



PROCEEDING BOOK OF  
4TH INTERNATIONAL  
CONFERENCE ON  
SCIENTIFIC AND  
ACADEMIC RESEARCH  
ICSAR 2024

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## **INTRODUCTION**

We had the great honor of organizing the ICSAR 2024. It was truly a great pleasure for us to greet a lot of participants from many different countries attending ICSAR 2024! We firmly believe that the conference will become an important international event in the field of cross-industry discussion about innovations in Academic Studies.

ICSAR 2024 was organized by All Science Academy located in Konya, Turkey.

Three cooperating organizations supported the two-day conference. There were 426 papers accepted for presentation at ICSAR 2024, contributed from different countries. We had plenary speeches and several well-known scientists and experts, to give invited talks at different sessions.

The purpose of ICSAR 2024 was to provide a forum for the participants to report and review innovative ideas, with up-to-date progress and developments, and discuss novel approaches to the application in the field of their own research areas and discuss challenges of doing science.

We sincerely hope that the exchange of ideas on doing research, science and improving education will help the participants, and international cooperation sharing the common interest will be enhanced.

On behalf the Organization Committee of ICSAR 2024, we would like to heartily thank our cooperating organizations for all they have done for the conference. We would also like to thank the authors for their contribution to the proceedings; the participants and friends of ICSAR 2024, for their interest and efforts in helping us to make the conference possible; and the Editorial boards for their effective work and valuable advice, especially the ICSAR 2024 secretariat and the ICSAR 2024 staff, for their tireless efforts and outstanding services in preparing the conference and publishing the Proceedings.

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991-1019	[2] Muhammad Quraish Shihab (Arabic: مُحَمَّد قُرَيْش شِهَاب; Muhammad Qurayş Şihāb; born 16 February 1944) is an Indonesian Muslim scholar in the sciences of the Qur'an, an author, an Academic Scholar, and former Minister of Religious Affairs in the Fourth Development Cabinet (1998).	Bengi Şentürk, Nağme Ebru Karabağ	Turkey, Turkey	Submission 1799
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86	Transport parameters of a homogeneous DBD discharge of the Ar - NH <sub>3</sub> gas mixture	Barkahoum LAROUCI, Amar Benmoussa, Ahmed BELASRI, Soumia BENDELLA	Algeria, Algeria, Algeria, Algeria	Submission 1350
87	Ferrofluid flow through an annulus	Jaswinder Singh Mehta	India	Submission 1352
88	Maximum Power Point Tracking Based on FLC Using DC/DC Boost Converter for PV System	Kellal Cherif, Mazouz Lakhdar, Ouacel Abdelkader, Kouzou Abdellah, Matilde Pietrafesa	Algeria, Algeria, Algeria, Algeria, Italy	Submission 1353
89	Tuning the PI controller for optimum performance in a VSC based HVDC system	Kellal Cherif, Mazouz Lakhdar, Ouacel Abdelkader, Kouzou Abdellah, Matilde Pietrafesa	Algeria, Algeria, Algeria, Algeria, Italy	Submission 1355
90	Effect of milking frequency on the hygienic and nutritional quality of raw milk in the Mid-Northern region of Algeria	SILARBI Tayeb, LAABAS Saadiya, CHAHBAR Mohamed, TEFIEL Hakim, GADOUM Abdelkader, ABDELLAH Fatiha, HAMDEN Khaled	Tunisia, Algeria, Algeria, Algeria, Algeria, Tunisia, Tunisia	Submission 1356
91	A comparison of FEM and FIT techniques for the optical modeling methodology used in the new nanostructured hybrid STPV cells	Oussama Baitiche, Fathi Bendelala, Ali Cheknane	Algeria, Algeria, Algeria	Submission 1426
92	Design and Simulation of Logic Circuits Using Phase Change Materials in a Kagome Structure	Ibrahim CINAR	Turkey	Submission 1500
93	The Effects of Lycopene on Health and Fields of Use	Halil İbrahim Binici, Adem Savaş	Turkey, Turkey	Submission 1532
94	Süspansiyon Parçalarından Rot mili Parçasının Yağlama Operasyonu Sürecinin Ürün Performansına Etkisinin İncelenmesi	Semih KÖSE, Muhammed Abdullah ÖZEL, Mehmet Yasin GÜL	Turkey, Turkey, Turkey	Submission 1479
95	DFT study and Spectral Analysis of a novel synthesized ketone derivative	SMATI Sabrina, BOUKABCHA Nouredine, MENAD Karima, CHOUAÏH Abdelkader	Algeria, Algeria, Algeria, Algeria	Submission 1334
96	Processing of data from a PCR-RAPD genetic fingerprint by UPGMA (Unweighted Pair Group Method With Arithmetic)	LAABAS Saadiya, CHAALAL Hichem, SILARBI Tayeb	Algeria, Algeria, Tunisia	Submission 1358
97	Antimicrobial properties of thyme ( <i>Thymus vulgaris</i> L.) essential oil	Amara Nacira, Amara Sabrina, Touati Souad	Algeria, Algeria, Algeria	Submission 1361
98	Therapeutic effect of curcuma longa L and geranium rosat Pelargonium Graveolens essential oils against lead acetate-induced testicular toxicity	Nacera Boulila, Lynda Lakabi, Massinissa Madouche, Samira Oudahmane-Akdader, Assia Kamel, Menad Rafik, Ferroudja Bensaad-Medjdoub	Algeria, Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1363
99	Exploring the impact of allelopathic crops on surrounding competitors in Agricultural systems	Soltane Sabrina, Benmeddour Tarek	Algeria, Algeria	Submission 1364
100	Global and local stability analysis of a heroin epidemic model	Zirar Imane Hana, Lakmeche Abdelkader, Touaoula Mohamed Tarik, Helal Mohamed, Bensid Yazid	Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1365
101	Fabrication Of Flexible Thin Film Substrates By The Extraction Of CNCs From Cellulosic Materials	Abdul Basit, Hafeez Anwar	Pakistan, Pakistan	Submission 1366
102	Enhancing Electricity Theft Detection in Smart Grids Using Temporal Convolutional Attention Networks and Variational Autoencoders	Hafiz Muhammad Azeem Akram	Azerbaijan	Submission 1371
103	Energy Efficiency in Gas Turbine Cooling: Techniques and Computational Fluid Dynamics Analysis Using ANSYS Fluent	Kamal ABOUELMAJD, Isamil LAGRAT	Morocco, Morocco	Submission 1375
104	Phase transitions in magnetic materials: Application to energy storage and heating systems	Abdelhak Boukhal, Youssef Chegrane, Nabil Hachem, Mohammed El Bouziani	Morocco, Morocco, Morocco, Morocco	Submission 1378
105	Control by AES spectroscopy and photoluminescence of Oxygen point defects in SnO <sub>2</sub> thin films	Zakia.LOUNIS, M.Salah HALATI, Moussaab BELARBI, Malika ACHOURI, Djamel GHAFFOR, Chawki Zegadi	Algeria, Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1379
106	Evaluation of Antibacterial Activity of <i>Thymus vulgaris</i> Extracts	Khiari Mohamed, Kechrid Zine	Algeria, Algeria	Submission 1383
107	On the regularity in Colomeau's algebra	Mohamed Helal, Mohamed El Amine Kherarba	Algeria, Algeria	Submission 1384
108	Machine Learning Supported Antenna Design for UHF RFID Applications	Emre Aksoy, Merih Palandöken	Turkey, Turkey	Submission 1524
109	Ochratoxin-A Toxicity in Broiler Birds and its Amelioration with N-Acetylcysteine Supplementation	Muhammad Imran, Muhammad Kashif Saleemi, Al-Hafiza Shafia Tehseen Gul, Aisha Khatoun,	Pakistan, Pakistan, Pakistan, Pakistan, Pakistan, Pakistan	Submission 1392

		Mughees Aizaz Alvi, Muhammad Imran		
110	Three-Dimensional Analysis of Free Vibration of Sandwich Plates with Composite Laminated Face Sheets and a Porous Functionally Graded Core	A. Guenanou, M. Hachemi, M.S.E. Hamroun, F. Touahra, R. Chebout, K. Bachari	Algeria, Algeria, Algeria , Algeria, Algeria , Algeria	Submission 1396
111	Analysis of Porous Sandwich Plates FGM Subjected To Free Vibration	MERDADI Slimane, HADJ MOSTEFA Adda, BOUCHAFA Ali	Algeria, Algeria, Algeria	Submission 1410
112	AI-Powered Fault Detection in MPPT Algorithms Utilizing Artificial Neural Networks for Enhanced Photovoltaic System Performance	Abdelouadoud Loukriz, Mohamed Dahmani, Zine Elabidine Dahmane, Abderrahim Zemmit	Algeria, Algeria, Algeria, Algeria	Submission 1411
113	Sihhi Seramik Makinesi Milinin Statik Yük Altında İncelenmesi	Fatih Karpat, Mehmet Kıvanç Turan, Murat Mandıracı	Turkey, Turkey, Turkey	Submission 1516
114	Control Battery Storage Strategy in Stand-Alone Photovoltaic Systems: A Study Under Irradiation Effects	Layate Zakaria, Bahi Tahar, Lekhchine Salima	Algeria, Algeria, Algeria	Submission 1519
115	Servis Uygulamaları İçin Kural Tabanlı Proses Takip Yazılımının Geliştirilmesi	Cengiz SERTKAYA, Fidan Khalilbayli	Turkey, Turkey	Submission 1526
116	Microalgae Based Bioplastics and Their Utilization as Fertilizer	Wiem Jebahi, Bengü Özüğür Uysal	Turkey, Turkey	Submission 1533
117	Farklı Gedik Tiplerinden Kaynaklanan Ani Baraj Yıkılması Akışının Bir Binaya Etkisinin Sayısal Olarak İncelenmesi	Emrah Sevinç	Turkey	Submission 1551
118	Effects of Supplemental Feeding of Fenugreek and Fennel Seeds on Milk Production Properties in Assaf Sheep	Ömer Berk KARABACAK, Birol DAĞ	Turkey, Turkey	Submission 1563
119	Myofascial Release Exercises in the Treatment of Plantar Fasciitis: A Traditional Review	Mehmet SÖNMEZ	Turkey	Submission 1567
120	Free Vibration Analysis of Functionally Graded Nanoplates	Soufiane Benounas, Mohamed-Ouejdi Belarbi	Algeria, Algeria	Submission 1413
121	Bending Analysis of Functionally Graded Nanoplates	Soufiane Benounas, Mohamed-Ouejdi Belarbi	Algeria, Algeria	Submission 1414
122	Bending Analysis of Functionally Graded Sandwich Hyperbolic Paraboloid Shells with Different Boundary Conditions	Soufiane Benounas, Mohamed-Ouejdi Belarbi	Algeria, Algeria	Submission 1415
123	Hysteresis behavior of a graphene monolayer in the presence of a transverse crystal field	M. Salama, T. Mouhrach, N. Hachem, E.B. Choubabi	Morocco, Morocco,Morocco,Morocco	Submission 1420
124	Analyzing Fuzzy Differential Equations: Application of Tarski's Fixed Point Theorem to Establish Solution Existence and Uniqueness.	Bellabes Zineb, Naima Boussekine	Algeria, Algeria	Submission 1422
125	Polyamide-Graphene oxide: synthesis, characterization, and electrochemical properties for different applications	Assia Tounsi, Ouafia BELGHERBI, Leila LAMIRI, Bousaha BOUCHOUL, Meriem MESSAOUDI, Nourdinne BOUMAAZA, Farid HABELHAMES, Ahmed BAHLOUL	Algeria, Algeria, Algeria, Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1423
126	Study of the effect of marble powder on the subsidence potential	Mohamed DACHER, Ouassila BAHLOUL, Samir BENMOUSSA, Chafai BECHTELLA	Algeria, Algeria, Algeria, Algeria	Submission 1424
127	Optimization of Robotic Manipulator Structure for Strawberry Harvesting Applications	Inas SAOUD, Asaad CHAHBOUN	Algeria, Algeria	Submission 1430
128	Bioethanol Production by Alcoholic Fermentation Using Saccharomyces cerevisiae and Valorization of Prickly Pear Juice Waste	FERROUDJ Nawal, BENSEFIA Chaima, KAHALERRAS Fatma	Algeria, Algeria, Algeria	Submission 1431
129	Influence of Urban Play Areas on Children's Social Integration in Cities	Marouane Samir Guedouh, Mohamed Amine Khadraoui, Soumaya Besbas	Algeria, Algeria, Algeria	Submission 1436
130	Numerical optimization of the workpiece positioning errors	CHAMI M, RAHOU M, SEBAA F	Algeria, Algeria, Algeria	Submission 1439
131	THE INFLUENCE OF THE ELECTRIC FIELD ON THE ELECTRONIC AND MECHANICAL PROPERTIES OF NONOTUBES	BAIRA Fayçal	Algeria	Submission 1447
132	Analysis of the mechanical properties of biopolymer - natural filler composite systems	Marcell János Tóth, Annamária Polyákné Kovács	Hungary, Hungary	Submission 1453
133	Flexural and thermal characterization of a lightweight clay and sawdust based compressed bricks	Belkacem MEZIANI, Mohamed Amin BOUZIDI, Chabane SI AHMED	Algeria, Algeria, Algeria	Submission 1459
134	Characterization and bioactivity of lepidium sativum seeds polysaccharide	Achat yasmine, Lefsih Khalef, Boulekbache Lila, Djenad Fatima, Beddar Siham, Idir Sabrina	Algeria, Algeria, Algeria , Algeria, Algeria , Algeria	Submission 1461
135	Plakanın Serbest Titreşiminde Öz değerlerin Galerkin Yöntemiyle Bulunması	Birkan DURAK	Turkey	Submission 1560

136	Modeling the Stability of Nanofluids Using Artificial Neural Networks and Investigating Their Effects on Thermal Conductivity	Fevzi SAHIN	Turkey	Submission 1571
137	İÇSEL PAZARLAMA UYGULAMALARI VE ÖRGÜTSEL BAĞLILIK İLİŞKİSİNİN İŞ PERFORMANSINA ETKİSİ: BARTIN ÜNİVERSİTESİ'NDE BİR ÇALIŞMA	Gizem BAYLANÇİÇEK, Selman KARAYILMAZLAR	Turkey, Turkey	Submission 1575
138	Microorganisms isolated from local soil as a tool for efficient bioremediation	Barbara Bertović, Monika Šabić Runjavec, Marija Vuković Domanovac	Croatia, Croatia, Croatia	Submission 1603
139	Artificial Intelligence Supported Optimization of Nanofluid Usage in PV Panel Cooling	Omer GENC	Turkey	Submission 1607
140	IMPACTS OF CLIMATE CHANGE ON THE PRODUCTIVITY OF TOBACCO CROP IN PAKISTAN	Haroon Khan, Ömer Süha Uslu, Osman Gedik	Turkey, Turkey, Turkey	Submission 1522
141	A multi-objective scheduling of renewable energy sources in a smart grid system	Rameez Hassan, Muhammad Bilal, Hasnain Ali Shah, Fazal Muhammad	Pakistan, Pakistan, Pakistan, Pakistan	Submission 1601
142	Migration Processes in Azerbaijan and their Effects on the Sustainable Development of the Enterprise Economy	Maryam Adli	Azerbaijan	Submission 1261
143	Numerical study of the effect of focusing the absorber relative to the mirror in a parabolic trough concentrator (PTC) on mixed convection	Hassene Boutelis, Dalila Titouna, Ammar Benderradji, Lazhar Serir	Algeria, Algeria, Algeria, Algeria	Submission 1344
144	Regional Consensus on Political Settlement to the Principal Conflicts in Afghanistan	Maria Adli	Azerbaijan	Submission 1460
145	Evaluation of The Nanotoxicity of TiO <sub>2</sub> -NPs on Wistar rats	Sara BOUZENZANA, Rachid ROUABHI, Tahar GOUDJIL, Abdellali BOUZENZANA	Algeria, Algeria, Algeria , Algeria	Submission 1465
146	An Innovative Program to Train Future Nobel Laureates Belonging to Türkiye and Pakistan	Syed Arif Kamal	Pakistan	Submission 1469
147	Water trapping Technical changes in barrier trap selectivity for the management of coastal lagoons	Zakaria Adjou, Djamila Boufades, Mustapha Miloudi	Algeria, Algeria, Algeria	Submission 1470
148	Experimental investigation of the efficiency of CO <sub>2</sub> enhanced oil recovery (CO <sub>2</sub> -EOR) in sandstone cores from an Algerian oil field using NMR technology	Zakaria Adjou	Algeria	Submission 1471
149	Thermal and mechanical properties of lightweight mortar and its constituents at elevated temperatures	Mohamed sadak Merrakchi, Smain Benyamina	Algeria, Algeria	Submission 1473
150	Hidden Curriculum: Shaping Students' Character in Religious Studies	Doni Abadi Nababan, Tetty Suriani, Marlen Bailao, Joice Patty	Indonesia, Indonesia, Indonesia, Indonesia	Submission 1477
151	Experimental Analysis of High-Velocity Impact Damage in CFRP Laminates	Mustapha RABOUH, Kamel ZOUGGAR, Khelifa GUERRAÏCHE	Algeria, Algeria, Algeria	Submission 1483
152	Modeling and Analysis of Impact-Induced Damage in Carbon Fiber Reinforced Polymer Composites Using ABAQUS	Mustapha RABOUH, Kamel ZOUGGAR, Khelifa GUERRAÏCHE	Algeria, Algeria, Algeria	Submission 1484
153	Structural and tribological behaviour study of porous TiNiCu shape memory alloys processed by powder metallurgy method	Zineb Sadaoui, Latifa Kahloul, Soumaya Meddah	Algeria, Algeria, Algeria	Submission 1485
154	Existence for Caputo-Fabrizio Random Fractional Differential Equations	BEKADA FOUZIA	Algeria	Submission 1486
155	Effect of Crosslinkers on Swelling Behavior of Chitosan grafted Poly(Acrylic Acid) Hydrogel	Abir Derbali, Djallel Bouzid, Amel Sadj	Algeria, Algeria, Algeria	Submission 1488
156	Discontinuous Nonlinearities in Fractional p-Laplacian Problems: A Study of Solution Existence and Multiplicity	Hanaa Achour, Sabri Bensid	Algeria, Algeria	Submission 1489
157	Impregnation of an Ion Exchange Resin for a Pharmaceutical Application	DJERADA Thiziri, MOULAHCENE Lamia, SENHADJI Ounissa	Algeria, Algeria, Algeria	Submission 1490
158	Forecasting company failure using ensemble machine learning methods	Kaoutar El Madou, Moad El Kharrim, Mohamed El Merouani	Morocco, Morocco, Morocco	Submission 1491
159	STUDY OF THE ENZYMATICAL VARIATIONS OF THE MOSS «LEUCODON SCIUROIDES L.»	Khaoula Menaiaia, Hana Bouzahouane	Algeria, Algeria	Submission 1493
160	Ab-Initio Analysis of Structural and Mechanical Properties of Novel Lithium Tetrafluoroaurate (III) LiAuF <sub>4</sub>	Ishak Mebarkia	Algeria	Submission 1502
161	Improvement of fine Soil Properties with CKD for Road Project Applications	Zemouli Samira	Algeria	Submission 1507
162	Enhancing Earth Blocks with Alfa Fibers: A Sustainable Approach to Building	SI AHMED Chabane, BOUZIDI Mohamed amin, LILLOUCH Samir, MEZIANI Belkacem	Algeria, Algeria, Algeria, Algeria	Submission 1509
163	Enhancing Key Responses in Composite Bricks	Boutaina Mounni, Karima	Algeria, Algeria, Algeria,	Submission 1510

	through Experimental Design Optimization	Dokkar, Abdallah Oulmekki, Hayat Benmoussa	Algeria	
164	Contribution to the study of a characterization of mining waste, case of poor iron ore from the El Ouenza – Tébessa mine	BOUZERIBA Hadjer, BOUZIDI Nedjima, IDRES Abdelaziz, LAALA Imen	Algeria, Algeria, Algeria, Algeria	Submission 1512
165	Flood Hazard Assessment and Mapping in Arid and Semi-Arid Regions of Algeria Case Study of Doucen City, wilaya Ouled Djellal	Djafri Sid Ali, Houria Athmani, Djouheina Boukehlifi Kouider, Sofiane Bensefia	Algeria, Algeria, Algeria, Algeria	Submission 1515
166	Enhancing the soils geotechnical properties by using plastic waste	Lina ZAIDI, Fatima Zohra BENAMARA, Messaouda BENCHEIKH	Algeria, Algeria, Algeria	Submission 1517
167	Study on the Effect of Metallic Ion Concentration on the Physical Properties and Thickness of Ternary Fe <sub>x</sub> Ni <sub>y</sub> Cu <sub>z</sub> Alloy Thin Films (X+Y+Z=100) Prepared by Electrodeposition	Ala. Boulegane, Ikhlas Bar, Hadia Almi, Abderrahim Hadj Larbi, Delloula Lakhdari	Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1520
168	Study of Alpha-Amylase and Urease Inhibitory Activities of an Endemic Plant from the Genus Achillea	Renda CHAHNA	Algeria	Submission 1521
169	Picture Fuzzy B-spline Curve Approximation Model	Nur Azlida Ahmad, Mohammad Izat Emir Zulkifly	Malaysia, Malaysia	Submission 1528
170	Computational Analysis of Structural, Elastic, and Thermoelectric Properties of N <sub>3</sub> RhGe half-Heusler alloy Employing the Density Functional Theory Approach	Righi Aya, Bendahma Fatima, Labdelli Abess, Mechehoud Khedidja, Mana Mohamed, Achir Bilel	Algeria, Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1534
171	Elimination with bio-coagulant the mixture of two dyes ( malachite green and Gentian violet)	MOKHATI Aya, AISSOUS Bochra, FERROUDJ Nawal, BENALIA Abdelrezaq, DERBAL Kerroum	Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1538
172	Bioplastics: A Green Approach in Materials for Green Environment	Nadia Akram	Pakistan	Submission 1547
173	Turbo Ventilate Selector Phosphate Rejects From The Processing Chain Of Djebel-Onk Mine - Tebessa (NE Algeria) : Characterization	LAALA Imen, BOUZIDI Nedjima, ELICHE-QUESADA Dolores, BOUZERIBA Hadjer	Algeria, Algeria, Algeria, Algeria	Submission 1549
174	On Minimum Distance Density Estimation	Bensaber Fatna, Benyahia Wahiba	Algeria, Algeria	Submission 1553
175	Comparative Study of K-Nearest Neighbors and Random Forest for Predicting Lung Cancer	Samira Tared	Algeria	Submission 1556
176	Random Forest for Lung Cancer Prediction	Samira Tared	Algeria	Submission 1557
177	NanoVaccines Design and Development	Abdelali BOUSSIF, Khadidja LEMOUI	Algeria, Algeria	Submission 1558
178	Valorization and characterization of citrus peel by product	Sabrina SAHI-BOUBEKRI, Ounissa KEBICHE-SENHADJI, Fadila HEMMACHE-OUGHJIS	Algeria, Algeria, Algeria	Submission 1559
179	Preparation of activated carbon based on vegetal waste: Application to adsorption, kinetic and thermodynamic study	Z. Mekibes, K. Khalili, M. Benzekri Benallou, N. Douara, N. Benderdouche, B. Bestani	Algeria, Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1565
180	Comparative Hepatoprotective Potency of Green-Synthesized Moringa Nanoparticles in Ameliorating Oxidative Stress	Ayesha Rasool, Razia Noreena	Pakistan, Pakistan	Submission 1581
181	Green Synthesis and Characterization of Manganese Oxide Nanoparticles using Olive Leaf Extract: Thermal Stability and Phase Transformation Analysis	Abdelmalik Zemieche, Loubna Chetibi, Djamel Hamana, Slimane Achour	Algeria, Algeria, Algeria, Algeria	Submission 1583
182	Enhancement of the Efficiency of the CISSe/CdS/ZnO Solar Cell by optimization of the performances layers using SCAPS -1D	A. bayoud , S. Lachhab, A. Bliya, A.Raidou, Al Ibrahim, L. Dlimi, S. el bahjaouy	Morocco, Morocco, Morocco, Morocco, Morocco	Submission 1590
183	A Review of Artificial Intelligence and Machine Learning Algorithms	Amine Bayoud, Abderrahim Raidoua, Soulaïmane El Bahjaouy, Saadeddin Lachhab	Morocco, Morocco, Morocco, Morocco	Submission 1592
184	Characterization and comparative study of the adsorption of toxic heavy metals lead and cadmium from aqueous solution using a chemically modified green waste of the Euphorbiaceae family	Terkhi Mohammed Cherif, Belhadji Kinza Amel, Terkhi Sabria	Algeria, Algeria, Algeria	Submission 1593
185	Experimental Assessment of the Effects of Building Materials on Wi-Fi signal 2.4GHz and 5GHz	Sylhane Bytyqi	Kosovo	Submission 1595
186	Polyaniline-Modified Iron and Copper Doped Cerium Oxide Nanocomposites for Enhanced Photocatalytic Degradation of Organic Dyes: Synthesis, and Characterization	MADI Kamilia, BENKOUACHI Oumnia Rayane, TAHRAOUI Hichem, CHEBLI Derradj	Algeria, Algeria, France, Algeria	Submission 1597
187	Mechanical characterization of recycled HD-PE Biocomposites reinforced with Esparto grass and natural Pozzolan	Bouchra Achour, Abdelkader Ziadi	Algeria, Algeria	Submission 1609
188	Modeling of a GaN-Based Betavoltaic Cell	Fayçal Bouzid, Ammar Haboussi, Mohamed Salah Halati, Samir Gouga	Algeria, Algeria, Algeria, Algeria	Submission 1610

189	Analytical Modeling of InGaP/GaAs Heterojunction Stacked on a Ge Tandem	Fayçal Bouzid, Ammar Haboussi, Mohamed Salah Halati, Samir Gouga	Algeria, Algeria, Algeria, Algeria	Submission 1611
190	Histopathological changes in the liver of adult rats following repeated exposure to methyl thiophanate	CHELBI Narimene, MALLEM Leila, ABDENNOUR Cherif	Algeria, Algeria, Algeria	Submission 1614
191	Identification and Improvement of Defects in the Forging Production Process of 1040 Steel Suspension Part	Kemal NURVEREN, Serkan ERİKLİLİ	Turkey, Turkey	Submission 1619
192	New Hotend Design for 3D Printers for Highly Efficient Filament Flow	Caglar SEVIM	Turkey	Submission 1620
193	High-Efficiency Buck-Boost Converter for Rapid Active Balancing of Lithium-Ion Battery Packs in Electric Vehicles	Assia Redouani, Kamal Zared, Najiba El Amrani El Idrissi	Morocco, Morocco, Morocco	Submission 1622
194	A Novel Mobile Speed ConvNeXt Model for Accurate Gallbladder Cancer Detection	Ishak Pacal	Turkey	Submission 1626
195	Treatment of textile effluents with EPS waste	Dahdouh Nadjib, Hafesa Haroun, Chaabane Toufik	Algeria, Algeria, Algeria	Submission 1627
196	Arıcılıkta İn Vitro Yetiştiricilik	Dilek KABAKCI, Nuray ŞAHİNLER	Turkey, Turkey	Submission 1629
197	Optimizing Greenhouse Management through IoT-Enabled Automation and Sustainability	Ibrahim El Khalil MEKKI, Mohamed Bilel BELHAOUARI	Algeria, Algeria	Submission 1631
198	Sustainable Wastewater Treatment: Kinetic Modelling and Microbial Strategies in Bioremediation	Monika Šabić Runjavec, Ivana Stojmilović, Marija Vuković Domanovac	Croatia, Croatia, Croatia	Submission 1632
199	Investigation of Drilling Operator Efficiency for Drilling and Blasting Operations in an Underground Lead-Zinc Mine	Tugce Ongen	Turkey	Submission 1634
200	ENERAL SITUATION OF ORGANIC BEEKEEPING AND ORGANIC BEE PRODUCTS PRODUCTION	Nuray ŞAHİNLER, Dilek KABAKCI	Turkey, Turkey	Submission 1635
201	Control of Single Degree of Freedom Magnetic Pendulum with Non-Linear Feedback Linearization Method	Huseyin Yildiz	Turkey	Submission 1637
202	Industrial economic performance indicators: an international comparison	Yasmine Hariti, Nacira Boukhezer-Hammiche	Algeria, Algeria	Submission 1649
203	Modeling of soil consolidation around tunnels- Case study of Algiers Metro	Ibrahim MAHROUG, Abdelhafid MAHROUG	Algeria, Algeria	Submission 1655
204	Enhancing wool dyeing with clove bud (syzygium aramatics) based natural dyes via microwave treatment using a central composite design	Muhammad Yameen, Fariha Asghar, Shahid Adeel	Pakistan, Pakistan, Pakistan	Submission 1656
205	GG25 Dökme Demirde Karbon Eşdeğerinin Mikroyapı ve Mekanik Özelliklere Etkisi	Cevat Mehmetali, Gökhan Arıcı	Turkey, Turkey	Submission 1657
206	Evaluation of Sun Protection Factor Value and Antiaging Potential of Citrus clementina Hort. essential oil	Rukiye Boran Gülen	Turkey	Submission 1661
207	A techno-economic optimization of Renewable energy sources within a smart grid and battery system through evolutionary algorithms	Hasnain Ali Shah, Muhammad Bilal, Saddam Hussain, Rameez Hassan, Fazal Muhammad	Pakistan, Pakistan, Pakistan, Pakistan, Pakistan	Submission 1664
208	Exploring Phonological Processes in Child Language Development: A Comprehensive Study on Reduplication, Deletion, Consonant Cluster Reduction, Epenthesis, Diminutization, Coalescence, and Assimilation	Om Kumar, Tabish Mubeen	Pakistan, Pakistan	Submission 1666
209	Structure elucidation, and Combined Empirical-Computational studies of a hybrid chloride material with potential NLO properties	Ikram Jomaa, Nouredine Issaoui, Houda Marouani	Tunisia, Tunisia, Tunisia	Submission 1667
210	Design and Implementation of a Shunt Active Power Filter Based on Electric Vehicle Integration for Power Quality Improvement	Ahmed ELOTTRI, Lakhdar MAZOUZ, Abdellah KOUZOU, Nihel Bouthaina SALLAI, Ali TETA, Imad Eddine MOHAMMEDI	Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1670
211	In Silico Study of Chalcone Reductase from Diverse Fabaceae Family of Pakistan	Kamishka Iftikhar, Muhammad Akram	Pakistan, Pakistan	Submission 1674
212	DETERMINATION OF THE EFFECT OF AZITHROMYCIN ON UTERINE CYTOKINE LEVELS IN SEPTIC PREGNANT RATS	Gonca SONMEZ, Ozgur TUFAN, Muhammed Hudai CULHA, Tugba Melike PARLAK, Burak DIK, Ayse ER	Turkey, Turkey, Turkey, Turkey, Turkey, Turkey	Submission 1681
213	Full Factorial design applied for the optimization of CdS thin films deposited by Chemical bath deposition technique	Sara BOULAHDJEL, Samira SALI, Souad BOUAFIA, Salim KERMADI, Lyes ZOUGAR, Hadjira LABECHE, Massaouda AYACHI	Algeria, Algeria, Algeria, Algeria, Algeria, Algeria	Submission 1682
214	Towards the Optimization of Microstructure and Mechanical Properties of NbC-based Cermets	Abdul Basit, Asad Malik, Sadaqat Ali, Adeel Umer, Rafi-ud-Din	Pakistan, Pakistan, Pakistan, Pakistan, Pakistan	Submission 1684

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## CNC Program Development: Principles and Practices for Programming a Clutch Hub Turning Process

Violeta Krcheva

Faculty of Technical Sciences, University St. Kliment Ohridski - Bitola, Republic of North Macedonia

\*([violeta.krcheva@uklo.edu.mk](mailto:violeta.krcheva@uklo.edu.mk))

**Abstract** – This paper presents a systematic approach to the fundamental principles and practices essential for developing CNC programs, specifically for the clutch hub turning process. The process involves the turning operation necessary to machine a clutch hub from an initial workpiece, a forged clutch hub. CNC programming is pivotal in creating precise instructions that control the motions and operations of CNC machine tools for precise and efficient clutch hub machining. Key aspects highlighted in this study include the selection of appropriate cutting tools, the incorporation of cutting conditions (such as cutting speed, feed, and depth of cut), and the optimisation of cutting strategies during program development. The paper provides a practical framework for CNC program creation, from initial design through final implementation, emphasising both theoretical foundations and practical completion. The discussion primarily focuses on the integration of G-codes and M-codes into CNC programming, ensuring constant monitoring and control over manufacturing operations. Furthermore, the paper evaluates how advanced technologies such as CAD/CAM integration facilitate CNC programming by improving precision and efficiency. By analysing functional CNC programs, this research serves as a valuable resource for engineers and machinists aiming to deepen their expertise in CNC programming, particularly in the development of effective and dependable CNC programs for manufacturing processes.

**Keywords** – G-codes, M-codes, CNC Machine Tool, Cutting Tools, CAD/CAM

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### I. INTRODUCTION

In the contemporary context of manufacturing processes, precision and consistency are imperative in achieving optimal product quality and operational efficiency. The constant monitoring and control over dimensional tolerances, surface finish quality, and workpiece dimensions throughout the machining processes ensure compliance with design specifications, thereby enhancing product durability and reliability. This consistent practice promotes early detection and correction of dimensional imperfections, minimising waste and repairs while maintaining the quality of manufactured workpieces [1].

The advent of CNC (Computer Numerical Control) machine tools has revolutionised modern manufacturing, offering superior accuracy and repeatability in comparison with conventional machine tools. These machine tools are particularly designed for complex and demanding machining processes where precision is paramount. Central to the operation of CNC machine tools is CNC programming, a discipline focused on the transformation of design specifications into executable commands that direct the movements and actions of CNC machine tools [2].

CNC programming refers to the principles used to generate the instructions that drive the CNC machine tools. These instructions are structured into a program, which consists of G-codes and M-codes (Fig. 1a). G-codes, or geometric codes, control the motion of the CNC machine tool. They are standard commands

that begin with the letter "G" followed by a two-digit number, indicating various movements and positions of the machine tool's moving components. The commands dictate the precise geometric positions based on a coordinate system, enabling the machine to move the components and cutting tools accurately in a specified direction and position them precisely in 3D space (Fig. 1b) [3].

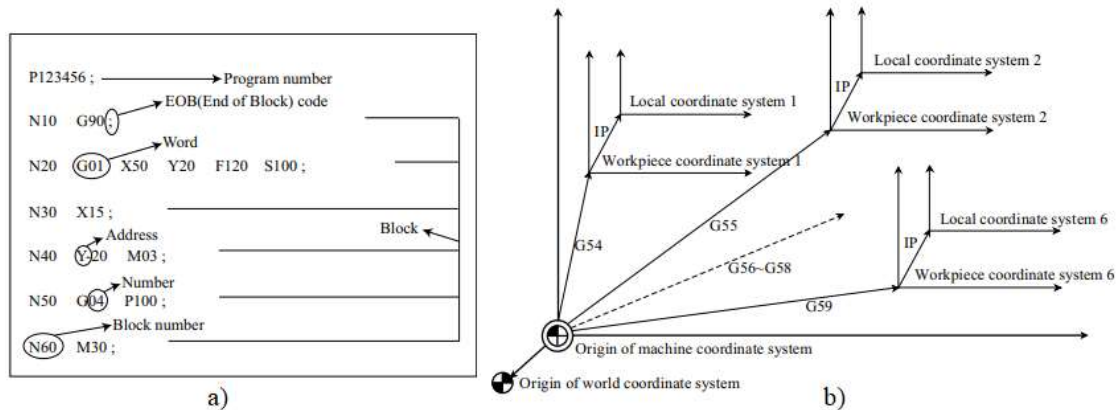


Fig. 1 a) Program structure; b) Machine, workpiece, and local coordinate systems [3]

In addition to G-codes, CNC programming encompasses M-codes, which regulate specific functions of the CNC machine tool, including spindle rotation speed, cutting tool feed rate, tool changes, and coolant application. The M-codes also adhere to an alphanumeric format, beginning with the letter "M" and being followed by two digits. These codes are essential for the operation control of the machine tool and ensure that each workpiece of the manufacturing process is machined correctly and efficiently [4].

The G-code, in the role of a programming language, facilitates the development of specific programs through Computer-Aided Manufacturing (CAM) systems that utilise Computer-Aided Design (CAD) information. These advanced systems play a crucial role in contemporary machining processes, effectively synchronising design with manufacturing. Specifically, CAM systems utilise CAD data to create precise instructions for CNC machine tools, which significantly improves both the design and productivity of machining processes. This integration of CAD and CAM systems facilitates the transition from design to production, thereby enhancing overall manufacturing efficiency and product quality [5].

The principle of developing CNC programs involves a sequence of steps that convert design specifications into commands readable by machine tools. These commands direct and control the movement of the machine tool's moving components and cutting tools during the machining process [6].

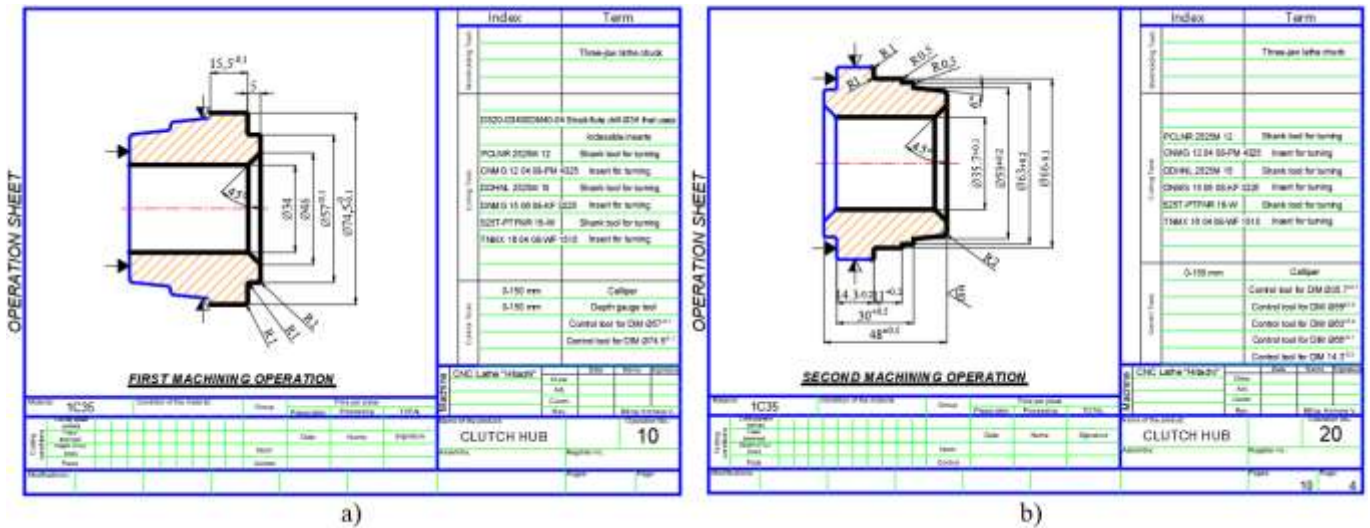
Initially, the process commences with designing and modelling the workpiece utilising Computer-Aided Design (CAD) software. This involves developing a detailed two-dimensional or three-dimensional model wherein all features, such as contours, holes, slots, and pockets, are identified and designed. The designed CAD model provides a precise representation of the workpiece to be manufactured [7].

The CAD model is then utilised to develop CNC programs of instructions that define the cutting tools' toolpaths. The toolpaths are the specific paths that the cutting tool traverses in order to machine the workpiece. During this step, the appropriate cutting tools are selected according to material and design requirements. Machining parameters, including spindle speed, rotation direction, feed, depth of cut, and coolant activation, are also defined in the programs of instructions [8].

When the toolpaths are created, they can be visualised as a continuous connection between a series of coordinates that correspond to specific data points. Each coordinate indicates a particular position in the machine tool's working space, defining the precise location of the cutting tool at the determined trajectory. As the machining process progresses, the cutting tool traverses from one coordinate to the next, ensuring precise material removal and shaping of the workpiece [9].

Prior to implementing the G-code on the actual CNC machine tool, the toolpaths can be simulated and verified by utilising the CAM software. This simulation facilitates the visualisation of the machining process and the identification of potential issues, such as collisions, tool breakage, or excessive material removal, which can be anticipated, detected, and eliminated [10].



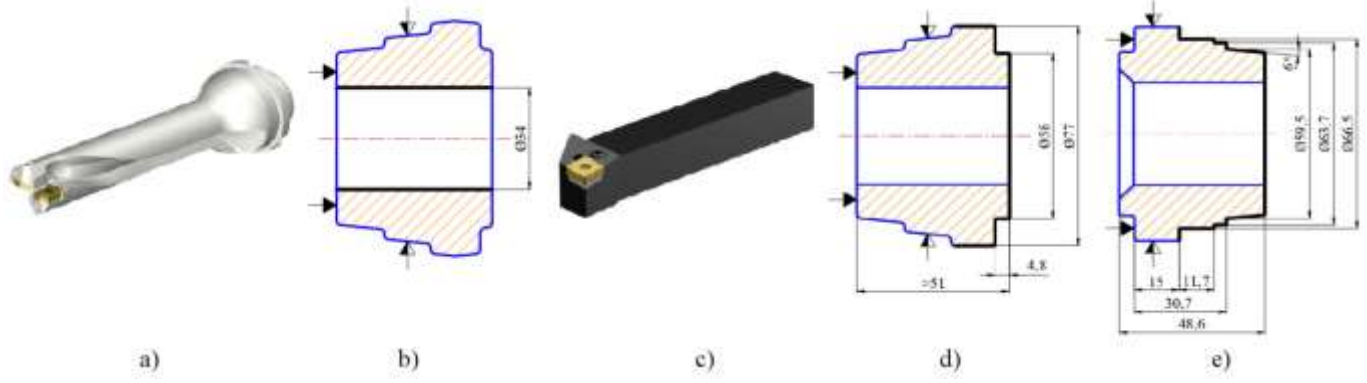


The first machining operation (Fig. 3a) comprises four passes. The first pass (Fig. 4b) involves drilling. The second (Fig. 4d) and third passes (Fig. 5b) involve turning and facing, respectively. The fourth pass (Fig. 6b) includes chamfering.

The second machining operation (Fig. 3b) comprises three passes. The first pass (Fig. 4e) involves turning and facing. The second pass (Fig. 5c) similarly includes turning and facing. The third pass (Fig. 6c) entails chamfering and boring.

The contours of the workpiece illustrated in the drawing play a crucial role in defining the geometry of the cutting tool for each machining pass. The shape and complexity of these contours directly influence the selection of cutting tool parameters such as cutting edge angle, tool lead angle, inclination angle, nose radius, etc. Each specific contour determines the required type of cutting tool holder and indexable insert shape that must precisely match the profile of the workpiece.

Specifically, for the first pass (in the first machining operation), the determined cutting tool is the DS20-D3400DM40-04 straight-flute drill with indexable inserts DS20-0508-P and DS20-0508-C, manufactured by Sandvik Coromant (Fig. 4a). The cutting tool geometry is characterised by a cutting edge angle of 81°, an inclination angle of 0°, and indexable insert corner radii of 0.8 mm and 0.35 mm.



For the second pass (in the first and second machining operations), the determined cutting tool is the PCLNR 2525M 12 shank tool for turning (Fig. 4c) that uses a CNMG 12 04 08-PM 4325 indexable insert, manufactured by Sandvik Coromant. The cutting tool geometry is characterised by a cutting edge angle of 95°, a lead angle of -5°, an inclination angle of -6°, an orthogonal rake angle of -6°, a corner radius of 0.8 mm, an effective length of the cutting edge of 12 mm, and a rhombic 80° insert shape.

The determined cutting tool for the third pass (in the first and second machining operations) is the DDHNL 2525M 15 shank tool for turning (Fig. 5a) that uses a DNMG 15 06 08-KF 3225 indexable insert, manufactured by Sandvik Coromant. The cutting tool geometry is characterised by a cutting edge

angle of  $107.5^\circ$ , a lead angle of  $-17.5^\circ$ , an inclination angle of  $-7^\circ$ , an orthogonal rake angle of  $-6^\circ$ , a corner radius of 0.8 mm, an effective length of the cutting edge of 14.7 mm, and a rhombic  $55^\circ$  insert shape.

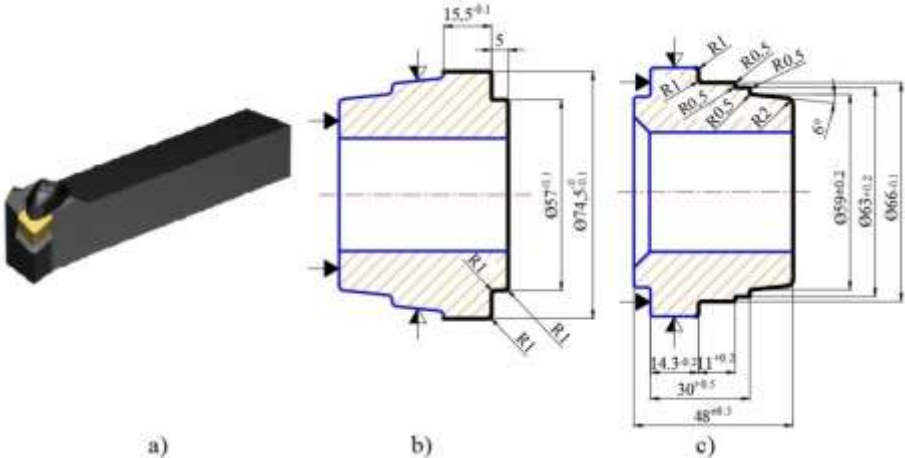


Fig. 5 a) Shank tool for turning; b) Third pass; c) Third pass

And for the last, fourth pass (in the first and second machining operations), the determined cutting tool is the S25T-PTFNR16 16-W shank tool for turning (Fig. 6a) that uses a TNMX 16 04 08-WF 1515 indexable insert, manufactured by Sandvik Coromant. The cutting tool geometry is characterised by a cutting edge angle of  $91^\circ$ , a lead angle of  $-1^\circ$ , a corner radius of 0.8 mm, an effective length of the cutting edge of 15.7 mm, and a triangular insert shape.

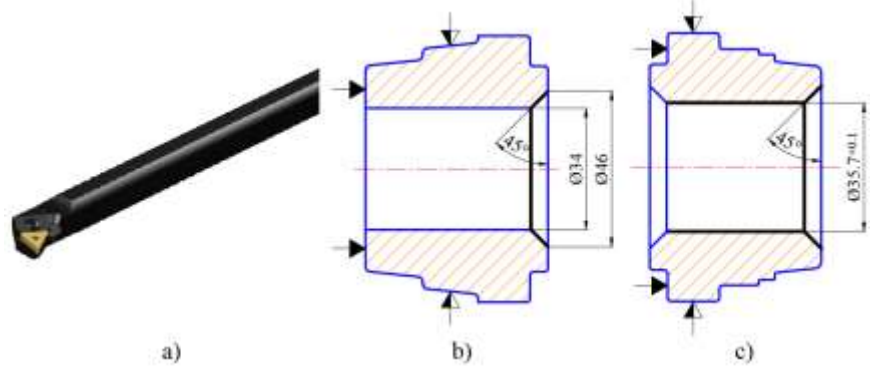


Fig. 6 a) Shank tool for turning; b) Fourth pass; c) Fourth pass

This CAD model has been meticulously developed to enable a precise analysis of turning operations, including all relevant passes. It serves as the essential foundation for providing coordinates from annotations and for the subsequent development of CNC programs. Through detailed examination, this model ensures accuracy in translating design intentions into executable CNC programs.

III. RESULTS

The development of the CNC programs involved a series of detailed steps to ensure the desired geometry and contour of the workpiece were followed by the cutting tool. The process began with understanding the workpiece CAD model design through two-dimensional design specifications, which included all dimensions, tolerances, and surface finish requirements.

Next, appropriate cutting tools were selected based on the material of the workpiece and the number and type of passes required. The geometry of the cutting tools, including diameters, linear and radial lengths, and shape, was considered as it directly affects the programming of the tool paths.

The workpiece coordinate system (WCS) was then established on the CNC turning centre `Hitachi`, with the origin point (X, Y, and Z coordinates) defined as the reference for all dimensions. The origin (0,0,0) was defined at the highest point and centre of the workpiece's surface.

%	N080 M40;	N175 G00 Z10.;	N265 X76.;
O77;	N085 G99;	N180 G28 U0 V0 W0 M5;	N270 G00 Z10.;
N005 M40;	N090 G18;	(THIRD PASS);	N275 G28 U0 V0 W0 M5;
N010 G99;	N095 G50 S750;	N185 T0500;	(FOURTH PASS);
N015 G18;	N100 G96 S750 M4;	N190 M40;	N280 T0300;
(FIRST PASS);	N105 G00 X82. Z10. Y0.;	N195 G99;	N285 M40;
N020 T0900;	N110 Z-5.7 M8;	N200 G18;	N290 G99;
N025 M40;	N115 G01 X58.7 F0.12;	N205 G50 S800;	N295 G18;
N030 G99;	N120 Z-1.1;	N210 G96 S800 M4;	N300 G50 S750;
N035 G18;	N125 X33.;	N215 G00 X33. Z10. Y0.;	N305 G96 S750 M3;
N040 G50 S450;	N130 Z2.;	N220 Z4.;	N310 G00 X46. Z10. Y0.;
N045 G96 S450 M3;	N135 G00 X33.;	N225 G01 Z-0.5 F0.2 M8;	N315 Z2.;
N050 G00 X0. Z30. Y0.;	N140 G01 Z-1.2;	N230 X53.;	N320 G01 Z-1. F0.12 M8;
N055 Z4.;	N145 X55.;	N235 G03 X56.8 Z-2. R2.;	N325 X34. Z-5.5;
N060 G01 Z-56. F0.07 M8;	N150 G03 X58. Z-2. R1.;	N240 G01 Z-5.5;	N330 G00 Z10.;
N065 G00 Z10. M9;	N155 G01 Z-5.9;	N245 X70.5;	N335 G28 U0 V0 W0 M5;
N070 G28 U0 V0 W0 M5;	N160 X77.;	N250 G03 X74.4 Z-7. R2.;	N340 M30;
(SECOND PASS);	N165 G01 Z-23.;	N255 G01 Z-21.9 F0.14;	%
N075 T0100;	N170 X77.;	N260 X73.4;	

Fig. 7 CNC program for the first turning operation

Planning the tool paths for turning involved identifying the contours and profiles that the cutting tool must follow, including outer and inner diameters, fillets, chamfers, and other features.

%	N080 X63.7;	N165 G18;	N255 Z10.;
O78;	N085 Z-21.3;	N170 G50 S900;	N260 G28 U0 V0 W0 M5;
N005 M40;	N090 X66.;	N175 G96 S900 M4;	(THIRD PASS);
N010 G99;	N095 Z-33.;	N180 G00 X30. Z1. Y0.;	N265 T0300;
N015 G18;	N100 X75.;	N185 G01 Z-3.9 F0.14 M8;	N270 M40;
(FIRST PASS);	N105 G00 Z-3.5;	N190 X52.3;	N275 G99;
N020 T0100;	N110 X59.;	N195 G03 X56.6 Z-5.2 R2.;	N280 G18;
N025 M40;	N115 G01 X32. F0.1;	N200 G01 X58.8 Z-16.5;	N285 G50 S750;
N030 G99;	N120 G00 Z-1.;	N205 X61.4;	N290 G96 S750 M3;
N035 G18;	N125 X59.;	N210 G03 X63.2 Z-17.5 R2.;	N295 G00 X46. Z0. Y0.;
N040 G50 S700;	N130 Z-4.4;	N215 G01 Z-21.7;	N300 G01 Z-0.8 F0.12 M8;
N045 G96 S700 M4;	N135 G01 X30.;	N220 X63.9;	N305 X35.7 Z-4.5;
N050 G00 X32. Z10. Y0.;	N140 Z10.;	N225 G03 X65.9 Z-22.7 R2.;	N310 Z-50.;
N055 Z0.;	N145 G28 U0 V0 W0 M5;	N230 G01 Z-32.9;	N315 G00 X30.;
N060 G01 Z-1. F0.12 M8;	(SECOND PASS);	N235 X72.;	N320 Z10.;
N065 X52.;	N150 T0500;	N240 G03 X74.4 Z-34.1 R2.;	N325 G28 U0 V0 W0 M5;
N070 G03 X57. Z-3.2 R2.5;	N155 M40;	N245 G01 Z-34.5;	N330 M30;
N075 G01 X59.5 Z-16.3;	N160 G99;	N250 G00 X76.;	%

Fig. 8 CNC program for the second turning operation

The CNC programs were developed using G-code that primarily control the movement of the CNC turning centre `Hitachi` along the axes (X, Y, and Z) and specify the type of motion to be performed. Additionally, M-codes were used to control various auxiliary functions of the CNC turning centre, such as tool changes, spindle speed, spindle control, feed rate, and other functions.

The developed CNC programs were specified for each machining operation and included all passes. For space conservation, these programs are presented as figures.

The program of instructions for the first turning operation (including four passes) is depicted in Fig. 7. and the second turning operation (including three passes) is depicted in Fig. 8.

#### IV. DISCUSSION

The first CNC program is structured to drive and control the CNC turning centre through a detailed series of instructions to shape the shorter side of the clutch hub. Each section of the program represents a specific phase of the turning process, referred to as a "pass". The program starts (and ends) with a command `%` to signal the beginning (and the end) of the program and the identifier `O77` is used to give the CNC program a unique identification number.

This program starts by preparing the CNC turning centre for the drilling operation. The code `T0900` is used to select the straight-flute drill that is placed in a designated position within the CNC turning centre's tool carousel and the code `S450` to set the spindle speed to 450 RPM. Rapid traverses (G00 commands) are used to quickly position the cutting tool to the initial cutting point at X0, Z30, and Y0. This initial position ensures precise alignment before the drilling pass is begun. Once in position, this pass is initiated by the program. Linear interpolation (G01) is used to slowly lower the cutting tool to the Z-56 coordinate at a feed rate of 0.07 units per revolution, ensuring a controlled penetration into the material. The spindle is rotated in the clockwise direction (M03), maintaining a consistent cutting speed. After the pass is completed, the cutting tool is rapidly moved to Z10, and the spindle is stopped (M09). To prepare for the next pass and cutting tool change, a return to the machine's reference point (G28 U0 V0 W0) with a spindle stop (M05) is commanded by the program.

In the second pass, the code `T0100` is used to select the determined cutting tool by the program, and the code `S750` is used to adjust the spindle speed to 750 RPM in the counterclockwise direction (M4). A rapid traverse to the defined point with coordinates X82, Z10, and Y0 is initiated to begin the actual pass. Then, linear interpolation (G01) is implemented in the program to make precise cuts at varying depths and contours. For instance, the cutting tool is moved from Z-5.7 to Z-1.1 while turning along the X-axis. A rapid movement to X33 is then implemented, and the process is repeated, demonstrating the ability of the CNC turning centre to perform complex machining tasks. Circular interpolation (G03) is used to facilitate curved cuts, which are essential for creating intricate geometries on the workpiece. Similar to the first pass, the second pass is finished with a command to return to the turning centre's reference point (G28 U0 V0 W0 M5) and preparation for the subsequent pass.

For the third pass, the determined cutting tool `T0500` is selected, with the spindle speed set to 800 RPM in a counterclockwise direction (M04). The turning process is accelerated by this higher spindle speed, which is suitable for machining tougher materials or achieving finer surface finishes. Rapid traverses and linear interpolations are commanded by the program to cut along designated paths, with adjustments made to the feed (F) and depth of cut (Z-axis) to meet turning requirements. Circular interpolations (G03) are utilised again to create fillets and curved surfaces, with movements exemplified by shifts from X53 to X70.5 and corresponding changes in Z-axis coordinates. Upon completion of the third pass, the CNC turning centre is directed by the program to return to its reference point (G28 U0 V0 W0 M05), ensuring accurate positioning and readiness for the next pass.

The determined cutting tool `T0300` is activated for the fourth pass, with the spindle speed set back to 750 RPM in a clockwise direction (M03). Optimal cutting conditions are provided for the specific cutting tool and material combination by this return to forward rotation. The program's systematic approach is continued, with linear interpolations employed to achieve the specified contours. Efficient chamfering operation is ensured by rapid traverses between the defined points, while accuracy throughout the

machining process is maintained by the program's code of spindle stops (M05) and return to reference points (G28 U0 V0 W0).

The second CNC program is structured to drive and control the CNC turning centre through a detailed series of operations to shape the longer side of the clutch hub. Each section of the CNC program represents the distinct phases of the turning process, referred to as "passes". The command `%` is used to signal the beginning and end of the program and `O78` is the unique identifier for this particular program.

The initial setup commands ensure that the CNC turning centre is ready for machining. The spindle is started by the `N005 M04` command. The feed mode is set by the `N010 G99` command, and the XZ plane for turning operation is selected by the `N015 G18` command.

For the first pass, the determined cutting tool `T0100` is selected. The spindle is set to rotate at a maximum speed of 700 RPM, maintaining a constant surface speed of 700 RPM in a counterclockwise direction (M04). The cutting tool is rapidly moved to the initial position at coordinates X32, Z10, and Y0. Then, it is descended to Z0 with the same rapid traverse command. The cutting process begins with a linear interpolation command, `N060 G01 Z-1. F0.12 M08`, that moves the cutting tool to Z-1 at a feed rate of 0.12 units per revolution, with coolant on. Various linear and circular interpolation commands are continued in the program to shape the workpiece. For instance, the cutting tool is moved to X52 by the `N065 X52` command, and a clockwise arc to X57, Z-3.2 with a radius of 2.5, is created by the `N070 G03 X57. Z-3.2 R2.5` command. Linear movements to specified coordinates are defined by the subsequent commands `N075 G01 X59.5 Z-16.3` and `N085 Z-21.3`. The rapid traverse command to X75 is then used to quickly move the cutting tool to the new positions without cutting. After performing the necessary cuts, the cutting tool is returned to the reference position using the `N145 G28 U0 V0 W0 M05` command with the spindle stopped.

The second pass is initiated by changing the cutting tool with the `N150 T0500` command. The spindle speed is increased to a maximum of 900 RPM using the `N170 G50 S900` command and set to maintain a constant surface speed of 900 RPM with the `N175 G96 S900 M04` command in a counterclockwise direction. The cutting tool is rapidly positioned at the point of X30, Z1, and Y0 coordinates using the `N180 G00 X30 Z1 Y0` command. The turning process begins with `N185 G01 Z-3.9 F0.14 M08`, moving the cutting tool to Z-3.9 at a feed rate of 0.14 units per revolution with coolant on. Similar to the first pass, various linear and circular interpolation commands are followed to shape the workpiece according to the desired geometry. A clockwise arc is created by `N195 G03 X56.6 Z-5.2 R2`, while a linear cut is defined by `N200 G01 X58.8 Z-16.5`. The program is continued with these commands to achieve the specified contours and depths. After the necessary cuts are completed, the cutting tool is returned to the reference position with `N260 G28 U0 V0 W0 M05`, ensuring the spindle is stopped and the CNC turning centre is ready for the next pass.

The determined cutting tool for the third pass is selected with the `N265 T0300` command. The spindle speed is set to a maximum of 750 RPM, and a constant surface speed of 750 RPM is maintained in a clockwise direction (M03). The cutting tool is rapidly moved to the starting position of X46, Z0, and Y0 coordinates with the `N295 G00 X46 Z0 Y0` command. The turning process is initiated with the `N300 G01 Z-0.8 F0.12 M08` command, moving the cutting tool to Z-0.8 at a feed rate of 0.12 units per revolution with coolant on. Various linear interpolation commands are used by the program to perform precise cuts along the specified paths. Specifically, the cutting tool is moved to the position at coordinates X35.7 and Z-4.5 with the `N305 X35.7 Z-4.5` command, and the pass is continued to Z-50 with the `N310 Z-50.` command. After the pass is completed, the cutting tool is rapidly returned to the reference position using the `N325 G28 U0 V0 W0 M05` command, with the spindle stopped.

## V. CONCLUSION

This paper presents a systematic approach to the fundamental principles and practices for the development of CNC programs specific to the clutch hub turning process. Through a detailed exploration of cutting tool selection and toolpath strategy optimisation, the study provides a practical framework for CNC program creation that spans from initial design to final implementation. The research highlights

methods to improve precision and efficiency in CNC programming by effectively integrating G-codes and M-codes and ensuring constant monitoring and control over machining operations.

The performance of optimising toolpaths and minimising errors underscores the importance of accuracy and reliability in CNC program development. Advanced technologies, such as CAD/CAM integration, are evaluated for their impact on improving precision and efficiency, demonstrating how modern technologies can significantly facilitate the CNC programming process. By analysing functional CNC programs, the paper serves as a valuable resource for engineers and machinists, contributing to the advancement of expertise in the creation of effective and dependable CNC programs for precise and efficient manufacturing operations.

In conclusion, this research not only demonstrates the theoretical foundations of CNC programming but also offers practical insights into the implementation of these principles. It underscores the critical role of well-structured and carefully chosen G-codes and M-codes in achieving high-quality CNC programs. As such, this paper is a valuable resource for those aiming to deepen their understanding and improve their skills in CNC programming, particularly in the context of developing robust programs for clutch hub turning processes.

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