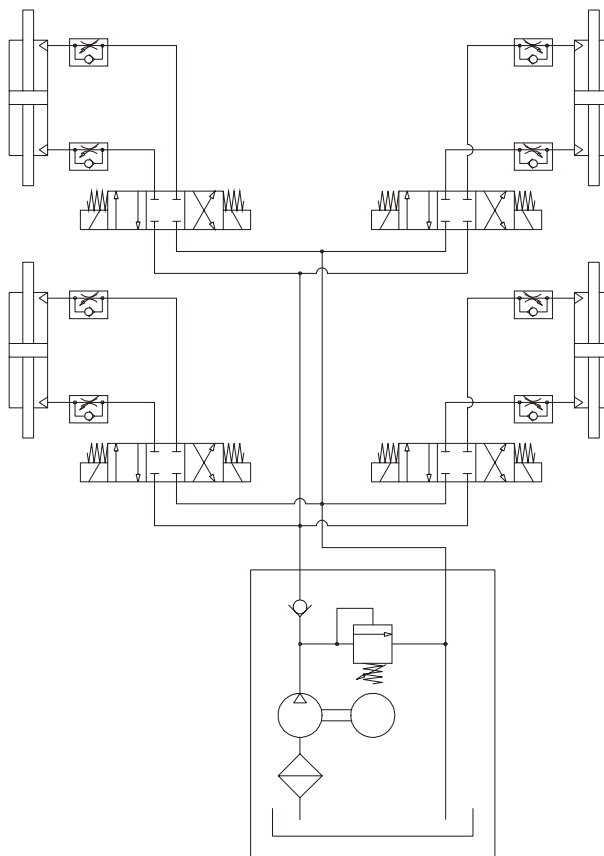
Sl. 13. Zadnja obesa vozila Renault safrane 2.2 RT
 Fig. 13. Back suspension of the Renault Safrane 2.2 RT



Sl. 14. Vpetje na zadnje podvozje vozila z merilnim mestom na nosilu preme [9]
 Fig. 14. Back connecting joint with the rubber block and the load cell [9]



Sl. 15. Krmilni sistem simulatorja zdrsra [8]
 Fig. 15. The skidding simulator control system [8]



Sl. 16. Hidravlični sistem [9]
 Fig. 16. Hydraulic system [9]

4 SKLEP

4 CONCLUSION

Krmiljenje zdrsa vozila na podlagi merjenja pravokotne sile med kolesom in podlago je nov postopek. S takšno razporeditvijo nadzornega sistema simulatorja zdrsa je mogoč boljši nadzor in stvarnejše obnašanje vozila pri drsenju. Merjenje sile je izvedeno na zelo zahtevnem mestu ob upoštevanju zadostne nosilnosti in preproste uporabe. Oblika nosilnega okvira ne ovira vstopanja v vozilo, ponuja manjšo težo in s tem manjši vpliv na vozne lastnosti vozila. Konstrukcija okvira omogoča preprosto montažo in transport kakor tudi dobro prilagodljivost različnim tipom vozila.

S pritrditvijo simulatorja v neposredno bližino členka roke smo zmanjšali napako učinka gugalnice na dvig kolesa vozila za 50% glede na znane rešitve [2]. Sprednje vpetje z gumasto pušo ne potrebuje dodatnega varovanja v primeru skrajnih obremenitev (trk, neravna podlaga). Izvedba zadnjega vpetja z gumastim blokom terja novo prečno vodilo kolesa pred montažo simulatorja na vozilo.

Krmilni sistem z zaznavalom pravokotne sile omogoča uporabo simulatorja v raziskovalne in študijske namene za testiranje novih pogonskih in varnostnih sistemov vozila.

A new approach to the control of vehicle slip involves measuring the normal force between the tyre and the driving terrain. With this arrangement it is possible to achieve better control and more realistic behaviour of the vehicle during skidding manoeuvres. The load cells are installed at locations where there is little space. Special design approaches take into account the strength and stiffness of the supporting frame structure. The selected shape of the supporting frame does not disturb entry to the test vehicle. The frame is lightweight and has a small influence on the driving characteristics of the test vehicle. The frame is easy to assemble and transport to other locations. The skidding simulator and the connecting joints can be adjusted for other vehicle models as a result of the simulator design.

With the connection joint placed near the suspension arm pivot, the swing effect of the mistake is reduced by 50% in terms of known solutions [2]. The design of the front connecting joint enables a simple and quick mounting on the front suspension arm, and it does not need any additional protection against extreme loads. The design of the back connection joint requires a new connecting rod.

The control system makes it possible to use the skidding simulator for testing new safety and power-train systems in the vehicle.

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