ISNN 3030-3907

2026
MAY
ISSUE - 5
VOLUME - 6

DEVELOPMENT OF SCIENCE

scientific journal



Development of science

Ilmiy jurnal

MAY 2026
Issue - 5, VOLUME – 6

ISSN 3030 -3907

Ilmiy jurnal OAK rayosatining 2024 yil 27 sentabrdagi 361-son qaroriga asosan 02.00.00 kimyo fanlari hamda 2025 yil 12 fevral 367- son qaroriga asosan 05.00.00 texnika fanlari bo‘yicha falsafa doktori (PhD) va fan doktori (DSc) ilmiy darajasiga talabgorlarning dissertatsiya ishlari yuzasidan dissertatsiyalari asosiy ilmiy natijalarini chop etish tavsiya etilgan milliy ilmiy nashrlar ro‘yxatiga kiritilgan.

BOSH MUHARRIR:
Temirov Alisher Hoshim o‘g‘li – texnika fanlari falsafa doktori (PhD),Dotsent.
TAHRIRIYAT KENGASH RAISI:
Fozilov Sadriddin Fayzullayevich – texnika fanlari doktori, professor
TAHRIRIYAT KENGASH A’ZOLARI

TEXNIKA FANLARI/ TECHNICAL SCIENCES/ ТЕХНИЧЕСКИЕ НАУКИ

Bozorov G‘ayrat Rashidovich
Buxoro Davlat Texnika Universiteti, professor
Abdurahmonov Olim Rustamovich
Buxoro Davlat Texnika Universiteti, professor
Adizov Bobur Zamirovich
O‘zbekiston Respublikasi Fanlar akademiyasi Umumiy va noorganik kimyo instituti, professor
Hayitov Ruslan Rustamjonovich
Buxoro Davlat Texnika Universiteti, professor
Jumayev Qayum Karimovich
Buxoro Davlat Texnika Universiteti, professor.
Berdiyev Dorob Murodovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor
Maxmudov Rafiq Amonovich
Buxoro Davlat Texnika Universiteti, professor.
Tilloyev Lochin Ismatilloyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Raxmonov Qahramon Sanakulovich
Buxoro Davlat Texnika Universiteti, dotsent.
Barakayev Nusratullo Rajabovich
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti, professor.
Jo‘rayev Xayrullo Fayziyevich
Buxoro Davlat Texnika Universiteti, professor.
Panoyev Erali Rajabboyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Ataullayev Sherzod Nabiullyevich
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Malik Negmurodovich
Buxoro Davlat Texnika Universiteti, dotsent.
Axmedova Ozoda Bahronovna
Islom Karimov nomidagi Toshkent Davlat Texnika Universiteti.
Safarov Bahri Jumayevich
Buxoro Davlat Texnika Universiteti, dotsent.
Xaydarov Axtam Amonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Safarov Jasur Alijon o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.

KIMYO FANLARI/ CHEMICAL SCIENCES/ ХИМИЧЕСКИЕ НАУКИ

Axmedov Voxid Nizomovich
Buxoro Davlat Texnika Universiteti, professor
Umarov Baqo Bafoyevich
Buxoro Davlat Universiteti, professor
Kodirov Abduaxad Abduraximovich
Qarshi davlat Universiteti, professor
Qurbonov Mingniqul Jumagulovich
Qarshi davlat Universiteti, dotsent
Turemuratov Sharibay Naurizbaevich
O‘zbekiston Respublikasi Fanlar akademiyasi Qoraqalpog‘iston bo‘limi Bosh ilmiy kotibi, professor
Tursunov Kaxor Shonazarovich
Qarshi davlat Universiteti, professor
Do‘stov Hamro
Buxoro Davlat Texnika Universiteti, professor
Panoyev Nodir Shavkatovich
Buxoro Davlat Texnika Universiteti, dotsent.
Olimov Bobur Bahodir o‘g‘li
Buxoro Davlat Texnika Universiteti, dotsent.
Kasimov Sherzod Abduazimovich
Termiz Davlat Universiteti, professor.
Aliqulov Rustam Valiyevich
Termiz Davlat Universiteti, professor
Tropov Xamza Tursunovich
Samarqand Davlat Universiteti, professor

IQTISODIYOT FANLARI/ ECONOMICS/ ЭКОНОМИЧЕСКИЕ НАУКИ

Nizamov Aslitdin Badreddinovich
Buxoro Davlat Texnika Universiteti, professor.
Boboyev Akmal Choriyevich
Buxoro Davlat Texnika Universiteti, professor.
Ergashxojayeva Shaxnoza Djasurovna
Toshkent davlat iqtisodiyot universiteti, professor
Saidaxmedova Nodira Ilxomovna
Toshkent davlat iqtisodiyot universiteti, professor
Muxsinov Bekzod Toxirovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shakarov Qulmat Ashirovich
Renessans ta'lim universiteti,dotsent.
Jumaeva Zulfiya Qayumovna
Buxoro Davlat Texnika Universiteti, dotsent.
Norova Salomat Yusupovna
Buxoro Davlat Texnika Universiteti, dotsent.
Avezova Shaxnoza Maxmudjonovna
Buxoro Davlat Texnika Universiteti, dotsent.
Jalilov Jamshid G‘anijonovich
Toshkent davlat iqtisodiyot universiteti, dotsent
Xasanova Gulruh Djumanazarovna
Buxoro Davlat Texnika Universiteti, dotsent.

PEDAGOGIKA FANLARI/ PEDAGOGICAL SCIENCES / ПЕДАГОГИЧЕСКИЕ НАУКИ

Siddiqova Sadoqat G‘afforovna
Buxoro Davlat Texnika Universiteti, dotsent.
Zoyirov Erkin Xalilovich
Buxoro Davlat Texnika Universiteti, DSc, professor
Gaffarov Feruz Hasanovich
Puchon Universiteti, *professor*
Ruziyev Davron Yuldashevich
Buxoro Davlat Universiteti, professor
Muradova Firuza Rashidovna
Buxoro Davlat Texnika Universiteti, professor.
Yunusova Gulandon Samiyevna
Buxoro Davlat Texnika Universiteti, professor.
To‘xtayeva Zebo Sharifovna
Buxoro Davlat Texnika Universiteti, professor.
Navro‘zova Gulchixra Nigmatovna
Buxoro Davlat Texnika Universiteti, dotsent.
Uzoqova Laylo Polvonovna
Buxoro muhandislik – texnologiya instituti, dotsent.
To‘raqulova Marjona Qiyom qizi
Buxoro Davlat Texnika Universiteti, dotsent.
Muradova Zarina Rashidovna
Buxoro Davlat Texnika Universiteti, dotsent.
Murodov Sanjar Aslonovich
Buxoro Davlat Texnika Universiteti, dotsent.
Shodiyev Jahongir Jo‘raqulovich
Buxoro Davlat Texnika Universiteti, dotsent
Gaffarov Laziz Hasanovich
Buxoro muhandislik – texnologiya instituti, dotsent.

Tahririyat a’zolarning to‘liq ro‘yxati jurnalning www.devos.uz saytida keltirilgan.

Tahririyat hay’ati a’zolarining tarkibini o‘zgartirish hamda qo‘shimcha kiritish yoki tahririyat a’zoligidan chiqarish bosh muharrir tomonidan amalga oshiriladi.

ISSN 3030-3907

Development of science ilmiy jurnali 2024 yil 15 aprel kuni №256445 sonli guvohnoma bilan Davlat ro‘yxatidan o‘tgan.

To‘plam elektron ko‘rinishda (pdf formatida) mualliflarga taqdim etiladi. To‘plamga kiritiladigan maqolalarning mazmuni, ulardagi statistik ma’lumotlar va me’yoriy hujjatlarning to‘g‘riligiga hamda har qanday fikr - mulohazalarga mualliflarning o‘zlari mas’ul hisoblanadilar. Talablarga javob bermaydigan maqolalar to‘plamga kiritilmaydi. Tashkiliy qo‘mita maqola matnini qisqartirish, qisman tuzatish kiritish, seksiyalarga joylashtirish huquqiga ega.

ISSN 3030-3907

RESEARCHING ON HYBRID TECHNOLOGIES FOR CNC MACHINES AND ADDITIVE TECHNOLOGIES.

Oybek Khaydarov
Department of Mechanical Engineering, Navoi State University of Mining and Technologies ,Navoi, Uzbekistan
E-mail: oybekkhaydaroff@gmail.com
Sayfidinova Makhliyo
PhD student, Navoi State University of Mining and Technologies
Oripov Dostonjon
Department of Mechanical Engineering, Navoi State University of Mining and Technologies ,Navoi, Uzbekistan

Abstract. Trend of mass customization of lightweight construction in industry became more popular due to economical efficiency. Nevertheless, many researchers find it extremely complicated to research synergy hybrid technologies for CNC machines and additive technologies. More flexible processes are needed which were improved by the additive manufacturing technology. This production method offers a high-micro-geometrical freedom and elaborate utilization of the used material. To compensate contradictions like form inexactitude and surface roughness, hybrid machines combining additive and subtractive manufacturing are developed. Furthermore the combination of additive and subtractive manufacturing allows the production of ready to use products within one single machine. Undoubtedly, researching is often vital for career advancement, to obtain funding, to obtain academic qualifications, or for all these reasons. Scientists are trying to achieve 4 main goals-developing of suitable materials, improve surface quality, implement special tools and inexpensive producing of materials. In this scientific article we describe the basic steps to follow researching and making the overall result attractive and acceptable for publication.

Keywords: Additive manufacturing, industry, CNC, hybrid processes, combination

Аннотация. Тенденция массовой индивидуализации легких конструкций в промышленности становится всё более популярной благодаря экономической эффективности. Тем не менее многие исследователи считают изучение синергии гибридных технологий для станков с ЧПУ и аддитивных технологий достаточно сложной задачей. Требуются более гибкие производственные процессы, которые были усовершенствованы благодаря технологии аддитивного производства. Данный метод производства обеспечивает высокую свободу микрогеометрического формообразования и эффективное использование применяемого материала. Для устранения таких противоречий, как неточность формы и

ISSN 3030-3907

шероховатость поверхности, разрабатываются гибридные станки, объединяющие аддитивное и субтрактивное производство. Кроме того, сочетание аддитивного и субтрактивного производства позволяет изготавливать готовые к использованию изделия в пределах одного станка. Несомненно, научные исследования часто имеют важное значение для карьерного роста, получения финансирования, приобретения академической квалификации или достижения всех этих целей одновременно. Ученые стремятся достичь четырех основных целей: разработки подходящих материалов, улучшения качества поверхности, внедрения специальных инструментов и снижения стоимости производства материалов. В данной научной статье описываются основные этапы проведения исследований и подготовки общего результата таким образом, чтобы он был привлекательным и приемлемым для публикации.

Ключевые слова: аддитивное производство, промышленность, ЧПУ, гибридные процессы, комбинирование.

Annotatsiya. Sanoatda yengil konstruksiyalarni ommaviy individuallashtirish tendensiyasi iqtisodiy samaradorlik tufayli tobora ommalashib bormoqda. Shunga qaramay, ko‘plab tadqiqotchilar CNC dastgohlari va additiv texnologiyalar uchun gibrid texnologiyalar sinergiyasini tadqiq qilishni juda murakkab deb hisoblaydilar. Additiv ishlab chiqarish texnologiyasi yordamida takomillashtirilgan yanada moslashuvchan jarayonlarga ehtiyoj mavjud. Ushbu ishlab chiqarish usuli yuqori darajadagi mikrogeometrik erkinlikni hamda foydalanilayotgan materialdan samarali foydalanishni ta’minlaydi. Shakl noaniqligi va sirt g‘adir-budurligi kabi qarama-qarshiliklarni bartaraf etish uchun additiv va subtraktiv ishlab chiqarishni birlashtiruvchi gibrid dastgohlar ishlab chiqilmoqda. Bundan tashqari, additiv va subtraktiv ishlab chiqarishning kombinatsiyasi tayyor mahsulotlarni bitta dastgohning o‘zida ishlab chiqarish imkonini beradi. Shubhasiz, ilmiy tadqiqotlar ko‘pincha martaba rivoji, moliyalashtirish olish, akademik malakaga ega bo‘lish yoki ushbu maqsadlarning barchasiga erishish uchun muhim ahamiyatga ega. Olimlar to‘rtta asosiy maqsadga erishishga intilmoqda: mos materiallarni ishlab chiqish, sirt sifatini yaxshilash, maxsus asboblarni joriy etish va materiallarni arzon ishlab chiqarish. Ushbu ilmiy maqolada tadqiqot olib borish va umumiy natijani nashr uchun jozibador hamda maqbul holatga keltirishda amal qilinishi lozim bo‘lgan asosiy bosqichlar bayon etilgan.

Kalit so‘zlar: additiv ishlab chiqarish, sanoat, CNC, gibrid jarayonlar, kombinatsiya.

INTRODUCTION.

ISSN 3030-3907

Every researcher has been face to face with a blank page at some stage of their career, wondering where to start and what to write first. Describing one's research work in a format that is comprehensible to others, and acceptable for publication is not easy task. When you invest a lot of time, energy and often money in your research, you become intimately and emotionally involved. Naturally, you are convinced of the value of your research, and of its seriousness for the scientific community. [1]

The rapid progress of digital innovations of and the transition to next-generation manufacturing models are driving a rapid transformation of traditional manufacturing methods. One key area of this transformation is the integration of additive manufacturing with high-precision subtractive machining methods implemented on computer numerical control (CNC) machines. Hybrid manufacturing systems, which combine additive and subtractive processes within a single technological complex, significantly expand the capabilities of modern mechanical engineering, increasing the precision, efficiency and flexibility of manufacturing complex parts. [2]



Figure 1. The distinction between subtractive and additive manufacturing processes.

Here we can see difference between subtractive and additive manufacturing. With the first technologies, we can see raw materials being processed using a CNC machine, obtaining finished products, but at the same time, we experience material loss in the form of metal shavings, which in turn affects the price of the final product. In the second case we can see additive manufacturing which offers us raw material in powder form and layer-by-layer printing The end result is a part that is in no way inferior to one prepared using a

ISSN 3030-3907

CNC machine, and what's important is that there are virtually no losses in the form of chips, which in turn also affects pricing, that is, it reduces the cost price and increases the corporation's income.

The excellence of hybrid systems lie not only in increased productivity, but also in the ability to locally strengthen materials, reduce the number of equipment transitions, increase surface quality and optimize material consumption. Despite significant advances in this field, optimization of the interconnected processes of deposition and subsequent machining, increased stability of process modes and the development of universal modeling and control methods remain pressing. [3]

Technology	Achievable quality	Layer height	Minimum wall thickness	Tolerance	Cost	Strength
SLS-3D Printing	High	32-50µm	0.3mm	L <100mm, +/-0.1mm; L>100mm, +/-0.1%*L	Affordable	High
MJF-3D Printing	High	50µm	0.5mm	L <100mm, +/-0.15mm; L>100mm, +/-0.15%*L	Affordable	High
DMLS-Metal-3D Printing	High	50-100µm	0.5mm	L <100mm, +/-0.1mm; L>100mm, +/-0.1%*L	A bit expensive but affordable	Super
FDM-3D Printing	Low to medium	50-200µm	0.8mm	L <100mm, +/-0.25mm; L>100mm, +/-0.25%*L	Cheap to expensive	Low to high(based on materials)
SLA-3D Printing	High	25-100µm	0.5mm	L <100mm, +/-0.1mm; L>100mm, +/-0.1%*L	Cheap	Low
CNC-Plastics	High	NA	NA	0+/-0.1mm	Cheap	High
CNC-Metals	High	NA	NA	0+/-0.03mm-0.1mm	Affordable	Super

Figure 2. Here presents the technology types with along achievable quality, surface finish, minimum wall thickness, allowable variation, cost and the mechanical strength of the final product.

In this regard, the study of hybrid manufacturing systems based on a combinations of additive technologies and CNC machine tools represents an important scientific and practical challenge. It allows us to identify key patterns in the formation of material properties and geometric accuracy during sequential processes of material addition and removal, as well as propose new approaches to the design, control and digitalization of such technological systems.

This study aims to analyze the architecture of hybrid manufacturing systems, study their operational characteristics and identify factors influencing the quality and efficiency of manufacturing. The results obtained may contribute to the further development of integrated manufacturing technologies and enhance the competitiveness of high-tech industries.[4]

MATERIALS AND METHODS.

This study was based on an analytical review of additive, subtractive and hybrid manufacturing technologies. Scientific publications, technical data and

ISSN 3030-3907

graphical materials related to CNC machining and additive manufacturing were used as research materials.

The methodology included three main stages. First, additive and subtractive manufacturing processes were analyzed. Second, hybrid manufacturing systems combining additive manufacturing and CNC machining were classified. Third, the main technological indicators, such as material use, surface quality, dimensional accuracy and production efficiency, were compared.

RESULTS.

The analysis of hybrid manufacturing technologies showed that the combination of additive manufacturing and CNC machining provides several technological advantages. Additive manufacturing allows producing complex parts by layer-by-layer deposition of material, while CNC machining improves dimensional accuracy and surface quality by removing excess material.[5]

According to the reviewed materials, additive manufacturing reduces material losses because the part is formed directly from powder or filament material. In contrast, subtractive manufacturing produces chips during machining, which increases material waste and affects the cost of the final product. Therefore, hybrid manufacturing can be considered a more efficient approach because it combines the material-saving advantage of additive manufacturing with the accuracy of CNC machining.[6]

The results also showed that different finishing methods can improve the quality of additively manufactured parts. Abrasive finishing reduces stair-stepping marks, barrel finishing smooths rough surfaces, and chemical finishing improves surface appearance. However, CNC machining remains one of the most effective methods for improving dimensional accuracy and surface finish after additive manufacturing.

The main advantages of hybrid additive–subtractive manufacturing are summarized in Table 1.

Table 1.

Main results of hybrid additive–subtractive manufacturing analysis

Technological aspect	Result
Material use	Material waste is reduced compared with traditional CNC machining
Surface quality	CNC machining and finishing methods improve surface roughness
Dimensional accuracy	Final accuracy is increased after post-machining

ISSN 3030-3907

Production flexibility	Complex parts can be manufactured more easily
Manufacturing process	Additive and subtractive operations can be combined in one machine
Final product quality	Ready-to-use products can be obtained with fewer technological transitions

Thus, the results confirm that hybrid manufacturing systems are effective for producing complex parts with improved quality. The combination of additive and subtractive manufacturing makes it possible to reduce material waste, improve surface finish, increase accuracy and produce ready-to-use parts within one technological system. This idea is also stated in the article, where hybrid machines are described as systems that combine additive and subtractive manufacturing to compensate for form inaccuracy and surface roughness.[7]

DISCUSSION.

The general model of a hybrid manufacturing system can be expressed as:

ISSN 3030-3907

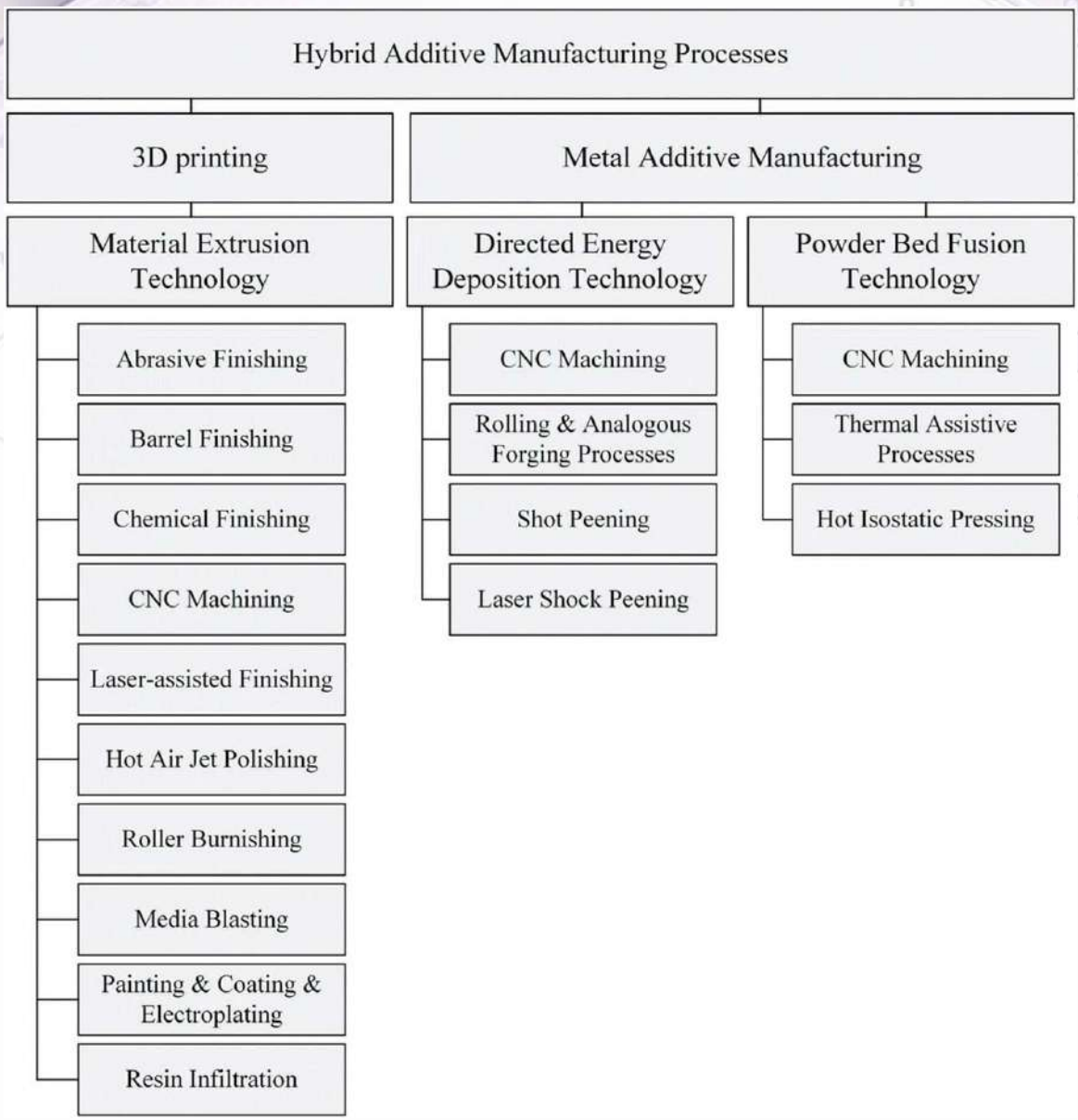


Figure 3. The classification of the hybrid additive processing is illustrated in this figure 3 [1]

Hybrid processes in the field of 3D printing. Layered formation of polymetric 3D objects throughout material extrusion, referred to as fused filament fabrication has been largely performed through solidification of molten base material deposited via a nozzle head on particular extrusion path. Rapid fabrication of typical thermoplastics causes accompanying issues with the appearance and the strength. A viable route for partial determination of specified drawbacks is the rational selection of deposition path, build orientation, raster angle, road width and slice thickness. Still, a complete solve impossible without synergy hybrid processes.[8]

Abrasive finishing. Researchers have taken superiority of abrasive flow machining on eradicating the stair-stepping leftover on the parts manufactured by stereolithography. Lately, researchers have examined the effect of abrasive flow

ISSN 3030-3907

machining on both external and internal features of samples produced by fused filament fabrication, where abrasive particles (silicon carbide, cubic boron nitrate) sustained in a particular medium does the actual material removal work. The researchers have reported that hundred-micron-sized abrasives decrease the average surface roughness (R_a) up to 1 μm and 6 μm for an external arc and internal hole. As inferred from the study, the achievable quality of internal surfaces is a significant barrier for abrasive finishing methods.

Barrel finishing. Barrel finishing is interchangeably used to designate the process of smoothing rough surfaces in a rotating unit filled with a particular media as well as water or preferable lubricants. Thermoplastic parts retained in a centrifugal barrel containing the main media can be polished after several hours, which makes barrel finishing a comparatively slow post-processing option. The researchers have reported an developed surface roughness (R_a=5 μm) with the application of a 16 hour barrel finishing on sample part. Even though surface quality and machining time are highly governed by the initial surface morphology, the thickness of the abraded layer at the best case still reaches to a hundred microns.[9]

Chemical finishing. The dissolution of engineering polymers in particular chemical agents called chemical finishing, conducts to the best surface finish among all methods and is characterized by a shiny appearance. Cheap chemicals provide the fastest way of decreasing stair-steps in typical 3D printing applications (acetone) dissolves acrylonitrile butadiene styrene in a few seconds. Instead of pure liquid immersion, making use hot vapor or cold vapor of the chemical is preferable depending on the inteded characteristics. CNC machining. Coupling of the mechanical engineering technology with CNC machining offers faster production capability, because the additive stage of the fabrication might be handled employing thinker material layers. Furthermore, parts' dimentional accuracy becomes independed of imprefections originating from the additive technology since it is controllable upon post-machining. In recent years, the researchers has aimed more emphasis on the development of hybrid platforms (additive and subtractive) and modification for hybridizing some existing ones. CNC machining influence the industrial adoption of material extrusion technology by enabling scalability, for example-the coupling of large-volume additive manufacturing (with fiber-reinforced polymer) and CNC milling rapidly speeds up the process. A variety of trending attempts on this category can also include hybrid manufacturing cells comprising of fused filament fabrication machines, CNC mills, pick and place robots and multi-robotic arms with both additive and subtractive tools.

ISSN 3030-3907

		Secondary Process	Surface Quality Ra [µm]	Processing Time [min]	Processed Layer [µm]
Subtractive Combinations	Initial / Final	CNC Machining	2-4	10-42	200-690
		Chemical Finishing	0.1-1	3-40	40-800
		Barrel Finishing	3-5	100-1000	50-400
		Abrasive Finishing	1-6	20-60	50-350
Transformative Combinations	Initial / Final	Laser-assisted Finishing	0.3-10	4-10	-
		Hot Air-jet Polishing	0.2-4	3-5	-
		Roller Burnishing	0.11-0.15	2-5	300-350
		Media Blasting	4-12	1-5	-
Additive Combinations	Initial / Final	Painting/ Coating	0.7-4	60-3000	60-180
		Resin Infiltration	-	3-240	40-800

Figure 4. This figure illustrates various metal processing methods, along with surface roughness in R_a , (µm), processing time (min.) and layer thickness µm [1]

In most cases, subtractive methods integrated with directed energy deposition technology is associated with the milling (and occasionally turning) process. The main principle used in the establishment of the artifacts is to manufacture an oversized near net shape with additive manufacturing and accompanying material removal thereafter. Sometimes, the production bases on the intermediate machining strategy in certain intervals of additive layers, especially for the intricate parts with fine features.

ISSN 3030-3907

For precision manufacturing of high-complexity parts CNC machining is still reasonable to employ followed by layerwise milling on the near net shape features. [3]

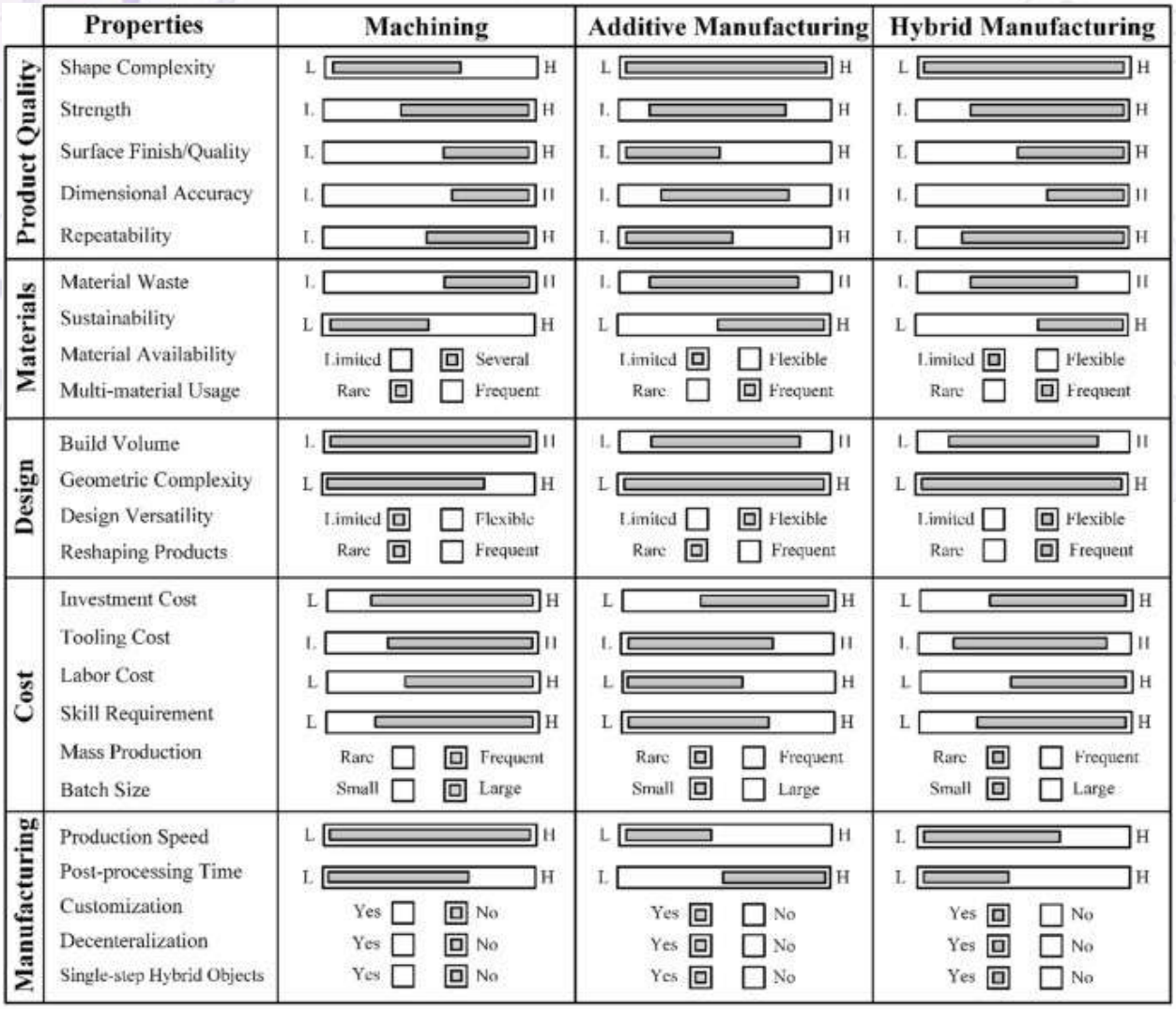


Figure 5. It is evident that different manufacturing approaches present distinct advantages and limitations across various quality metrics.

CONCLUSION. To sum up, due to pivotal advantages of hybrid manufacturing over the conventional and additive manufacturing processes, researchers have been conducting their works on different dimensions of this entirely new approach to make it more captivating in the market. Their primary goals include : 1) increasing the number of suitable materials, 2) achieving a better surface quality of the resulting products, 3) increasing special design tools for better efficiency, 4) diminish the cost of the fabrication and machinery.

REFERENCES

1. Dilberoglu, U. M., Gharehpapagh, B., Yaman, U., & Dolen, M. (2021). Current trends and research opportunities in hybrid additive manufacturing. The International Journal of Advanced Manufacturing Technology, 113(3), 623-648.

ISSN 3030-3907

2. Merklein, M., Junker, D., Schaub, A., & Neubauer, F. (2016). Hybrid additive manufacturing technologies–an analysis regarding potentials and applications. Physics procedia, 83, 549-559.
3. Yamazaki, T. (2016). Development of a hybrid multi-tasking machine tool: integration of additive manufacturing technology with CNC machining. Procedia Cirp, 42, 81-86.
4. Owen, W.S., Grujicic, M., 1999. Strain aging of austenitic Hadfield manganese steel. Acta Materialia 47(1), 111–126.
5. Bouaziz, O., Allain, S., Scott, C.P., Cugy, P., Barbier, D., 2011. High manganese austenitic twinning induced plasticity steels: A review of the microstructure properties relationships. Current Opinion in Solid State and Materials Science 15(4), 141–168.
6. Karaman, I., Sehitoglu, H., Beaudoin, A.J., Chumlyakov, Y.I., Maier, H.J., Tomé, C.N., 2000. Modeling the deformation behavior of Hadfield steel single and polycrystals due to twinning and slip. Acta Materialia 48(9), 2031–2047.
7. Khamroev, N., Egamberdiev, I., Ashurov, K., Asatov, S., & Khamidov, B. (2024, November). Exploring the influence of the casting process, structural components and heat treatment on the mechanical properties of high-chromium cast irons: A review. In AIP Conference Proceedings (Vol. 3244, No. 1, p. 060021). AIP Publishing LLC.
8. Yakhshiev, S., Egamberdiev, I., Mamadiyarov, A., Ashurov, K., Khamroev, N., Yakhshiev, S., ... & Khamroev, N. (2023). Accuracy evaluation of the output of the spindle assembly of the NT-250I lathe machine. Research on Engineering Structures and Materials.
9. Khamroev, N., Egamberdiev, I., & Ashurov, K. (2026). Effect of Chromium Content and Heat Treatment Conditions on the Structure of Wear-Resistant White Cast Irons. Archives of Metallurgy and Materials, 253-261.

ISSN 3030-3907