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Evaluating Machining Performance of Used Vegetable Oil as an Eco-Friendly Dielectric Fluid in Electric Discharge Machining

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Abstract: Electrical Discharge Machining is a spark erosion machining process where removal of material takes place between workpiece and tool electrode by electric discharges in presence of dielectric fluid. Despite of many advantages EDM still has some sustainability issues like more power consumption, emission of hazardous gases and operators health concerns. In this present study used vegetable oil is taken as alternate green dielectric fluid to investigate its effect on the output responses. Machining was done on superalloy superni 909 by considering discharge current, pulse on time, voltage, pulse off time and electrode as process variables. The responses like MRR, TWR, and SR were analyzed to check the feasibility of used vegetable oil as dielectric medium. Using Taguchi Design of Experiments a mathematical model is generated to study the effect of process parameters on output responses. The goal of this research is to provide eco-friendly environment by using green dielectrics which give satisfactory output.

Keywords: EDM, used vegetable oil, hybrid tool, MRR, TWR

1. Introduction

EDM is a non-conventional machining process which uses thermoelectric energy sources for machining hard and difficult to cut materials. The major advantage of EDM process is to produce high degree of accuracy and surface finish and to create complicated die counters in most intense to cut materials at elevated temperatures. Sparks are generated at high temperatures of about 13000k by high frequency electric energy due to disintegration of dielectric fluid. This high temperature will cause the workpiece material to melt and vaporize to get the desired shape and size of the component.

As stated by ISO 14000 sustainability is the major issue concerned with manufacturing or machining process in leveling commercial and environmental views. It is vitally important for the manufacturing industries to be focused on reducing environmental impact and cost for their products and process in addition to enhancing the quality. This viewpoint is used to reduce the cause of pollution to attain green manufacturing that is in accord with ISO 14000 regulation. In this study used vegetable oil is exploited as dielectric fluid. Incorporating this oil will reduce the environmental pollution by mainly waste to use philosophy.

To meet the technological advancements in manufacturing industries new materials with good physical and mechanical properties are required. To reach this requirement superalloys with extensively high strength, heat and corrosion resistance can be employed. These properties make them a better choice for applications in harsh environmental industries like aerospace, petrochemical and automobile etc. The machinability of superalloys is difficult using conventional methods due to their superior properties. Therefore nontraditional machining methods are generally employed for cutting superalloys. EDM is a popular unconventional method which can be adopted for cutting superalloys.

2. Materials and methods

In the present work used vegetable oil sourced from cooking process is used as ecofriendly and cost effective alternative to conventional dielectric fluids. Sample of used vegetable oil is shown in figure 2.1. Superalloy superni 909 is used as workpiece. Four distinct hybrid tool electrodes are used to drill 10mm diameter holes on workpiece. The hybrid electrodes are prepared by varying the percentage of copper in aluminium 2021 in stir casting process. List of tools used is given in table below.

Taguchi Design of Experiments was used in planning the number of trials to get the optimum results. Discharge current, pulse on time, voltage, pulse off time and hybrid tool are selected as input parameters. Five input parameters are varied at four levels, their values are shown in table below**.** The feasibility of used vegetable oil as dielectric was checked by evaluating the output responses material removal rate (MRR), tool abrasion rate (TWR), surface roughness (SR).

Fig. 2.1 Sample of used vegetable oil

Fig. 2.2 Schematic diagram of EDM machine

S.No	Hybrid Tool	Al2021%	Cu%
1	T1	93.2	6.8
2	T2	86.4	13.6
3	T3	79.6	20.4
4	T4	75	25

Parameter	Units	Level 1	Level 2	Level 3	Level 4
Current(A)	A	10	20	30	40
Pulse on Time(μs)	μs	250	500	750	1000
Pulse off Time (μs)	μs	100	200	300	400
Voltage (V)	V	30	40	50	60
Electrode		T1	T2	T3	T4

3. Experimental procedure

The experimentations were carried out using ELECTRONICA ELECTRAPLUS PS 50 ZNC machine. The pictorial representation of experimental setup is shown in the figure 2.2. Experimentation was done as per L16 orthogonal array by setting the input parameters corresponding to each trial. MRR, TWR and SR were computed for each experiment by using the equations (1), (2). The results obtained are listed in table below.

$$\text{MRR} = \frac{\text{initial mass of workpiece} - \text{final mass of workpiece}}{\text{machining time}} \qquad (1)$$

$$\text{TWR} = \frac{\text{initial mass of electrode} - \text{final mass of electrode}}{\text{machining time}} \qquad (2)$$

S No	T_{on}	T_{off}	I	V	Tool	MRR (g/hr)	TWR (g/hr)	SR (μm)
1	250	100	10	30	T1	4.32	0.54	4.75
2	250	200	20	40	T2	5.4	1.08	5.315
3	250	300	30	50	T3	4.32	0.96	6.177
4	250	400	40	60	T4	5.16	1.38	6.052
5	500	100	20	50	T4	5.28	0.72	5.535
6	500	200	10	60	T3	3.96	0.54	7.746
7	500	300	40	30	T2	7.32	0.96	4.497
8	500	400	30	40	T1	4.68	0.96	3.59
9	750	100	30	60	T2	10.26	1.08	4.438
10	750	200	40	50	T1	7.44	0.9	4.78
11	750	300	10	40	T4	2.82	0.72	6.153
12	750	400	20	30	T3	4.86	0.96	4.636
13	1000	100	40	40	T3	9.36	0.9	3.989
14	1000	200	30	30	T4	4.68	0.78	3.735
15	1000	300	20	60	T1	5.4	0.72	4.585
16	1000	400	10	50	T2	5.1	0.54	3.697

4.Results and Discussions

4.1 Impact of process parameters on MRR

Figure 4.1 illustrates the variations of MRR due to process parameters. From figure 4.1(a) and (c) increment in MRR is observed with respect to pulse on time and current. Voltage does not have much impact on MRR and it is almost constant as observed in figure 4.1(d). Pulse off time and percentage increment of copper in hybrid tool have inverse effect on MRR. The main reason for rise in metal removal is generation of high electric sparks which melt and evaporate the metal.

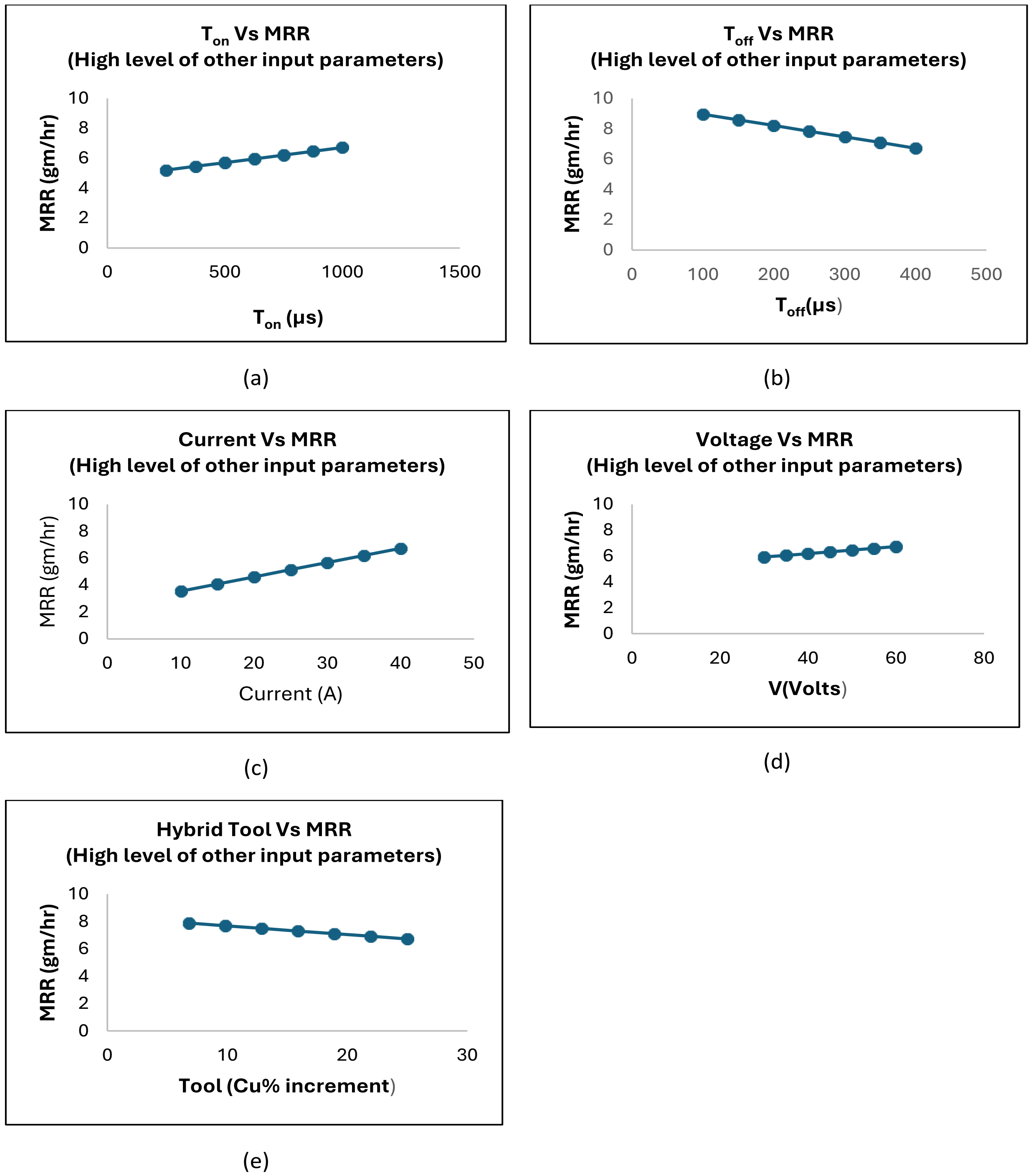

Fig. 4.1 Variations of MRR with (a) pulse on time, (b) pulse off time, (c) current, (d) Voltage and (e) Hybrid tool

4.2 Impact of process parameters on TWR

Figure 4.2 portrays the disparity in TWR for various cases. Remarks drawn from the figure are TWR is reducing with pulse on time and increasing with respect to current and addition of copper in hybrid tool. Pulse off time and voltage do not have considerable impact on TWR. As the discharge current is increased greater heat is created near the hybrid tool which causes it to erode rapidly.

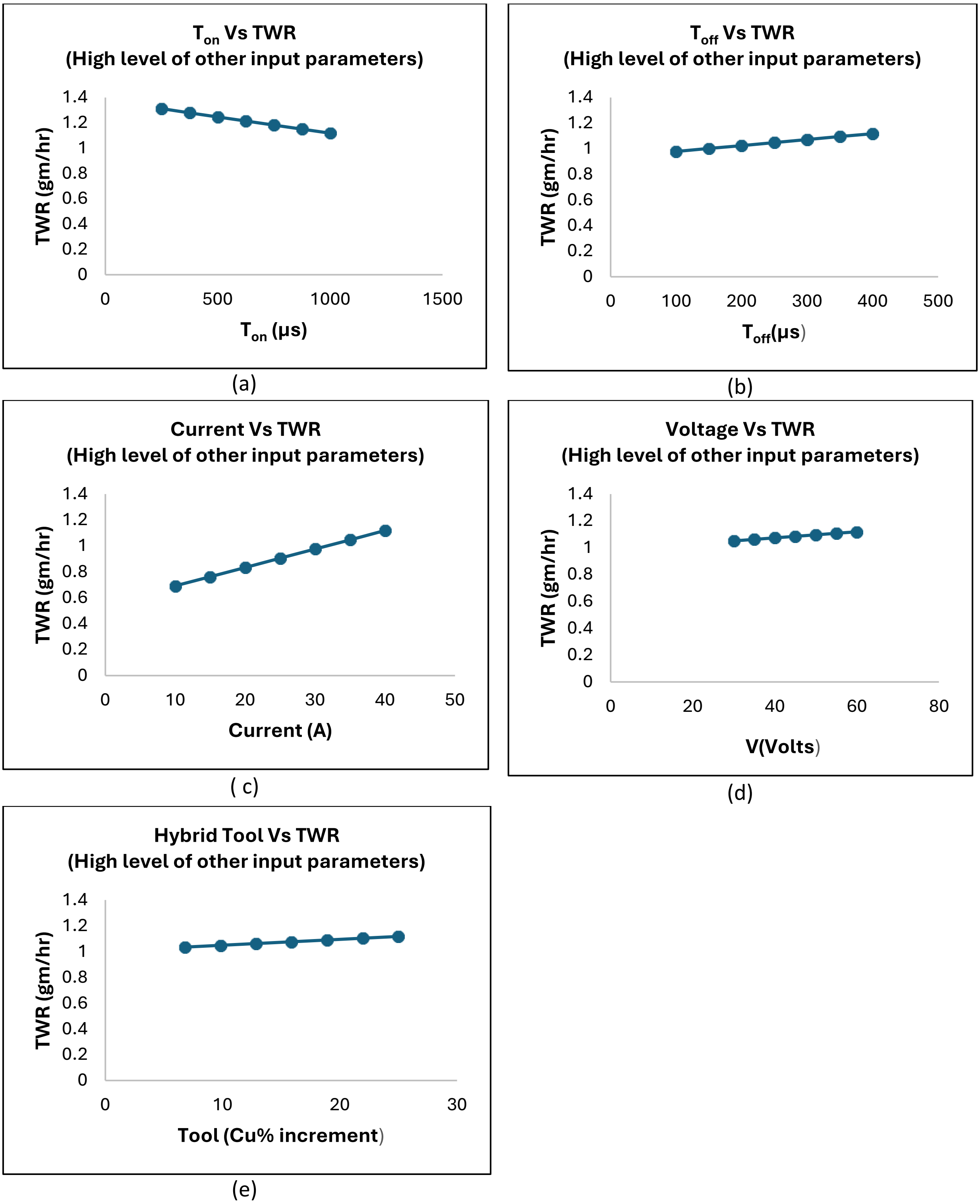

Fig. 4.2 Variations of TWR with (a) pulse on time, (b) pulse off time, (c) current,(d)Voltage and (e) Hybrid tool

4.3 Impact of process parameters on SR

Figure 4.3 represents the variations of surface roughness regarding input parameters. Statements which can be made from the figure are SR is rising with increment in pulse on time, current and voltage. Pulse off time does not contribute much to the variation of SR. A better SR is gained with the addition of copper in hybrid tool. Higher current values will create more sparks which melt more amount of metal forming uneven surfaces.

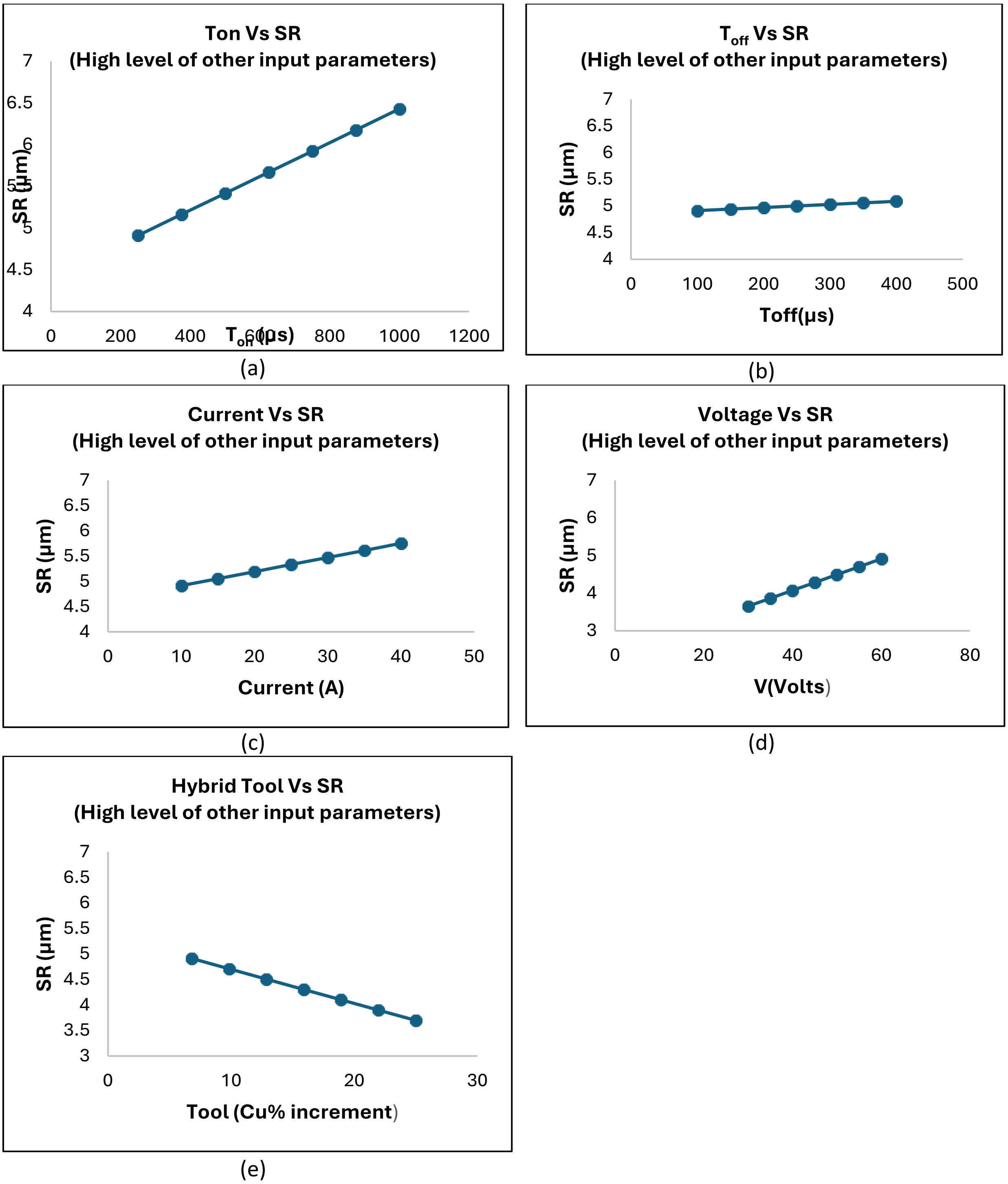

Fig. 4.3 Variations of SR with (a) pulse on time, (b) pulse off time, (c) current, (d) Voltage and (e) Hybrid tool

5. Conclusions

Based on the results drawn with used vegetable oil as dielectric fluid observations made are listed below.

- Maximum metal removal rate value of 10.26g/hr is attained and major factors contributing to it are pulse on time and discharge current.
- Optimum tool abrasion rate is given by using hybrid tool T1.
- Hybrid tools play a vital role in achieving better surface finish and tool T4 is best suitable if good surface is of primary importance.
- Vegetable oils are biodegradable and they can be easily disposed of after machining without causing harmful effect on environment.

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