JOURNAL OF TRANSPORT

ISSUE 2, 2026 vol. 3
E-ISSN: 2181-2438
ISSN: 3060-5164

SLIB.UZ
Scientific library of Uzbekistan

RESEARCH, INNOVATION, RESULTS

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI

Tashkent state transport university

JOURNAL OF TRANSPORT

RESEARCH, INNOVATION, RESULTS

E-ISSN: 2181-2438

ISSN: 3060-5164

VOLUME 3, ISSUE 2

JUNE, 2026

jot.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

JOURNAL OF TRANSPORT

SCIENTIFIC-TECHNICAL AND SCIENTIFIC INNOVATION JOURNAL

VOLUME 3, ISSUE 2 JUNE, 2026

The **"Journal of Transport"** established by Tashkent State Transport University (TSTU), is a prestigious scientific-technical and innovation-focused publication aimed at disseminating cutting-edge research and applied studies in the field of transport and related disciplines. Located at Temiryo'lchilar Street, 1, office 465, Tashkent, Uzbekistan (100167), the journal operates as a dynamic platform for both national and international academic and professional communities. Submissions and inquiries can be directed to the editorial office via email at jot@tstu.uz.

The Journal of Transport showcases groundbreaking scientific and applied research conducted by transport-oriented universities, higher educational institutions, research centers, and institutes both within the Republic of Uzbekistan and globally. Recognized for its academic rigor, the journal is included in the prestigious list of scientific publications endorsed by the decree of the Presidium of the Higher Attestation Commission No. 353/3 dated April 6, 2024. This inclusion signifies its role as a vital repository for publishing primary scientific findings from doctoral dissertations, including Doctor of Philosophy (PhD) and Doctor of Science (DSc) candidates in the technical and economic sciences.

Published quarterly, the journal provides a broad spectrum of high-quality research articles across diverse areas, including but not limited to:

- Economics of Transport
- Transport Process Organization and Logistics
- Rolling Stock and Train Traction
- Research, Design, and Construction of Railways, Highways, and Airfields, including Technology
- Technosphere Safety
- Power Supply, Electric Rolling Stock, Automation and Telemechanics, Radio Engineering and Communications
- Technological Machinery and Equipment
- Geodesy and Geoinformatics
- Automotive Service
- Air Traffic Control and Aircraft Maintenance
- Traffic Organizatsion
- Railway and Road Operations

The journal benefits from its official recognition under Certificate No. 1150 issued by the Information and Mass Communications Agency, functioning under the Administration of the President of the Republic of Uzbekistan. With its E-ISSN 2181-2438, ISSN 3060-5164 the publication upholds international standards of quality and accessibility.

Articles are published in Uzbek, Russian, and English, ensuring a wide-reaching audience and fostering cross-cultural academic exchange. As a beacon of academic excellence, the "Journal of Transport" continues to serve as a vital conduit for knowledge dissemination, collaboration, and innovation in the transport sector and related fields.

Investigation of the mechanism and factors influencing the process of dephosphorization during the smelting of 20GL steel

N.K. Tursunov[1][a], N.K. Kodirova[1], Z.F. Rakhmatova[1], M.B. Abdulazizov[1]
[1]Tashkent state transport university, Tashkent, Uzbekistan

Abstract: This article examines the influence of hydrogen in 20GL cast steel on metal properties, as well as methods for reducing its content. Hydrogen is present in molten form within steel, and its excessive concentration causes the formation of flukes, internal cracks, and other structural defects. In the study, the thermodynamic state of hydrogen was modeled using Sivertz's law and interaction parameters based on the chemical composition of 20GL steel. The activity coefficient and equilibrium concentration of hydrogen were calculated, and it was found that an increase in temperature between 1848–1898 K increases the solubility of hydrogen in the metal. Based on the results obtained, the importance of optimizing the pouring temperature in limiting the amount of hydrogen is substantiated. The effectiveness of off-furnace argon blowing and vacuum treatment methods in reducing hydrogen was also analyzed. The research results serve as a scientific and practical basis for improving hydrogen control in the production of high-quality cast steel and preventing irreversible defects such as floken.

Keywords: steel grade 20GL, hydrogen degradation, Sieverts' law, thermodynamic modeling, activity coefficient, flakes, ladle metallurgy, argon purging, vacuum degassing

20GL markali po‘lat tarkibidagi vodorodning metall xossalariga ta’siri hamda uni kamaytirish jarayonlarini tadqiq etish

Tursunov N.Q.[1][a], Qodirova N.Q.[1], Raxmatova Z.F.[1], Abdulazizov M.B.[1]
[1]Toshkent davlat transport universiteti, Tashkent, O‘zbekiston

Annotatsiya: Ushbu maqolada 20GL markali quyma po‘lat tarkibidagi vodorodning metall xossalariga ta’siri hamda uning miqdorini kamaytirish usullari o‘rganilgan. Vodorod po‘lat tarkibida erigan holda mavjud bo‘lib, uning ortiqcha konsentratsiyasi flokenlar, ichki yoriqlar va boshqa strukturaviy nuqsonlarning hosil bo‘lishiga sabab bo‘ladi. Tadqiqotda 20GL po‘latining kimyoviy tarkibi asosida vodorodning termodinamik holati Siverts qonuni va o‘zaro ta’sir parametrlari yordamida modellashtirilgan. Vodorodning aktivlik koeffitsiyenti hamda muvozanat konsentratsiyasi hisoblanib, haroratning 1848–1898 K oralig‘ida ortishi metalldagi vodorod eruvchanligini oshirishi aniqlangan. Olingan natijalar asosida quyish haroratini optimallashtirishning vodorod miqdorini cheklashdagi ahamiyati asoslab berilgan. Shuningdek, pechdan tashqari argon bilan puflash va vakuum ostida ishlov berish usullarining vodorodni kamaytirishdagi samaradorligi tahlil qilingan. Tadqiqot natijalari yuqori sifatli quyma po‘lat ishlab chiqarishda vodorod nazoratini takomillashtirish va floken kabi qaytarib bo‘lmaydigan nuqsonlarning oldini olish uchun ilmiy-amaliy asos bo‘lib xizmat qiladi.

Kalit so‘zlar: 20GL markali po‘lat, vodorod destruksiyasi, Siverts qonuni, termodinamik modellashtirish, floken, pechdan tashqari ishlov berish, argon bilan puflash

1. Kirish

Zamonaviy metallurgiya sanoatida po‘lat va qotishmalar sifatini ta’minlash muammosi ilmiy va amaliy jihatdan tobora dolzarb ahamiyat kasb etmoqda. Po‘latning mexanik xossalari, xizmat muddati va ekspluatatsion ishonchliligi ko‘p jihatdan uning tarkibidagi gaz va gaz hosil qiluvchi elementlar, yani vodorod, azot va kislorod miqdori hamda taqsimlanish xususiyatlariga bog’liqdir. Ushbu gazsimon moddalalar orasida vodorod o‘zining yuqori diffuzion harakatchanligi, kichik atom radiusi va metallga nisbatan yashirin, ammo zararli ta’siri tufayli alohida o‘rin egallaydi. Aynan vodorod metall va qotishmalardagi nuqsonlarning eng xavfli turlaridan biri - ichki tuzilishdagi vodorod yoriqlarini, ya’ni flokenlarni keltirib chiqarishi bilan mashhur bo‘lib, metall ishlab chiqarishda to‘g’rilab bo‘lmaydigan bu nuqsonlar sirasiga kiradi. Makroshliflar yuzasiga ishlov berilganda 10 mm gacha bo‘lgan kichik uzunlikdagi tukchalar ko‘rinishida kuzatiladigan po‘latning ichki yoriqlariga flokenlar deyiladi.

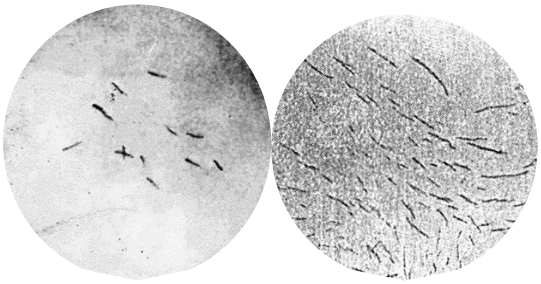
Mikroskopda qaralganda flokenlar juda mayda tishsimon qirrali yoriqlar ko‘rinishida namoyon bo‘ladi, bu esa yoriqlarning metall donalarining sirpanish tekisliklari bo‘ylab siljishi natijasidir.

Flokenlar sinishda, ayniqsa termik ishlov berilgan po‘latda oson topiladi, bunda ular umumiy mayda donali yoki tolali fonda kumushsimon ovalsimon dog‘lar ko‘rinishida ko‘zga tashlanadi. Kumushsimon dog‘lar ichki

[a] https://orcid.org/0009-0008-7910-3980

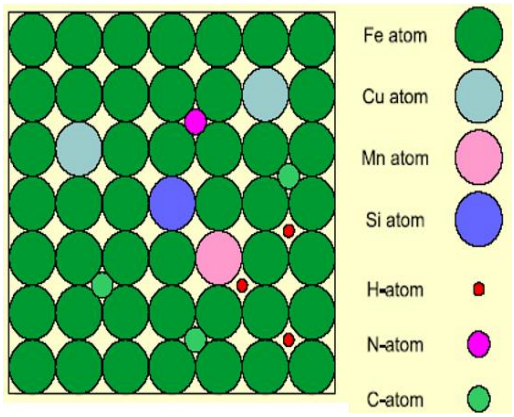
yoriqlarning devorlaridan iborat (1-rasm).

Vodorod temir va uning qotishmalarida atomar holatda, ya'ni kiritma eritmasi shaklida eriydi va uning eruvchanligi Siverts qonuniga bo'ysunadi. Qattiq metallda vodorod bir necha ko'rinishda mavjud bo'ladi: kristall panjarasining bo'sh oraliq tugunlarida joylashgan erkin, diffuzion harakatchan atomar (proton) vodorod; vakansiyalar, dislokatsiyalar va fazalararo chegaralar bilan bog'langan atomar (kovalent) vodorod; mikrog'ovaklar va yoriqlar ichida molekulyar (H_2) holida joylashgan vodorod; hamda titan, sirkoniy, niobiy va nodir-yer metallari bilan kimyoviy birikma - gidridlar hosil qilib bog'langan vodorod. Har bir ko'rinish po'latning xossalariga turlicha ta'sir ko'rsatadi va ularni nazorat qilish metallurgik jarayonning asosiy vazifalaridan biri hisoblanadi.



1-rasm. Po'lat tuzilishidagi flokenlar

Vodorod miqdori va taqsimlanishi po'latda bir qancha xarakterli nuqsonlarni keltirib chiqaradi. Eng xavflisi va keng tarqalgani - flokenlar bo'lib, ular ichki vodorod yoriqlar ko'rinishida namoyon bo'ladi. Flokenlar po'latning sinish sirtida kumushsimon dog'lar shaklida ko'rinadi va GOST 10243 standartiga muvofiq templetin sindirilishi orqali aniqlanadi. Bu nuqson qaytarib bo'lmaydigan xususiyatga ega, ya'ni floken hosil bo'lgan po'latni qayta ishlov berib tiklash mumkin emas. Bundan tashqari, vodorod metall ichida vodorod g'ovaklari va pufakchalar ham hosil qilishi mumkin. Qaysi nuqson turi paydo bo'lishi po'latdagi vodorod miqdori va prokat qalinligiga bog'liq: qalin kesimli (50 mm dan yuqori) konstruktsiyalarda - balkalar, relslarda - floken xavfi eng yuqori bo'lib, 28-40 ppm dan ortiq vodorod konsentratsiyasida yuzaga keladi; o'rtacha qalinlikdagi (18-28 mm) quvurli va kema po'latlarida - vodorod g'ovaklari xarakterli; yupqa (1-5 mm) sovuq va issiq prokatda esa vodorod pufakchalari dominant nuqson hisoblanadi.



2-rasm. Temirning γ-fazasidagi hajmi markazlashgan kubik kristall panjarasida erigan element atomlarining joylashish sxemasi

Vodorodning po'latga asosiy kirib kelish manbalari sifatida nam shlak hosil qiluvchi materiallar, ayniqsa yuqori gigroskopiklikka ega bo'lgan ohak, ferroqotishma va zanglagan metalloshixta, suvli sovutish tizimining germetik emasligi, shuningdek, metall vanna purkaladigan kislorod ko'rsatiladi. Shu boisdan metallurgik amaliyotda vodorod miqdorini kamaytirish uchun bir qancha usullar qo'llaniladi: oksidlanish davrida uglerod bilan (kamida 0,20–0,30 % C); metallni argon bilan puflash; pechdan tashqari vakuum ishlov berish; flokenga qarshi toblash va metallning ma'lum muddat saqlash usuli. RH vakuumator qurilmasida vakuumlash vaqtining oshishi bilan vodorod miqdori keskin kamayishi eksperimental ma'lumotlar bilan tasdiqlangan.

2. Tadqiqot metodologiyasi

Metall tarkibidagi vodorodni aniqlash uchun, 20ГЛ markali po'lat tanlandi. 1-jadvalda ГОСТ 22703-2012 hamda 32400-2013 bo'yicha ushbu markani kimyoviy tarkibi keltirilgan.

1-jadval

20GL po'lat kimyoviy tarkibi, % (mass.)

C	Si	Mn	P	S	Al	Fe
0,20	0,35	1,15	0,019	0,017	0,040	qolgani

Suyuq metalldagi vodorodning eruvchanligi Siverts qonuniga bo'ysunadi va quyidagicha ifodalanadi:

$$\frac{1}{2}\{H_2\}=[H] \quad (1)$$

Bu (1) reaksiyaning Gibbs energiyasi (2) muvozanat konstantasi (3) ifodaga teng:

$$\Delta G = 36500 + 30{,}46T \quad (2)$$

$$\lg K_P = -\frac{\Delta G}{2{,}3RT} = -\frac{(36500+30{,}46T)}{2{,}3\cdot 8{,}314\cdot T}; \quad (3)$$

bu yerda:$R = 8{,}314$J/(mol·K) - universal gaz doimiysi;
T- absolyut harorat, K.

Ikkinchi tarafdan, 4-tenglamaga ko'ra muvo-zanat doimiysi P=1 atm.da, (4) ifodaga teng:

$$K_P = \frac{a_H}{\sqrt{P_{H_2}}} = [H]\cdot f_H. \quad (4)$$

Agar (4) ifoda logarifmlanib (3) ifodaga tenglashtirilib hamda amallar bajarilgandan so'ng (5) va (6) ifoda hosil bo'ladi:

$$lgK_P = lg[H] + lgf_H \quad (5)$$

$$lg[H] = \frac{1900}{T} - 1{,}59 - lgf_H. \quad (6)$$

bu yerda: $[H]$ – metal tarkibidagi vodorodning miqdori, %;

f_H– vodorodning aktivlik koeffitsiyentlari.

5-tenglamadan foydalanib turli harorat uchun muvozanat konstantasi hisoblanadi. Vodorodning aktivlik koeffitsiyentini turli haroratlarda hisoblash uchun 7-ifodadan foydalanildi.

$$lgf_H = \frac{T}{1873}\cdot(e_H^C[C] + e_H^{Mn}[Mn] + \\ + e_H^{Si}[Si] + e_H^P[P] + e_H^S[S] + e_H^{Al}[Al]); \quad (5)$$

https://doi.org/10.56143/2181-2438-2026-2-262-265 Research, Innovation, Results

bu yerda: $e_H^R[R]$ – metal tarkibidagi [R] komponentining vodorod bilan ta‘sirlashish parametri.

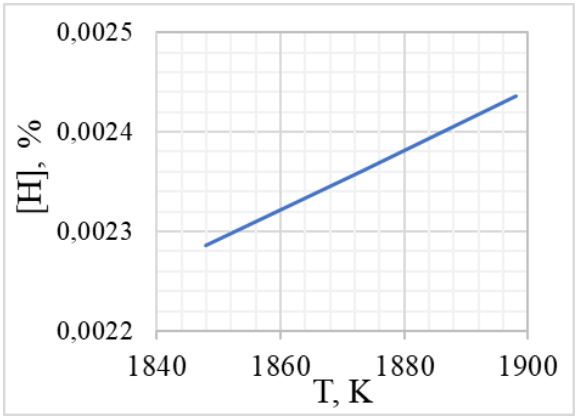
Metall tarkibidagi komponentlarning vodorod bilan ta‘sirlashish parametrlari 2-jadvalda keltirilgan.

2-jadval

Birinchi tartibli ta’sirlashish parametrlari

e_H^R	[C]	[Si]	[Mn]	[P]	[S]	[Al]
e_H	0,06	0,027	-0,0014	0,011	0,008	0,013

Keltirilgan hisob-kitoblar asosida metall tarkibidagi vodorod miqdorini haroratga bog’liqlik grafigi 3-rasmda keltirilgan.



3-Rasm. Metal tarkibidagi vodorod miqdorini haroratga bog’liqlik grafigi

3-rasmda keltirilgan hisobiy natijalardan ko‘rinadiki, 1848–1898 K harorat oralig‘ida 20GL markali po‘latdagi vodorodning muvozanat konsentratsiyasi muntazam ravishda ortib boradi. Haroratning oshishi bilan vodorodning suyuq temirdagi eruvchanligi ortishi Siverts qonuni bilan izohlanadi va bu holat metallning gazlarni yutish qobiliyatining kuchayishini ko‘rsatadi. Hisoblash natijalariga ko‘ra, mazkur harorat diapazonida vodorod miqdori taxminan 0,00229 % dan 0,00244 % gacha oshadi, ya’ni o‘sish miqdori 6–7 % ni tashkil etadi. Bu esa quyish haroratining ortishi metallning vodorod bilan to‘yinish xavfini sezilarli darajada kuchaytirishini ko‘rsatadi. Natijada qotish jarayonida vodorodning ajralib chiqishi qiyinlashib, metall ichida flokenlar, mikroyoriqlar va gaz g‘ovaklari hosil bo‘lish ehtimoli ortadi. Shuning uchun yuqori sifatli quyma po‘lat olishda quyish haroratini texnologik jihatdan maqbul darajada ushlab turish, shuningdek, pechdan tashqari argon bilan puflash va vakuumlash kabi degazatsiya usullaridan foydalanish muhim ahamiyat kasb etadi. Olingan natijalar 20GL markali po‘lat ishlab chiqarishda vodorod miqdorini nazorat qilish va vodorod bilan bog‘liq nuqsonlarning oldini olish uchun ilmiy asos bo‘lib xizmat qiladi.

3. Xulosa

Ushbu maqolada po‘latdagi vodorodning miqdoriy ko‘rsatkichlari, uning kristall panjara bilan o‘zaro ta‘siri, turli qotishma elementlarining vodorod eruvchangligiga ta’siri, vodorod keltirib chiqaradigan nuqsonlarning tasnifi hamda ularning oldini olishga qaratilgan zamonaviy metallurgik usullar chuqur o‘rganildi.

Vodorod miqdorini kamaytirish bo‘yicha metallurgik usullar tahlili asosida eng samarali yondashuv - pechdan tashqari vakuum ishlov berish, metallni argon bilan ko‘rsatildi. Xususan, argon bilan puflash usuli alohida ahamiyat kasb etadi: kovsh yoki pechning tubiga o‘rnatilgan g‘ovak tosh orqali suyuq metall ichiga yuborilgan argon pufakchalari metallda erigan vodorod va azotni ushlab yuqoriga chiqarib yuboradi, nometall qo‘shimchalarni sirtga ko‘taradi hamda metallning tarkibini bir xillaydi. Argonning inert gaz sifatida metall bilan hech qanday kimyoviy reaksiyaga kirmasligi uni ushbu jarayon uchun eng maqbul tanlov qiladi. Oksidlanish davrida kamida 0,20–0,30 % uglerodning oksidlanishi esa pechda qayta ishlov berishning majburiy bosqichi sifatida o‘z ahamiyatini saqlaydi.

Xulosa qilib aytganda, po‘latdagi vodorod muammosi - bu faqat kimyoviy yoki fizikaviy hodisa emas, balki xom ashyo tayyorlashdan tortib tayyor mahsulotni saqlashgacha bo‘lgan barcha texnologik bosqichlarni qamrab oluvchi kompleks masaladir. Maqolada olingan natijalar yuqori sifatli po‘lat ishlab chiqarishda vodorod nazoratini takomillashtirish va floken kabi qaytarib bo‘lmaydigan nuqsonlarning oldini olishga qaratilgan amaliy tavsiyalar ishlab chiqish uchun mustahkam ilmiy asos bo‘lib xizmat qiladi.

Foydalangan adabiyotlar / References

[1] Лунев В.В., Аверин В.В. Сера и фосфор в стали. М.: “Металлургия”, 1988 г. -256 с.

[2] К.В. Григорович, Т.В. Шибаева, А.М. Арсенкин. Влияние технологии раскисления трубных сталей на состав и количество неметаллических включений. Металлы. 2011. № 5. С. 164–170.

[3] Григорян В. А., Стомахин А. Я., Уточкин Ю. И. и др. Физико-химические расчеты электросталеплавильных процессов: Сб. задач с решениями. – 2-е изд., перераб. и доп. – М.: МИСиС. - 2007. – 318 с.

[4] Raxmatova, Z., Qodirova, N., & Tursunov, N. (2025). Cho ‘yan turlarining kimyoviy tarkibi, mexanik xossalari va mikrotuzilishining kompleks tahlili. Journal of Transport, 2(4), 172-175.

[5] Инновационное производство высоколегированной стали и сплавов: теория и технология выплавки стали в индукционных печах: учеб. пособие / А.Е. Семин, Н.К. Турсунов, К.Л. Косырев. – М.: Изд. Дом НИТУ «МИСиС», 2017. – 166 с.

[6] Tursunov, N., Qodirova, N., & Raxmatova, Z. (2025). 20GL markali po ‘latning desulfuratsiyalash jarayonini tadqiq qilish. Journal of Transport, 2(4), 75-78.

[7] Tursunov, N., Qodirova, N., Raxmatova, Z., & Urazbayev, T. (2025). 20ГЛ markali po‘latni oksidsizlantirish va desulfuratsiyalash jarayonlarining termodinamik tahlili. Journal of Transport, 2(4), 268-272.

[8] Urazbayev, T., Tursunov, N., & Tursunov, T. (2024, March). Steel modification modes for improving the cast parts quality of the rolling stock couplers. In AIP Conference Proceedings (Vol. 3045, No. 1, p. 060015). AIP Publishing LLC.

[9] Valieva, D., Yunusov, S., & Tursunov, N. (2023). Study of the operational properties of the bolster of a freight car bogie. In E3S Web of Conferences (Vol. 401, p. 05017). EDP Sciences.

[10] Kayumjonovich, T. N. (2022). Non-metallic inclusions in steel processed with modifiers. Web of Scientist: International Scientific Research Journal, 3(5), 1848-1853.

[11] Toirov, O. T., Tursunov, N. Q., Nigmatova, D. I., & Qo'Chqorov, L. A. (2022). Using of exothermic inserts in the large steel castings production of a particularly.

[12] Турсунов, Н. К., & Тоиров, О. Т. (2021). Снижение дефектности рам по трещинам за счёт применения конструкции литниковой системы.

Mualliflar to'g'risida ma'lumot/ Information about the authors

Tursunov Nodirjon / Nodirjon Tursunov	Toshkent davlat transport universiteti "Materialshunoslik va mashinasozlik" kafedrasi mudiri, t.f.d., professor E-mail: Tel.:+998712990169 https://orcid.org/0009-0008-7910-3980
Qodirova Nodira / Nodira Kodirova	Toshkent davlat transport universiteti "Materialshunoslik va mashinasozlik" kafedrasi magistranti E-mail: nodiraqodirova300@gmail.com Tel.:+998933807767
Raxmatova Zarifa / Zarifa Rakhmatova	Toshkent davlat transport universiteti "Materialshunoslik va mashinasozlik" kafedrasi magistranti E-mail: zarirakhmatova@gmail.com Tel.:+998999439905
Abdulazizov Muhammadjon / Mukhammadjon Abdulazizov	Toshkent davlat transport universiteti "Materialshunoslik va mashinasozlik" kafedrasi magistranti E-mail: m.abdulazizov@autospring.uz Tel.: +998998304930

CONTENT / MUNDARIJA