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Analysis of the material composition and structural properties of road milling machine teeth

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Abstract: This article analyzes the material composition and structural properties of three different types of teeth used in road milling machines. The aim of the research is to determine the influence of the metallic composition and microstructure of the teeth on their operational characteristics. In the course of the study, samples were examined using metallographic observation, chemical analysis, and hardness measurement methods. Based on the obtained results, it was established that the differences in the internal structure of tooth materials directly affect their wear resistance. An increase in strength and heat resistance was also observed in materials rich in high-carbon and alloying elements. Based on the research findings, practical recommendations were developed for selecting the optimal material for road milling cutter teeth. The scientific novelty of the article includes the determination of the relationship between material composition and structural stability.

Keywords: road milling machine, tooth material, metal composition, microstructural analysis, hardness, wear resistance, materials science

Yo‘l freza mashinalari tishlarining material tarkibi va strukturaviy xususiyatlarini tahlil qilish

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Annotatsiya: Ushbu maqolada yo‘l freza mashinalarida qo‘llaniladigan uch xil turdagi tishlarning material tarkibi va strukturaviy xususiyatlari tahlil qilingan. Tadqiqotning maqsadi - tishlarning metall tarkibi, mikrostrukturasi hamda ularning ekspluatatsion xususiyatlariga ta’sirini aniqlashdan iborat. Ish jarayonida namunalar metallografik kuzatuv, kimyoviy analiz va qattiqlikni o‘lchash usullari yordamida o‘rganildi. Olingan natijalar asosida tish materiallarining ichki struktura farqlari ularning yeyilishga bardoshliligiga bevosita ta’sir ko‘rsatishi aniqlangan. Shuningdek, yuqori uglerodli va qotishma elementlarga boy materiallarda mustahkamlik hamda issiqlikka chidamlilikning ortishi kuzatildi. Tadqiqot natijalari asosida yo‘l frezasi tishlari uchun optimal material tanlash bo‘yicha amaliy tavsiyalar ishlab chiqildi. Maqola ilmiy yangilik sifatida material tarkibi bilan strukturaviy barqarorlik o‘rtasidagi bog‘liqlikni aniqlashni o‘z ichiga oladi.

Kalit so‘zlar: yo‘l freza mashinasi, tish materiali, metall tarkibi, mikrostrukturaviy tahlil, qattiqlik, yeyilishga chidamlilik, materialshunoslik

1. Kirish

Zamonaviy yo‘l qurilish texnologiyalarida freza mashinalarining ahamiyati tobora ortib bormoqda. Ushbu mashinalarning samarali ishlashi ko‘p jihatdan ularning asosiy ishchi elementi - tishlarning mustahkamligi va yeyilishga bardoshligiga bog‘liq[1]. Tish materiali tarkibi va strukturaviy tuzilmasi ularning ekspluatatsion xususiyatlarini belgilovchi eng muhim omillardandir. Shu bois, turli materiallardan tayyorlangan freza tishlarining metallografik tahlili hamda kimyoviy tarkibini o‘rganish amaliy va ilmiy jihatdan dolzarb masala hisoblanadi[11].

Ilgari olib borilgan tadqiqotlarda asosan tishlarning geometrik shakli va kesish burchaklari o‘rganilgan bo‘lsa, ushbu ishda ularning material tarkibi va ichki struktura xususiyatlariga e’tibor qaratildi[5]. Maqolaning asosiy maqsadi - uch xil turdagi yo‘l frezasi tishlari namunalarining kimyoviy tarkibi va mikrostrukturasi o‘rtasidagi bog‘liqlikni aniqlash, ularning yeyilishga chidamliligiga ta’sirini baholashdir.

2. Tadqiqot metodologiyasi

Tadqiqot ishlari yo‘l freza mashinalarida qo‘llaniladigan uch xil turdagi tish namunalarida olib borildi. Namunalar material tarkibi va ishlab chiqarish texnologiyasiga ko‘ra farqlanadi. Barcha namunalar tarkibida asosiy element temir

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(Fe) bo‘lib, bu po‘lat asosli tish materiallari uchun xos ko‘rsatkich hisoblanadi[6].

Tadqiqotda tishlarning kimyoviy tarkibini aniqlash uchun spektrometrik analiz usuli, strukturaviy o‘ziga xosliklarini o‘rganish uchun esa metallografik mikroskop yordamida mikrotuzilma tahlili amalga oshirildi[2,3]. Har bir namunada donalar o‘lchami, fazalar taqsimoti va qotishma komponentlarining joylashuvi o‘rganildi.

Bundan tashqari, Rockwell qattiqlik o‘lchov usuli orqali tish yuzalarining mexanik chidamliligi baholandi[8]. Har bir sinov uch marta takrorlanib, o‘rtacha qiymatlar aniqlanib, statistik ishonchlilik darajasi tekshirildi. Olingan natijalar asosida turli materiallardan tayyorlangan tishlarning strukturaviy barqarorligi, qattiqligi va yeyilishga bardoshlilik darajalari solishtirildi.

3. Tahlil va natijalar

Tadqiqot davomida uch xil ishlab chiqaruvchiga tegishli yo‘l frezasi tishlari korpuslari kimyoviy tarkibi tahlil qilindi. Olingan natijalar shuni ko‘rsatdiki, barcha namunalar tarkibida asosiy element sifatida temir (Fe) mavjud bo‘lib, ularning miqdori 97,3–97,9 % oralig‘ida o‘zgaradi. Bu esa po‘lat asosli tish materiallari uchun xos ko‘rsatkich hisoblanadi.

O‘zbekistonda ishlab chiqarilgan 35G po‘lati namunasi tarkibida marganets (1,067 %) va uglerod (0,371 %) nisbatan yuqori miqdorda bo‘lib, bu uning zarbaga bardoshligi va plastiklik xususiyatlarini yaxshilaydi[4]. Rossiyada ishlab chiqarilgan 35G2RPS po‘latida marganets (1,253 %) va xrom (0,201 %) miqdori biroz yuqori, bu esa metallning yeyilishga chidamliligini oshiradi. Eng yuqori legirlangan material esa Germaniyada ishlab chiqarilgan 35XM po‘lati bo‘lib, uning tarkibida xrom (1,012 %) va molibden (0,187 %) mavjudligi kuzatildi. Ushbu elementlar metallning strukturaviy barqarorligini ta’minlab, qattiqlik va issiqlikka chidamlilikni sezilarli darajada oshiradi[7].

Tahlil natijalariga ko‘ra, 35XM po‘lati tarkibida legiruvchi elementlar nisbatan ko‘p bo‘lgani sababli, u freza tishlari uchun eng yuqori ishga chidamli material sifatida tavsiya etiladi. Shu bilan birga, 35G va 35G2RPS po‘latlari iqtisodiy jihatdan tejamkor va texnologik ishlov berishga yaroqli variantlar sifatida amaliy qo‘llanishda o‘z o‘rniga ega[10].

Metallografik tahlil natijalari

Tadqiqot davomida yo‘l freza mashinasi tishlarining materiallari — 35G, 35G2RPS va 35XM po‘latlarining metallografik strukturasi 200× kattalashtirishda o‘rganildi[2]. Tahlil natijalari har bir materialda ferrit, perlit va sementit fazalarining miqdori hamda donalarning o‘lchamiga ko‘ra sezilarli farqlar mavjudligini ko‘rsatdi. Ushbu farqlar po‘latlarning mexanik xususiyatlariga, xususan yeyilishga bardoshlilik, qattiqlik va plastiklik darajalariga bevosita ta’sir etadi[4].

1-namuna – 35G po‘lati

35G po‘lati namunasi strukturasi ferrit–perlitli tuzilishga ega bo‘lib, perlit donalari aniq ko‘rinishda, ferrit esa ular orasida notekis taqsimlangan. Donalar nisbatan yirik (o‘rtacha 25–35 mkm) bo‘lib, bu metallning o‘rtacha qattiqlikka ega, biroq yaxshi plastiklik xususiyatlarini saqlab qolishini ta’minlaydi[12].

Struktura bo‘yicha kuzatishlar shuni ko‘rsatadiki, bu po‘latdagi uglerod (≈0,37%) va marganets (≈1,0%) miqdori optimal darajada bo‘lib, zarbaga bardoshlilikni oshiradi. Shu bilan birga, donalarning yirikligi materialning issiqlikka chidamliligini biroz pasaytiradi. Shuning uchun 35G po‘lati tishlari o‘rta yuklama sharoitida ishlaydigan freza mashinalari uchun mos hisoblanadi[9]

1-jadval

Uch xil turdagi yo‘l frezasi tishlarining kimyoviy tarkibi

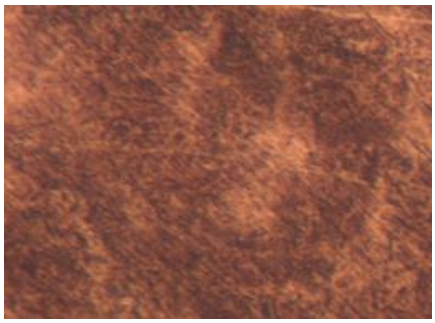
35G		35G2RPS		35XM	
Metall nomi	Ulushi (%)	Metall nomi	Ulushi(%)	Metall nomi	Ulushi (%)
Fe	97,917	Fe	97,848	Fe	97,340
Mn	1,067	Mn	1,253	Cr	1,012
C	0,371	C	0,377	Mn	0,677
Si	0,276	Cr	0,201	C	0,396
Cr	0,119	Si	0,188	Si	0,247
Ni	0,063	Ti	0,035	Mo	0,187
Cu	0,060	P	0,025	Ni	0,029
Ti	0,036	Ni	0,018	Cu	0,027
Al	0,029	Al	0,016	P	0,023
P	0,025	Cu	0,010	Al	0,022
Mo	0,012	Mo	0,0071	Co	0,0092
S	0,011	Co	0,0067	V	0,0080
Co	0,0078	V	0,0048	Ti	0,0073
V	0,0042	As	0,0047	As	0,0046
As	0,0033	S	0,0035	S	0,0025
Nb	0,0021	Nb	0,0020	Nb	0,0022
		W	0,00001	W	0,00001

1-rasm. 35G po‘latining struktura tuzilishi

2-namuna – 35G2RPS po‘lati

35G2RPS po‘lati namunasi nozik ferrit-perlit strukturasi bilan ajralib turadi. Donalar 35G po‘latiga nisbatan maydaroq (15–20 mkm), perlit lamellalari zichroq joylashgan. Strukturada xrom (≈0,2%) va marganets (≈1,25%) elementlarining mavjudligi tufayli diffuziya jarayonlari cheklangan va bu metallning qattiqlik hamda yeyilishga bardoshliligini oshirgan.

Mikrostrukturada yengil dispersli sementit zarralari aniqlanib, ular kesuvchi qirralarda mustahkamlikni oshiradi. Natijada 35G2RPS po‘lati barqaror struktura va yuqori ishlov berish qobiliyatiga ega bo‘lib, uzoq muddatli ekspluatatsiya uchun maqbul material sifatida baholandi[12].

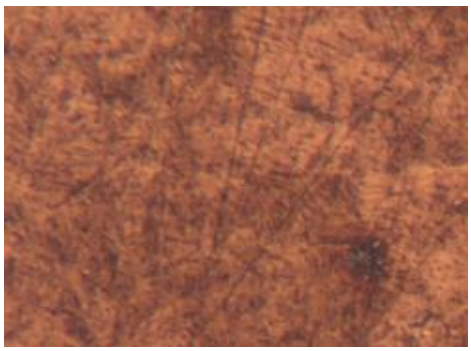


2-rasm. 35G2RPS po‘latining struktura tuzilishi

3-namuna – 35XM po‘lati

35XM po‘lati namunasi murakkab legirlangan ferrit-perlit-karbidli struktura bilan tavsiflanadi. 200× kattalashtirishda xrom karbidli fazalar va molibden asosidagi nozik dispersli inkluziyalar kuzatildi. Bu esa strukturaning yuqori haroratda ham barqarorligini ta’minlaydi. Donalar o‘rtacha 10–15 mkm bo‘lib, juda zich joylashgan va perlit lamellalari orasidagi masofa minimal darajada.

Bunday tuzilma materialning qattiqligini oshiradi (≈40–45 HRC), shuningdek, issiqlikka va termik charchoqqa chidamlilikni kuchaytiradi[6,7]. Shu sababli 35XM po‘lati yo‘l freza mashinasining eng yuqori yuklama ostida ishlaydigan tishlari uchun eng samarali material sifatida tavsiya etiladi.



3-rasm. 35XM po‘latining struktura tuzilishi

Solishtirma tahlil

35G, 35G2RPS va 35XM po‘latlarining namunalari mikrostrukturaviy jihatdan solishtirilganda quyidagi qonuniyat aniqlanadi:

Legirlangan elementlar (xrom, molibden, marganets) miqdori ortgan sari perlit donalari zichligi ham ortadi;

Donalarning yiriklik darajasi kamaygani sari qattiqlik va yeyilishga bardoshlilik ortadi;

Eng murakkab tuzilmaga ega bo‘lgan 35XM po‘lati eng yuqori mexanik barqarorlikni namoyon etadi.

Shunday qilib, metallografik tahlil natijalari 35XM po‘latining strukturaviy jihatdan eng barqaror va yuqori yuklamalarga chidamli material ekanini ko‘rsatdi. Shu bilan birga, 35G2RPS po‘lati ishlab chiqarish qulayligi va texnologik soddaligi sababli o‘rta sinf yo‘l freza mashinalarida qo‘llash uchun maqbul hisoblanadi, 35G po‘lati esa iqtisodiy tejamkorlik jihatidan ustunlikka ega, biroq yuqori termik yuklamalar uchun tavsiya etilmaydi[6].

4. Xulosa

O‘tkazilgan tadqiqotlar yo‘l freza mashinalarida qo‘llaniladigan tish materiallarining tarkibi va mikrostrukturasi ularning ekspluatatsion xususiyatlariga bevosita ta’sir etishini ko‘rsatdi. Uch turdagi po‘lat namunalar — 35G, 35G2RPS va 35XM metallografik hamda kimyoviy tahlil orqali solishtirildi.

Natijalar shuni ko‘rsatadiki, 35G po‘lati o‘zining soddaligi va arzonligi bilan ajralib turadi, biroq uning ferrit–perlit strukturasi yirik donali bo‘lgani sababli yuqori haroratli ish sharoitlarida termik barqarorlik pastroq. 35G2RPS po‘lati legirlangan elementlarga boyligi tufayli mayda donali, qattiqligi yuqori va yeyilishga chidamli material sifatida o‘rtacha yuklama ostida samarali ishlaydi. Eng yuqori texnik ko‘rsatkichlar 35XM po‘latida kuzatildi — unda karbid fazalarning mavjudligi tufayli struktura mustahkam, qattiqlik yuqori (40–45 HRC), termik charchoqqa bardoshlilik esa ancha yaxshilangan.

Tadqiqot natijalariga ko‘ra, 35XM po‘lati yo‘l freza mashinalarining intensiv yuklama ostida ishlaydigan tishlari uchun eng optimal material hisoblanadi. Shu bilan birga, 35G2RPS po‘lati o‘rta sinf mashinalar uchun iqtisodiy va texnologik jihatdan maqsadga muvofiq, 35G po‘lati esa arzonligi sababli cheklangan sharoitlarda qo‘llanishi mumkin.

Ushbu ish ilmiy yangilik sifatida tish materiali tarkibidagi legirlangan elementlarning miqdori bilan mikrostrukturaviy barqarorlik o‘rtasidagi bog‘liqlikni aniqladi hamda freza tishlarining mustahkamlik zaxirasini baholash uchun amaliy asos yaratdi.

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