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Experimental Investigation of Mustard Oil Based Nano Cutting Fluid on CNC Turning Operation

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Abstract: ***The surface roughness is paying a very dominant role in manufacturing industries. It is one of the parameters that cannot be avoided in machining process. Investigation was done on turning EN19 with TIC-coated carbide insert in a CNC lathe. During machining on titanium, the high cutting temperature found, because of that friction in tool causes, for that purpose we are carry more cutting fluid, cutting tool & actual machining parameter.***
The present work shows the concentration of multi-walled carbon nanotube (MWCNT) is in used. The Nano fluid is prepared by using various ratios of nano-particles (MWCNT), blended oil as a base fluid. The statistical planningof the experiment is done by using Taguchi method.

I. INTRODUCTION

Machining is a process in which a cutting tool is used to remove small chips of material from the workplace. It is required for desired shape & size of the product. The main forces on machining asper customer requirements the product should be at low cost & good quality. Almost all industriesoutput products are depending on surface quality, cutting force, tool wear, power consumption etc. while machining, a large amount of heat generated at the tip of tool in such condition cutting fluidplaying very important role as a coolant to reduced that kind of problems during machining. Steel and its alloy have the prime choice for many fields of applications.

This grade possesses high strength to weight ratio, ductility, Corrosion resistance. we take this material as a challengingbecause it is hard to machine. so, to achieve the success on EN19 we need to take proper selection of method, machining parameter, cutting tool & most important cutting fluid.

In the work dry machining, Conventional machining, pure MQL (only Base fluid), and nano fluidare cared out by using cutting fluid on (EN19).

we compare that on which Parameter the good surfaces finish obtained.

While dry machining it is observed that the high temperature occurs in this process required cutting tool to withstand elevated temperature. In conventional cooling method Causing problem for the manufacturers, as substance present in them caused serious health effects on the worker and secondary environment, for the environmental safety pure MQL (only base fluid) is prepared as a cutting fluid on turning operation. Then finally it comes to used nanofluid (MWCNT) with uncoated carbide insert for a good cutting fluid, high thermal conductivity and lower contact angle or higher weldability.

These properties help in reducing the operating temperature, cutting force, improvement in the life of tool and surface finish. Preparation shown that dispersion at nano particles in base fluid after the thermo physical behaviour of their fluids.

As per Study MNCNT was selected for preparing nano fluid as it has high thermal Conductivity than any other nano -particles. It has been found that Musturd oil as a base fluid comes into picture.

A. Turning Operation

Turning is the removal of metal from the outer diameter of a rotating work piece. Turningis used to reduce the diameter of the work piece, usually to a specified dimension, and to producea smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.

Turning is the machining operation that produces cylindrical parts. In its basicform, it can be defined as the machining of an external surface:

With the Work piece rotating.

With a Single point cutting tool,

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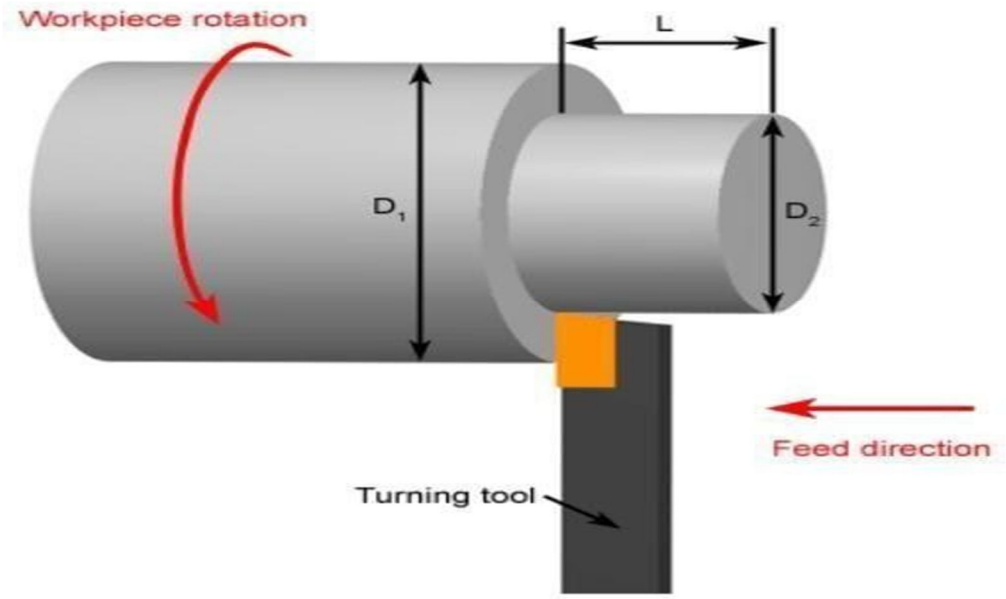


Figure 1.1: Adjustable parameters in turning operation

1) Adjustable Cutting Factors in Turning

The three primary factors in any basic turning operation are speed, feed, and depth of cut.Other factors such as kind of material and type of tool have a large influence, of course, but thesethree are the ones the operator can change by adjusting the controls, right at the machine.

a) *Speed:* Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute(rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before thecut is started. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though
The rotating speed remains the same.V=1000 m/min
Here, v is the cutting speed in turning, D is the initial diameter of the work piece in mm, and N isthe spindle speed in RPM.

b) *Feed:* Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cuttingpath. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.
Fm = f. N mm/min
Here, Fm is the feed in mm per minute, f is the feed in mm/rev and N is the spindle speed inRPM

c) *Depth of Cut:* Depth of cut is practically self-explanatory. It is the thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is important to note, though, that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of thework.

2) Nanocoolant

In recent years, remarkable improvement is shown by the inclusiveness of nanoparticles. Nanofluid offers heat transfer capabilities, reduction in coefficient of friction, wear effect to enhance the efficiency and reliability of machined parts. For improving the properties of lubricants or coolants, nano-size solid particles are dispersed into the base fluids such as water, lubricating oils, etc. Excellent properties of the Nano-fluid can be beneficial for cooling and lubricating in machining. Coefficient of friction can also be improved by implementing the Nano lubricants. Mending effect is achieved by the deposits made by the nano particles on the friction surface. Nanofluids seem to be potential replacement of conventional coolants in engine cooling system. Recently there has been considerable research findings reported which highlights superior heat transfer performances of Nanofluids.

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II. LITERATURE SURVEY

A. Literature Review

Laval, S.A. Choudhury (2012) [51] Higher material removal rate can be achieved with vegetable oil-based fluids. Vegetable oil based fluids are environmentally friendly. Vegetable oil-based fluids performed satisfactoryduring machining process.

Kuram, E, Ozcelik, B., Huseyin Cetin, M., Demirbas, E., & Askin, S. (2012) [52]

In this work, the machinability of AI 7075-T6 was tested using four different types of vegetable-based cutting fluids (VBCFs) in comparison to a commercial mineral cutting fluid. The addition of severe pressure improves the lubrication characteristics of VBCFs.

For performance studies of cutting fluids during force and tool wear data were collected.Compared to commercial mineral cutting fluid, VBCFs showed gains in cutting, feed and radial forces ranging from 1.70 to 38.25%.

With blended cutting fluid containing 12% of extreme pressure, the lowest averageflank and nasal wear values for the commercial mineral cutting fluid were 0.18 and 0.15 mm. The results of the scanning electron microscope revealed that the rake had workpiece material attached to it.

Gugulothu, S., & Pasam, V. K. (2020)[53]. Due to the synergistic effect of the distinct nano materials disparate properties working together in the base fluid, hybrid nano-fluids have the potential to be used in a wide range of engineering applications including heat transfer.

In the current work, a total of six samples of hybrid nano cutting fluids in a range of concentrations were generated. In order to characterise fluids following a sedimentationtest and determine whether they might be used in machining in MQL mode. As the concentration of CNT/MoS2 nanoparticle in sesame oil increased, thermal conductivity, specific heat, and viscosity also increased. The pin-on- disc test demonstrated that the coefficient of friction reduced as particle concentration grew up to 2% by weight beyond that point, then slightly increased. 2 wt% concentration of CNT/MoS2 hybrid nano cutting fluid has demonstrated improved performance in reducing the cutting forces, temperature, surface roughness and tool flank wear compared to other concentrations.

Chinnasamy Natarajan [50] Considering the individual parameters, feed rate has been found to be themost influencing parameter, followed by spindle speed and depth of cut. that the average percentage of error is 12.93%.

B. Research Gap

From the literature we found that turning operation of (Steel alloy- EN19) has done. But this operation hasalso performed on various different condition such as dry machining, conventional cooling, pure MQLandcutting fluid. considering Our response parameter is surface roughness so that we are using nano-fluid. Because the nano-fluid have high thermal conductivity. Due to high thermal conductivity, it reduces cutting temperature, tool wear, and the lower values of machining parameters. Practically it is not possibleto be produced perfectly smooth surface finish by any manufacturing process. The poor surface quality falls to satisfy functional requirement of product. While extremely high surface quality causes high production cost and low overall productivity.

So, to full-fill the research gap of our project we are using the combination and permutation method.

For further process the selection of nano-fluid is MWCNT. We are added this nano- fluid in base fluidto prepare the cutting fluid. According to research, Coconut oil, Mustard Oil and blended oil (Mustard oil
+ coconut oil) considered as a base fluid. Because the cooling property of vegetable- based cuttingfluid offers a competitive performance with that of conventional mineral- based oil.

we proposed the new thing in this study that is blended oil as a base fluid.

The blended oil is a mixture oftwo fluid like 50% of coconut oil + 50% of Mustard oil that we proposed in this work.

The many researchers used blended oil as a pure base fluid but not any research found on the combination of blendedoil with nano material.

So, we proposed in this study that is BLENDED OIL (MUSTARD OIL + COCONUT OIL)/ MUSTARDOIL/ COCONUT OIL + NANO MATERIAL (MWCNT)

III. RESEARCH METHODOLOGY AND EXPERIMENTATION

1) *Selection Of Work Piece Material:* The cylindrical bar of 20mm diameter and 30mm length of commercially available alloy steel (EN19) has been selected for the present investigation.
2) *Selection of Tool Insert:* The cutting tool preferred for turning of steel alloy (EN19) was square shaped TIC-coated carbide inserts.The insert use in current study were ISO designation of WNMA 080408. The cutting insert were mounted on a tool holder that have ISO designationPSBNR2020K12.

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3) Machining Parameters:

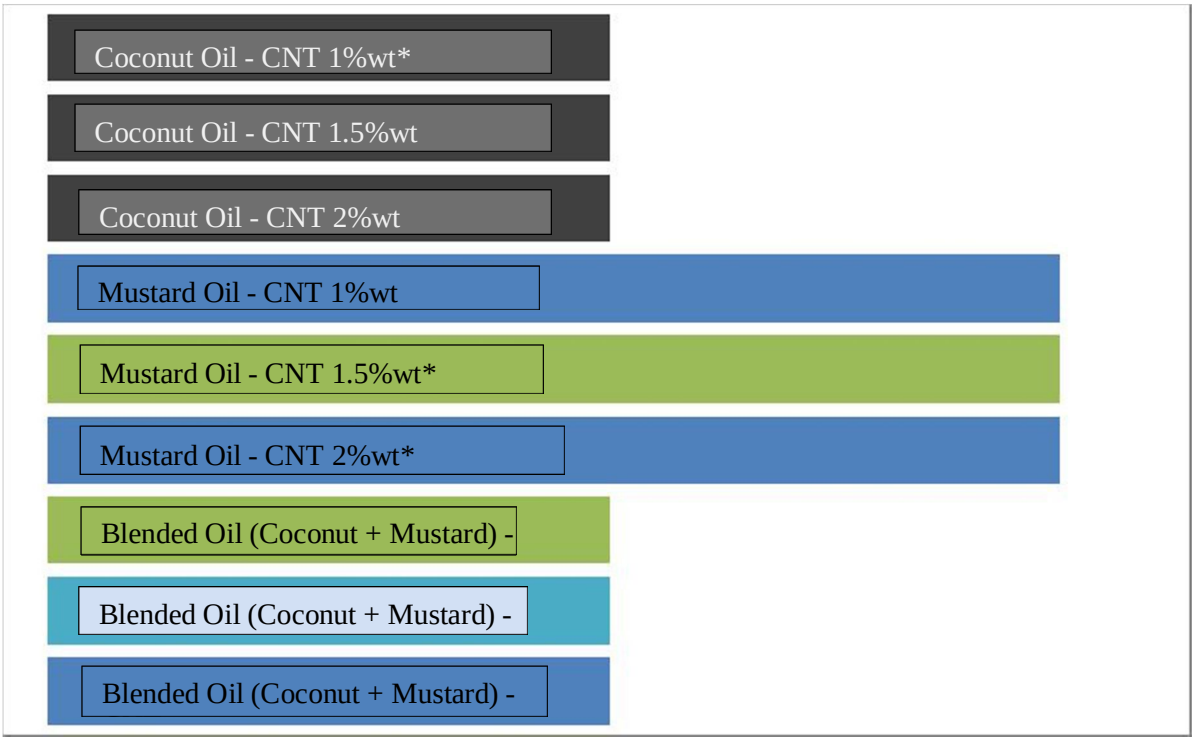
Machining Parameters	Unit	Level		
		Level 1	Level 2	Level 3
Cutting Speed *'Vc'*	m/min	90	120	150
Feed Rate *'f'*	mm/rev	0.18	0.27	0.36
Depth of Cut *'dc'*	mm	0.2	0.4	0.5

4) Characterization of Nano particles: After selection of nano particles, we are done characterization by SEM-EDX (Scanning Electron Microscope & energy dispersive x-ray) FTIR (Fourier Transform Infrared Spectroscopy) XRD (X-ray diffraction analysis) TGA (Thermogravimetric analysis)BIT (Brunauer–Emmett–Teller)

5) Nano-Fluid Preparation

a) According to research, we have adopted to take Mustard oil [3], Coconut oil [4] and blended oil(50% of Mustard oil + 50% of coconut oil) [5] as a base fluid.

b) Then we added MWCNT (1%, 1.5%, 2%) nanoparticle with base fluid.



FLOW CHART OF NANO-FLUID PREPARATION

- *Design Of Experiment By Taguchi Method*

The L9 array is formed with the help of Taguchi Method.

- *MQL Setup*

Setting the arrangement of MQL with compressor having pressure 1 MPa

- *Turnin Operation*

Turning operation is done with L9 ORTHOGNAL ARRAY and different cooling condition (drymachining, conventional cooling, pure MQL, nanofluid MQL.

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- *Result*

Surface roughness is to be measured.

- *Analysis*

Analysis was done by using ANOVA method.

IV. NANO COOLANTSYNTHESIS

A. Sonication

The process in which sound waves are used for agitating the particles in the solutions. These disruptions are used for mixing of the solutions, to increase the speed of dissolution of a solid into a liquid, and for the removal of dissolved gases from the liquids. The process in which sound waves are used for agitating the particles in the solutions. These disruptions are used for mixing of the solutions, to increase the speed of dissolution of a solid into a liquid, and for the removal of dissolved gases from the liquids The sonication process uses ultrasonic sound waves. During the process, there is a production of thousands of microscopic vacuum bubbles in the solution due to applied pressure. The formed bubbles collapse into the solution during the process of cavitation. The collapsing of bubbles takes place in the cavitation field leading to the generation of enormous energy as there is a production of waves. This results in the disruption of the molecular interactions between the molecules of water. As there is a reduction in the molecular interactions, the particles start to separate and allow the mixing process to take place. There is a release of energy from the sound waves that result in friction in the solution. Sonication is the most important process in the preparation of nanofluids. Sonication is carried out in anultrasonication path, ultrasonic vibrator, and mechanical homogenizer following the magnetic stirring of mixture in magnetic stirrer. Ultrasonication frequency is reported to be 20–40 kHz. Apart from sonication frequency and power, sonication time is the most crucial part of the process. Stability of the prepared nanofluid is greatly dependent on the time of sonication. Researchers have linked the stability of the nanofluids directly with the sonication span; however, there comes a point past which the stability and thermophysical properties start to deter. Time taken by the three samples is 3 hours, thus our nine samples takes time about three hours.



FIGURE: Sonicator Top view

B. Experimentation

1) Selection of Work piece and Tool: The cylindrical bar of 20mm diameter and 30mm length of commercially available alloy steel (EN19) has been selected for the present investigation. Alloy Steel have become best material choices in aerospace, marine petro-chemical, medical, nuclear and energy industries due to theirinherent assets such as highest strength-to-weight ratio and excellent resistance to corrosion and deformation under high temperature and pressure.

However, the foremost challenge that encounter during Steel machining includes generation of high temperature at cutting zone owing to its low thermal conductivity. The chemical affinity of these alloys is also reported more than that of other similar materials. Therefore, Steeland its alloys are specifically characterized as hard-to-cuttype material. Poor thermal conductivity leads to rapid upsurge in temperature near machining zone particularly at chip-tool interface region. High temperature at cutting zone sturdily accelerates tool wear and hence reduces the tool life to agreat extent. Further, steel and its alloys are capable of maintaining their strength even at higher temperature (because of highest strength-to-weight ratio) which at the same time contributes to deteriorate the performance of cutting tool inserts while machining at higher cutting speed. High chemical affinity of titanium alloys often offers severe tool damage at pre mature stage beyond the aforementioned speed limit.

Therefore, in order to attain a reasonable tool life along with good surface quality even at high cutting speeds, an efficient and effective cooling or lubrication approach should be applied. In such situations, cutting fluids such as water-soluble oil and vegetable oil are strategically employed as cooling media to reduce the temperature at chip-tool interface region. It also helps in improving surface quality and wearresistance in combination with substantial reduction in cutting forces.

Chemical composition of EN19 as shown in table.

Element	Content (%)
Carbon, C	0.35 to 0.45%
Manganese, Mn	0.5 to 0.8 %
Silicon, Si	0.5 to 0.8%
Chromium, Cr	0.9 to 1.5 %
Sulfur, S	0.05 %
Phosphorus, P	0.035 %
Molybdenum ,Mo	0.2 to 0.4



FIGURE: EN19 alloy steel

2) Advantages of DOE

With real engineering examples, Czitrom listed the following advantages of DOE:

1) A good amount of data can be obtained with lesser resources (experiments, time, material,etc.).
2) The estimates of the effect of each factor (variable) on the response are more precise.
3) It is a systematic way to estimate the interactions between the process factors.

A survey was carried out within the industry which identifies the needs of using an efficient and practical technique for the experimentation. It was surveyed that 76% of industries con-sider themselves in need of a methodology. So here are listing some of the techniques that are in use in Industries. The list of the techniques considered is far from being complete since the aim of the section is just to introduce the reader into the topic showing the main techniques which are used in practice.

3) L9 Orthogonal Array

Total Degrees of Freedom: 9

The most suitable orthogonal array for experimentation is L9 array as shown in TableTherefore, a total nine experiments are to be carried out.

Table no: 4.4 L9 ORTHOGONAL ARRAY

Experiment No.	Control Factors		
	Cutting speed	Feed rate	Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

For the turning operation on CNC machine, we select the four different conditions Dry turning, conventional cooling, MQL turning with rice bran oil as a base fluid and another again MQL with edible oil as a base fluid. Then finally we get nanofluid MQL. Following is the experimental tablefor all this condition showing the range of Cutting speed, feed rate, and depth of cut.

V. SUMMARY AND CONCLUSION

A. Summary

Design of Experiments was done by Taguchi's technique. For three parameters and three levels L9 orthogonal array was selected. From the study the selected levels are cutting speed 90, 120, 150 feed rates are 0.18, 0.27, 0.36 and depth of cut are 0.2, 0.4, and 0.5.

B. Conclusion

1) ANOVA test has been accomplished to determine the significant cutting parameter for the
2) surface roughness. From the above analysis, cutting speed was observed as the most significant parameter on Taguchi method. It has the percentage contribution of %followed by feed rate which has contribution effect of % and depth of cut has been notified as thirdmost effective machining variable with %
3) Nanofluid MQL significantly reduces cutting force and tool-tip temperature when compared to conventional cooling, pure MQL and dry machining. This is due to excellentthermal conductivity of MWCNT which facilitates effective heat dissipation from the cutting zone and hence better cooling effect and surface finish is obtained.

C. Scope for Future Work

1) In our project we have proposed the concentration of nano material and combination ofbase fluid (blended oil) to study the various effect of technologies on surface finish.
2) The future scope of this project is to find the effect of those concentration/ combinationon material, chip formation, analysis of chip properties, Analysis of thermal stresses induced during machining processes.

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VI. RESULT

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TEST REPORT

To, Prof. Suhas Rewatkar
J. D. College of Engineering & Management,
Nagpur.

T.R.No. PMS/22/O-614-1
Date. 07/10/2022
Pg. 01/01

Received Under Your Challan No. SRAF — Dt. 25/09/2022
Date of receipt of sample: 25/09/2022 — Lab Ref.: 22-O-614

Description / Identification of sample: 1) Steel Samples to check surface roughness. — No. of Samples: 16

Sample Drawn By: Party

Standard Specification / Test Compliance: ---

The above sample has been tested and the results are as below: -

SURFACE ROUGHNESS

Date of Performance: 07/10/2022 — Test: RA Value
Instrument: Vertex
Observations:

Sample ID .	Sample ID .	Readings (RA µm)	Average (RA µm)
Regular Coolant	N9	0.63, 0.40, 0.55	0.53
	N4	1.93, 2.20 , 1.40	1.84
	N1	2.39, 2.0, 1.59	1.99
1.5 % CNT+ Coconut	6.5	1.15, 1.26, 1.20	1.20
	6.7	1.83, 1.69, 1.74	1.75
	6.2	1.63, 1.53, 1.59	1.58
Dry Only	D2	0.69, 0.50, 0.55	0.58
	D5	0.72, 0.57, 0.63	0.64
	D9	1.10, 1.07, 1.02	1.06
1 % CNT + Coconut +Mustard	7.3	1.31, 1.24 ,1.13	1.22
	7.6	1.23, 1.19, 1.21	1.21
	7.9	1.30, 1.19, 1.45	1.31
1.5 % CNT+ Mustard	5.1	0.53, 0.45, 0.52	0.50
	5.6	1.22, 1.09, 1.16	1.16
	5.9	1.45, 1.25, 1.58	1.43
1% CNT + Mustard	8.1	0.51, 0.53, 0.52	0.52

Observation found in respect of the sample tested.

Project Name : **Experimental Investigation of Nano coolant on CNC turning operation**

Prepared by:
(Partik More)

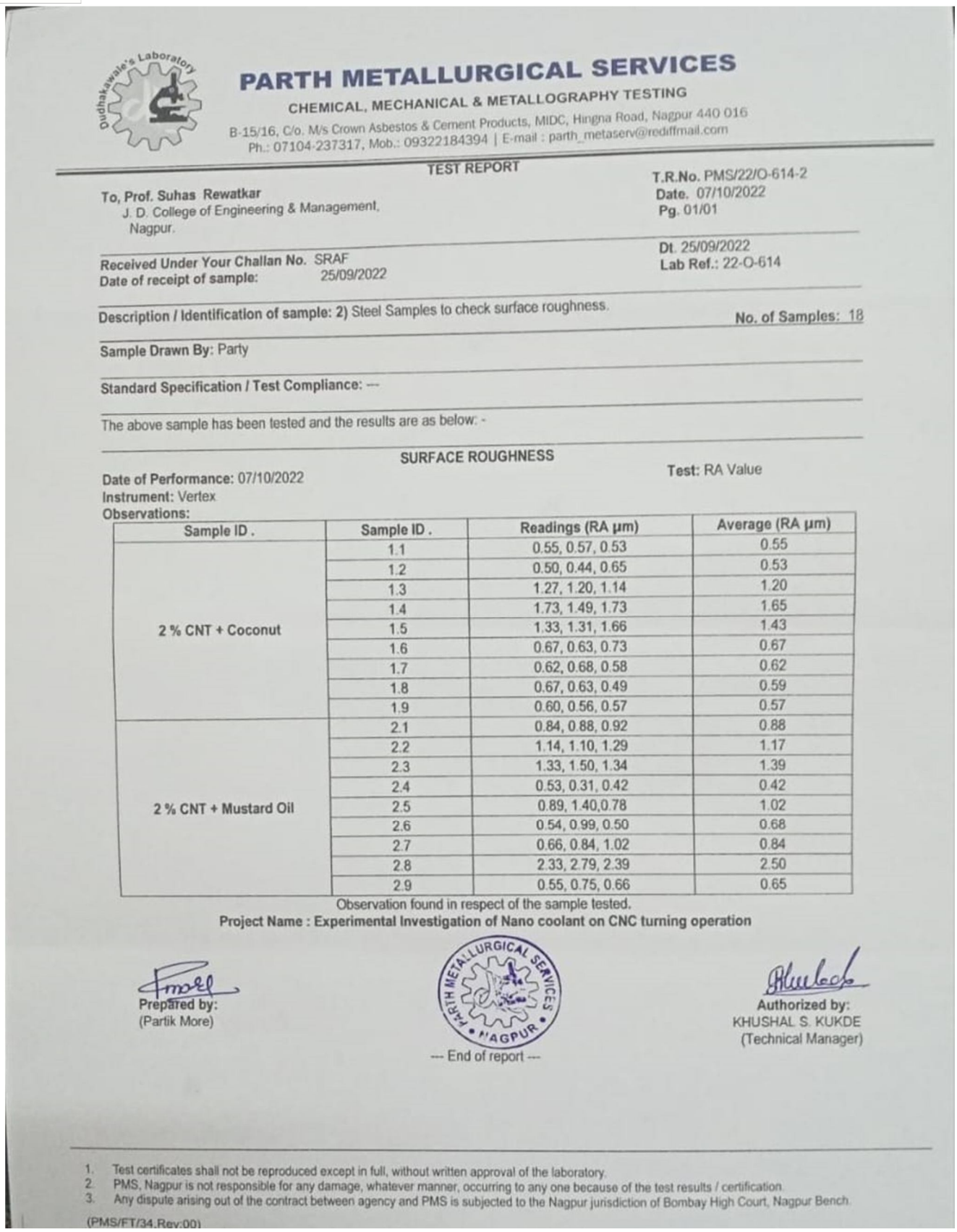
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Authorized by:
KHUSHAL S. KUKDE
(Technical Manager)

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To, Prof. Suhas Rewatkar
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T.R.No. PMS/22/O-614-2
Date. 07/10/2022
Pg. 01/01

Received Under Your Challan No. SRAF
Date of receipt of sample: 25/09/2022

Dt. 25/09/2022
Lab Ref.: 22-O-614

Description / Identification of sample: 2) Steel Samples to check surface roughness. No. of Samples: 18

Sample Drawn By: Party

Standard Specification / Test Compliance: ---

The above sample has been tested and the results are as below: -

SURFACE ROUGHNESS

Date of Performance: 07/10/2022
Instrument: Vertex
Test: RA Value
Observations:

Sample ID .	Sample ID .	Readings (RA µm)	Average (RA µm)
2 % CNT + Coconut	1.1	0.55, 0.57, 0.53	0.55
	1.2	0.50, 0.44, 0.65	0.53
	1.3	1.27, 1.20, 1.14	1.20
	1.4	1.73, 1.49, 1.73	1.65
	1.5	1.33, 1.31, 1.66	1.43
	1.6	0.67, 0.63, 0.73	0.67
	1.7	0.62, 0.68, 0.58	0.62
	1.8	0.67, 0.63, 0.49	0.59
	1.9	0.60, 0.56, 0.57	0.57
2 % CNT + Mustard Oil	2.1	0.84, 0.88, 0.92	0.88
	2.2	1.14, 1.10, 1.29	1.17
	2.3	1.33, 1.50, 1.34	1.39
	2.4	0.53, 0.31, 0.42	0.42
	2.5	0.89, 1.40,0.78	1.02
	2.6	0.54, 0.99, 0.50	0.68
	2.7	0.66, 0.84, 1.02	0.84
	2.8	2.33, 2.79, 2.39	2.50
	2.9	0.55, 0.75, 0.66	0.65

Observation found in respect of the sample tested.

Project Name : Experimental Investigation of Nano coolant on CNC turning operation

Prepared by:
(Partik More)

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Authorized by:
KHUSHAL S. KUKDE
(Technical Manager)

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TEST REPORT

To, Prof. Suhas Rewatkar
J. D. College of Engineering & Management,
Nagpur.

T.R.No. PMS/22/O-614-3
Date. 07/10/2022
Pg. 01/01

Received Under Your Challan No. SRAF
Date of receipt of sample: 25/09/2022

Dt. 25/09/2022
Lab Ref.: 22-O-614

Description / Identification of sample: 3) Steel Samples to check surface roughness.

No. of Samples: 18

Sample Drawn By: Party

Standard Specification / Test Compliance: —

The above sample has been tested and the results are as below: -

SURFACE ROUGHNESS

Date of Performance: 07/10/2022
Instrument: Vertex
Test: RA Value
Observations:

Sample ID .	Sample ID .	Readings (RA µm)	Average (RA µm)
2 % CNT + Coconut + Mustard	3.1	1.03, 1.01, 0.85	0.96
	3.2	3.14, 3.28, 3.20	3.20
	3.3	1.48, 1.10, 1.35	1.31
	3.4	1.45, 1.22, 1.08	1.25
	3.5	1.09, 0.89, 0.72	0.90
	3.6	1.30, 1.07, 1.41	1.26
	3.7	0.93, 1.07, 0.77	0.92
	3.8	0.41, 0.51, 0.46	0.46
	3.9	1.68, 1.43, 1.50	1.53
1.5% CNT + Coconut + Mustard	4.1	1.32, 1.22, 1.12	1.22
	4.2	1.66, 1.82, 1.73	1.74
	4.3	0.75, 0.83, 0.70	0.76
	4.4	1.40, 1.60, 1.50	1.50
	4.5	1.23, 1.19, 1.21	1.21
	4.6	6.36, 6.10, 6.50	6.32
	4.7	1.70, 1.15, 1.30	1.38
	4.8	0.94, 0.89, 0.92	0.92
	4.9	6.15, 6.35, 6.72	6.40

Observation found in respect of the sample tested.

Project Name : Experimental Investigation of Nano coolant on CNC turning operation

Prepared by:
(Partik More)

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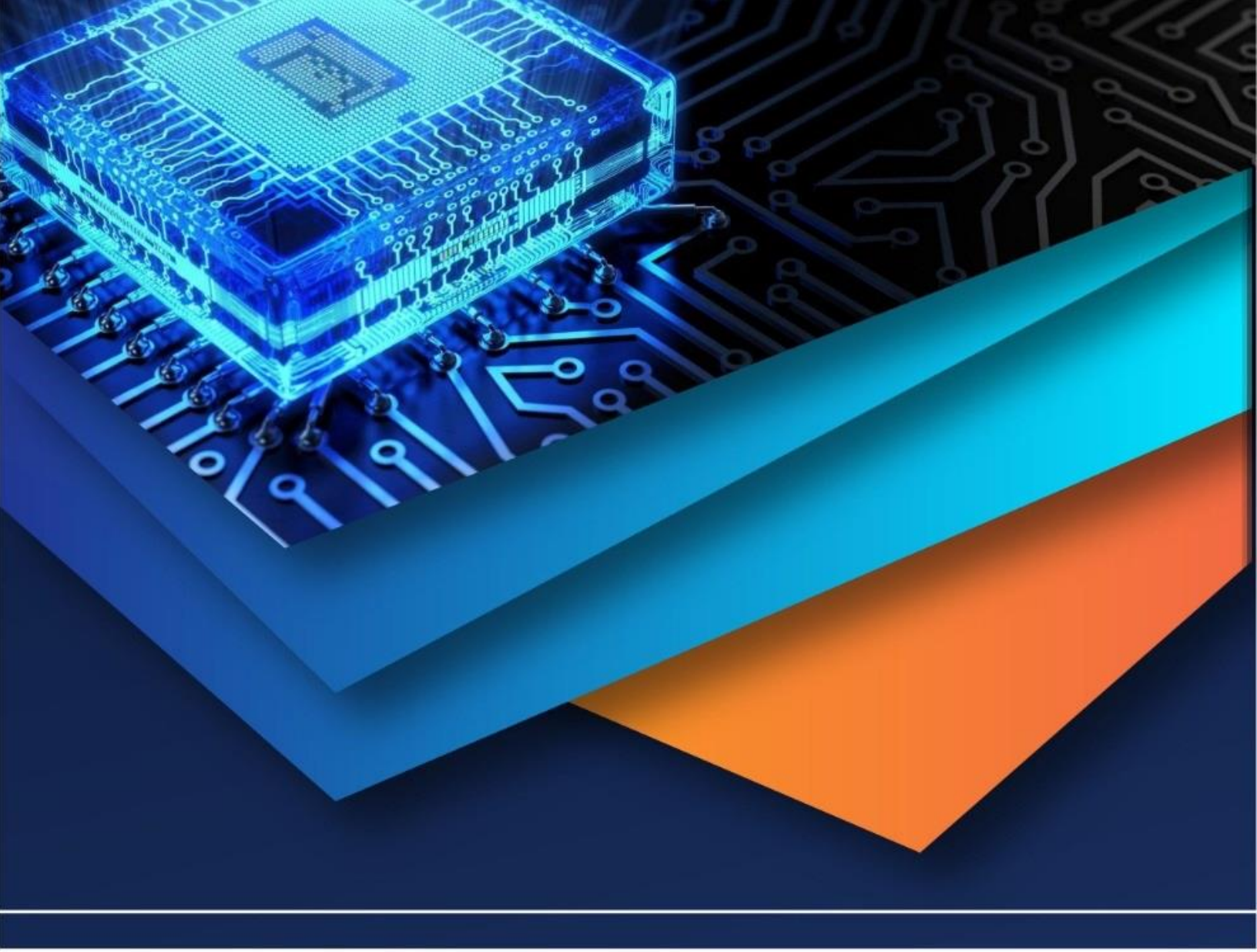
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