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Performance Comparison of PCD Insert and Uncoated Insert in Novel CNC Green Machining of SS316L Stainless Steel for Maximizing Material Removal Rate

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Abstract

Aim: *This research is about comparing the performance of poly-crystalline diamond (PCD) insert and uncoated cemented carbide insert for improving the material removal rate (MRR) in CNC turning.* ***Materials and Methods:*** *The material investigated in this research was SS316L. PCD insert was set as the experimental group and uncoated insert was set as the control group. The cutting parameters employed in this process were cutting speed, feed rate and depth of cut. Totally 27 samples per group were machined by using the selected parameters.* ***Results:*** *The mean MRR value obtained for the PCD tool is 0.22593 g/s, whereas it is 0.07600 g/s for the uncoated tool. The significance value obtained among the experimental group and control group is 0.000 ($p<0.05$).* ***Conclusion****: Within the limits of this study, the outcome of the research shows that MRR is more when the specimen is machined by PCD insert than machined by uncoated insert.*

Key-words: Green Machining, Material Removal Rate, PCD Insert, Uncoated Insert, SS316L Stainless Steel, Novel Machining.

1. Introduction

Turning is a basic conventional machining process in which a cutting tool is used to remove the material from the workpiece. In the seventies, lower productivity with less accuracy of components was the major problem to be rectified as far as the mass production is concerned. Machining performed without the usage of coolants is termed as green machining, which is environmental friendly. CNC machines are used to carry out the machining with more surface finish

and dimensional accuracy (Soares et al. 2017). Performance of PCD insert and uncoated insert were compared for improving the material removal rate to increase productivity (Dinesh et al. 2016). In this work, material investigated is SS316L stainless steel. Stainless steel has a wide range of applications such as chemical process equipment, aerospace components, for food, dairy and beverage industries (Nataraj and Balasubramanian 2017) (Kaladhar, Subbaiah, and Rao 2011) (Nataraj and Balasubramanian 2017).

There are 5560 similar works of maximizing MRR in CNC turning available in google scholar and 1350 works available in science direct. A comparison study on the machining performance of PCD and PCBN inserts in dry turning titanium alloy were observed in the findings of (Ren et al. 2019). In that work, the researcher concluded that PCD tools have better performance than PCBN tools. Statistical analysis of different machining characteristics of EN 24 alloy steel during dry hard turning with multilayer coated cermet inserts were studied in the findings of (Das et al. 2019). In that work, the researcher analysed the effect of flank wear on surface roughness parameters, dimensional deviations and effect of MRR on different patterns of crater wear. It is found that the influence of coating material and cutting parameters on material removal rate and surface roughness in the turning process using the Taguchi method (Moganapriya et al. 2018). In that study, the author determined a predictive equation for determining MRR and surface roughness with a given set of parameters in CNC turning. A study on machining experiments of AISI 304L austenitic stainless steel with a PVD (Physical vapor deposition) coated cermet tool was carried out (Kaladhar, Subbaiah, and Rao 2011). In that study, the researchers highlighted that the feed was the predominant parameter on the machined surface followed by nose radius. In addition, the depth of cut was found as the most important parameter influencing the MRR followed by feed. Among all these papers the best cited paper is: Influence of coating material and cutting parameters on surface roughness and material removal rate in turning process using taguchi method (Moganapriya et al. 2018).

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

Based on all these studies it is found that lower productivity is the main criteria to be improved. Hence the aim of the study is to compare and evaluate the performance of PCD insert and uncoated insert for improving the MRR to increase the productivity.

2. Materials and Methods

The workpiece material considered for turning purpose was SS316L and the cutting tool insert used was PCD and uncoated carbide insert. The workpiece material was difficult to machine. Hence these two inserts were considered in this work. This study was carried out in the CNC turning centre available at Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. The total number of groups involved in this project was 2 (experimental group and control group). In this work, novel machining specimens with PCD insert was set as an experimental group and novel machining with uncoated cemented carbide insert used was set as control group. The sample size per group was 27. Clinical online sample size calculator was used to calculate the sample size with 80% g power. During the calculation, the mean value and standard deviation considered for the experimental work was 0.22 and 0.25, respectively (Ramana, Venkata Ramana, and Kumar 2018).

SS 316L is more attractive material because of its properties such as high hardness, toughness, yield strength, excellent ductility, super resistance to corrosion and oxidation. SS316L stainless steel cylindrical rod was cut into the required dimension (20mm diameter and 55mm length) for conducting experiments. The cylindrical rods were obtained from Mehta metals, Chennai. Chemical composition of S316L is given in Table 1.

Table 1 - Chemical Composition of Workpiece Specimen SS316L in Weight Percentage; it contains Chromium, Nickel, Molybdenum and Manganese

Elements	**Cr**	**Ni**	**Mo**	**Mn**
Wt%	16.00 -18.00	10.00 -14.00	2.00 – 3.00	2.00 Max

A polycrystalline structure of diamond particles sintered together, creating a hard and wear-resistant material with high thermal conductivity for quick removal of heat from the cutting edge. PCD material is a synthetic material sintered under high temperature and high pressure. PCD insert which is shown in Fig. 1 is used generally for machining non-ferrous metals, high-silicon aluminum, carbon fiber, and fiber-reinforced plastics. It was obtained from CERATIZIT India Pvt. Ltd, Chennai. The nomenclature of the PCD tool used is: TNMG 160408.

Uncoated carbide insert which is shown in Fig. 2 are ideal for applications involving non-ferrous materials, such as aluminum. The specification of the insert is TNMG 160408. It was also obtained from CERATIZIT India Pvt. Ltd, Chennai.

Fig. 2 - Uncoated insert - Specification- TNMG 160408 EN - CF; CF - Negative relief angle; Insert included angle 60 degrees, Cutting edge length 16.5 mm; Insert thickness 4.76 mm; Corner radius 0.8 mm; Cutting edge condition code E - Rounded; Insert hand N-Neutral; Fixing hole diameter -3.81 mm

Fig. 3 - CNC Machining centre - Super jobber - Specification: Swing over bed -500 mm, Swing over carriage - 260mm, Maximum turning dia - 320 mm, Maximum turning length - 400 mm, Distance between centres - 425 mm, Maximum spindle speed - 3500 rpm, No. of stations - 8)

In this work, the turning process was carried out by using a CNC turning centre (Super jobber) shown in Fig. 3. The cutting tool holder used to hold the PCD and uncoated insert is MTJNL 2525 M16, a solid square rod of dimension 25 x 25 mm with an approach angle of 35 degrees. The experiments by using CNC machining and weighing of the specimens to calculate the MRR were carried out at Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. The workpiece specimen was fixed in the head

stock of the lathe and the insert was fixed in the tool holder which was fixed in the tool station. Selected cutting parameters were cutting speed (m/min), feed rate (mm/rev) and the depth of cut (mm) (Frifita et al. 2020). The cutting parameters were set in CNC machines (Senthilkumar, Sudha, and Muthukumar 2015). Weight loss method was used for determining the MRR during machining. The workpiece having dimensions of 20mm diameter and 55mm length was machined using PCD and uncoated carbide inserts and subsequently MRR was calculated. The MRR per unit time was noted for each experiment trial for both PCD insert and uncoated carbide insert. Cutting speed was set as 100 m/min, feed rate as 0.10mm/min with a depth of cut of 0.6 mm. Before the machining process, weight of the specimen was measured by using a weighing machine. A stopwatch was used to measure the time taken for material removal in seconds during machining and after machining the weight of the specimen was again measured. By using the difference in weight, MRR was calculated. Material removal rate was calculated by using the following simple formula (Senthilkumar, Tamizharasan, and Anandakrishnan 2014):

$$MRR\ (g/s) = \frac{Weight\ of\ specimen\ before\ machining\ -Weight\ of\ specimen\ after\ machining}{Time\ taken\ during\ machining} \quad (1)$$

Statistical Analysis

SPSS v.26 statistical software was used to calculate mean, standard error and standard deviation. Totally, 27 experiments were carried out for analysis for each group so that 95% confidence level can be achieved with P value < 0.05. In this work the independent variables used are cutting speed, feed rate, depth of cut and the dependent variables is material removal rate (MRR). Independent sample T-test was used to analyze the outputs to identify the significance among PCD and uncoated inserts.

3. Results

As per the machining setup and constant machining parameters, the calculated MRR values for both PCD and uncoated inserts are tabulated in Table 2. Table 2 reveals experimental details carried out with parameters of cutting speed 100 m/min, feed rate as 0.10 mm/min and depth of cut of 0.6 mm for both inserts. Group statistics values are tabulated in Table 3. From the table it is observed that mean value (0.22593) and standard deviation value (0.251379) are obtained for the PCD tool.

Table 2 - Experimental details with Calculated MRR for Polycrystalline diamond insert and uncoated insert with set machining parameters

Trial no.	MRR for PCD insert g/s	MRR for uncoated insert g/s
1	0.052	0.040
2	0.058	0.049
3	0.054	0.051
4	0.078	0.040
5	0.076	0.039
6	0.073	0.041
7	0.081	0.062
8	0.082	0.061
9	0.086	0.063
10	0.824	0.094
11	0.856	0.091
12	0.832	0.090
13	0.477	0.104
14	0.468	0.106
15	0.452	0.102
16	0.193	0.113
17	0.196	0.115
18	0.197	0.111
19	0.101	0.072
20	0.104	0.074
21	0.109	0.076
22	0.091	0.070
23	0.093	0.068
24	0.095	0.071
25	0.121	0.083
26	0.124	0.085
27	0.127	0.081

Table 3 - Group Statistics - Polycrystalline diamond insert provides higher MRR as compared with uncoated insert. Mean value of 0.22593 and standard deviation value of 0.251379 is obtained for the PCD tool for 27 samples. The standard error mean value for PCD insert is 0.048378 and uncoated insert is 0.004568

Group	N	Mean	Std. Deviation	Std. Error Mean
PCD	27	.22593	.251379	.048378
UC	27	.07600	.023737	.004568

Table 4 - Outputs of independent sample T test. A significant difference between the control group and experimental group is observed - significance value P=0.000 (P < 0.05). (t value is 3.085 & 3.085; and the df is 52 and 24.464)

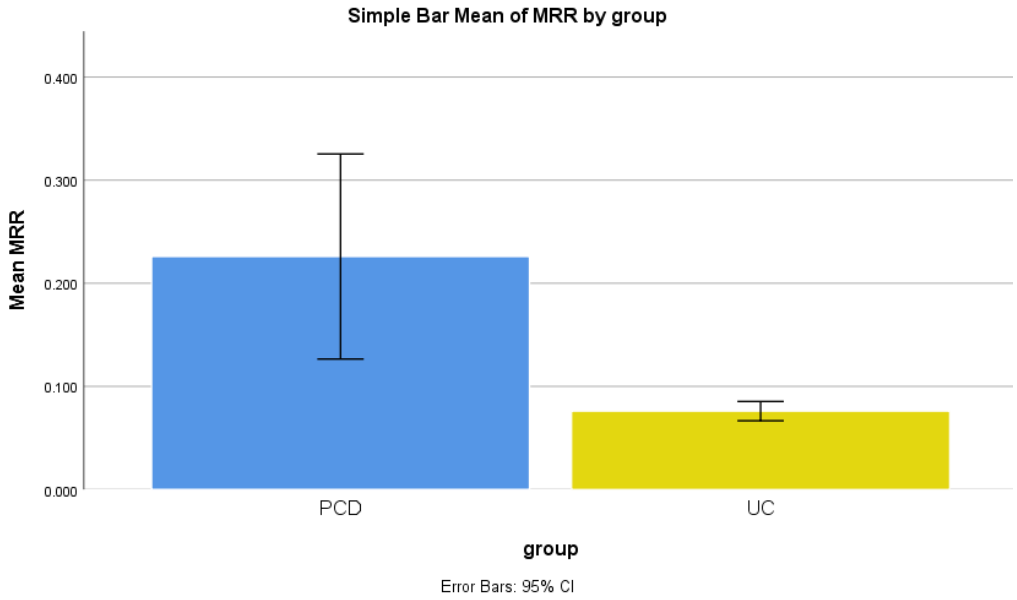
	F	Significance	t	df
MRR - Equal variances assumed	29.654	.000	3.085	52
MRR - Equal variances not assumed			3.085	26.464

The outcomes of the independent sample T test is shown in Table 4. It is learnt from the table that among the control group and experimental group a significant difference is obtained P=0.000 (P < 0.05). Bar chart (Fig. 4) shows the comparison of PCD insert and uncoated insert in terms of mean accuracy and standard deviation. PCD insert has better mean accuracy than uncoated insert and it also has slightly better standard deviation than uncoated insert.

4. Discussion

From the results obtained, the performance of PCD insert appears to perform significantly better than uncoated insert when material removal rate is concerned during machining SS316L. The fischer value obtained for this study is 29.564, with a significance value of 0.000 that is < 0.05 which shows that a significance difference exists between the two tools.

Fig. 4 - Comparison of PCD insert and uncoated insert in terms of mean accuracy. The mean accuracy of PCD insert is better than uncoated insert and the standard deviation of PCD insert is slightly better than uncoated insert. X Axis: PCD insert vs uncoated insert. Y axis: Mean accuracy of detection ± 1 SD



From the bar chart (Fig. 4), it is clearly observed that higher MRR is obtained when the specimen is machined by PCD insert and MRR is lower when the same is machined by uncoated cemented carbide insert (Senthilkumar, Tamizharasan, and Anandakrishnan 2014). This is mainly due to the higher hardness and capability of PCD tool (Mashinini, Soni, and Gupta 2019).The finding of the above researchers is in compliance with the findings of this work. Depth of cut is a more significant factor for material removal rate for both the coated tools ((Ramana, Venkata Ramana, and

Kumar 2018). The above researchers mentioned that interaction between factors is significantly influencing the material removal rate with a minor percentage of contributions. The findings of the above authors are not in line with the findings of this work. The reason for this conflict may be due to interaction between factors considered by the above authors whereas constant input parameters followed in this work. In the turning process, parameters such as materials,tools geometry and cutting conditions (Cutting speed, feed rate and depth of cut) have an impact on material removal rate (Kuppusamy and Ramalingam 2018).

Our institution is passionate about high quality evidence based research and has excelled in various fields ((Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019; Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

Limitations involved in this study is the high cost of the PCD insert and formation of the built-up chip due to high contact temperature. In future work, the same study of comparing coated and uncoated inserts for turning of SS316L can be tried by using low cost inserts which provide more MRR.

5. Conclusion

The turning was performed on SS316L using PCD and uncoated carbide inserts to compare the material removal rate using CNC machine using a set of cutting parameters. The effect of MRR is dependent on cutting parameters considered. From the results it is concluded that PCD insert provides higher MRR (0.22593 g/sec) than the uncoated carbide (0.07600 g/sec) insert during machining SS316L material.

Declarations

Conflict of Interest

The authors of this paper declare no conflict of interest.

Authors Contribution

Author KBP was involved in data collection, data analysis and manuscript writing. Author CT was involved in conceptualization, data validation, and critical review of manuscript.

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References

Das, Anshuman, Saroj Kumar Patel, Tapano Kumar Hotta, and Bibhuti Bhushan Biswal. 2019. "Statistical Analysis of Different Machining Characteristics of EN-24 Alloy Steel during Dry Hard Turning with Multilayer Coated Cermet Inserts." *Measurement*. https://doi.org/10.1016/j.measurement.2018.10.065.

Dinesh, S., A. Godwin Antony, K. Rajaguru, and V. Vijayan. 2016. "Investigation and Prediction of Material Removal Rate and Surface Roughness in CNC Turning of En24 Alloy Steel." *Asian Journal of Research in Social Sciences and Humanities*. https://doi.org/10.5958/2249-7315.2016.00654.7.

Ezhilarasan, Devaraj, Velluru S. Apoorva, and Nandhigam Ashok Vardhan. 2019. "Syzygium Cumini Extract Induced Reactive Oxygen Species-Mediated Apoptosis in Human Oral Squamous Carcinoma Cells." *Journal of Oral Pathology & Medicine: Official Publication of the International Association of Oral Pathologists and the American Academy of Oral Pathology* 48 (2): 115–21.

Frifita, Wassila, Sahbi Ben Salem, Abdelkrim Haddad, and Mohamed Athmane Yallese. 2020. "Optimization of Machining Parameters in Turning of Inconel 718 Nickel-Base Super Alloy." *Mechanics & Industry*. https://doi.org/10.1051/meca/2020001.

Gheena, S., and D. Ezhilarasan. 2019. "Syringic Acid Triggers Reactive Oxygen Species-Mediated Cytotoxicity in HepG2 Cells." *Human & Experimental Toxicology* 38 (6): 694–702.

Jose, Jerry, Ajitha, and Haripriya Subbaiyan. 2020. "Different Treatment Modalities Followed by Dental Practitioners for Ellis Class 2 Fracture – A Questionnaire-Based Survey." *The Open Dentistry Journal* 14 (1): 59–65.

Kaladhar, M., K.V. Subbaiah, and C.S. Rao. 2011. "Performance Evaluation of Coating Materials and Process Parameters Optimization for Surface Quality during Turning of AISI 304 Austenitic Stainless Steel." *International Journal of Engineering, Science and Technology*. https://doi.org/10.4314/ijest.v3i4.68545.

Ke, Yang, Mohammed Saleh Al Aboody, Wael Alturaiki, Suliman A. Alsagaby, Faiz Abdulaziz Alfaiz, Vishnu Priya Veeraraghavan, and Suresh Mickymaray. 2019. "Photosynthesized Gold

Nanoparticles from Catharanthus Roseus Induces Caspase-Mediated Apoptosis in Cervical Cancer Cells (HeLa)." *Artificial Cells, Nanomedicine, and Biotechnology* 47(1): 1938–46.

Krishnaswamy, Haribabu, Sivaprakash Muthukrishnan, Sathish Thanikodi, Godwin Arockiaraj Antony, and Vijayan Venkatraman. 2020. "Investigation of Air Conditioning Temperature Variation by Modifying the Structure of Passenger Car Using Computational Fluid Dynamics." *Thermal Science* 24 (1 Part B): 495–98.

Kuppusamy, Sivasakthivel, and Dillibabu Ramalingam. 2018. "Optimization of Process Parameters in CNC Turning of Titanium Alloy with Carbide Coated Tool Inserts Using Grey Based Taguchi Analysis." *Journal of Advanced Mechanical Design, Systems, and Manufacturing*. https://doi.org/10.1299/jamdsm.2018jamdsm0094.

Malli Sureshbabu, Nivedhitha, Kathiravan Selvarasu, Jayanth Kumar V, Mahalakshmi Nandakumar, and Deepak Selvam. 2019. "Concentrated Growth Factors as an Ingenious Biomaterial in Regeneration of Bony Defects after Periapical Surgery: A Report of Two Cases." *Case Reports in Dentistry* 2019 (January): 7046203.

Mashinini, P.M., Hargovind Soni, and Kapil Gupta. 2019. "Investigation on Dry Machining of Stainless Steel 316 Using Textured Tungsten Carbide Tools." *Materials Research Express*. https://doi.org/10.1088/2053-1591/ab5630.

Mathew, M.G., S.R. Samuel, A.J. Soni, and K.B. Roopa. 2020. "Evaluation of Adhesion of Streptococcus Mutans, Plaque Accumulation on Zirconia and Stainless Steel Crowns, and Surrounding Gingival Inflammation in Primary …." *Clinical Oral Investigations*. https://link.springer.com/article/10.1007/s00784-020-03204-9.

Mehta, Meenu, Deeksha, Devesh Tewari, Gaurav Gupta, Rajendra Awasthi, Harjeet Singh, Parijat Pandey, et al. 2019. "Oligonucleotide Therapy: An Emerging Focus Area for Drug Delivery in Chronic Inflammatory Respiratory Diseases." *Chemico-Biological Interactions* 308 (August): 206–15.

Moganapriya, C., R. Rajasekar, K. Ponappa, R. Venkatesh, and S. Jerome. 2018. "Influence of Coating Material and Cutting Parameters on Surface Roughness and Material Removal Rate in Turning Process Using Taguchi Method." *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2017.11.550.

Muthukrishnan, Sivaprakash, Haribabu Krishnaswamy, Sathish Thanikodi, Dinesh Sundaresan, and Vijayan Venkatraman. 2020. "Support Vector Machine for Modelling and Simulation of Heat Exchangers." *Thermal Science* 24 (1 Part B): 499–503.

Nataraj, M., and K. Balasubramanian. 2017. "Parametric Optimization of CNC Turning Process for Hybrid Metal Matrix Composite." *The International Journal of Advanced Manufacturing Technology*. https://doi.org/10.1007/s00170-016-8780-4.

Pc, J., T. Marimuthu, and P. Devadoss. 2018. "Prevalence and Measurement of Anterior Loop of the Mandibular Canal Using CBCT: A Cross Sectional Study." *Clinical Implant Dentistry and Related Research*. https://europepmc.org/article/med/29624863.

Ramadurai, Neeraja, Deepa Gurunathan, A. Victor Samuel, Emg Subramanian, and Steven J. L. Rodrigues. 2019. "Effectiveness of 2% Articaine as an Anesthetic Agent in Children: Randomized Controlled Trial." *Clinical Oral Investigations* 23 (9): 3543–50.

Ramana, M. Venkata, M. Venkata Ramana, and Goutham Kumar. 2018. “Optimization of Material Removal Rate in Turning of AISI 321 Stainless Steel Using Taguchi Methodology.” *Materials Today: Proceedings*. https://doi.org/10.1016/j.matpr.2017.12.074.

Ramesh, Asha, Sheeja Varghese, Nadathur D. Jayakumar, and Sankari Malaiappan. 2018. “Comparative Estimation of Sulfiredoxin Levels between Chronic Periodontitis and Healthy Patients - A Case-Control Study.” *Journal of Periodontology* 89 (10): 1241–48.

Ren, Zhaojun, Shengguan Qu, Yalong Zhang, Fujian Sun, Xiaoqiang Li, and Chao Yang. 2019. “Machining Performance of PCD and PCBN Tools in Dry Turning Titanium Alloy Ti-6Al-0.6Cr-0.4Fe-0.4Si-0.01B.” *The International Journal of Advanced Manufacturing Technology*. https://doi.org/10.1007/s00170-018-3074-7.

Samuel, Melvin S., Jayanta Bhattacharya, Sankalp Raj, Needhidasan Santhanam, Hemant Singh, and N.D. Pradeep Singh. 2019. “Efficient Removal of Chromium (VI) from Aqueous Solution Using Chitosan Grafted Graphene Oxide (CS-GO) Nanocomposite.” *International Journal of Biological Macromolecules* 121 (January): 285–92.

Samuel, Srinivasan Raj, Shashidhar Acharya, and Jeevika Chandrasekar Rao. 2020. “School Interventions-Based Prevention of Early-Childhood Caries among 3-5-Year-Old Children from Very Low Socioeconomic Status: Two-Year Randomized Trial.” *Journal of Public Health Dentistry* 80 (1): 51–60.

Sathish, T., and S. Karthick. 2020. “Wear Behaviour Analysis on Aluminium Alloy 7050 with Reinforced SiC through Taguchi Approach.” *Journal of Japan Research Institute for Advanced Copper-Base Materials and Technologies* 9 (3): 3481–87.

Senthilkumar, N., J. Sudha, and V. Muthukumar. 2015. “A Grey-Fuzzy Approach for Optimizing Machining Parameters and the Approach Angle in Turning AISI 1045 Steel.” *Advances in Production Engineering & Management*. https://doi.org/10.14743/apem2015.4.202.

Senthilkumar, N., T. Tamizharasan, and V. Anandakrishnan. 2014. “Experimental Investigation and Performance Analysis of Cemented Carbide Inserts of Different Geometries Using Taguchi Based Grey Relational Analysis.” *Measurement*. https://doi.org/10.1016/j.measurement.2014.09.025.

Sharma, Parvarish, Meenu Mehta, Daljeet Singh Dhanjal, Simran Kaur, Gaurav Gupta, Harjeet Singh, Lakshmi Thangavelu, et al. 2019. “Emerging Trends in the Novel Drug Delivery Approaches for the Treatment of Lung Cancer.” *Chemico-Biological Interactions* 309 (August): 108720.

Soares, R.B., A.M.P. de Jesus, R.J.L. Neto, B. Chirita, P.A.R. Rosa, and A. Reis. 2017. “Comparison Between Cemented Carbide and PCD Tools on Machinability of a High Silicon Aluminum Alloy.” *Journal of Materials Engineering and Performance*. https://doi.org/10.1007/s11665-017-2870-9.

Sridharan, Gokul, Pratibha Ramani, Sangeeta Patankar, and Rajagopalan Vijayaraghavan. 2019. “Evaluation of Salivary Metabolomics in Oral Leukoplakia and Oral Squamous Cell Carcinoma.” *Journal of Oral Pathology & Medicine: Official Publication of the International Association of Oral Pathologists and the American Academy of Oral Pathology* 48 (4): 299–306.

Varghese, Sheeja Saji, Asha Ramesh, and Deepak Nallaswamy Veeraiyan. 2019. “Blended Module-Based Teaching in Biostatistics and Research Methodology: A Retrospective Study with Postgraduate Dental Students.” *Journal of Dental Education* 83 (4): 445–50.

Venu, Harish, V. Dhana Raju, and Lingesan Subramani. 2019. “Combined Effect of Influence of Nano Additives, Combustion Chamber Geometry and Injection Timing in a DI Diesel Engine Fuelled with Ternary (diesel-Biodiesel-Ethanol) Blends.” *Energy* 174 (May): 386–406.

Venu, Harish, Lingesan Subramani, and V. Dhana Raju. 2019. “Emission Reduction in a DI Diesel Engine Using Exhaust Gas Recirculation (EGR) of Palm Biodiesel Blended with TiO2 Nano Additives.” *Renewable Energy* 140 (September): 245–63.

Vignesh, R., Ditto Sharmin, C. Vishnu Rekha, Sankar Annamalai, and Parisa Norouzi Baghkomeh. 2019. “Management of Complicated Crown-Root Fracture by Extra-Oral Fragment Reattachment and Intentional Reimplantation with 2 Years Review.” *Contemporary Clinical Dentistry* 10 (2): 397–401.

Vijayakumar Jain, S., M.R. Muthusekhar, M.F. Baig, P. Senthilnathan, S. Loganathan, P.U. Abdul Wahab, M. Madhulakshmi, and Yogaen Vohra. 2019. “Evaluation of Three-Dimensional Changes in Pharyngeal Airway Following Isolated Lefort One Osteotomy for the Correction of Vertical Maxillary Excess: A Prospective Study.” *Journal of Maxillofacial and Oral Surgery* 18 (1): 139–46.

Vijayashree Priyadharsini, Jayaseelan. 2019. “In Silico Validation of the Non-Antibiotic Drugs Acetaminophen and Ibuprofen as Antibacterial Agents against Red Complex Pathogens.” *Journal of Periodontology* 90 (12): 1441–48.