Novel and Sustainable Techniques for Machinability Enhancement of DTC Materials

KAPIL GUPTA, Professor (Mechanical and Industrial Engineering Technology)

Jan 09, 2023

UNIVERSITY OF JOHANNESBURG

Organization of the Presentation

- Introduction

Machining Challenges with DTC Materials and Possible Solutions

- Sustainable Machining Techniques

- Case Study

- Conclusion and Call to Action

Kapil Gupta

Specialization/Expertise

Advanced and Sustainable Manufacturing

Advanced Machining Processes
(EDM/Wire-EDM, Laser Cutting, AWJM)

Sustainable/Green Machining
(Sustainable Cooling & Lubrication- MQL, Coated and Textured Tool Based Machining, Machinability enhancement of Hard and Soft materials)

Micro and Precision Machining

Gear Technology
(Advanced Machining of Miniature Gears and Sustainable Manufacturing of Gears)

Intelligent Machining

Research Outputs

International Journal Articles- 40
International Conference Articles- 50
International Books - 20
'C' Rated Researcher by NRF (South Africa)

Professional Services

Associate Editor, Journal of Process Mechanical Engineering (IF- 1.6) and Journal of Mechanical Engg. Science (IF- 1.76), Sage Publications (UK)

Postgraduate Supervision

Supervised 4 PhDs, 10 Masters, 4 Postdocs
5 PhDs and 8 Masters Ongoing

Funding

2.0 Million ZAR from Royal Academy of Engineering (UK), National Research Foundation (South Africa), Department of Higher Education and Training (South Africa)

Collaborations

Working jointly on academic and research projects with-

- CSIR, Pretoria (South Africa)
- Jendamark Automation, PE (South Africa)
- London South Bank University, London (UK)
- Swansea University, Swansea (UK)
- Indian Institute of Technology Indore (India)

Professional Memberships

- Professional Engineering Technologist, ECSA
- South African Young Academy of Science
- South African Institute of Mechanical Engineering
- South African Institute of Industrial Engineering
- South African Society for Engineering Education

Introduction

Difficult-To-Cut (machine) Materials

Hard and Soft Materials

Metals and Nonmetals

-Titanium, NiTi, Ni alloys

SS, High Strength Steel- Tool & Die etc.

-Al, Mg

Problems with Machining of DTC Materials

- Poor machinability (frequent tool wear, and deterioration in surface quality of the part being machined, due to generation of excessive heat)
- High consumption of energy and resources (Lubricants and tool inserts frequent change and resharpening)
- High environmental emissions

High hardness

Low elastic modulus

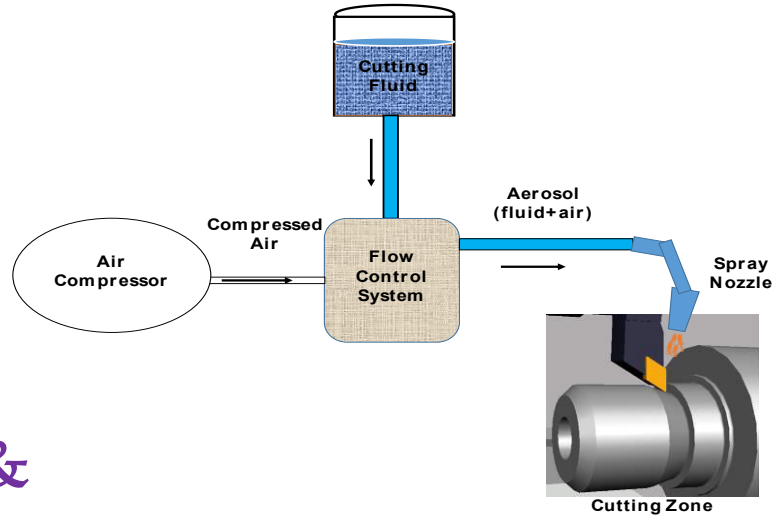
High chemical reactivity

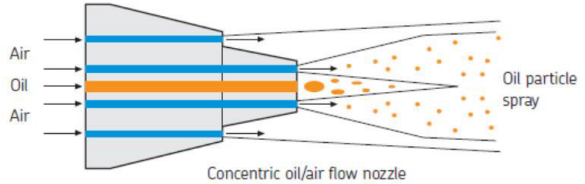
High workhardening

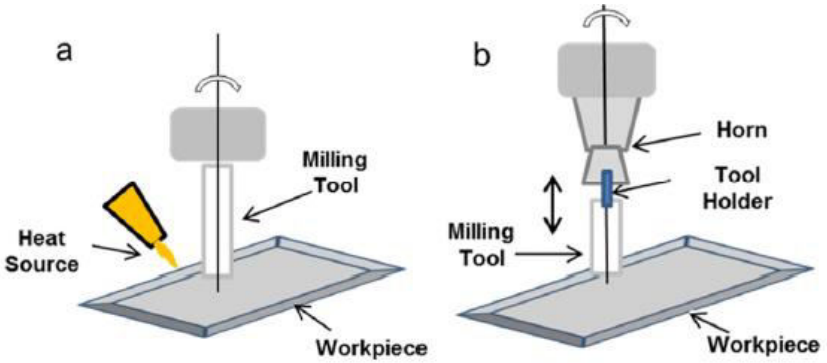
Low thermal conductivity

Possible Solutions to Enhance the Machinability

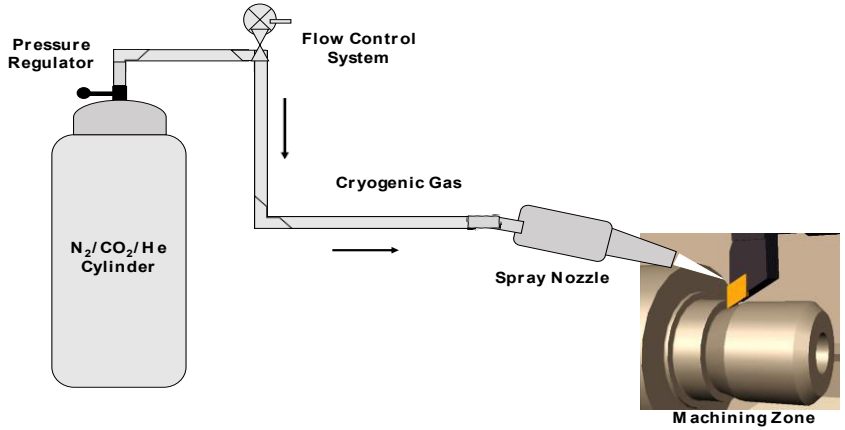
- ✓ Machining Parameter Optimization
- ✓ Employing Coated and Treated/Textured Tools
- ✓ Using Green Lubricants and Sustainable Cooling & Lubrication Techniques
- ✓ Adopting Hybrid Methods of Machining (Assistance of Heat and Vibration etc.)







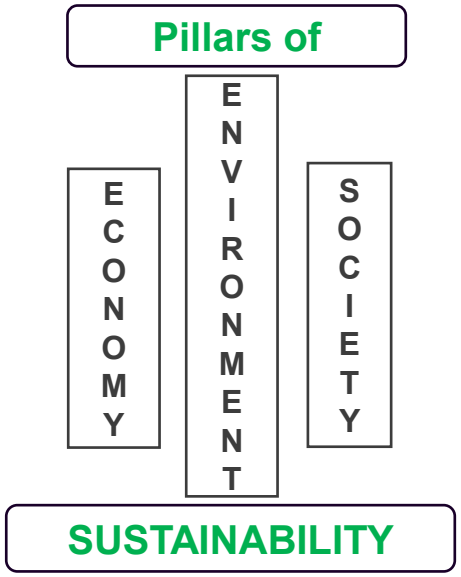
a. Heat assisted machining
b. Vibration assisted machining



Sustainability is the **ability to exist constantly**

In general '*sustainability*' is the **ability to continue a defined behaviour indefinitely**

The United Nations defines sustainability as:
"*Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*"



According to U.S. Department of Commerce, ***Sustainable Manufacturing*** is defined as:-

"the creation of manufactured products using processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers, and are economically sound"

(a) the manufacturing of "sustainable" products- exploring sources of renewable energy, green and social equity-related products

(b) the sustainable manufacturing of all products- developing and establishing energy efficient, non-polluting, economical and viable processes for manufacturing of products

[The International Trade Administration, U.S. Department of Commerce. How does commerce define sustainable manufacturing, http://www.trade.gov/competitiveness/ Sustainable manufacturing/how_doc_defines_SM.asp]

UN's General Assembly in 2015 set 17 SDGs and 169 targets to promote economic prosperity, social inclusion and environmental sustainability…….**for a better world** by 2030

Adapted as per guideline from https://www.un.org/sustainabledevelopment/news/communications-material/

"[University of Johannesburg] supports the Sustainable Development Goals"

The overall performance of all 193 UN Member States

2022 Rankings for SDGs

Country's total progress towards achieving all 17 SDGs

Source: Sustainable Development Report 2022. Cambridge: Cambridge University Press.

86.51	Finland	1
85.63	Denmark	2
85.19	Sweden	3
80.54	Poland	12
63.72	South Africa	108
60.32	India	121
39.05	South Sudan	163

A score of 100 indicates that all SDGs have been achieved

Sustainable Development and Industry 4.0 in Poland

Responsible Development Plan ('Morawiecki Plan') 2016

The Strategy for Responsible Development (SRD) 2017

Adopted by the council of ministers

The main objective of all activities and undertakings provided for in the SRD is to create conditions for increasing incomes of the Polish citizens along with increasing cohesion in the social, economic, environmental and territorial dimensions.

The Ministry of Entrepreneurship/Economic Development and Technology

A special **Task Force** for the Coherence of the Strategy for Responsible Development (SRD) by 2020 (with aperspective to 2030) with the 2030 Agenda and its Sustainable Development Goals (SRD Coherence Task Force) was appointed.

Poland's development priorities focusing on the "5Ps" of the 2030 Agenda (People, Planet, Prosperity, Peace, Partnership)

Poland GDP- 674 Billion USD (2021)
~716 Billion (2022)

32% Industry (17% Manufacturing)
65% Service
3% Agriculture

Initiative for Polish Industry 4.0 –
"The Future Industry Platform"

Digital Poland 2014-2020
operated by the Ministry of Digitalisation

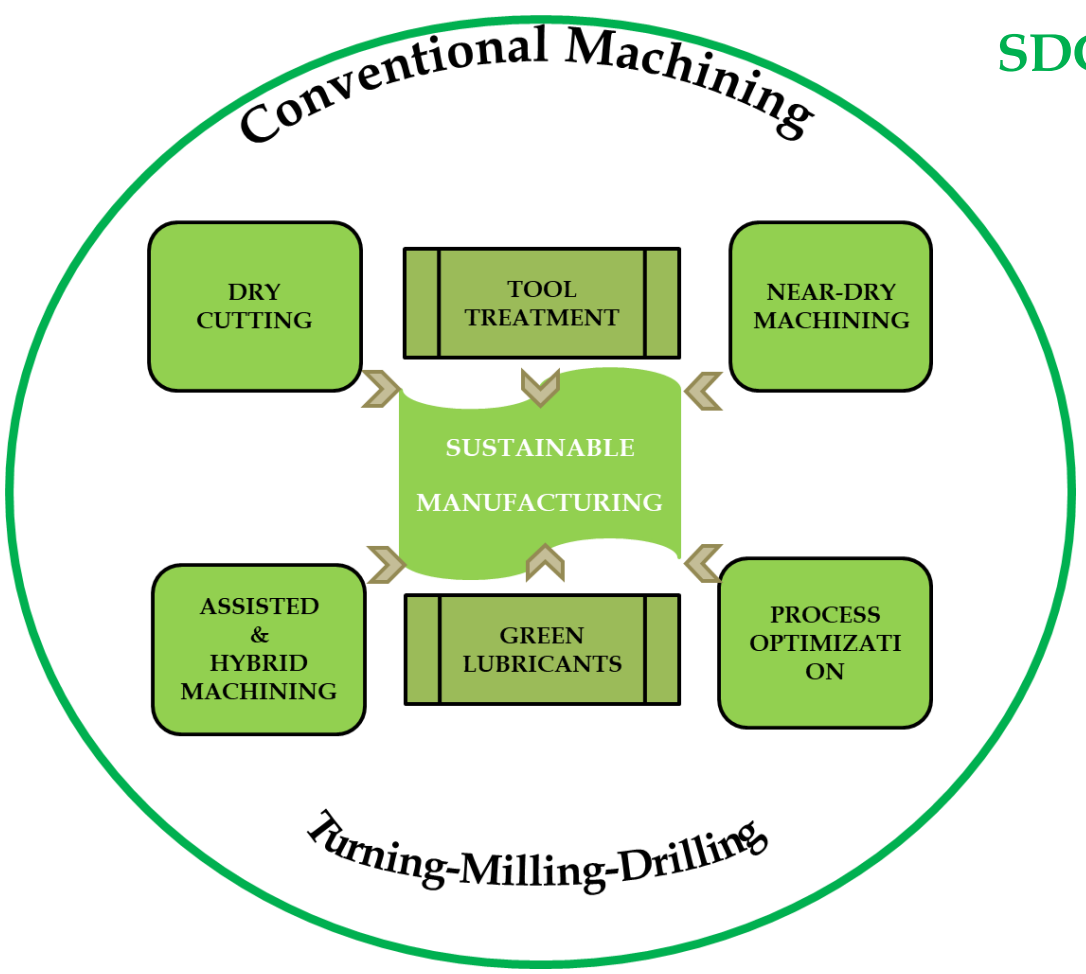
Sustainable Machining Techniques

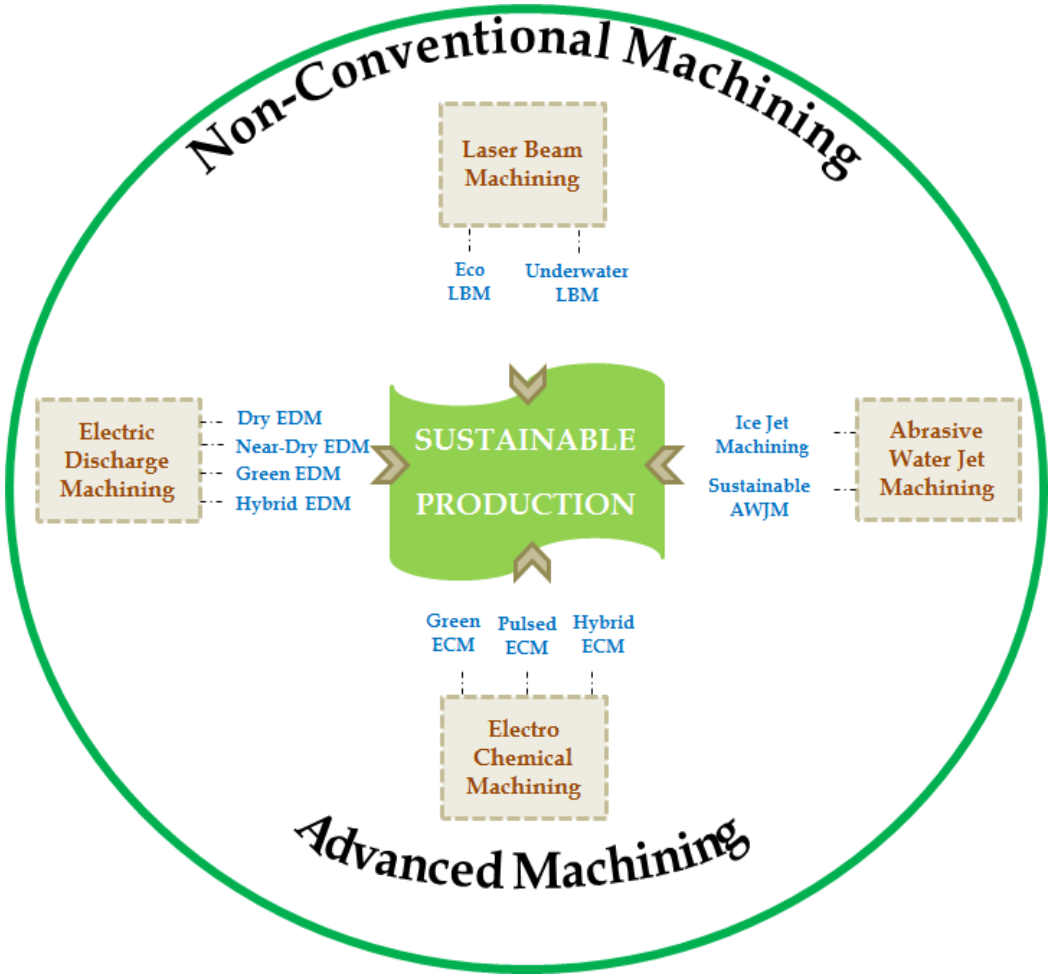
SDG 3

SDG 9

SDG 12

SDG 8

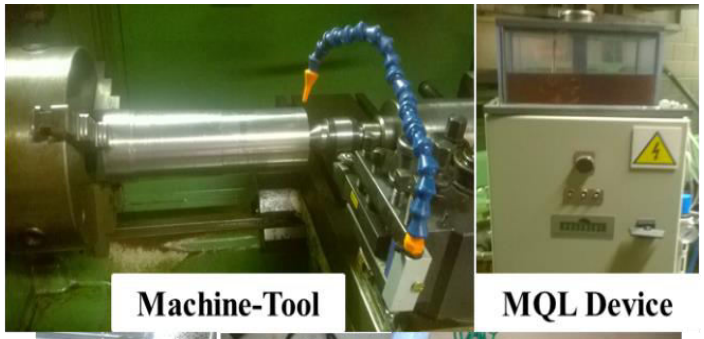


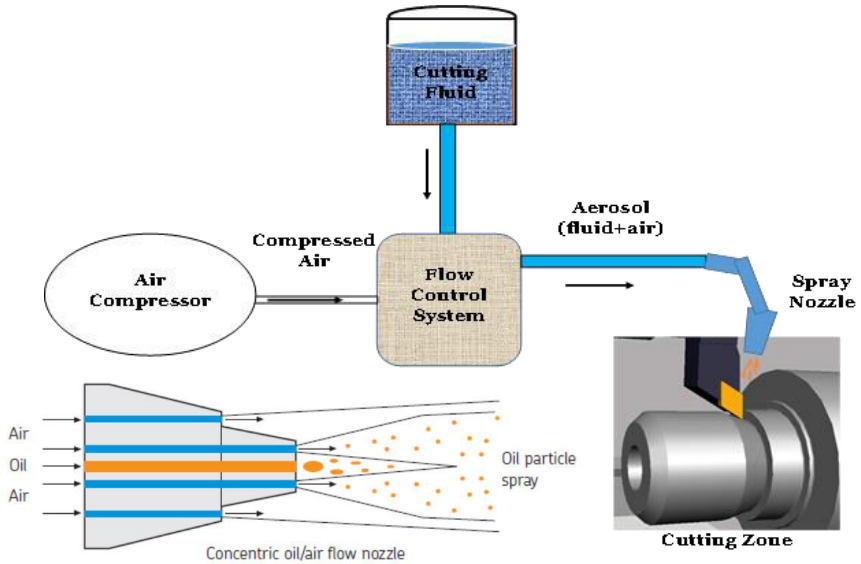


Kapil Gupta (2019), "Developments in Conventional Machining for Sustainability-A State of Art Review". Proceedings of the International Conference on Industrial Engineering and Operations Management, Toronto, Canada, Oct 23-25, 2019 pp 890-896. ISSN: 2169-8767 ISBN: 978-1-5323-5949-1.

Kapil Gupta and Munish Kumar Gupta **(2019)**, "Developments in Non-Conventional Machining For Sustainable Production-A State of Art Review", **Proc. IMechE, Part C: Journal of Mechanical Engineering Science** (Sage), 233 (12), 4213-4232.

Minimum Quantity Lubrication in Metal Cutting

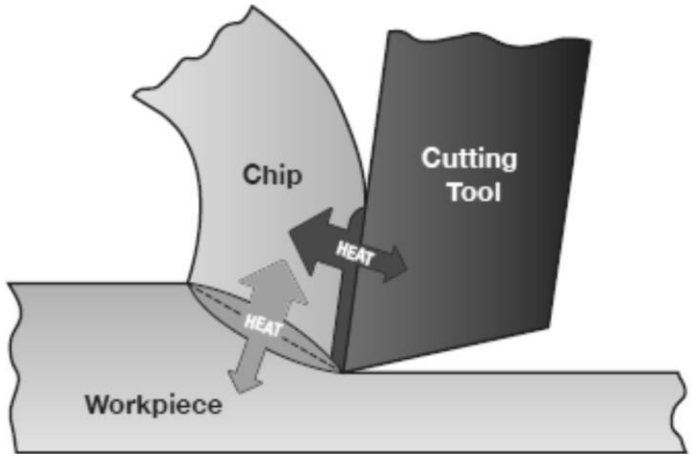




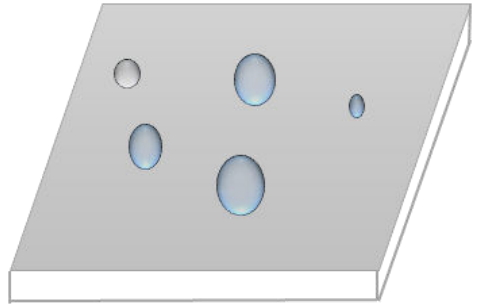
Heat Generation in Metal Cutting

Flood Cooling

Non-uniform lubrication at the work and tool surface

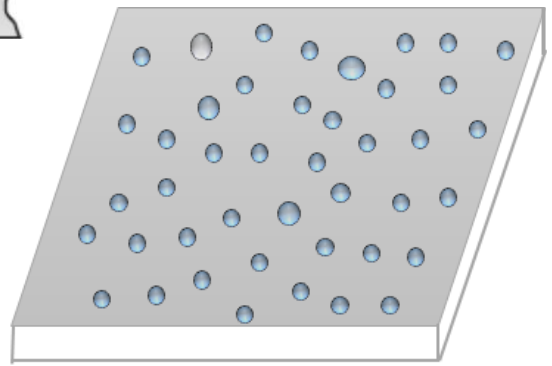


- Primary shear zone
- Secondary shear zone



MQL

Uniform lubrication



Important Facts abt MQL:

- **'MQL is used as a lubrication method rather than cooling**

(It does not **take heat out of the tool or the work piece rather it reduces only the amount of heat produced** by the chip moving up the face of the tool and the energy used to slide the cutting tool over a freshly cut work surface)

'Manages the heat rather than Eliminate'

- **'Micro-lubrication technique' facilitates Near-dry machining**
- **Utilizes vegetable oils or synthetic esters, less harmful**
- **Consumption of cutting fluid only 10-150 ml/h**

MQL Parameters:

- Air pressure
- nozzle distance
- flow rate

Advantages offered by MQL:

- ✓ Effective lubrication
- ✓ Use of extremely small amount of oil
- ✓ Permits high machining speeds
- ✓ Results in much better work surface integrity
- ✓ Long tool life ✓Low power consumption
- ✓ Reduces environment emissions and wastes

Textured Tools in Metal Cutting

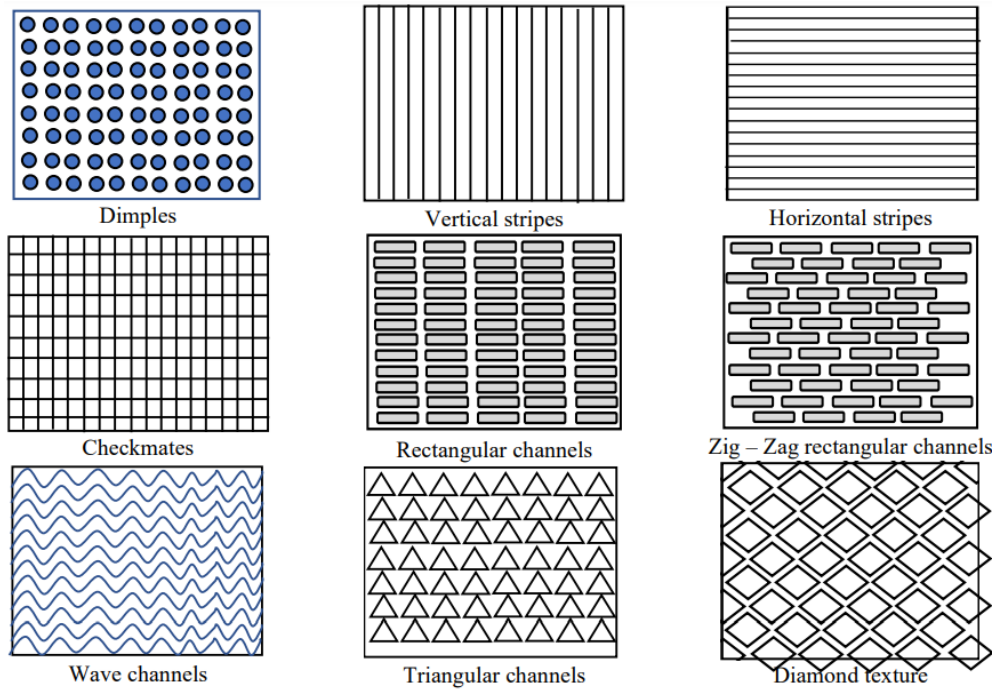
Texturing by
Laser engraving, ion beam texture process, electro-discharge machining, electrochemical processing and photolithography techniques

dimples, holes, grooves and tracks in different angles

Flank and Rake Face of Carbide Tools
Decreases
Friction, thermal/heat energy gradient, Tool Wear
Converts
Adhesive type severe Wear to Abrasive Wear when Machining Superalloy type DTM Materials even in Dry environment
Longer Tool Life compared to non-textured tools and makes High Speed Machining possible

to reduce the friction,
manage the machining heat, and
facilitate chip removal

Minimizes the cutting fluid requirement

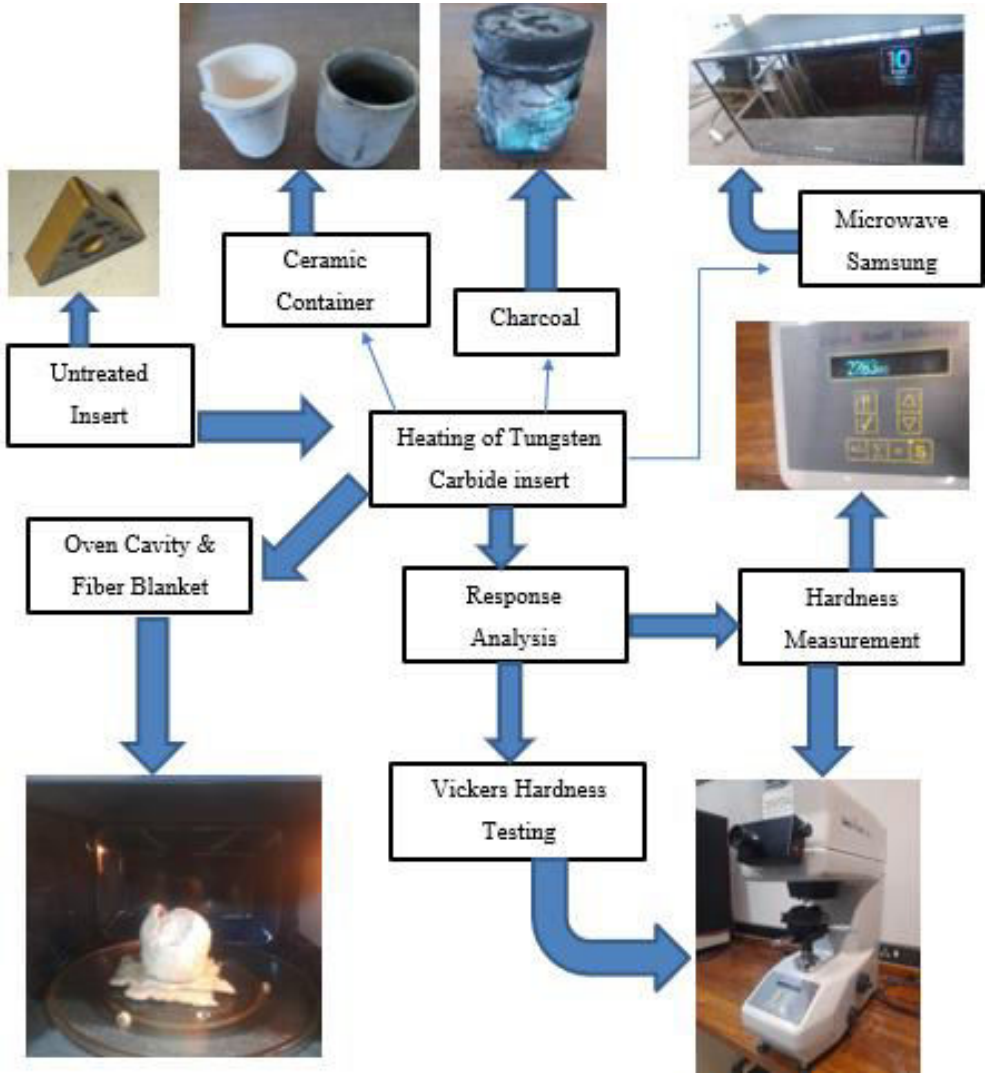


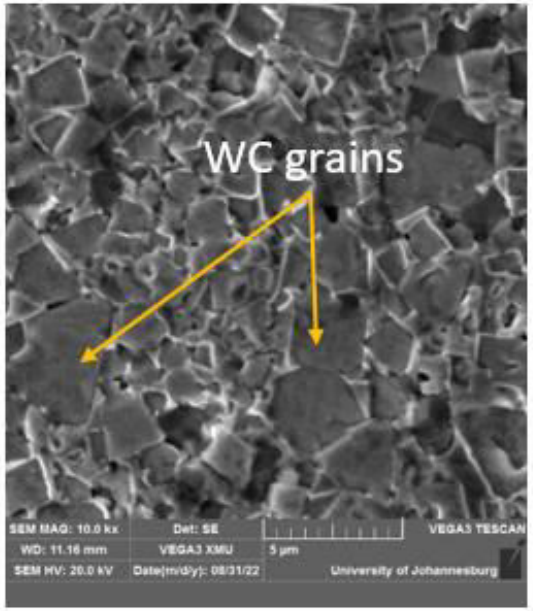
Can reduce the tool–chip friction coefficient and the chip thickness ratio

Adam Khan M and **Kapil Gupta (2020)**, "A Study on Machinability of Nickel based Superalloy using Micro-Textured Tungsten Carbide Cutting Tools", **Materials Research Express** (IOP Science), 7, 016537.

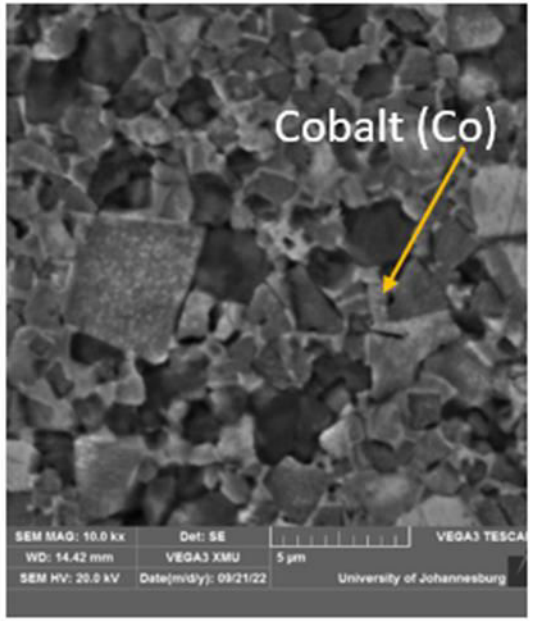
Case Study Microwave Treated Tool based Machining of SS316

Design of Experiment, Analysis, and Optimization for Machinability Enhancement of Stainless Steel 316 Using Microwave Treated Tungsten Carbide Cutting Tool Inserts

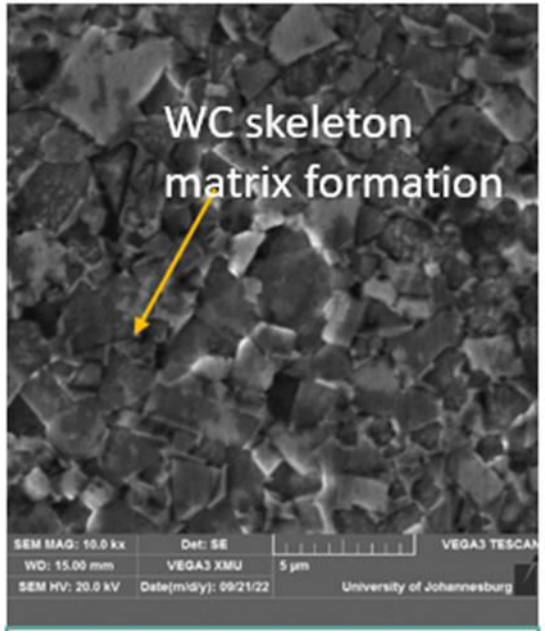




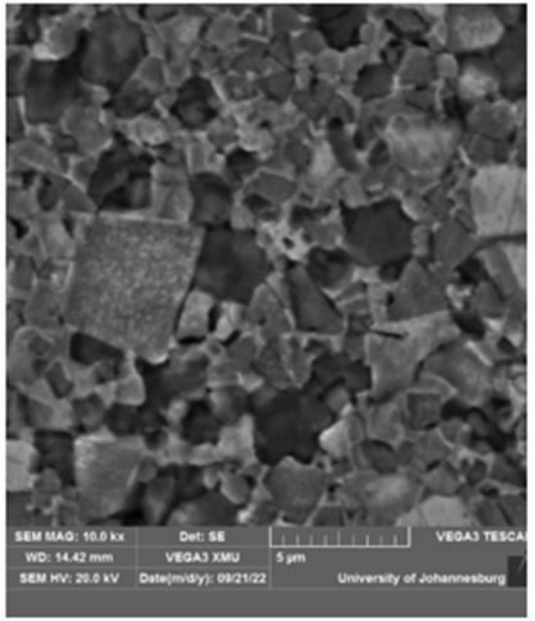
Plain tool



10 min treated tool

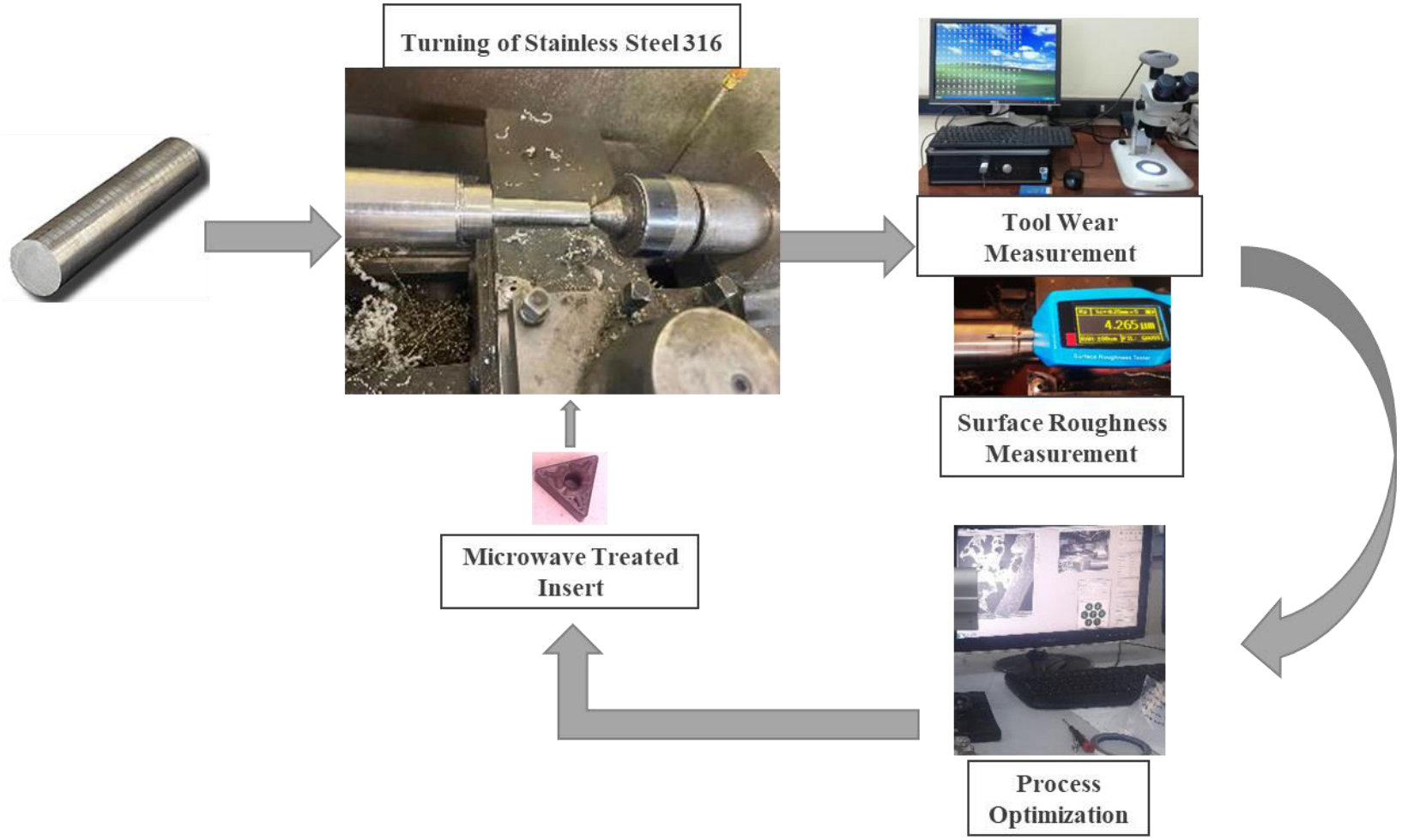


20 min treated tool

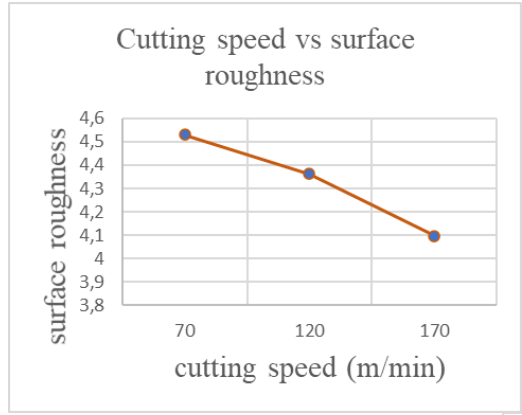


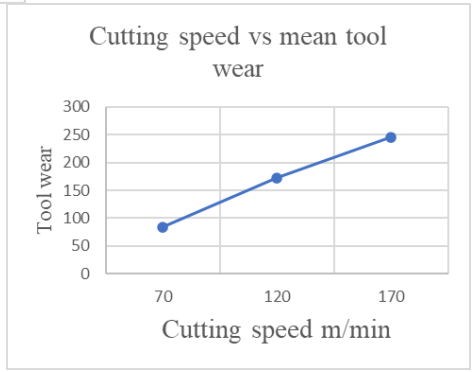
30 min treated tool

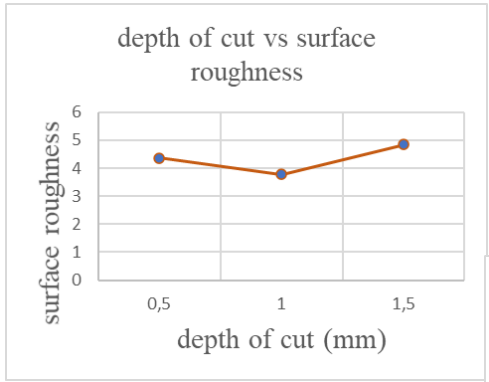
Trials	Plane WC insert tool	Microwave-treated WC insert tool		
		10 min	20 min	30 min
1	1724	1822	2160	2251
2	1604	1834	2160	2251
3	1734	1917	2033	2283
Average	1787.33	1857.7	2127.7	2261.7

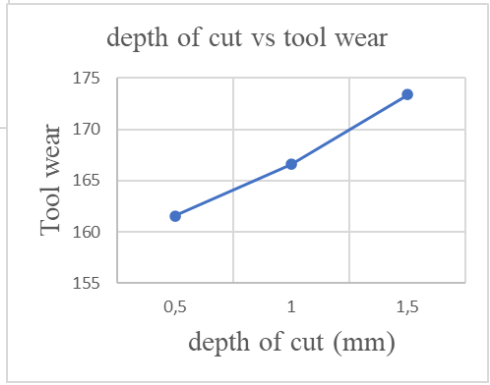


Machining time- 330 seconds


Cutting speed vs surface roughness
surface roughness
4,6
4,5
4,4
4,3
4,2
4,1
4
3,9
3,8
70
120
170
cutting speed (m/min)


Cutting speed vs mean tool wear
Tool wear
300
250
200
150
100
50
0
70
120
170
Cutting speed m/min


depth of cut vs surface roughness
surface roughness
6
5
4
3
2
1
0
0,5
1
1,5
depth of cut (mm)


depth of cut vs tool wear
Tool wear
175
170
165
160
155
0,5
1
1,5
depth of cut (mm)

Levels	Initial Setting Parameters	Optimum Parameters
Cutting speed (m/min)	70	170
Depth of cut (mm)	0.5	1.0
Feed rate (mm/rev)	0.1	0.2
Surface roughness (µm)	5.381	3.808
Tool wear (µm)	71.135	242.21
Grey Relational Grade	0.556	1

	Previous study				**Current study**	
Cutting insert tool type	Coated (TNMG 332EN-M60) & Uncoated (TNMG 160408-45)				(TNMG 160408-45)-Microwave heat treated	
Hardness of the insert tool	Coated (1460 HV) & Uncoated				Before heating (1734 HV) & after heating (2127.7 HV1)	
Work piece material	Stainless steel 304				Stainless steel 316	
Results						
	Uncoated		**Coated**		**20 min heat treated**	
Machining Responses (Tw, Rz)	**Tw(µm)**	**Rz(µm)**	**Tw(µm)**	**Rz(µm)**	**Tw(µm)**	**Rz(µm)**
Experiment 1	168.3	5.442	92.52	5.505	71.135	5.381
Experiment 2	286.8	9.562	231.8	8.687	168.78	5.366
Experiment 3	462.9	8.892	399.2	7.144	258.785	3.808

University of Johannesburg

Quacquarelli Symonds (QS)

7 Faculties

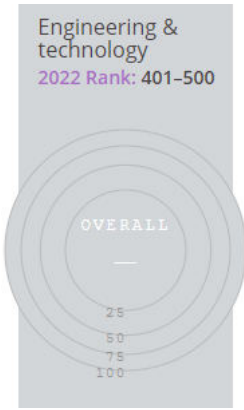
Faculty of Engineering and the Built Environment

13 Departments under 5 Schools

School of Electrical Engineering
School of Civil Engineering and the Built Environment
School of Mechanical and Industrial Engineering
School of Mining, Metallurgy and Chemical Engineering
Postgraduate School of Engineering Management

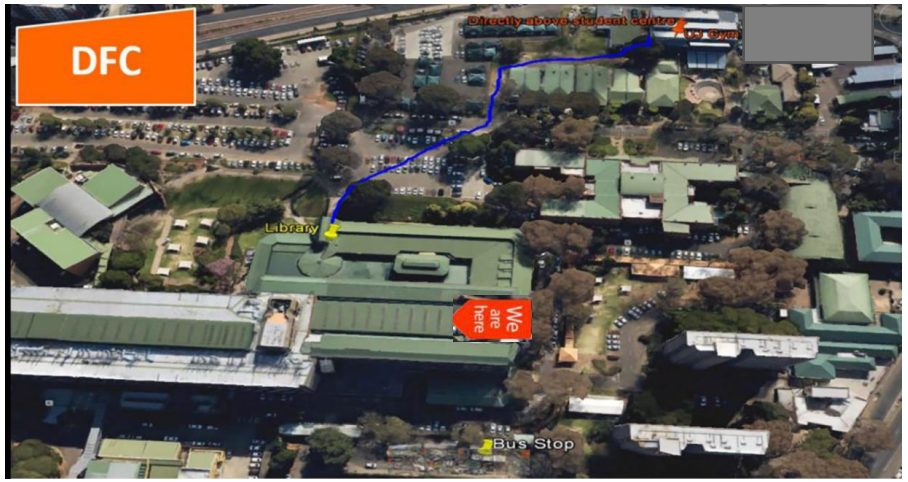
Department of Mechanical Engineering Science
Department of Mechanical and Industrial Engineering Technology
Department of Industrial Engineering Technology
Department of Quality and Operations Management

601–800th
World University Rankings 2022



Department of Mechanical and Industrial Engineering Technology

Doornfontein Campus (DFC)
Doornfontein, Johannesburg
Total 4 Campuses



BEngTech (Hons)- 4 Years
BEngTech- 3 Years
Masters and Doctoral Degree Courses
25 Faculty Members

Specialization/Expertise-Research Groups

-Advanced Materials Processing and Manufacturing
-Industrial Engineering, Quality, and Management-
-Energy Systems and Infrastructure
-Engineering Education
-Industry 4.0 and Sustainability

State-of-the-art Facilities

Fibre Laser, 3D Printers, EDM & WEDM CNC Machining Centres, Metal Casting Technology Station, Nano-Tribology Lab, Atomic Layer Deposition Centre,
Injection Moulding, Robotics and Material Handling Devices
Measurement, Testing, Characterization Facilities- Roughness and Microhardness Testers, XRD, SEM, TEM

School of Mechanical and Industrial Engineering, Quality and Operations Management

Vision and Mission

A school that pursues excellence in its academic and research output and establishes itself as an internationally acclaimed and recognized School in Mechanical, Industrial, Quality and Operations.

Vision

To become and sustain as the most academically productive school at UJ by contributing towards UJ's Strategic Objectives and being aligned with its policies and procedures.

Mission

To work for the growth of UJ and its stakeholders especially the school and faculty members and students, and to provide them mentorship and assistance to achieve excellence and sustainability.

Strategic Objectives

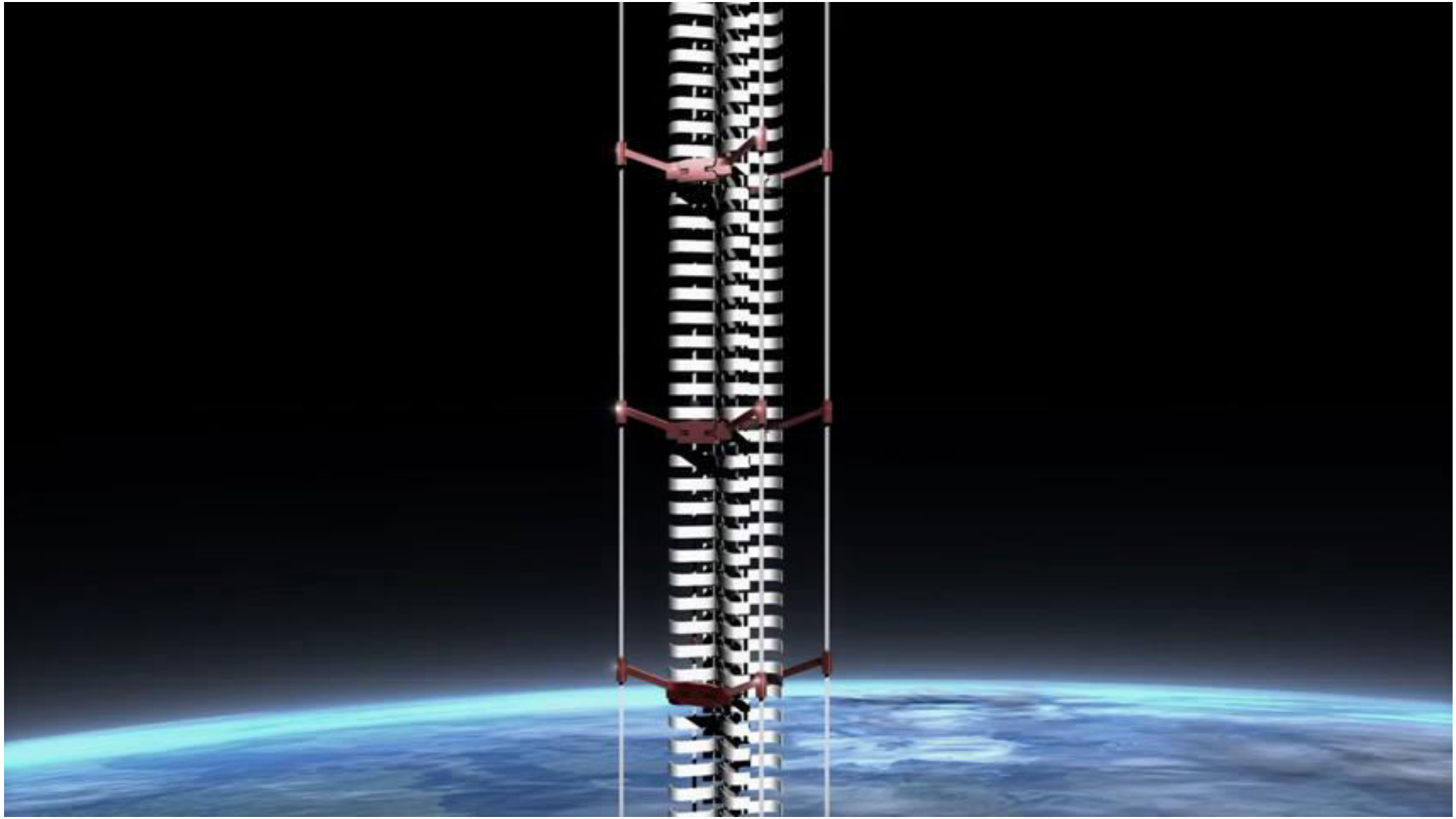
1. **Excellence in Research and Innovation**
2. **Excellence in Teaching and Learning**
3. **International Profile for Global Excellence and Stature**
4. **Enriching Student-Friendly Learning and Living Experience**
5. **National and Global Reputation Management**
6. **Fitness for Global Excellence and Stature, including Sustainability**

by

Mentorship Leadership Partnership

PURSUING EXCELLENCE

Corporate Video of the University of Johannesburg



Possible Collaboration Opportunities

Joint Conferences, Webinars, Summer Schools, Workshops

Collaborative projects funded by European Agencies

Joint publications and students' supervision

Journals' Sp. Issues

Edited and/or Authored Books for the series I am editing

CRC Press

Series 1- Advanced Materials Processing and Manufacturing
https://www.routledge.com/Advanced-Materials-Processing-and-Manufacturing/book-series/CRCAMPM

Series 2- Industrial Engineering, Systems, and Management
https://www.routledge.com/Indutstrial_Engineering_Systems_and_Management/book-series/%20CRCIESM

Conclusion and Call To Action

- **Sustainability is a Global Responsibility**
- SDG based Teaching and Research is the need of the day
- Novel and Sustainable Techniques can strengthen the three pillars

  Society, Economy, Environment of SUSTAINABILITY

Call to Action: Let's Collaborate To Contribute towards a Sustainable World

DZIĘKUJĘ