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BIORAZGRADLJIVE MAZIVE MASTI I NJIHOVA PRIMJENA NA ŽELJEZNICI

Sažetak

Za kritična mjesta podmazivanja kod kojih se postavljaju strogi ekološki uvjeti sve se više koriste biorazgradljive masti. Takve masti moraju u kratkom vremenskom razdoblju imati visok stupanj biološke razgradljivosti. Ukoliko to nemaju, mogle bi štetno djelovati ako dospiju u okoliš bilo u tlo bilo u vode.

S obzirom da mazive masti na osnovi rafiniranih mineralnih ulja ne mogu zadovoljiti ove uvjete, biorazgradljive masti se izrađuju iz prirodnih ili sintetičkih estera. Biorazgradljive mazive masti moraju biti neotrovne, a u pravilu su višenamjenske s EP svojstvima, te se primjenjuju i za ručno i za automatsko podmazivanje.

U radu su izneseni podaci o izradi dvije biorazgradljive mazive masti različite konzistencije na osnovi litijevih i kalcijevih sapuna i sintetičkih biorazgradljivih estera. Također su izneseni podaci o primjenskim ispitivanjima u HŽ Hrvatskim željeznicama.

UVOD

U Hrvatskoj se godišnje potroši više od 1000 tona mazivih masti. Sve te masti su konvencionalnog tipa na osnovi mineralnog ulja malog stupnja biorazgradljivosti. Znatan dio njih s kritičnih mjesta primjene dospijeva u okoliš. Kada dospiju u okoliš, bilo u zemlju ili u vode ostaju dugo vremena u svome izvornom obliku uzrokujući kontaminaciju. Gotovo 50 tona maziva u Hrvatskoj svake godine dospijeva u okoliš samo kao posljedica podmazivanja tračnica i vijenaca kotača te skretnica na željeznici, uzrokujući kontaminacijsku opasnost za floru i faunu. Takva onečišćenja okoliša mogu se znatno smanjiti uporabom mazivih masti koje su biorazgradljive.

U svrhu doprinosa očuvanju okoliša razvijene su domaće biorazgradljive mazive masti na osnovi litijevih i kalcijevih sapunskih zgušnjavala i sintetičkih biorazgradljivih estera, te su odgovarajuća zamjena konvencio-nalnim mastima koje se sada koriste na kritičnim mjestima podmazivanja u željezničkom i tramvajskom prometu. Ove masti na mjestu primjene vrše svoju funkciju podmazivanja i nema razgradnje. Tek nakon iscurenja s mjesta primjene i u kontaktu s okolišem i poradi djelovanja prirodnih mikroorganizama kao što su bakterije, fungiji ili alge u kratkom vremenu od nekoliko tjedana do nekoliko mjeseci (ovisno o vremenskim uvjetima) mast se razgradi. Konačni produkti biorazgradnje su jednostavni prirodni spojevi kao što su ugljični dioksid i voda.

TEORETSKI DIO

1. Biorazgradljive mazive masti

Potreba za proizvodima manje štetnog djelovanja na okoliš započela je s tekućim mazivima. Krajem 70-ih godina najprije se počelo s uvođenjem biorazgradljivih ulja za izvanbrodske motore. Nešto kasnije nastavljeno je s uljima za lance motornih pila. Biorazgradljive mazive masti dobile su svoje istaknuto mjesto početkom 90-ih godina. Danas biorazgradljive masti na mnogim tehničkim područjima igraju važnu ulogu u pogledu optimalnog podmazivanja mnogih strojnih elemenata s visokim stupnjem zaštite okoliša.

1.1. Sastav biorazgradljivih masti

U osnovi biorazgradljive mazive masti imaju istu građu kao i konvencionalne masti na osnovi mineralnih ulja, a sastoje se od disperzije zgušnjavala u tekućem mazivu uz dodatak različitih aditiva. Kod odabira sirovine za formuliranje biorazgradljivih mazivih masti, osim biorazgradljivosti potrebno je uzeti u obzir i sljedeće aspekte: bioakumulaciju, otrovnost (na ljude) i ekotoksičnost (ribe, dafnije, biljke).

a) Bazne tekućine - Za formuliranje biorazgradljivih masti koriste se sljedeća bazna ulja:
- biljna ulja (prirodni esteri),
- biorazgradljivi sintetički esteri.

Biljna ulja i sintetički esteri pokazuju u biti istu kemijsku građu. Zbog toga su i njihova svojstva slična. Međutim, sintetički esteri imaju jasne prednosti u pogledu stabilnosti na starenje, visokotemperaturna svojstva i ponašanje na niskim temperaturama pred biljnim uljem i time opravdavaju svoju višu cijenu.

b) Zgušnjavala - Izbor zgušnjavala mnogo ovisi o zahtjevima koje mora zadovoljiti maziva mast. U biorazgradljivim mastima koriste se zgušnjavala neutralna za okoliš, kao što su:
- litijev ili kalcijev 12-OH-stearat ili njihova smjesa,
- aluminijev kompleksni sapun,
- bentonit/silika gel.

c) Aditivi - Aditivi koji se koriste u biorazgradljivim mastima po mogućnosti moraju biti biorazgradljivi, niskootrovni bez sadržaja mineralnog ulja i teških metala, te da ih se koristi u najmanjoj mogućoj koncentraciji. Uobičajeni aditivi su:
- antioksidanti - amini ili fenoli,
- za zaštitu od korozije - derivati masnih kiselina,
- EP (extreme pressure) aditivi za povećanje čvrstoće mazivog sloja te aditivi protiv trošenja - S-P spojevi.

1.2. Metode ispitivanja biološke razgradljivosti

Postoje brojne metode za ispitivanje biološke razgradljivosti maziva, ali većina njih nije primjenjiva za takve kompleksne smjese kao što su mazive masti. U Europi se koriste sljedeće tri metode za utvrđivanje stupnja biorazgradljivosti mazivih masti:
- Modificirana Sturm metoda,
- Closed-bottle test,
- CEC-L-33-A-93 test.

Kriteriji za ocjenu biološke razgradljivosti prema navedenim metodama jasno se razlikuju. Kod Sturm metode mjeri se količina CO_2 nastalog potpunom razgradnjom organske tvari, kod Closed-bottle testa mjeri se potrošnja O_2, dok se kod CEC metode stupanj biološke razgradljivosti određuje prema stupnju razgradnje CH_3-CH_2- lanaca. Mazive masti koje po Sturm metodi i Closed bottle testu imaju stupanj biorazgradljivosti najmanje 60%, odnosno kod CEC metoda 80%, smatraju se biološki brzo razgradljivima.

2. Tribološki sustav kotač/tračnica i primjeri trošenja

Pri eksploataciji željezničkih vozila sustav kotač/tračnica uzrokuje godišnje ogromne troškove zbog trošenja i oštećenja u kontaktnom području. Ove štete ne vode samo do materijalnih gubitaka, nego i do smanjenja sigurnosti odvijanja prometa, kao i dodatnih ograničavanja pokretljivosti kao što su zastoji ili prisilna preusmjeravanja. Također i putnici osjećaju trošenje i oštećenje smanjenjem udobnosti putovanja u obliku trešnje i buke, posebno neugodnog cviljenja prilikom vožnje uzduž zavoja.

Da bi se smanjilo trenje valjanja a time trošenja i oštećenja vijenaca kotača i bočnih strana tračnica, te povećao faktor sigurnosti protiv iskliznuća, kao i drugih nepoželjnih popratnih pojava, koriste se uređaji za podmazivanje. Zadaća tih uređaja pravodobno je podmazivanje vijenaca kotača ili tračnica. Pravilnim podmazivanjem postiže se također, ovisno o vrsti terena, pruga i vlakova ušteda na gorivu od 3 do 10%, što je značajna ušteda s obzirom na veliku potrošnju goriva na željeznici. Na slici 1 se vidi tribološki sustav kotač/tračnica.

Slika 1: Sustav kotač/tračnica
Figure 1: The wheel/track tribological system

Zona podmazivanja=Lubrication zone
Glava= head
Vijenac kotača=wheel rim
Unutarnji rub=Inner edge

Kotač=wheel
Kotrljajuća površina= Rolling surface
Tračnica=track

U idealnim uvjetima dodirno područje je samo kotrljajuća površina između kotača i tračnica. Međutim, u praksi postoji značajan dodir vijenca kotača i unutarnjeg ruba tračnice. Postoji više razloga zbog kojih dolazi do dodira vijenca kotača i tračnice. Ako propisani razmak (1435 mm) između tračnica kod njihovog postavljanja nije točno namješten, mogućnost dodira je veća. Također sile koje uzrokuju bočno kretanje tjeraju vijenac kotača prema unutarnjem rubu tračnice (zato postoji vijenac kotača). Nadalje, ali i najvažnije, zbog učinka zavoja, centrifugalne sile tjeraju vijenac kotača u dodir s unutarnjim rubom glave vanjske tračnice.

Drugi važan element u opisivanju sustava kotač/tračnica i primjera njihova trošenja odnosi se na opterećenje na gornjem dijelu glave tračnice. Ova opterećenja su rezultat opterećenih vagona u stvaranju naprezanja veličine od 9000 kg/cm^2 do 10500 kg/cm^2 koja su dovoljna da uzrokuju plastične deformacije tračnica. Slika 2 prikazuje kako se mijenja oblik tračnica kao rezultat plastične deformacije i trošenja.

Slika 2: Plastične deformacije i trošenja
Figure 2: Plastic deformation and wear

Puna crta prikazuje oblik tračnice u tri slučaja nakon izvjesnog vremena. Izvorni oblik tračnice prikazan je prekidanom crtom. Kad je podmazivanje prisutno ili kad je kontakt između vijenca i unutarnjeg ruba glave najmanji, nastaje A oblik. To je rezultat plastičnog tečenja. U nekim slučajevima kontakt vijenac/kotač rezultira trošenjem (ili brušenjem) te tako nastaje oblik prikazan kao B. Ako trošenje napreduje, dobije se oblik C.

2.1. Geometrija vijenca ovoja kotača

Propisani profil ovoja kotača s vijencem i krug kotrljanja kotača osigurava sigurnu vožnju željezničkih vozila, te utječe na mirnoću hoda vozila kao i na intenzitet trošenja vijenca kotača. Intenzitet trošenja ovoja kotača je ovisan također i o materijalu kotača i tračnica, uravnoteženju vozila, opterećenju i brzini, konfiguraciji (brdska-ravničarska) i stanju pruge. U eksploataciji se kontroliraju sljedeći parametri vijenca ovoja kotača (slika 3):

Slika 3: Parametri vijenca ovoja kotača
Figure 3: Wheel rim parameters

Parametri vijenca	Način mjerenja	Dopuštena granica u mm

V_v - visina vijenca, mjeri se od kruga valjanja do vrha vijenca. Kod novog profila ili nakon tokarenja, visina vijenca iznosi 28 mm, koja se u eksploataciji povećava, te se tolerira do 33 mm, jer inače ugrožava sigurnost prometa (može oštetiti skretnicu ili dolazi do loma vijenca).

D_v - debljina vijenca, mjeri se na visini od 10 mm iznad kruga valjanja. Kod novog profila ili nakon tokarenja debljina vijenca iznosi 32.5 mm, koji se u eksploataciji smanjuje, te se tolerira do 25 mm. Smanjenjem debljine vijenca pogoršava se mirnoća hoda vozila i može doći do loma vijenca.

q_R - oštrina vijenca, mjeri se od visine točke 10 mm iznad kruga valjanja pa do visine točke od 2 mm ispod visine vijenca, te se tolerira do 6,5 mm. Ispod ove vrijednosti oštrine vijenca može doći do iskliznuća kotača s tračnice.

Ukoliko je istrošenje površine kotača blizu maksimalne dopuštene vrijednosti ($V_v \geq 33$ mm, $D_v \leq 25$ mm i $q_R \leq 6,5$ mm), obavlja se tokarenje na novi profil ili, ako to nije moguće, mora se mijenjati ovoj kotača ili kotač.

2.2. Sustavi podmazivanja vijenca kotača i tračnica

Postoje tri osnovne metode primjene podmazivanja vijenca kotača i tračnica, a to su:

- sustavi vezani na vozilo (On-board),
- sustavi vezani na tračnice (Wayside),
- podmazivanje specijalnim vozilom (Hy-rail).

Kod podmazivanja sustavom vezanim na vozilo (On-board) obično su mazalice montirane na lokomotivi. Ovisno o tipu mazalice koriste se grafitni štapići, mazivo ulje ili mazive masti koje povremeno ili neprekidno podmazuju vijence kotača lokomotive. Mazivo se prenosi s vijenaca kotača lokomotive na tračnicu onda kada vijenci kotača i tračnica dođu u dodir. Nakon toga s tračnice se prenaša na kotače spojenih vagona. U ovom slučaju potrebno je osigurati dostatno podmazivanje između vijenaca svih kotača vlaka od 50 i više vagona i tračnica, prenošenjem maziva na tračnicu s vijenaca kotača lokomotive.

Sustavom vezanim na tračnice (Wayside), maziva mast podmazuje unutarnji rub glave tračnice. Mazalica se aktivira mehanički ili elektronski prolaskom kotača. Mast se prenosi s tračnice na vijenac kotača prilikom kontakta vijenca kotača s tračnicom. Na ovaj način mast se prenosi dalje duž tračnice do udaljenosti uvjetovane raznim parametrima uključujući i svojstva korištene masti.

Podmazivanje specijalnim vozilom (Hy-rail) mazalice su ugrađene na samohodnom vozilu modificirano tako da je omogućen rad na željeznici. Širok asortiman maziva može se koristiti kod ovog načina podmazivanja. Mazivo se neposredno nanaša na tračnice, prema potrebi neprekidno ili povremeno. Zbog razumljivih razloga ovaj sustav podmazivanja u biti je pogodan onda kad promet vlakova nije velik i pruge nisu preduge.

3. Kritična mjesta podmazivanja na željeznici

Na željeznici kritična mjesta podmazivanja s kojih mazivo neposredno odlazi u okoliš su vijenci ovoja kotača, tračnice, te skretnice. S obzirom da se podmazivanje skretnica vrši svakodnevno, a vijenci kotača i tračnica podmazuju se cijelo vrijeme prometanja željezničkih vozila, potrošnja maziva je znatna. Kratko vrijeme nakon podmazivanja mazivo gotovo u cijelosti dospijeva u okoliš.

3.1. podmazivanje vijenca kotača na lokomotivima (on-board)

Na mnogim lokomotivama podmazivanje vijenaca kotača vrši se pomoću centralnog sustava podmazivanja, a kao mazivo koriste se mazive masti polutekuće konzistencije (NLGI 00). Na slici 4 je dan shematski prikaz centralnog sustava za podmazivanje vijenaca kotača vodeće osovine lokomotive.

Slika 4: Shematski prikaz centralnog sustava podmazivanja
Figure 4: Schematic presentation of the central lubrication system

Na okretnom postolju lokomotiva ugrađuju se po dva centralna sustava za podmazivanje, koji podmazuju vijence kotača vodećih osovina, prve ili šeste osovine, ovisno o smjeru vožnje. Sustav se sastoji od elektroničkog upravljačkog uređaja, elektropneumatskog ventila, spremnika za masti, cijevnih vodova za dovod maziva i stlačenog zraka, te mazalica sa sapnicom. Podmazivanje se obavlja u intervalima od 100 do 500 m prevaljenog puta lokomotive ili u kratkim vremenskim razmacima ovisno o podešenosti sustava. Mala količina masti (30 do 100 mm^3) raspprši se preko brizgaljke pod tlakom od 5 bara u sitne kapljice unutar nekoliko sekundi. Za to vrijeme kotač lokomotive okrene se nekoliko puta. Debljina mazivog sloja je tada manja od 0.003 mm a njegova širina je između 10 i 15 mm.

Osnovni zahtjevi za mazive masti za podmazivaje vijenaca kotača su:

- smanjenje trenja i trošenja u području vijenac/unutarnji rub tračnice za postizanje sigurnosti od iskliznuća, kao i za smanjenje buke u dodirnoj zoni,
- dobra pumpabilnost i moć rasprskavanja u svim vremenskim uvjetima,
- visoka moć prianjanja i otpornost na ispiranje vodom i kišom,

– biorazgradljivost.

3.2. Podmazivanje tračnica u lukovima (Wayside)

U početku se podmazivanje tračnica u lukovima (zavojima) izvodilo ručno mazivim uljem, no sada se podmazivanje obavlja automatski mazivim mastima srednje konzistencije (NLGI 2) pomoću stabilnih mehaničkih mazalica. Na slici 5 se vidi stabilna mehanička tračnička mazalica, koja se koristi na mnogim željezničkim prugama u Europi.

Slika 5: Stabilna mehanička tračnička mazalica
Figure 5: Stable mechanical track spreader

Mjesto podmazivanja = Lubrication spot   Tračnica = Track   Ticalo = Contact tip

Ovakve tračničke mazalice se pričvrste u zavoju na samoj tračnici i mehanički se aktiviraju za vrijeme prolaza vlaka. Svaki kotač vlaka pritiskom na ticalo aktivira mazalicu na način da se određena količina masti izbaci preko otvora češlja na unutarnji rub glave vanjske tračnice. Potom se mast prenosi s tračnice na vijence kotača prilikom dodira vijenaca kotača i tračnica.

Osnovni zahtjevi za mazive masti za podmazivanje tračnica su:

– smanjenje trenja i trošenje vijenaca kotača i tračnica kao i smanjenje buke u dodirnoj zoni,
– visoka moć prianjanja, kako bi gubici zbog odbacivanja poradi velikih centrifugalnih sila na kotaču bili što manji, što doprinosi sniženju troškova na mazivu kao i smanjenju zagađenja okoliša,

- širok temperaturni interval primjene, tj. mogućnost primjene u sva četiri godišnja doba,
- velika otpornost na ispiranje vodom i kišom,
- biorazgradljivost.

3.3. Podmazivanje skretnica

Besprijekoran rad skretnica u svim vremenskim uvjetima je važan čimbenik u željezničkom prometu. Posebno se to odnosi na sigurnost i redovitost odvijanja prometa. Pravilan i siguran rad skretnica postiže se pravilnim podmazivanjem. Podmazivanjem se također smanjuje trošenje i štiti skretnica od oštećenja. Nasuprot podmazivanju vijenaca kotača i tračnica podmazivanje skretnica nije ni mehanizirano ni automatizirano, jer bi to bio suviše visok investicijski trošak. Skretnice se danas kao i prije pretežno podmazuju ručno, tj. pomoću četke ili specijalnog prenosnog aparata za podmazivanje.

Podmazivanje skretnica bori se danas s činjenicom, da su današnje konstrukcije skretnica prisiljene na podmazivanje često niskoviskoznim mazivim uljima koja se koriste u druge svrhe u željezničkom prometu. Ipak, iskustva iz mnogih primjena pokazuju da optimirana polutekuća mast produžuje rokove podmazivanja i time može znatno reducirati troškove kao i zagađenje okoliša, te su mnoge željeznice prešle na taj tip maziva.

Najvažniji zahtjevi za mazivo za skretnice su:

- smanjenje trenja za postizanje malenih sila kod prebacivanja i siguran krajnji položaj skretnica u svim vremenskim uvjetima,
- dobra zaštita od korozije tako da i pod najnepovoljnim uvjetima i tankim mazivim slojem budu zaštićeni svi dijelovi,
- vodootpornost i sposobnost prianjanja na suhe i mokre površine,
- dobra sposobnost prodiranja, tako da su dobro opskrbljene mazivom i na teško pristupačnim mjestima, npr. u stražnjem dijelu jezika skretnice gdje su promicanja vrlo mala,
- dobra maziva svojstva u širokom temperaturnom intervalu tako da je funkcija skretnice osigurana i kod ekstremno niskih u hladne zimske dane do relativno visokih temperatura kod primjene električnog ili plinskog grijanja skretnice (zimi) odnosno u vrućim ljetnim danima,
- biorazgradljivost.

EKSPERIMENTALNI DIO

4. Proizvodnja ispitnih masti i laboratorijska ispitivanja

Cilj ovog razvojnog projekta je bio razvoj biološki razgradljivih i netoksičnih mazivih masti namijenjenih kritičnim mjestima podmazivanja na željeznici, kao što su vijenci kotača, tračnice i skretnice, potom eksploatacijskim ispitivanjima u različitim godišnjim dobima u Hrvatskim željeznicama (HŽ) provjeriti njihova primjenska svojstva.

U tu svrhu u Istraživačkom laboratoriju INA Maziva Zagreb razvijene su dvije biološki razgradljive mazive masti na osnovi smjesa litijevog i kalcijevog 12-OH stearata kao sapunskog zgušnjavala, sintetičkih biorazgradljivih estera i ekološki prihvatljivih aditiva. Prva je biorazgradljiva mast srednje konzistencije (NLGI 2) pod oznakom BM 2, namijenjena podmazivanju željezničkih tračnica, dok je druga polutekuće konzistencije (NLGI 00) pod oznakom BM 00 namijenjena podmazivanju željezničkih vijenaca kotača kao i željezničkih skretnica.

Za potrebe primjenskih ispitivanja proizvedeno je u poluindustrijskom postrojenju po 200 kg svake masti. U tablici 1 iznesena su fizikalno-kemijska, mehaničko-dinamička svojstva, štetnost na vodene organizme te stupanj biorazgradljivosti proizvedenih masti BM 2 i BM 00.

Iz tablice 1 vidi se:

- da obje masti imaju visoki stupanj biorazgradljivosti i da nisu štetne za vodene organizme i ribe,
- da imaju vrlo dobra fizikalno-kemijska svojstva posebno oksidacijsku stabilnost, zaštitu od korozije i niskotemperaturna svojstva. Pumpabilnost obje masti na niskim temperaturama vrlo je dobra, što je posebno važno prilikom primjene u zimskim uvjetima. U centralnim sustavima za dovod obje masti do mjesta podmazivanja kod vrlo niskih temperatura potreban je pet puta manji tlak u odnosu na konvencionalne masti iste konzistencije.
- mehaničko-dinamička ispitivanjima pokazuju da obje masti imaju visoku sposobnost nošenja visokih pritisaka i zaštite metalne površine od trošenja, a kod BM 2 masti i sposobnost podmazivanja pri visokim temperaturama.

Tablica 1: Sastav, fizikalno-kemijska i mehaničko-dinamička svojstava, stupanj biorazgradljivosti te štetnost na vodene organizme masti BM 2 i BM 00
Table 1: Physico-chemical and mechanical/dynamical properties, biodegradability degree, and threat posed to water organisms of BM 2 and BM 00 greases

Oznaka masti - Grease Label	BM 2	BM 00
NLGI broj-number	2	00
Bazna tekućina-Base fluid	Sint. biorazgrad-biodegrad. ester	Sint. biorazgrad.-biodegrad.ester
Kinematička viskoznost baznog ulja pri 40°C, mm^2/s Base oil kinematic viscosity at 40°C, mm^2/s	115	55
Sapunsko zgušnjavalo-Soap thickener	Li/Ca 12-OH stearat	Li/Ca 12-OH stearat
Aditivi-Additives	Inhib. oks i korozije, EP Oxidat. and corros. inhibitors,EP	Inhib. oks i koroz., EP Oxidat. and corros. inhibitors,EP
Temperatura primjene masti, °C Grease application temperature, °C	-40 do 120	-40 do 110
Penetracija, nakon 60 udaraca, mm/10 Penetration, after 60 strokes, mm/10	274	410
Penetracija pri -20°C-Penetration at -20°C,mm/10	170	325
Korozija na Cu-Copper Corrosion, 3h/100°C	1a	1a
Oksid. stabilnost, 100h/100°C, pad tlaka Oxidation stability, 100h/100°C, pressure drop kPa	14	10
Ponašanje prema vodi-Behaviour towards water	1 - 60	1 - 60
Kapljište-Dropping point, °C	194	177
Srednji promjer istrošenja (test 4 kugle), mm Medium wear scar (4-ball test), mm	0.51	0.45
Točka zavarivanja (test 4 kugle), N Welding point (4-ball test), N	3000	2800
Sposobnost podmazivanja, SKF R2F, uvjet B, 120°C Lubrication capacity, SKF R2F, B, 120°C	zadovoljava-satisfactory	-
Zaštita od korozije, SKF Emcor test Corrosion protection, SKF Emcor test	0/0	0/0
Tlak tečenja kod -30°C-Flow pressure at, kPa	120	9.5
Pumpabilnost-Pumpability (φ=10 mm, l=1 m), kod 25°C, kPa kod -20°C, kPa kod -30°C, kPa	 200 - 370	 40 60 110
Stupanj biorazgradljivosti (mod. Sturm metoda), % Biodegradability degree (mod. Sturm method)	60	60
Utjecaj na vodene organizme i ribe Influence on water organisms and fish	Nije štetna-Not hazardous	Nije štetna-Not hazardous

5. Primjenska ispitivanja na željeznici i diskusija

Primjenska ispitivanja uzoraka razvojnih biorazgradljivih masti BM 2 i BM 00 su izvršena u Hrvatskim željeznicama. Biorazgradljiva mast srednje konzistencije BM 2 ispitana je na podmazivanju tračnica u lukovima (zavojima), dok je biorazgradljiva polutekuća mast BM 00 ispitana na podmazivanju vijenaca kotača vučnih električnih vozila, te željezničkih skretnica.

5.1. Podmazivanje tračnica u lukovima

Na 83.5 kilometru pruge Novska - Dugo Selo na desnoj tračnici, te 445.7 kilometru pruge Dugo Selo - Koprivnica na lijevoj tračnici postavljena je po jedna stabilna mehanička tračnička mazalica. Spremnici obje mazalice kapaciteta 8 dm^3 napunjeni su ispitnom masti BM 2. Mazalica na pruzi Novska-Dugo Selo podmazivala je skretnicu i tračnice na tri uzastopna luka polumjera R=980 m, R=2500 m i R=595 m, dok je mazalica na pruzi Dugo Selo-Koprivnica podmazivala skretnicu i tračnice na dva uzastopna luka polumjera R=2900 m, R=1042 m. Lukovi koji su odabrani za primjensko ispitivanje masti BM 2 su sa većim polumjerima, što je u svrhu podmazivanja nepovoljnije u odnosu na lukove s manjim polumjerima.

Primjensko ispitivanje je izvršeno u vremenskom intervalu travanj-listopad 1999. godine. Postavljene mazalice su cijelo vrijeme bile u funkciji, a prema potrebi ponovno su nadopunjavane novom količinom BM 2 masti. Tijekom ispitivanja svakih 7 do 14 dana učinjen je pregled obje mazalice, ponašanje masti te podmazanost tračnica u lukovima i u području skretnica.

Nakon šest mjeseci rada utvrđeno je da su cijelo vrijeme ispitivanja obje mazalice radile besprijekorno, tj. nije bilo začepljenja ili zastoja izazvanih uporabom ispitne masti. Kroz otvore češlja mazalice mast je automatski izlazila prilikom prolaska vlakova točno prema zadanoj količini bez obzira na vremenske uvjete. Nadalje, vizualnim je pregledom utvrđeno da su se kod obje pruge znatni tragovi ispitne masti nalazili u skretničkom području i na tračnici s obje strane mazalice u dužini od 2 km. Mast je pomoću vijenaca kotača bila prenošena uzduž tračnica u lukovima daleko od mjesta mazalice u dovoljnoj količini i nije došlo do njezinog ispiranja s tračnica ni za vrijeme obilnih kiša, te na kraju, zbog dobre podmazanosti tračnica buka je za vrijeme prolaza vlakova bila osjetno smanjena. Postignuti rezultati pokazuju da ispitna mast BM 2 u potpunosti zadovoljava zahtjeve koji se traže od maziva za takvu namjenu.

5.2. Podmazivanje vijenaca ovoja kotača

Za provedbu primjenskog ispitivanja biorazgradljive masti BM 00 za podmazivanje vijenaca ovoja kotača odabrana je električna lokomotiva tipa Ansaldo, serija 1061 br. 015 s centralnim sustavom podmazivanja, koja prometuje na brdskom terenu relacije Rijeka - Moravice. Tijekom srpnja 1999. godine obavljen je remont na navedenoj lokomotivi, te su na tijela kotača navučeni novi ovoji kvalitete B 5T. U oba spremnika sustava za centralno podmazivanje, kapaciteta 20 dm^3, ulivena je polutekuća mast BM 00, te se sustav podesio tako da se podmazivanje obavlja u intervalima za svakih prevaljenih 300 m.

Primjensko ispitivanje je provedeno u razdoblju kolovoz 1999.-ožujak 2000. godine. U tom vremenu lokomotiva je prešla ukupno 55.600 km. Pri tom su se pratili parametri vijenaca kotača koji se uobičajeno kontroliraju u eksploataciji vučnih vozila, a to su: debljina vijenca (D_v), visina vijenca (V_v) i oštrina vijenca ovoja kotača (q_R). Navedeni parametri na svih 12 kotača lokomotive su se mjerili jedanput mjesečno mjerkom MEBA.

Za vrijeme primjenskog ispitivanja vizualnim je pregledom utvrđeno da je mast BM 00 u oba spremnika bila homogena i nije došlo do izdvajanja uljne komponente od zgušnjavala, bez obzira na prisutnost stalnog tlaka u sustavu od 5 bara. Također je utvrđeno da nije došlo do začepljenja vodova centralnog sustava, te je potrošnja masti bez obzira na godišnje doba i ekstremne razlike u temperaturi bila ujednačena.

Tablica 2: Promjena debljine, visine i oštrine vijenaca kotača u razdoblju od 8 mjeseci
Table 2: Change in the thickness, height, and sharpness of wheel rims within the period of 8 months

R.br. osovine Axle No.	Strana lokomotive Locom. side	Broj ovoja kotača No. of wheel rims	ΔD_v (mm)	ΔV_v (mm)	Δq_R (mm)
1	desno-right	L 3493 B 5T 3.99	1.0	2.3	0.0
1	lijevo-left	L 3493 B 5T 3.99	0.5	2.1	0.0
2	desno-right	L 3493 B 5T 3.99	0.0	3.0	0.0
2	lijevo-left	L 3493 B 5T 3.99	1.0	1.5	0.0
3	desno-right	L 3493 B 5T 3.99	0.0	2.0	0.5
3	lijevo-left	L 3493 B 5T 3.99	1.0	2.0	0.0
4	desno-right	L 3493 B 5T 3.99	1.0	2.0	0.0
4	lijevo-left	L 3493 B 5T 3.99	1.3	1.2	0.0
5	desno-right	L 3493 B 5T 3.99	1.0	1.5	0.8
5	lijevo-left	L 3493 B 5T 3.99	1.0	2.0	0.2
6	desno-right	L 3493 B 5T 3.99	0.5	3.3	0.0
6	lijevo-left	L 3493 B 5T 3.99	1.3	2.5	0.0

U tablici 2 prikazani su rezultati promjena debljine, visine i oštrine vijenaca svakog kotača lokomotive u ispitnom razdoblju kolovoz 1999.-travanj

2000. godine, a u tablici 3 prikazano je prosječno trošenje po kotaču za isto razdoblje (8 mjeseci) kao i po prijeđenih 10.000 kilometara.

Tablica 3: Prosječno trošenje po kotaču nakon 8 mjeseci i po prijeđenih 10^4km
Table 3: Average wear per wheel after 8 months and 10^4 km covered

Prosjek trošenja po kotaču Average wear per wheel	ΔD_v /kotaču-wheel	ΔV_v /kotaču-wheel	Δq_R /kotaču-wheel
Nakon 8 mjeseci prometanja After 8 months of travelling	0.80 mm	2.09 mm	0.12 mm
Po prijeđenih 10^4 km After 10^4 km covered	0.14 mm	0.38 mm	0.02 mm

Iz tablica 2 i 3 se vidi da su se debljine D_v i oštrine vijenaca kotača $\mathbf{q_R}$ smanjile vrlo malo, prosječno 0.80 mm odnosno 0.12 mm po kotaču za razdoblje od 8 mjeseci, te 0.14 mm odnosno 0.02 mm za svakih prijeđenih 10.000 kilometara. Visine vijenaca kotača su porasle umjereno. Prosječna vrijednost visine se povećala za 2.09 mm po kotaču u razdoblju od osam mjeseci, odnosno u prosjeku 0,38 mm po kotaču za svakih prijeđenih 10.000 km. U usporedbi s prosječnim promjenama vijenaca kotača lokomotive podmazane sa konvecionalnom polutekućem masti koja je sada u uporabi u HŽ-u, postignuto je smanjenje trošenja vijenaca kotača za oko 20%. Postignuti rezultati primjenskih ispitivanja pokazuju da ispitna biorazgradljiva mast BM 00 posjeduje vrlo dobra maziva svojstva, posebno kod vrlo niskih temperatura i da je adekvatna zamjena za konvencionalne polutekuće masti koje su sada u uporabi.

5.3. Podmazivanje skretnica

Primjensko ispitivanje masti BM 00 na podmazivanju skretnica je izvršeno na ranžirnom kolodvoru u Zagrebu u vremenskom razdoblju siječanj-travanj 2000. godine. Ispitivanje je provedeno na ukupno osam skretnica, na četiri skretnice (br. 462, 463, 464 i 465) opremljene plinskim grijačima za otapanje snijega i leda u zimskim uvjetima, te na četiri skretnice (br. 146, 149, 206 i 208) opremljene električnim grijačima.

Klizni jastučići navedenih skretnica su jednom dnevno podmazani ispitnom masti. Mast je nanešena u tankom sloju ručno pomoću četke. Kasnije zbog dobre prionljivosti ispitne masti odnosno njezinog zadržavanja na površini jastučića interval domazivanja postupno je produžen, tako da je na kraju iznosio jedan put svaka četiri dana.

U tijeku ispitnog razdoblja od 4 mjeseca, premda je bilo zimsko vrijeme s niskim temperaturama i snijegom, nije bilo niti jednog zastoja, niti je bilo pojava poteškoća i neurednosti u radu ispitnih skretnica. Na podmazanim dijelovima skretnica također nije bilo nikakvih tragova korozije.

S obzirom da je za podmazivanje kliznih jastučića skretnica bilo dovoljno nanositi ispitnu mast u tankom sloju, kao i na produženju razdoblja domazivanja s jednog dana na četiri dana, postignuta je velika ušteda na mazivu.

Temeljem primjenskih ispitivanja mast BM 00 u odnosu na mazivo ulje mineralne osnove s malim stupnjem biološke razgradljivosti, koje je sada u uporabi za podmazivanje skretnica na području HŽ-a postiže znatne prednosti. To su: sigurnji rad skretnica u svim vremenskim uvjetima, posebno u hladnim zimskim danima, potrošnja maziva je manja za više od 10 puta, utrošak radnog vremena za domazivanje je tri puta manji, bolja zaštita od korozije a zagađenje okoliša je neusporedivo manje.

ZAKLJUČAK

1. Provedena primjenska ispitivanja u Hrvatskim željeznicama pokazala su da domaće biorazgradljive mazive masti BM 2 i BM 00 u potpunosti zadovoljavaju zahtjeve za podmazivanje tračnica odnosno podmazivanje vijenaca kotača lokomotiva te skretnica.
2. Obje BM 2 i BM 00 masti u odnosu na konvencionalna maziva koja su sada u uporabi na spomenutim kritičnim mjestima podmazivanja pokazale su bolja primjenska svojstva u zimskim uvjetima, a kod podmazivanja skretnica i znatnu uštedu na mazivu.
3. Zakonski propisi i povećana svijest o zaštiti okoliša u Hrvatskoj već utječu na povećani interes za primjenu biorazgradljivih mazivih masti, unatoč većoj cijeni koštanja.
4. U prilog povećanog interesa idu i visoka radna svojstva novo razvijenih biorazgradljivih masti koje zadovoljavaju i najzahtjevnija kritična mjesta podmazivanja.

BIODEGRADABLE LUBRICATING GREASES AND THEIR APPLICATION ON RAILWAYS

Abstract

Biodegradable lubricating greases are becoming increasingly used for critical application spots, on which severe environmental requirements are imposed. Such greases must be characterized by a high degree of biodegradability over a short period of time. If that is not the case, they could bear a harmful impact on either environment in general, or soil and waters.

Given that lubricating greases based on refined mineral oils cannot meet these requirements, biodegradable greases are made of either natural or synthetic esters. Biodegradable lubricating greases have to be non-toxic. As a rule, they are multipurpose and have EP properties, and are applied in both manual and automatized lubrication.

The paper provides data on the making of two biodegradable greases different thickeners, based on lithium soaps and synthetical biodegradable esters. It also provides data on field tests performed at HŽ (The Croatian Railways) company.

Introduction

Over 1,000 tons of lubricating greases are consumed in Croatia each year. All these greases are conventional, mineral-oil based, with low biodegradability. A considerable number of them from critical application spots ends up in the environment. Once they end up there - either in soil or in waters - they persist for a long time in their original form, causing contamination. In Croatia, nearly 50 tons of lubricants end up each year in the environment as a result of railway track, wheel rim and switch lubrication, causing contamination threatening both flora and fauna. This kind of environmental pollution may be significantly reduced by using biodegradable lubricating greases.

For the purpose of environmental protection, domestic biodegradable lubricating greases have been developed, based on lithium and calcium soap thickeners and biodegradable synthetic esters. They constitute a proper substitute to conventional greases still used on critical lubrication spots for railways and cable cars. These greases fulfill their lubrication duty on the application spot, while there is no degradation. It is only after having leaked from the application spot or through the contact with the environment, as well as due to the activity of natural microorganisms, such as bacteria, fungi, or algae, within the period of several weeks up to several months (depending on the weather conditions), that they disintegrate. End biodegradation products are simple natural products, such as carbon dioxide and water.

THE THEORETICAL PART

1. Biodegradable Lubricating Greases

The need for less environmentally harmful products has appeared along with liquid lubricants. Towards the end of the 70's, biodegradable oils were initially introduced for outboard engines. Somewhat later, this was continued with chain saw oils. Biodegradable lubricating greases have gained their prominent position towards the beginning of the 90's. Today they play an important role in many technical areas, in terms of optimal lubrication of numerous machine parts, with a high degree of environmental protection.

1.1. The Composition of Biodegradable Greases

Basically, biodegradable lubricating greases have the same composition as conventional mineral-oil based greases. They consist of thickener dispersion within a liquid lubricant, with the addition of various additives. When selecting the feed for formulating biodegradable lubricating greases, apart from biodegradability, one should also take into account the following aspects: Bioaccumulation, toxicity (for humans), and ecotoxicity (for fish, daphnea/?/, and plants).

a) Base fluids - The following base oil are used for formulating biodegradable lubricating greases:

- Vegetable oils (natural esters),
- biodegradable synthetic esters.

Vegetable oils and synthetic esters show basically the same chemical composition. That is why their properties are also similar. However, synthetic esters have some clear advantages as to the stability to ageing, high temperature performances, and low temperature behaviour - when compared to vegetable oil, thus justifying their higher price.

b) Thickeners - The choice of thickeners depends heavily on the requirements to be met by the lubricating grease in question. Thickeners used in biodegradable greases are those environmentally neutral, such as:

- lithium or calcium 12-OH-stearate or their compound,
- complex aluminum soap,
- bentonite/silica gel.

c) Additives - Additives used in biodegradable greases must preferably be biodegradable, with low toxicity, without mineral oil and heavy metal content, and used in the lowest concentration possible. The usual additives are:

- antioxidants - amines or phenols,
- for protection against corrosion - fatty acid derivatives,
- EP (extreme pressure)/antiwear - S-P compounds.

1.2. Biodegradability Test Methods

There are numerous methods for testing lubricant biodegradability. However, most of them are not applicable to such complex blends as lubricating greases. The following three methods are used in Europe for determining the lubricating grease biodegradability degree:

- The Modified Sturm Method
- The Closed-bottle Test
- The CEC-L-33-A-93 Test.

Criteria for evaluating biodegradability according to the above methods are strictly different. In the case of The Sturm Method, what is measured is the volume of CO_2 generated through a complete disintegration of the organic substance. The Closed-bottle test measures O_2 consumption, while, in the case of the CEC method, the biodegradability degree is determined according to the CH_3-CH_2 chain disintegration degree. Lubricating greases which, according to The Sturm Method and The Closed Bottle Test, have at least a 60% biodegradability degree, i.e., in the case of CEC methods, 80% - are considered as fastly biodegradable.

2. The Wheel/Track Tribological System and Wear Instances

During the exploitation of railway vehicles, the wheel/track system annually causes huge expenses due to wear and damage in the contact area. This damage results not only in financial losses, but also in reduced traffic safety, as well as further mobility limitations, such as standstills or unavoidable changes of direction. The passengers also feel wear and damage through the reduction of comfort (shaking, noise), and particularly through the most unpleasant squeeking sound while driving through curves.

In order to reduce the friction of rolling, and thus also the wear and damage of wheel rims and lateral track sides, as well as to increase the safety factor against the train suddenly leaving the tracks and other undesirable side effects, lubrication devices are used. Their task is to timely lubricate wheel rims or tracks. Proper lubrication makes it possible also to save 3-10% of the fuel, depending on the type of terrain, tracks, and trains. This constitutes major savings, given the large fuel consumption in the railroad. Figure 1 shows the wheel/track tribological system.

Under ideal circumstances, the contact area is only the rolling surface between the wheel and the tracks. However, in practice, there occurs also a considerable contact between the wheel rim and the inner track edge. There are several reasons because of which the contact between the wheel rim and the track occurs. If the prescribed distance (1,435 mm) between the tracks has not been observed during their installation, the possibility for a contact increases. Also, the forces causing lateral movement push the wheel rim towards the inner track edge (that is, in fact, why the wheel rim exists). Furtherly, and most importantly, due to curve effect, the centrifugal forces push the wheel rim into contact with the main outer track inner edge.

Another important element in the description of the wheel/track system and the example of their wear referrs to the load on the upper part of the track head. These loads result from burdened vaggons, creating loads ranging from 9,000 kg/cm^2-10,500 kg/cm^2, sufficient for causing plastic track deformations. Figure 2 shows how the track form is changed as a result of plastic deformation and wear.

The full line shows track shape in three instances, after a certain amount of time. The original track shape is shown by the dotted line. When there is lubrication, or when the contact between the rim and the inner head edge is the least, we end up with form A. This is the result of a plastic flow. In some cases the rim/track contact results in wear (or sharpening), thus creating the shape shown as B. If the wear progresses, we end up with shape C.

2.1. Geometry of the Wheel Rim

The prescribed profile of the wheel coating with the rim and the wheel circulation range ensures safe riding of railway vehicles, and impacts the stillness of vehicle movement, as well as the wheel rim wear intensity. The wheel coating wear intensity is dependent also on the material from which both the wheels and the tracks are made, vehicle balance, load, speed, and track configuration (hill/plain) and condition. The following wheel rim parameters are being monitored in field tests (Figure 3):

- Rim parameters/ Type of measurement/ Permissible limit in mm
- Rim height
- Rim thickness
- Rim sharpness

V_v - rim height, measured from the circulation range to the top of the rim. In the case of a new profile or after turning, the rim height is 28 mm, increased in exploitation, and hence tolerated up to 33 mm, otherwise threatening traffic safety (it may damage the switch or the rim may be broken).

D_v - rim thickness, measured at the height of 10 mm above the rolling range. In the case of a new profile or after turning, the rim thickness amounts to 32.5 mm. This is decreased in exploitation, and tolerated down to 25 mm. Rim thickness decrease disturbs the vehicle movement stillness and may cause rim breaking.

q_R - rim sharpness, is measured from the height point of 10 mm above the rolling circle to the height point 2 mm below the rim height, and is tolerated up to 6.5 mm. Below this rim sharpness value, the wheels may slide off the track.

If the wheel surface wear approaches the maximum permissible value (V_v ³ 33 mm, D_v £ 25 mm, and q_R £ 6.5 mm), then turning is performed to a new profile, or, if this is not possible, either the wheel coating or the wheel itself must be replaced.

2.2. Wheel Rim and Track Lubrication Systems

There are three basic methods of applying the lubrication of wheel rims and tracks, as follows:

- On-board systems
- Wayside systems
- Hy-rail lubrication.

In the case of On-board systems, the spreaders are usually installed on the locomotive. Depending on the spreader type, one may use graphite sticks, lubricating oil, or lubricating greases, occasionally or continuously lubricating the locomotive wheel rims. The lubricant is transmitted from the locomotive wheel rims to the track when the two come into contact. After that, it is transmitted from the tracks to the connected vaggons' wheels. In this case, it is necessary to ensure sufficient lubrication among the rims of all the train's wheels consisting of 50 and more vaggons and tracks, through the transmitting of lubricant from the locomotive wheel rims to the track.

In the Wayside system, the lubricating grease lubricates the inner edge of the track head. The spreader is activated either mechanically or electronically, by the passing of the wheels. The grease is transmitted from the track to the wheel rim during its contact with the track. In this way, the grease is being transmitted further along the track up to the distance conditioned by various parameters, including, among other things, also the used grease properties.

Hy-rail lubrication: The spreaders are installed on a self-mobile vehicle, adapted for the use on railways. This kind of lubrication enables the use of a wide variety of lubricants. The lubricant is being spread directly on the tracks - either continuously or occasionally, whichever is necessary. For obvious reasons, this particular lubrication system is suitable when the traffic is not heavy and when the rails are not too long.

3. Critical Railway Lubrication Spots

Critical railway lubrication spots, from which the lubricant is disposed directly to the environment, are the wheel rims, tracks, and switches. Given that the lubrication of switches is performed on a daily basis, whereas that of wheel rims and tracks is performed by movement of the railway vehicles, the lubricant consumption is indeed a considerable one. Shortly after lubrication, the lubricant ends up in the environment almost in entirety.

3.1. On-Board Locomotive Wheel Rim Lubrication

On many locomotives, the lubrication of wheel rims is performed by means of a central lubrication system, using semi-fluid lubricating greases (NLGI 00). Figure 4 provides a schematic presentation of the central lubrication system for the main locomotive axle wheel rims.

Two central lubrication systems are installed on the mobile locomotive platform, lubricating the wheel rims of the leading axles: The first or the sixth, depending upon the direction of the ride. The system consists of an electronic control device, an electro-pneumatic valve, a grease container, pipes for conducting lubricant and pressurized air, and spreaders with a nozzle. The lubrication is performed within the intervals of 100 to 500 m of the locomotive's mileage covered, or within short periods of time, depending on how the system has been set.

A small amount of grease (30-100 mm^3) is spread over the nozzle under the pressure of 5 bar and turns into tiny drops within just a few seconds. During that time, the locomotive wheel rotates several times. The lubricating film thickness is then less than 0.003 mm, while its width ranges between 10 and 15 mm. The basic requirements imposed upon lubricating greases for the lubrication of wheel rims are as follows:

- Friction reduction in the area of rim/inner track edge, in order to achieve safety against sliding out, as well as noise reduction within the contact zone.
- Good pumpability and splashing possibility under all weather conditions,
- High adhesiveness and resistance to water and rain washing out,
- Biodegradability.

3. Wayside Track Lubrication

Originally, wayside (curve) track lubrication was performed manually, using lubricating oil. However, today, it is performed automatically, with medium consistency lubricating greases (NLGI 2), using fixed mechanical spreaders. Figure 5 shows a fixed mechanical track spreader, used on many railway tracks in Europe.

Such track spreaders are fixed onto the very tracks in curves and are mechanically activated when the train passes. Each train wheel activates the spreader by pushing the contact tip, and the given quantity of grease is then spread - through the comb opening - to the outer track head's inner edge. After that, the grease is transmitted from the track to the wheel rims, during the contact between wheel rims and tracks. The basic requirements imposed upon lubricating greases for track lubrication are as follows:

- reduction of friction and wear of wheel rims and tracks, as well as noise reduction in the contact zone,
- high adhesiveness, in order for the losses due to rejection caused by powerful centrifugal forces on the wheel to be as low as possible, thus contributing to lubricant cost and environmental pollution reduction,
- a wide temperature application interval i.e. possibilities of application in all weather conditions,
- high resistance to water and rain washing out,
- biodegradability.

3.3. Switch Lubrication

Impeccable switch performance under all weather conditions is an important factor in railway traffic. This particularly regards traffic safety and regularity. Safe and regular operation of switches is achieved by proper lubrication. Lubrication also reduces wear and protects the switches against damage. Unlike the lubrication of wheel rims and tracks, switch lubrication is neither mechanized nor automatized, since it would simply incur to much costs. Same as before, switches are mostly lubricated manually i.e. using a brush or a special portable lubrication device.

Switch lubrication is still faced with the fact that the present switch structures are frequently used to be lubricated with low viscosity lubricating oils used for other purposes in the railway traffic. Still, experience gathered over many applications has shown that optimized semi-fluid grease extends lubrication intervals and may thus considerably reduce costs, as well as environmental pollution, which is why many railways have switched to that particular type of lubricants.

The most important requirements imposed upon switch lubricants are as follows:

- friction reduction for the achievement of low forces at switching and a safe ultimate switch position under all weather conditions,
- good corrosion protection, so that, even under the most unfavourable of circumstances, and with a thin lubricating film, all the parts may be protected,
- water resistance and possibility of adhesion to both dry and wet surfaces,
- good penetrating ability, so that they are well supplied by lubricants even on the not easily accessible spots, such as, for instance, in the back part of the switch tip, where there is very little room,
- good lubricating properties within a wide temperature interval, so that the switch function is ensured even at extremely low temperatures during cold winter days, as well as at relatively high temperatures when applying electric or gas switch heating (in wintertime) i.e. in the hot days of summer,
- biodegradability.

THE EXPERIMENTAL PART

4. Test Grease Production and Laboratory Testing

The aims of the presented project was the development of biodegradable and non-toxical lubricating greases intended for critical railway lubrication spots, such as wheel rims, tracks, and switches. The next step was then to check their application performances through field tests performed in different seasons at the Croatian Railways. For this purpose, two biodegradable lubricating greases have been developed at the Research Laboratory of INA Maziva Zagreb, based on lithium and calcium 12-OH stearate as soap thickener, biodegradable synthetic esters, and environmentally acceptable additives. The first one was a medium consistency biodegradable grease (NLGI 2), labelled BM 2, intended for the lubrication of railway tracks, while the other one is of semi-liquid consistency (NLGI 00), labelled BM 00, intended for the lubrication of railway wheel rims, as well as switches. For the needs of field tests, 200 kg of each grease was produced at a semi-industrial plant. Table 1 lists the physico-chemical and mechanical-dynamical properties, threat posed to water organisms, and biodegrability degree of the BM 2 and BM 00 greases produced.

The following may be derived from Table 1:

- Both greases have a high biodegradability degree, and that they are not hazardous for water organisms or fish,
- They have very good physico-chemical properties, - particularly oxidation stability, corrosion protection, and low temperature properties. Low temperature pumbability of both greases is very good, which is of particular importance during application under wintertime conditions. In central systems for the supply of both greases to the lubrication spots at very low temperatures, it takes a five times lower pressure with regard to conventional greases of the same consistency.
- Mechanical/dynamical tests have revealed that both greases have high load carrying properties and metal surface protection against wear, and, in the case of the grease BM 2, also the capacity of lubrication at high temperatures.

5. Railway Field Tests and Discussion

Field tests of developed biodegradable greases BM 2 and BM 00 have been performed at Croatian Railways. The medium consistency biodegradable grease BM 2 was tested for track lubrication in curves, while the semi-liquid biodegradable grease BM 00 was tested for the lubrication of electric locomotives wheel rims, as well as of railway switches.

5.1. Track Lubrication in Curves

Stable mechanical track spreaders were positioned each on the 83.5th kilometer of the Novska-Dugo Selo line, on the right track, and, on the 445.7th kilometer of the Dugo Selo-Koprivnica line, on the left track. Both of the spreaders' containers, with the capacity of 8 dm^3, were filled with the test grease BM 2.

The spreader on the Novska-Dugo Selo track was lubricating the switch and tracks on three consecutive curves with diameters of R=980 m, R=2,500 m, and R=595 m respectively, while the spreader on the Dugo Selo-Koprivnica track was lubricating the switch and tracks on two consecutive curves with diameters of R=2,900 m, and R=1,042 m. The curves that were chosen for the field test of grease BM 2 had larger diameters, which is more unfavourable - when it comes to lubrication - than the curves with smaller diameters.

The field test was performed in the period between April and October, 1999. The spreaders installed were operating throughout that period. Whenever necessary, they were topped up with new BM 2 grease volumes. During the tests, both spreaders were checked every 7-14 days, along with grease behaviour and track lubrication in curves and at switches.

After six months of operation, it has been established that both spreaders were operating excellently throughout the tests. In other words, there were no clogs or standstills caused by the use of the test greases. The grease was coming out automatically through the nozzles openings when the trains were passing. The volume was precisely as set, regardless of weather conditions. Furtherly, visual inspection has revealed that considerable traces of the test grease could be found near switches and on tracks from both sides of the spreader in the length of 2 km, in the case of both tracks. With the help of wheel rims, the grease was being transmitted along the tracks in curves far from the position where the spreaders were installed. The volumes were sufficient, and it was not washed off the tracks, not even with heavy rain. Finally, owing to good track lubrication, the noise caused by the passing of trains was considerably reduced. The results achieved show that the test grease BM 2 fully meets the requirements imposed upon lubricants for this particular purpose.

5.2. Wheel Rim Lubrication

For the performance of field tests of the biodegradable grease BM 00 for the lubrication of wheel rims, we have chosen the electric locomotive of Ansaldo type, series 1061, no. 015, with central lubrication system, covering the hilly Rijeka-Moravice track. In July, 1999, overhaul was performed on the said locomotive. The wheels were fitted with new rims, of B 5T quality. Both reservoirs of the central lubrication system, with the capacity of 20 dm^3, have received semi-liquid grease BM 00. The system was then set for the lubrication to be performed after every 300 m covered.

Field tests were performed in the August 1999-March 2000 period. During that time, the locomotive covered the total of 55,600 km. The wheel rim parameters monitored were those usually controlled in the exploitation of locomotives, as follows: Rim thickness (D_v), rim height (V_v), and wheel rim sharpness (q_R). The said parameters were measured once a month, using the MEBA instrument, on all of the locomotive's 12 wheels.

During field tests, visual inspection has established that the BM 00 grease was homogenous in both reservoirs and there was no separation of the oil from the thickener in grease structure, regardless of the constant pressure presence in the system in the amount of 5 bar. It has also been established that the central system's fittings were not clogged, and that grease consumption was constant regardless of the season or the temperature differences.

Table 2 shows the results of changes in the thickness, height, and sharpness of each locomotive wheel rim within the test period of August 1999-April 2000, while Table 3 presents average wear per wheel for the same period of 8 months, as well as after 10,000 km covered. Tables 2 and 3 show that the wheel rim thickness D_v and the sharpness q_R lowered very little, 0.80 and 0.12 mm respectively per wheel on the average, within the said 8-month period. Wheel rim heights have recorded only a moderate increase. On the average, height value went up by 2.09 mm per wheel over the eight month period, i.e. 0.38 mm per wheel on the average for every 10,000 km covered. Compared to average changes of locomotive wheels lubricated with conventional semi-fluid grease, currently employed by The Croatian Railways, we have achieved wheel rim wear reduction of about 20%. The results achieved by field tests have shown that the biodegradable grease BM 00 tested has very good lubrication properties, particularly at low temperatures. As such, it constitutes a suitable replacement for conventional semi-liquid greases currently in use.

5.3. Switch Lubrication

Field tests of the BM 00 grease on the lubrication of switches have been performed in Zagreb Railway Station between January and April, 2000. The tests were performed on the total of eight switches: Four equipped by gas heaters for the melting of snow and ice in winter conditions (no. 462, 463, 464, and 465), and on four switches equipped with electric heaters (no. 146, 149, 206, and 208).

The sliding pads of the said switches were lubricated once a day with the test grease. The grease was introduced manually, using a brush, creating a thin film. Later on, owing to the good adherence of the test grease, i.e. its keeping on the pad surface, the additional lubrication periods were gradually prolonged, so that, eventually, it occurred once in every four days.

During the 4-month testing period, although it was wintertime, the temperatures were low, and there was snow, there was not a single standstill or any difficulties or interruptions whatsoever in the operation of tested switches. The lubricated switch parts also showed no corrosion traces.

Since only a thin film was sufficient for the lubrication of switch sliding pads, and since the additional lubrication period could be prolonged up to four days, major lubricant savings were achieved.

Based on application testing, the grease BM 00 has - with regard to the mineral-based lubricating oil with low biodegradability, now in use for switch lubrication at Croatian Railways - shown some major advantages. They are: Safer switch operation under all weathering conditions, and especially in the cold winter days; lubricant consumption is lower by more than 10 times; time spent on additional lubrication is three times lower, better corrosion protection is achieved, while environmental pollution is considerably lower.

CONCLUSION

1. The field tests performed at Croatian Railways have shown that the locally produced biodegradable lubricating greases BM 2 and BM 00 fully meet the requirements for track lubrication i.e. for the lubrication of locomotive wheel rims and switches.
2. With regard to conventional lubricants currently in use on the above mentioned critical lubrication spots, both greases (BM 2 and BM 00) have shown better application properties in wintertime conditions, while, in the case of switch lubrication, they have also enabled major savings.
3. Legal regulations and increased environmental awareness in Croatia have already resulted in an increased interest in the application of biodegradable lubricating greases, in spite of their higher price.
4. The said increased interest is substantiated also by high performances of the newly developed biodegradable greases, meeting even the most demanding critical lubrication spots.

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576.343 biorazgradljivost	biodegrability
614.7 zagađivanje i zaštita okoliša	environment pollution and protection
621.135.2 vijenac kotača lokomotive	locomotive wheel rim
625.282.032.3 interakcija kotača i tračnica	wheel and track interaction
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