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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.

Tribotechnical analysis of tungsten carbide additives in mining drilling practice

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Abstract: In oil and gas extraction, especially in complex geological conditions, effective and reliable drilling is extremely important. This study presents a comprehensive failure analysis of tungsten carbide-cobalt (WC-Co) tool inserts used in rock drilling operations. The examination included visual inspection, optical microscopy, FESEM imaging, EDS, WDXRF, XRD, and microhardness tests. The results show that abrasive wear and material adhesion are the main failure mechanisms, with wear localized on the edges of the tool due to the influence of high stress and heat. Elemental analysis revealed transferred materials such as Fe, Ca, and Si on the worn surfaces, indicating tool-rock interaction during service. The high average hardness of WC inserts was 1350 Hv, which is suitable for their application. Despite excellent intrinsic properties, the study shows that in-service degradation limits the tool's lifespan. Recommendations include optimizing microstructure, suitable lubricating materials, binder composition, and surface design to improve performance in abrasive drilling environments.

Keywords: WC-Co, drilling tools, abrasive wear, geologically complex conditions, FESEM, optical, EDS, WDXRF, XRD, microhardness, lubricating materials, binder composition, surface design

Tog‘-kon burg‘ulash amaliyotida volfram karbidi qo‘shimchalarining tribotexnik tahlili

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Annotatsiya: Neft va gaz qazib olishda, ayniqsa murakkab geologik sharoitlarda, samarali va ishonchli burg‘ilash juda muhim. Ushbu tadqiqotda tog‘ jinslarini burg‘ilash ishlarida qo‘llaniladigan volfram karbid-kobalt (WC-Co) asbob qistirmalarining to‘liq buzilish tahlili keltirilgan. Tekshiruv vizual tekshiruv, optik mikroskopiya, FESEM tasvirlash, EDS, WDXRF, XRD va mikroqattiqlik sinovlarini o‘z ichiga olgan. Natijalar shuni ko‘rsatadiki, abraziv yeyilish va materialning yopishishi asosiy buzilish mexanizmlari bo‘lib, yuqori kuchlanish va issiqlik ta’siri tufayli yeyilish asbobning chetlarida joylashgan. Elementlar tahlili yeyilgan yuzalarda Fe, Ca va Si kabi ko‘chirilgan materiallarni aniqladi, bu esa xizmat ko‘rsatish jarayonida asbob-tog‘ jinslarining o‘zaro ta’sirini ko‘rsatadi. WC qistirmalarining yuqori o‘rtacha qattiqligi 1350 Hv ni tashkil etdi, bu ularning qo‘llanilishiga mos keladi. Ajoyib ichki xususiyatlarga qaramay, tadqiqot shuni ko‘rsatadiki, xizmatdagi degradatsiya asbobning umrini cheklaydi. Tavsiyalarga abraziv burg‘ilash muhitida ish unumdorligini oshirish uchun mikrostruktura, mos moylash materiallari, bog‘lovchi moddalar tarkibi va sirt dizaynini optimallashtirish kiradi.

Kalit so‘zlar: WC-Co, burg‘ilash asboblari, abraziv yeyilish, geologik murakkab sharoit, FESEM, optik, EDS, WDXRF, XRD, mkroqattiqlik, moylash materiallari, bog‘lovchi moddalar tarkibi, sirt dizayni

1. Kirish

Neft va tabiiy gaz global birlamchi energiya iste’molining 57% ni tashkil qiladi va rivojlanayotgan mamlakatlarda iqtisodiy va ijtimoiy rivojlanish uchun muhim bo‘lib qoladi [1]. Ushbu resurslar, odatda, yer osti uglevodorodlarini olish uchun chuqur quduqlarni yaratish bilan bog‘liq burg‘ulash ishlari orqali qazib olinadi [2]. Burg‘ilash tizimlariga ekstremal sharoitlarda ishlaydigan turli xil tribologik komponentlar - burg‘ilar, podshipniklar va klapanlar kiradi [3].

Burg‘i va moylash materiallari ko‘pincha yuqori haroratda ishdan chiqadi, bu esa ish unumdorligining pasayishiga, qimmatga tushadigan almashtirishlarga va ishlab chiqarish yo‘qotishlariga olib keladi. Bunday buzilishlar ko‘p jihatdan burg‘ilash dolotolarida qo‘llaniladigan materiallarning cheklanganligi bilan bog‘liq. Burg‘ilash samaradorligi va ishonchliligini oshirish yanada mustahkam materiallarni ishlab chiqishni va buzilish mexanizmlarini aniq tushunishni talab qiladi.

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Volframning sementlangan karbidlari kesish va burg‘ilash uchun keng qo‘llaniladi, chunki ular tezkesar po‘lat va olmos kabi materiallarga nisbatan yuqori qattiqlik va qovushqoqlikka ega [4]. Ularning xossalari qattiq WC fazalari, Co asosidagi metall bog‘lovchi va ishlov berishning o‘ziga xos parametrlari kombinatsiyasiga bog‘liq [5,6]. Sementlangan karbidlardagi asosiy fazalarga geksagonal WC, aralash kubik karbid/karbonitrid (y-faza) va Co bog‘lovchisi kiradi. Bu materiallar, odatda, toblangan po‘lat korpuslarga kiritilgan vkladishlar - knopkalar, konus uchlari, radial uchlar ko‘rinishida ishlatiladi. Navlar WC donalarining o‘lchami (1-10 mkm) va kobalt miqdori (3-20%) bilan farqlanadi [7].

WC burg‘ilarining yeyilishi va ishdan chiqishi ko‘plab tadqiqotlarda o‘rganilgan. Dewangan et al. [7] va Angseryd et al. [8] WC donasining o‘lchami kamayishi bilan qattiqlik oshishini, yeyilish esa donning o‘lchami va kobalt miqdori bilan ortishini aniqladilar. Cha va boshqalar [9] WC donasining o‘lchamini 4 mkm dan 300 nm gacha kamaytirish qattiqlikni 1200 HV dan 1900 HV gacha oshirganini xabar qilishdi. Bog‘lovchi tarkibidagi HCP/FCC nisbatlarining yuqori bo‘lishi uzilish qovushqoqligini yaxshiladi. Okamoto va boshqalar [10] katta WC donalari (20-30 mkm) egiluvchanlikni kuchaytirishini kuzatgan bo‘lsa, Saito va boshqalar [11] WC donalari hajmining oshishi ham, kobalt tarkibining ko‘payishi ham yeyilish tezligini oshirishini tasdiqladi.

Ushbu topilmalar shuni ko‘rsatadiki, mikrostruktura, bog‘lovchi modda miqdori va WC donasining o‘lchami asbobning ishlashiga sezilarli ta’sir ko‘rsatadi. Ushbu parametrlarni ma’lum muhitlarga moslashtirish chidamlilikni oshirishi va yeyilishni kamaytirishi mumkin.

Qattiq va yumshoq materiallarning mavjudligi tufayli bitta burg‘ilash teshigida ham asbobning ishlashi o‘zgaruvchanligini hisobga olgan holda, WC asboblarining ishdan chiqishini tahlil qilish yeyilish mexanizmlarini aniqlash va dizaynni takomillashtirish uchun muhimdir. Ushbu tadqiqotda tog‘-kon va burg‘ilash maydonlaridan yig‘ilgan burg‘ilash dolotolarining tizimli buzilish tahlili keltirilgan.

2. Tadqiqot metodologiyasi

Burg‘ilash asboblari dolotalarining buzilishini tahlil qilishda tizimli yondashuv uchun xronologik tartibda quyidagi tartib qabul qilindi:

I. Sayt inspeksiyasi

Ekspluatatsiya sharoiti: burg‘ilash chuqurligi, tog‘ jinsi, harorat, bosim, burg‘ilash tezligi haqida ma’lumot to‘plash.

Asbobdan foydalanish tarixi, jumladan, davomiylik, yuklanish sikllari va nosozliklar chastotasini to‘plang.

II. Namuna olish

Ishdan chiqqan va yeyilgan burg‘ilarni daladan olib chiqish.

III. Ko‘zdan kechirish

Muvaffaqiyatsizlikning makroskopik belgilarini aniqlash uchun batafsil vizual tekshiruv o‘tkazing: parchalanish, yorilish, parchalanish yoki haddan tashqari yeyilish.

Yuzani dastlabki baholash uchun optik mikroskopiyadan foydalaning.

IV. Metallografik ekspertiza

Namuna tayyorlashning standart usullariga muvofiq ishdan chiqqan asbob dolotalarining ko‘ndalang kesimlarini tayyorlash.

Mikrostruktura, don chegaralari va yeyilgan/sinish yuzalarini o‘rganish uchun skanerlovchi elektron mikroskopiya (SEM) va optik mikroskopiyadan foydalaning.

V. Materiallar tarkibini tahlil qilish

Material tarkibini tasdiqlash va fazalarni aniqlash uchun energiya dispersion rentgen spektroskopiyasi (EDS), to‘lqin uzunligi dispersion rentgen-fluoressent spektroskopiyasi (WDXRF), rentgen difraksiyasi (XRD) va Raman spektroskopiyasini o‘tkazing.

VI. Qattiqlikka sinash

Asbobning turli sohalarida qattiqlikni o‘lchash (masalan, Vikers, Rokvell).

3. Tahlil va natijalar

1. Namunani ko‘zdan kechirish

1a va 1b-rasmlarda faol kon maydonidan olingan burg‘ilash asbobi keltirilgan bo‘lib, unda asbobning ishdan keyingi holati ko‘rsatilgan. Asbob sakkizburchak shaklidagi kesuvchi tiqinlar bilan ta’minlangan bo‘lib, ular aylanma burg‘ilash jarayonida tog‘ jinslarini samarali kirib borishini ta’minlash uchun uning atrofiga o‘rnatiladi. Dastlabki vizual tekshiruvda WC qistirmalarining chetlari va burchaklarida to‘plangan sezilarli yeyilish va materialning yemirilishi aniqlanadi. Vkladishlar yuzasining morfologiyasi notekis ko‘rinadi, o‘yiqlar va qirralarning yumaloqlanishi ko‘zga tashlanadi, bu esa abraziya va qirilish kabi mexanik yeyilish mexanizmlarining boshlanishidan dalolat beradi.

Ushbu dastlabki baholash shuni ko‘rsatadiki, ustun yeyilish mexanizmlarini tushunish va ekspluatatsion kuchlanishlar ostida qistirmaning ishlashini baholash uchun qo‘shimcha batafsil mikrostrukturaviy va sirt tahlili zarur.

a b

1-rasm. Asbobning yuqori (a) va yon tomondan (b) ko‘rinishi

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1-jadval

Asbobning fizik parametrlari

Buyum	Miqdor	Shakl	O‘lchamlar	Ashyo
Asbob	1	Silindr shaklidagi (1 va 2-rasmlarda ko‘rsatilganidek)	UD- 70mm ID-55mm Uzunligi -80mm	Legirlangan po‘lat
Vstavkalar	8 har bir asbob uchun	Sakkiz burchakli	Kengligi - 6 mm Uzunligi-15mm	Karbid- volfram

1. Material tavsifi / Kompozitsiya tahlili

Burg‘ilash dolotalarining element tarkibi to‘lqin uzunlikli dispersion rentgenofluoressent (WDXRF) spektroskopiyasi yordamida tahlil qilindi. Material tarkibini to‘g‘ri aniqlash muhim ahamiyatga ega, chunki u komponentning fizik-mexanik, issiqlik va funksional xususiyatlariga bevosita ta’sir qiladi. WDXRF - bu rentgen fluoressensiyasi tamoyiliga asoslangan yuqori sezgir va buzmaydigan tahlil usuli bo‘lib, bunda tushayotgan rentgen nurlari namunadagi atomlarni qo‘zg‘atadi va ularning ikkilamchi (fluoressent) rentgen nurlarini chiqarishiga sabab bo‘ladi. Chiqarilgan rentgen nurlari mavjud elementlar uchun xos bo‘lgan energiyaga ega bo‘lib, ayniqsa og‘irroq elementlar uchun aniq sifat va miqdoriy element tahlilini o‘tkazish imkonini beradi.

Tahlildan oldin namunalar sirtning bir xilligi va analitik muvofiqligini ta’minlash uchun standart metallurgiya usullari yordamida tayyorlandi. WDXRF natijalari shuni ko‘rsatdiki, asosiy tarkibiy qismlar volfram (W) va uglerod (C) ning o‘rtacha og‘irlik ulushlari mos ravishda taxminan 92,86% va 7,14% ni tashkil etdi. Ushbu tarkib an’anaviy volfram karbidi (WC) asbobsozlik materiallarining tarkibiga mos keladi, ular o‘zining yuqori qattiqligi, yeyilishga chidamliligi va termik barqarorligi bilan mashhur bo‘lib, bu xususiyatlar yuqori samarali ishlov berish dasturlari uchun juda muhimdir.

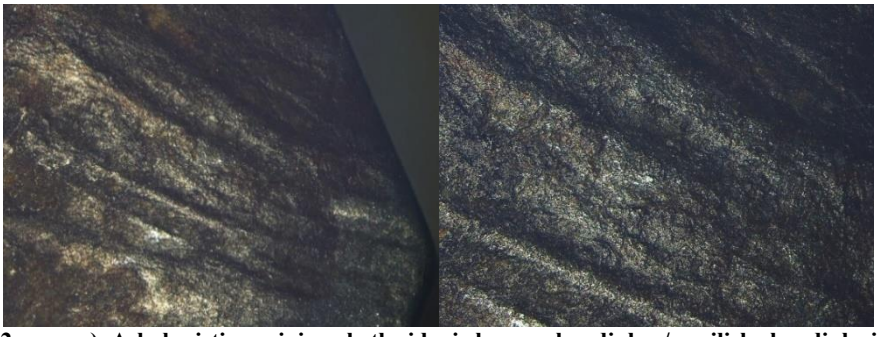
Asbob qistirmalari tutqichdan kesib olinib, mikroskopda tekshirishga tayyorlandi.

2. *Optik mikroskopik tekshiruv:*

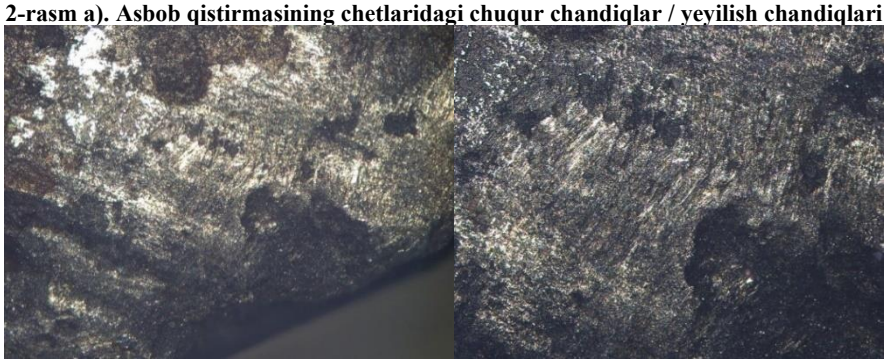
Namunaning chetlarida ham, o‘rta qismida ham 100X va 200X kattalashtirishlarda optik mikroskop yordamida batafsil mikroskopik tadqiqot o‘tkazildi. Ushbu tahlil namunaning turli qismlarida sirtning yeyilish darajasi va xususiyatini baholashga qaratilgan. 2-rasmda tasvirlanganidek, tekshirilgan sakkizta qirra orasida faqat bir yoki ikkitasi sezilarli darajada eskirish belgilarini ko‘rsatganligi aniqlandi. Ushbu o‘ziga xos qirralar sezilarli to‘mtoqlikni ko‘rsatdi, bu esa xizmat ko‘rsatish jarayonida ishqalanish kuchlari yoki abraziv o‘zaro ta’sirlar tufayli yuzaga kelgan mahalliy mexanik yemirilishni ko‘rsatadi.

Sinchiklab qaralganda, yeyilgan qirralarning morfologiyasi sirt bo‘ylab chuqur, noto‘g‘ri o‘yiqlar mavjudligini ko‘rsatdi. Bu ariqchalar yeyilish chandiqlarining o‘ziga xos xususiyatlari bo‘lib, odatda abraziv yoki yelimli yeyilish mexanizmlari yordamida hosil bo‘ladi. Bundan tashqari, ba’zi hududlarda materialning yopishish dalillari kuzatildi, bu esa materialning qarama-qarshi yuzadan yoki ajralgan bo‘laklarning qayta yotqizilishidan o‘tishi mumkinligini ko‘rsatadi. Chuqur yeyilish izlari va yopishgan materialning kombinatsiyasi mexanik va issiqlik ta’sirini o‘z ichiga olgan murakkab yeyilish mexanizmini ko‘rsatadi.

Bundan farqli o‘laroq, namunaning markaziy qismi nisbatan butun ko‘rindi, ikkala kattalashtirishda ham sirtning minimal shikastlanishi kuzatildi. Yeyilishning bunday fazoviy o‘zgarishi namunaning qirralari yemirilishga ko‘proq moyil ekanligini ko‘rsatadi, bu ehtimol kuchlanish konsentratsiyasi yoki periferiyadagi kontakt kuchlarining yuqori ta’siri tufayli yuzaga kelgan.



2-rasm a). Asbob qistirmasining chetlaridagi chuqur chandiqlar / yeyilish chandiqlari

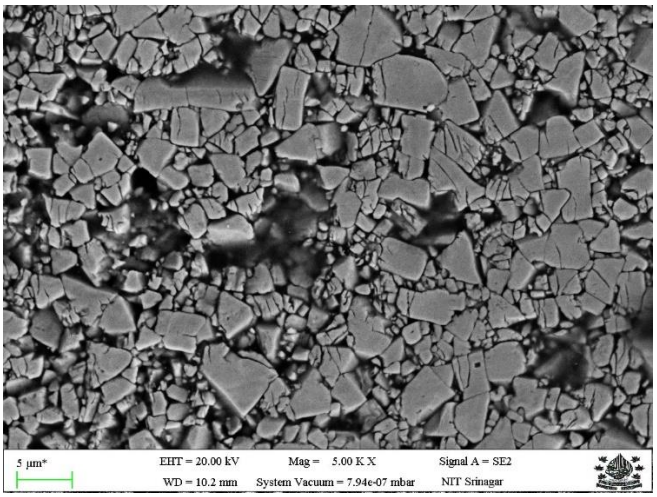


2-rasm b). Asbob qistirmasi yuzasidagi materiallarning yopishishi

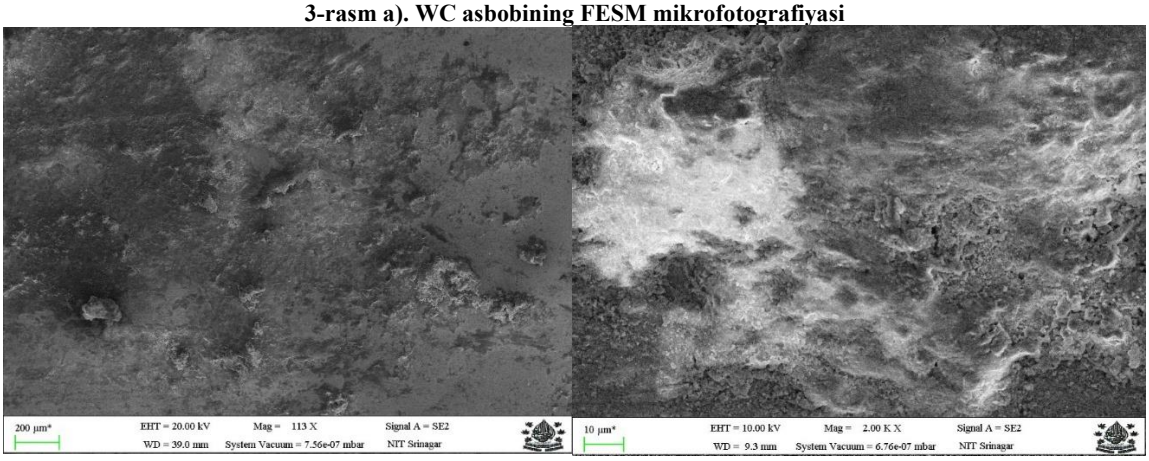
2-rasm v). Asbob qistirmasining o‘tmas qirrasi

1. Elektron mikroskopiya va energetik dispersion spektroskopiya

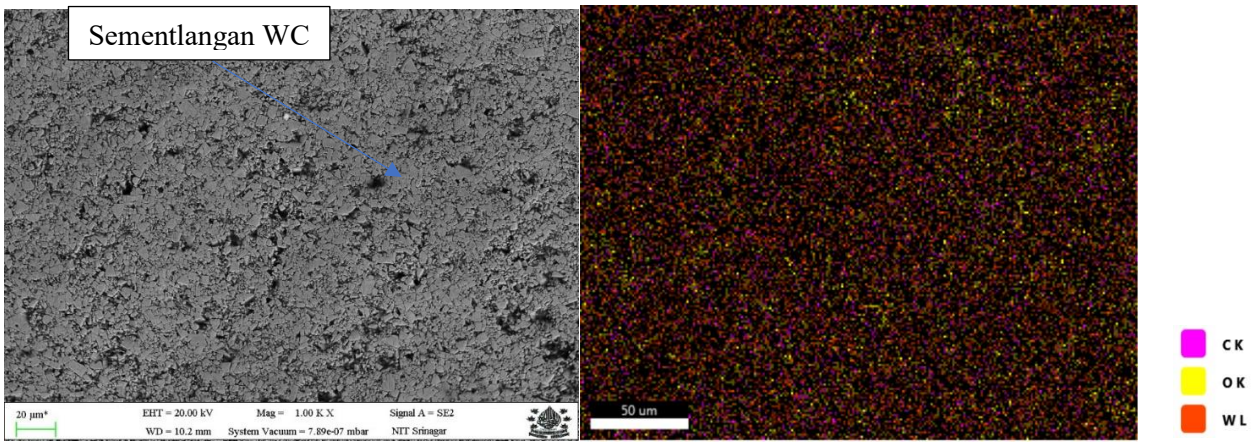
WC asbobi yuzasidagi materialning adgeziyasini yanada chuqurroq o‘rganish uchun Field Emission Scanning Electron Microscope (FESEM) qo‘llanildi. 4-rasmda keltirilgan yuqori aniqlikdagi FESEM tasvirlari bimodal morfologiyani namoyon qiluvchi o‘ziga xos sementlangan volfram karbidi (WC) mikrostrukturasini aniqladi. Bu struktura ancha mayda WC zarrachalaridan iborat matritsaga kiritilgan yirik WC donalarining mavjudligi bilan ajralib turadi, bu esa yaxshi pishirilgan.



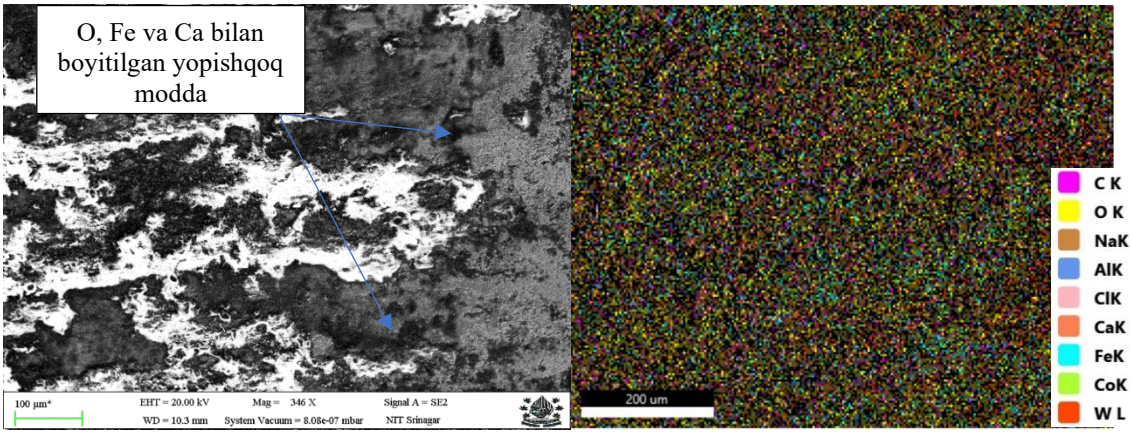
3-rasm a). WC asbobining FESM mikrofotografiyasi



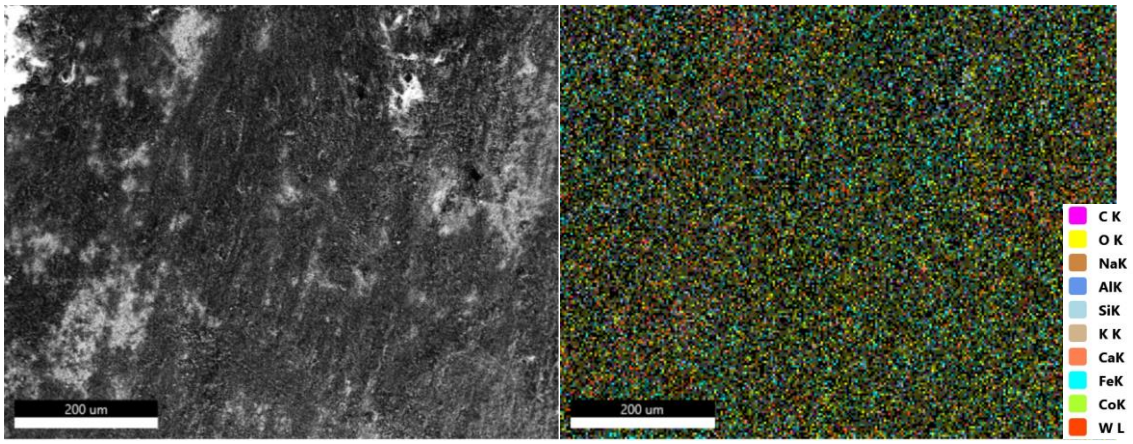
3-rasm b). FESM asbob qistirmasida materialning yopishishini ko‘rsatuvchi mikrofotografiya



4-rasm: a) ERI elementli xaritasi asbob qistirmasi yuzasidagi elementning taqsimlanishini ko‘rsatadi (Toza/Yeyilmagan maydon)



4-rasm: b) ERI elementli xaritasi asbob qistirmasi yuzasi-joylashuvi 1 da yopishgan material bilan elementning taqsimlanishini ko‘rsatadi



4-rasm: c) ERI element xaritasi asbob qistirmasi yuzasida yopishgan material bilan elementning taqsimlanishini ko‘rsatadi

Joylashuv 2

1. Qattiqlikka sinash

Materialning mahalliy plastik deformatsiyaga chidamliligini baholash uchun WC (volfram karbidi) asbob qistirmasining mikroqattiqligini sinash aniq mikroqattiqlikni sinash mashinasi yordamida amalga oshirildi. Sinov 100 kgs (kilogramm-kuch) nazorat qilinadigan yuk ostida o‘tkazildi, bu namuna yuzasi bo‘ylab ishonchli va bir xil chuqurlikni ta’minlaydi.

Vikkersning qattiqlik usuli qo‘llanildi, ya’ni namunaning silliqlangan yuzasiga olmos shaklidagi indentorni (geometriyada piramida shaklida) bosish va hosil bo‘lgan izning diagonallarini o‘lchash. Bu usul, ayniqsa, volfram karbidi kabi qattiq va mo‘rt materiallar uchun mos keladi va hatto mikro miqyosda ham aniq va takrorlanadigan natijalarni beradi.

WC asboblari namunalari uchun olingan Vickers mikroqattiqligining o‘rtacha qiymati taxminan 1350 Hv ni tashkil etdi, bu qattiqlikning yuqori darajasini ko‘rsatadi.

Bunday qattiqlik darajasi sementlangan qattiq qotishmali materiallarga xos bo‘lib, yuqori kuchlanishli ishlov berish sharoitida yuqori yeyilishga chidamlilikni, asbobning uzoq muddat ishlashini va ish unumdorligini ta’minlashda muhim rol o‘ynaydi.

4. Xulosa

Tog‘ jinslarini burg‘ilash ishlarida qo‘llaniladigan WC-Co asbob qistirmalari asosan abraziv yeyilish tufayli ishdan chiqdi, bu mikroskopik tekshiruvlarda kuzatilgan chuqur ariqchalar va yeyilgan qirralar bilan tasdiqlanadi.

Qistirma yuzalarida materiallarning yopishishi aniqlandi, yopishgan materiallar kislorod (O), temir (Fe) va kalsiy (Ca) ga boy bo‘lib, ehtimol burg‘ilangan tog‘ jinslari yoki atrof-muhitning ifloslanishidan kelib chiqqan.

Vizual va optik mikroskopiya shuni ko‘rsatdiki, chetki hududlar eng ko‘p to‘mtoqlashgan va egatchalar hosil bo‘lgan, markaziy hududlar esa nisbatan butun qolgan.

Yelimlangan sohalarning EDS tahlili tashqi elementlar (masalan, Fe, Ca, Si) mavjudligini ko‘rsatdi, bu esa ish paytida materialning burg‘ulash tagligidan asbob yuzasiga o‘tishini tasdiqlaydi.

Buzilish tahlili shuni ko‘rsatadiki, yaxshi o‘ziga xos qattiqlik va qovushqoqlikka qaramay, abraziv kesish va material uzatish kabi xizmat ko‘rsatishdagi yeyilish mexanizmlari ekstremal kon sharoitlarida asbobning ishlash muddatini cheklaydi.

Kelajakda ish unumdorligini oshirishga sirt qoplamalari, to‘g‘ri moylash, WC donasi o‘lchami va Co bog‘lovchisi tarkibini optimallashtirish yoki yuqori kuchlanishli chekka hududlarda yeyilishni kamaytirish uchun moslashtirilgan qo‘shimcha geometriyalar orqali erishish mumkin.

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