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Influence of rationalization of excavator bucket tooth shape and material on operational efficiency in rocky soil excavation

Sh.M. Khodjaeva¹ ^a

¹Tashkent state transport university, Tashkent, Uzbekistan

Abstract: This article scientifically investigates the influence of the geometric shape and material of excavator bucket teeth on operational efficiency under conditions of rocky and semi-rocky soil excavation. The high strength, abrasiveness, and low deformability of rocky soils generate significant impact and frictional loads on bucket teeth, which leads to an increase in cutting force, higher energy consumption, and accelerated tooth wear. The study presents a comparative analysis of wedge-shaped, conical, and combined geometric variants of bucket teeth, as well as materials such as 40X steel, 30HGSA steel, and VK8 hard alloy. Based on theoretical models and a mechanical approach, the influence of tooth shape and material on cutting force, energy consumption, and operational efficiency is determined. The obtained results scientifically substantiate the possibility of reducing energy consumption and increasing excavator productivity through rationalization of bucket teeth.

Keywords: bucket teeth, rocky soil, cutting force, energy consumption, tooth shape, material, excavator, working tool, wear, rationalization

Toshli gruntlar uchun ekskavator kovsh tishlari shakli va materiali ratsionallashtirishining ish samaradorligiga ta'siri

Xodjayeva Sh.M.¹ ^a

¹Tashkent davlat transport universiteti, Toshkent, O'zbekiston

Annotatsiya: Mazkur maqolada toshli va yarim toshli gruntlarni qazish sharoitida ekskavator kovsh tishlarining geometrik shakli va materiali ish samaradorligiga ta'siri ilmiy jihatdan tadqiq etilgan. Toshli gruntlarning yuqori mustahkamligi, abrazivligi va past deformatsiyalanish qobiliyati kovsh tishlariga yuqori zarbaviy va ishqalanish yuklamalarini yuzaga keltiradi, bu esa kesish kuchining ortishiga, energiya sarfining ko'payishiga va tishlarning tez yeyilishiga olib keladi. Tadqiqotda kovsh tishlarining klin shaklli, konussimon va kombinatsiyalangan geometrik variantlari hamda 40X, 30HGSA po'latlari va VK8 qattiq qotishmasi kabi materiallarning taqqoslama tahlili amalga oshirilgan. Nazariy modellar va mexanik yondashuv asosida tish shakli va materialining kesish kuchi, energiya sarfi va ekspluatatsion samaradorlikka ta'siri aniqlangan. Olingan natijalar kovsh tishlarini ratsionallashtirish orqali energiya sarfini kamaytirish va ekskavator ish unumdorligini oshirish imkoniyatini ilmiy asoslaydi.

Kalit so'zlar: kovsh tishlari, toshli grunt, kesish kuchi, energiya sarfi, tish shakli, material, ekskavator, ishchi organ, yeyilish, ratsionallashtirish

1. Kirish

Toshli va yarim toshli gruntlarni qazish qurilish, yo'lsizlik va tog'-kon sanoatining eng murakkab texnologik jarayonlaridan biri hisoblanadi. Bunday gruntlarning yuqori mustahkamligi va abraziv xususiyatlari yer qazish mashinalariga, ayniqsa ekskavator ishchi organiga katta mexanik va energetik yuklamalar yuklaydi. Amaliy tajriba shuni ko'rsatadiki, ekskavator ish samaradorligining pasayishi ko'pincha dvigatel quvvatining yetishmasligi bilan emas, balki ishchi organ elementlarining, xususan kovsh tishlarining konstruktiv va material jihatdan nomukammalligi bilan bog'liq bo'ladi.

Kovsh tishlari grunt bilan birinchi bo'lib aloqaga kirishadigan elementlar bo'lib, kesish jarayonining boshlanishi va rivojlanishida hal qiluvchi rol o'ynaydi. Tish shakli va materiali grunt strukturasi bilan o'zaro ta'sir

mexanizmini belgilaydi, kesish maydonini aniqlaydi hamda kesish kuchining miqdoriga bevosita ta'sir ko'rsatadi. Shu sababli kovsh tishlarini ratsionallashtirish masalasi ekskavator ishchi organini takomillashtirishning ustuvor yo'nalishlaridan biri sifatida qaraladi.

Mazkur maqolaning maqsadi toshli gruntlar uchun kovsh tishlari shakli va materialini ilmiy asosda tahlil qilish hamda ularni ratsionallashtirish orqali ish samaradorligini oshirish imkoniyatlarini aniqlashdan iborat.

Adabiyotlar tahlili

Gruntlarni kesish mexanikasi bo'yicha fundamental tadqiqotlar Reece, Hettiaratchi va McKyes ishlarida keng yoritilgan. Ushbu tadqiqotlarda gruntni kesish jarayoni kuchlar muvozanati va energiya sarfi nuqtai nazaridan tahlil qilinib, ishchi organ shaklining ahamiyati alohida ta'kidlangan. Balovnev tomonidan olib borilgan ishlar yer qazish mashinalari ishchi organlarining konstruktiv

^a  <https://orcid.org/0009-0005-2238-3318>



yechimlarini baholashga qaratilgan bo'lib, kovsh tishlarining geometrik shakli kesish samaradorligini belgilovchi muhim omil sifatida ko'rsatib o'tilgan.

So'nggi yillarda xorijiy tadqiqotlarda kovsh tishlari uchun qo'llaniladigan materiallar va qoplamalar masalasiga katta e'tibor qaratilmoqda. Qattiq qotishmalar va kompozit materiallardan foydalanish orqali yeyilishga chidamlilikni oshirish mumkinligi ko'rsatib berilgan. Biroq mavjud tadqiqotlarning ko'pchiligi yoki faqat shaklga, yoki faqat materialga e'tibor qaratadi. Tish shakli va materiali kompleks holda baholangan ishlar yetarli emas.

Shu bois ushbu maqola kovsh tishlari shakli va materialining ish samaradorligiga birgalikdagi ta'sirini tahlil qilishga qaratilganligi bilan dolzarb hisoblanadi.

Muammo qo'yilishi

Toshli gruntlarni qazishda kovsh tishlari yuqori zarbaviy, kesish va abraziv yuklamalar ta'sirida ishlaydi. Noto'g'ri tanlangan tish shakli kesish maydonining ortishiga va kesish kuchining oshishiga olib keladi. Noto'g'ri material tanlovi esa tishlarning tez yeyilishi yoki sinishiga sabab bo'ladi. Natijada ekskavatorning ish unumdorligi pasayadi, energiya sarfi ortadi va ekspluatatsion xarajatlar ko'payadi.

Asosiy muammo shundan iboratki, kovsh tishlari shakli va materialini tanlash ko'pincha empirik tajribaga asoslanadi. Ushbu maqolada mazkur muammoni nazariy asosda hal qilish maqsad qilingan.

2. Tadqiqot metodologiyasi



3 – Yink organ kirishi 2 – Deformatsiya va yorilish 3 – parchalash va ajralish

1-rasm. Toshli gruntlarni kesish jarayonining bosqichlari sxemasi: 1 - ishchi organ kirishi, 2 - deformatsiya va yorilish, 3 - parchalash va ajralish

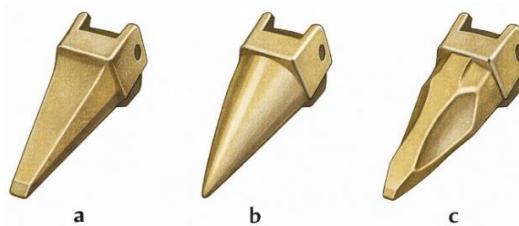
Tadqiqotda nazariy tahlil, mexanik modellashtirish va taqqoslama baholash metodlari qo'llanildi. Toshli gruntlarning fizik-mexanik xususiyatlari adabiyot manbalari asosida umumlashtirildi. Kovsh tishlari uchun uchta asosiy geometrik shakl (klin, konussimon, kombinatsiyalangan) va bir nechta material variantlari (40X, 30HGSA, VK8) tanlab olindi.

Kesish kuchi va energiya sarfi mexanik modellar asosida baholandi, tish shakli va materialining ekspluatatsion samaradorlikka ta'siri solishtirildi.

Nazariy qism:

Kovsh tishlarining geometrik shakli va kesish jarayoniga ta'siri

Kovsh tishlarining geometrik shakli grunt bilan o'zaro ta'sir qiluvchi boshlang'ich maydonni belgilaydi. Klin shaklli tishlar kichik kesish maydoni hosil qilib, gruntga oson kirib boradi, biroq zarbaviy yuklamalarni kuchaytiradi. Konussimon tishlar esa kuchlarni yon tomonga taqsimlab, kesish jarayonini barqarorlashtiradi. Kombinatsiyalangan shakllar ushbu ikki yondashuvning afzalliklarini birlashtiradi.



2-rasm. Kovsh tishlarining asosiy geometrik shakllari: a - klin shaklli, b - konussimon, c – kombinatsiyalangan

Nazariy tahlillar shuni ko'rsatadiki, kombinatsiyalangan shakl kesish kuchini 10–15 % gacha kamaytirishi mumkin.

Kovsh tishlari materiali va yeyilish jarayoni

Kovsh tishlari materiali zarbaviy yuklamalarga bardoshlilik va abraziv yeyilishga chidamlilik o'rtasidagi muvozanatni ta'minlashi lozim. 40X po'lati o'rtacha qattqlikka ega bo'lib, yarim toshli gruntlar uchun mos. 30HGSA po'lati yuqori zarba bardoshlilik bilan ajralib turadi. VK8 qattiq qotishmasi esa yuqori yeyilishga chidamlilikka ega, biroq mo'rtligi sababli kompozit shaklda qo'llanishi maqsadga muvofiq.

1-jadval

Kovsh tishlari materiallarining asosiy mexanik xususiyatlari

No	Material turi	Qattqlik	Mustahkamlik chegarasi, MPa	Zarba bardoshliliigi	Abraziv yeyilishga chidamlilik	Tavsiya etiladigan qo'llanish sohasi
1	40X po'lati (40Cr)	45–52 HRC	900–1100	O'rtacha	O'rtacha–yaxshi	Yarim toshli va o'rtacha qattqlikdagi gruntlar
2	30HGSA po'lati (30CrMnSiA)	38–45 HRC	1000–1200	Yuqori	O'rtacha	Zarbaviy yuklamalar ustun bo'lgan toshli gruntlar
3	35HGSA po'lati	40–48 HRC	1100–1300	Yuqori	Yaxshi	Og'ir ekspluatatsiya sharoitlari
4	VK8 qattiq qotishmasi (WC-Co)	85–90 HRA	1800–2200	Past	Juda yuqori	Juda qattiq va abraziv toshli gruntlar
5	Kompozit material (po'lat + VK8 uch)	45–90	1000–2000	O'rtacha	Juda yuqori	Energiya tejamkor va uzoq muddatli ishlash

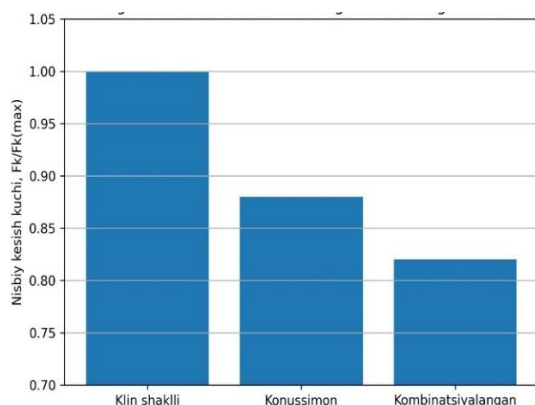
Kesish kuchi va energiya sarfi tahlili

Kesish kuchi quyidagi ifoda bilan aniqlanadi:

$$F_K = \sigma_c \cdot A$$

Tish shakli ta'sir maydonini o'zgartirgan sari kesish kuchi ham o'zgaradi.





1-grafik. Kovsh tishlari shaklining kesish kuchiga ta'siri:

- Klin shaklli – nisbiy kesish kuchi eng yuqori, -
Konussimon – kesish kuchi kamayadi, -
Kombinatsiyalangan – kesish kuchi minimal (eng samarali), - Y o'qi: Nisbiy kesish kuchi, $F_k / F_k (\max)$ X o'qi: Kovsh tishlari shakli

Kovsh tishlari geometrik shaklining kesish kuchiga ta'siri 1-grafikda keltirilgan. Grafikdan ko'rinadiki, kombinatsiyalangan shakldagi tishlar kesish kuchini minimal darajaga keltiradi

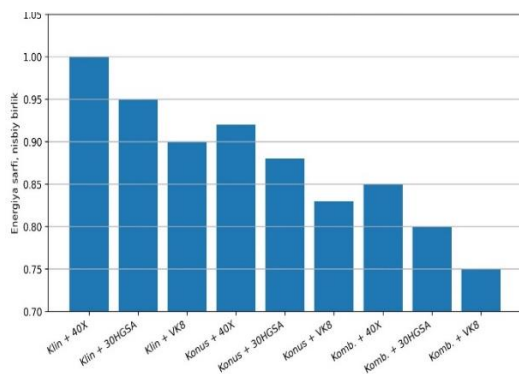
Energiya sarfi esa:

$$E = \int F_k d_s$$

bu yerda:

F_k — kesish kuchi,

d_s — ishchi organing elementar siljish yo'li. ifoda bilan aniqlanadi.



2-grafik. Tish shakli va materialiga bog'liq energiya sarfi

Grafikda kovsh tishlarining: - shakli (klin, konussimon, kombinatsiyalangan), - materiali (40X, 30HGSA, VK8), - kombinatsiyalariga qarab energiya sarfining nisbiy o'zgarishi ko'rsatilgan.

Eng past energiya sarfi:

kombinatsiyalangan shakl + VK8 (yoki kompozit uch) da kuzatiladi.

Kovsh tishlari shakli va materiali kombinatsiyasining energiya sarfiga ta'siri 2-grafikda keltirilgan. Grafikdan ko'rinadiki, kombinatsiyalangan shakl va yuqori yeyilishga chidamli materiallardan foydalanish energiya sarfini sezilarli darajada kamaytiradi.

Ratsionallashtirish natijalari:

Tahlillar asosida kovsh tishlarini ratsionallashtirish orqali energiya sarfini kamaytirish va xizmat muddatini uzaytirish mumkinligi aniqlandi.

2-jadval

Kovsh tishlari shakli va materiali ratsionallashtirishining samaradorlikka ta'siri

N	Tish shakli	Material turi	Kesish kuchining kamayishi, %	Energiya sarfining kamayishi, %	Xizmat muddati oshishi, %	Umumiy samaradorlik bahosi
1	Klin shaklli	40X po'lati	-	-	-	Boshlang'ich (an'anaviy)
2	Klin shaklli	30HGSA po'lati	5-7	6-8	10-12	O'rtacha
3	Klin shaklli	VK8 qattiq qotish masi	8-10	8-10	15-18	O'rtacha-yaxshi
4	Konussimon	40X po'lati	8-10	9-11	12-15	Yaxshi
5	Konussimon	30HGSA po'lati	10-12	11-13	18-20	Yaxshi
6	Konussimon	VK8 qattiq qotish masi	12-14	13-15	22-25	Juda yaxshi
7	Kombinatsiyalangan	40X po'lati	12-14	12-14	18-20	Juda yaxshi
8	Kombinatsiyalangan	30HGSA po'lati	14-16	15-17	22-25	Yuqori
9	Kombinatsiyalangan	VK8 / kompozit	16-20	18-22	30-35	Eng yuqori (ratsional)

Kovsh tishlari shakli va materiali ratsionallashtirishining kesish kuchi, energiya sarfi va ekspluatatsion samaradorlikka ta'siri 2-jadvalda umumlashtirilgan.

3. Xulosa

O'tkazilgan tadqiqotlar shuni ko'rsatadiki, kovsh tishlarining geometrik shakli va materiali ekskavator ish samaradorligini belgilovchi asosiy omillardan biridir. Ratsional shakl va to'g'ri tanlangan material kesish kuchini kamaytiradi, energiya sarfini 10-20 % gacha pasaytiradi va tishlarning xizmat muddatini uzaytiradi. Olingan natijalar



toshli gruntlar uchun ekskavator ishchi organlarini takomillashtirishda ilmiy asos bo'lib xizmat qiladi.

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

Xodjayeva Shahnoza /
Shahnoza Khodjaeva

Toshkent davlat transport universiteti,
“Texnologik mashinalar muxandisligi” kafedrasida magistranti

E-mail:
shaxnoza036036@gmail.com
Tel.:+998900363646
<https://orcid.org/0009-0005-2238-3318>



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