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A REVIEW ON MICROCONTROLLER POWERED PORTABLE CNC MILLING MACHINE

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Abstract

To reduce the weight & size of something is a very difficult task. But its advantages are numerous. Making a milling machine smaller in size but maintaining its power & purpose is very tedious. This review article emphasizes on fabrication & working of the MINI CNC MILLING Machine. CNC's are widely used in various industries. Portable CNC's are becoming a trend these days as they are efficient in some perspective. Using a Microcontroller for computing devices for a milling machine is the core concept of this project.

Keywords: Microcontroller, PCB, Pareto ANOVA, Rake angle.

1.Introduction:

In this paper, a review of the previous research project that is related to this project will be discussed. These kinds of surveys were held as one of the tools to have some ideas on how this project works. It is based on other achievements and also to formulate the advantage of the proposed solution. This may help in problem-solving skills and options required for the design and development of a mini CNC miller.

2.CNC using Microcontrollers:

A computer numerical control (CNC) machining system has been developed for the machining process. These systems include a three-axis milling/drilling machine, a microprocessor, system software, and an automatically programmed tools (APT) processor. The objective of developing this machining system is to enable new features to be introduced, especially for the tutorial environment. A unique feature of the system is that the use of a general-purpose microprocessor as a controller. The CNC system is meant to incorporate fundamental features with a simple software format and a little scale construction. These make the system a versatile educational tool. An APT processor is developed, which may be wont to link a geometrical file devised by a billboard computer-aided design software package to the CNC machine. [1]

3.Manufacturing of low-*cost PCB* using Milling machines:

The need for fabricating a prototype circuit arises frequently in electronics, including education and research laboratories. In resource-poor countries within the developing world, this is often hindered by the high cost of economic computer circuit Board (PCB) prototyping machines and long turn-around commercial fabrication process. Practical, hands-on laboratory teaching and experimentation are important to enhance learning in electronics. In this paper, a low-cost build-your-own (BYO) semi-automated three-axis PCB miller for double-sided PCB prototyping is developed using commercial components and open-source hardware and free open source software, to supply students, teachers, and

engineers an accessible and affordable resource for PCB prototyping. Also, most problems encountered during the fabrication of PCB are mentioned, and therefore the techniques wont to solve them are discussed intimately. [2]

4. Multi-Purpose Vertical Milling Machine:

A Reconfigurable machine developed by the utilization of mechanical, control, hydraulic/pneumatic, and electrical modules, rapid adaptability is often achieved. The main goal of a reconfigurable machine is to handle various changes within the merchandise or parts to be machined. By the event of machine modules that may be quickly assembled and disassembled, one can enhance the efficiency of the machine. Designing different machining processes, using an equivalent machine, can reduce the entire energy consumption during the manufacturing process, the necessity for larger floor space within the plant, and the cost per part. In this paper, the planning and implementation of modular machine subsystems that permit various machining processes on an equivalent CNC vertical miller are reviewed. Milling, ceramic grinding, and chrome steel polishing are administered on an equivalent machine, using modular designed subsystems. [3]

5.Study of Machining Parameters:

Experimental methods for quantifying the proportions of thermal errors of the machine, tool, and work piece within the total thermal error are emphasized. For this purpose, the work piece was subsequently measured and both the machine-internal and additionally built-in measuring sensors were wont to quantify displacement errors. The static errors must also be detected. Based on the measured values, thermal states are calculated by multivariate analysis and included within the evaluation. The percentages of the only errors were calculated and gave a transparent statement about the time sequences and therefore the thermal influence of the components regarding the entire error in a milling process. The results allow an assessment of relevant areas that contribute to positioning errors. [4]. The main goal of this work is to optimize the quadratic mean roughness Rq and thus the machining time T in ball-end milling of the Titanium alloy Ti-6Al-4V. The Taguchi method was applied during this research to research the impact of every milling parameter on the surface roughness and therefore the machining time. An orthogonal array L9, a sign-to-noise ratio S/N analysis, and Pareto ANOVA were wont to select the combination of the optimum level of the milling parameters and to investigate the impact of each milling parameter on the machining time and surface roughness. [5]

6.Working in a Software:

A CNC carving of digital images within the sort of lookalike three-dimensional (3D) surfaces on wooden or metallic plaques is discussed. This work is focused on the development of a single page windows-based console application for conversion of a two-dimensional (2D) digital image into a 3D free form surface representation within the sort of some extent cloud data and STL format. Subsequently, the 3D surface data is then used for generating an efficient tool path data for 3-axis CNC finish machining employing a ball end mill tool. The results from the developed algorithm are validated employing a machining simulation within the virtual environment of Open-GLbased3D graphical simulator tools. [6]. The manufacturing industry largely contributes towards the economy of a rustic. However, it leaves a big environmental footprint mainly caused by process energy. With the stress on sustainable means of producing, this study focuses on the sustainability of milling. An industrial milling operation is monitored to gather the energy consumption data using an energy data logger. SimaPro LCA software is employed with ISO 14044 guidelines to quantify the environmental impact related to the milling unit processes. The results show that different parameter combinations significantly affect the entire environmental impact. It concludes by suggesting favorable parameter combinations

resulting in better environmental performance. [7]. CNC milling is often wont to rapidly machine a spread of parts with minimal human intervention for process planning. The methodology presented uses a layer-based approach (like traditional rapid prototyping) for the rapid, semi-automatic machining of commonly manufactured part geometries during a kind of materials. Parts are machined employing a plurality of 2½-D tool paths from orientations to a few rotary axes. Process parameters such as the number of orientations, tool containment bound-arise, and tool geometry is derived from CAD slice data. Besides, automated fix Turing is accomplished through the utilization of sacrificial support structures added to the CAD geometry. The paper begins by describing the machining methodology then presents a variety of critical issues needed to form the method automatic and efficient. Exam- pre parts machined using these methodologies are then pre- scented and discussed. [8]

7.Force Analysis study:

The design and development of the 3-component force sensor have been proposed for particular installation onto the 3-axis mini CNC miller. The system is combined with 3 beam type load cells which have one measured direction, properly laid on each axis so as for detecting and measuring in X, Y, and Z directions, respectively. The Arduino board with a load cell amplifier (HX711 board) is employed to demonstrate the graphical and numerical results of cutting force signals via proper programming on Arduino software. The key finding results reveal that the accurate range of measurements should be 120-190 N. [9]. In this study, the influence of Severe Plastic Deformation (SPD) through end milling (machining) with varying tool nomenclatures like Radial Rake Angle (RRA) of end mill cutter and cutting conditions like table feed velocity on the roughening to faceting phenomena and Grain Boundary Characteristic Distribution (GBCD) alongside its dependency on corrosion behavior of end milled alloys have been reported. The experimental result confirms that the decrement in tool nomenclature like RRA of cutter features a greater and significant effect on the facet morphologies also as corrosion behavior of SPD processed samples followed by a cutting condition and confirmed that the SPD process through machining has a greater impact over the corrosion resistance of machined surface compared to the as-received sample. [10]

8.Conclusion:

To build a mini CNC milling machine with effectiveness equal to the big size CNC milling, all these parameters mentioned by the above publishers must be taken into account. Before commencing our project, all these articles were read & their valuable points were considered. The requirements for these small-sized machines are growing all over the world. However, a mini-scale machine cannot be as efficient as an original CNC Milling machine.

9.References:

1. *Tseng, A. A., Kolluri, S. P., &Radhakrishnan, P. (1989). A CNC machining system for education. Journal of Manufacturing Systems, 8(3), 207-214.*
2. *Sathyakumar, N., Balaji, K.P., Ganapathi, R. and Pandian, S.R., 2018. A build-your-own three axis CNC PCB milling machine. Materials Today: Proceedings, 5(11), pp.24404-24413.*
3. *Hung, J.P., Lai, Y.L., Lin, C.Y. and Lo, T.L., 2011. Modeling the machining stability of a vertical milling machine under the influence of the preloaded linear guide. International Journal of Machine Tools and Manufacture, 51(9), pp.731-739.*
4. *Putz, M., Regel, J., Wenzel, A. and Bräunig, M., 2019. Thermal errors in milling: comparison of displacements of the machine tool, tool and workpiece. Procedia CIRP, 82, pp.389-394.*
5. *Mersni, W., Boujelbene, M., Salem, S.B. and Singh, H.P., 2020. Machining time and quadratic mean roughness optimization in ball end milling of titanium alloy Ti-6Al-4V–Aeronautic*

field. Materials Today: Proceedings, 26, pp.2619-2624.

6. Sood, S., Duvedi, R.K., Bedi, S. and Mann, S., 2018. 3D representation and CNC machining of 2D digital images. Procedia Manufacturing, 26, pp.10-20.
7. Kurukulasuriya, M., Gamage, J. and Mangala, J., 2020. Sustainable machining: Assessment of environmental performance of milling. Procedia Manufacturing, 43, pp.455-462.
8. Frank, M.C., Wysk, R.A. and Joshi, S.B., 2004. Rapid planning for CNC milling—A new approach for rapid prototyping. Journal of Manufacturing Systems, 23(3), pp.242-255.
9. Lapsomthop, W., Wongsirirax, N. and Sawangsri, W., 2019. Design and experimental investigation on 3-component force sensor in mini CNC milling machine. Materials Today: Proceedings, 17, pp.1931-1938.
10. Gowthaman, S. and Jagadeesha, T., 2020. Effect of severe plastic deformation through machining on the microstructure and corrosion behavior of end milled nimonic 263 alloy. Materials Letters, 275, p.128102.
11. Venkatesh, S., Kumar, R.S., Sivapirakasam, S.P., Sakthivel, M., Venkatesh, D. and Arafath, S.Y., 2020. Multi-objective optimization, experimental and CFD approach for performance analysis in square cyclone separator. Powder Technology, 371, pp.115-129.
12. Kumar, R.S., Alexis, J. and Thangarasu, V.S., 2017. Optimization of high speed CNC end milling process of BSL 168 Aluminium composite for aeronautical applications. Transactions of the Canadian society for Mechanical Engineering, 41(4), pp.609-625.
13. Kumar, S.R., Alexis, J.S. and Thangarasu, V.S., 2017. Experimental Investigation of Influential Parameters in High Speed Machining of AMS 4205. Asian Journal of Research in Social Sciences and Humanities, 7(2), pp.508-523.
14. Alexis, J. and Thangarasu, V.S., 2016. Prediction of machining parameters for A91060 in end milling. Advances in Natural and Applied Sciences, 10(6 SE), pp.157-164.
15. Kumar, R.S., Thangarasu, V.S. and Alexis, S.J., 2016. Adaptive control systems in CNC machining processes--a review. Advances in Natural and Applied Sciences, 10(6 SE), pp.120-130.
16. Suresh Kumar, R., John Alexis, S. and Thangarasu, V.S., 2015. Application of GA & ANN for the optimization of cutting parameters for end milling operation-A comparison. International Journal of Applied Engineering Research, 10(20)
17. T Ramakrishnan, M SatheshBabu, S Balasubramani, K Manickaraj, R Jeyakumar., 2021.Effect of Fiber Orientation and Mechanical Properties of Natural Fiber Reinforced Polymer Composites-A Review.paideumajournal.14 (3), pp.17-23.
18. Jeyakumar R, Balasubramanian K, Ramamoorthi R, Ramakrishnan T.,2021,Development Of Compact Electro Gear Pump For Airborne Applications. paideumajournal.14 (3), pp.50-57.
19. Ramakrishnan, T. and Sampath, P.S., 2017. Dry sliding wear characteristics of new short agave angustifoliamarginata (AAM) fiber-reinforced polymer matrix composite material. Journal of Biobased Materials and Bioenergy, 11(5), pp.391-399.
20. Thirumalaisamy, R. and SUBRAMANI, S.P., 2018. Investigation of physico-mechanical and moisture absorption characteristics of raw and alkali treated new agave angustifoliamarginata (AAM) fiber. Materials Science, 24(1), pp.53-58.
21. Jeyakumar, R., Sampath, P.S., Ramamoorthi, R. and Ramakrishnan, T., 2017. Structural, morphological and mechanical behaviour of glass fibre reinforced epoxy nanoclay composites. The nternational Journal of Advanced Manufacturing Technology, 93(1), pp.527-535.
22. Ramakrishnan, T. and Sampath, P.S., 2017. Experimental investigation of mechanical properties of untreated new Agave AngustifoliaMarginatafiber reinforced epoxy polymer matrix composite material. Journal of Advances in Chemistry, 13(4), pp.6120-6126.
23. Ramakrishnan, T., Sampath, P.S. and Ramamoorthi, R., 2016. Investigation of mechanical properties and morphological study of the alkali treated agave angustifoliamarginatafiber reinforced epoxy polymer composites. Asian Journal of Research in Social Sciences and Humanities, 6(9), pp.461-472.

24. Sathish, K., Ramakrishnan, T. and Sathishkumar, S., 2016. Optimization of turning parameters to improve surface finish of 16 Mn Cr 5 material. Advances in Natural and Applied Sciences, 10(6 SE), pp.151-157.
25. Ramakrishnan, T., Sathish, K., Sampath, P.S. and Anandkumar, S., 2016. Experimental investigation and optimization of surface roughness of AISI 52100 alloy steel material by using Taguchi method. Advances in Natural and Applied Sciences, 10(6 SE), pp.130-138.
26. Ramakrishnan, T. and Sampath, P.S., 2016. Thermogravimetric Analysis (TGA) and the Effect of Moisture Absorption on the Mechanical Properties of New Agave AngustifoliaMarginata 3 Fiber (AAMF) Reinforced Epoxy Polymer Composite Material. International Journal of Printing, Packaging & Allied Sciences, 4(5), pp.3245-3256.
27. Gokilakrishnan, G. and Varthanan, P.A., 2019. Development of manufacturing-distribution plan considering quality cost. International Journal of Enterprise Network Management, 10(3-4), pp.280-304.
28. Varthanan, P.A. and Gokilakrishnan, G., 2018. Simulation Based Swarm Intelligence to Generate Manufacturing-distribution Plan for a Bearing Industry under Uncertain Demand and Inventory Scenario. International Journal of Pure and Applied Mathematics, 119(12), pp.2117-2134.
29. Gokilakrishnan, G.E., Divya, S., Rajesh, R. and Selvakumar, V., 2014. Operating torque in ball valves: a review. Int J Technol Res Eng, 2(4), pp.311-315.
30. Venkatesh, S., Sivapirakasam, S.P., Sakthivel, M., Ganeshkumar, S., Prabhu, M.M. and Naveenkumar, M., 2021. Experimental and numerical investigation in the series arrangement square cyclone separator. Powder Technology, 383, pp.93-103.
31. Venkatesh, S., Sakthivel, M., Saranav, H., Saravanan, N., Rathnakumar, M. and Santhosh, K.K., 2020. Performance investigation of the combined series and parallel arrangement cyclone separator using experimental and CFD approach. Powder Technology, 361, pp.1070-1080.
32. Venkatesh, S., Sakthivel, M., Avinasilingam, M., Gopalsamy, S., Arulkumar, E. and Devarajan, H.P., 2019. Optimization and experimental investigation in bottom inlet cyclone separator for performance analysis. Korean Journal of Chemical Engineering, 36(6), pp.929-941.
33. Venkatesh, S., Sakthivel, M., Sudhagar, S. and Daniel, S.A.A., 2018. Modification of the cyclone separator geometry for improving the performance using Taguchi and CFD approach. Particulate Science and Technology.
34. Venkatesh, S. and Sakthivel, M., 2017. Numerical investigation and optimization for performance analysis in Venturi inlet cyclone separator. Desalination and Water treatment, 90, pp.168-179.
35. Venkatesh, S., Bruno Clement, I., Avinasilingam, M. and Arulkumar, E., 2017. Design of Experiment Technique for Improving the Performance of Stirling Engine. International Research Journal of Engineering and Technology, 4(5), pp.62-65.
36. Vennilaa, D.B., Karuppusami, G. and Senthil, P., 2016. Analysis of different infiltration effect for selective laser sintering process through Taguchi method. Australian Journal of Mechanical Engineering, 14(3), pp.217-223.
37. NaveenPrabhu, V., SaravanaKumar, K., Suresh, T. and Suresh, M., 2016. Experimental investigation on tube-in-tube heat exchanger using nanofluids. Advances in Natural and Applied Sciences, 10(7 SE), pp.272-279.
38. Justin Dhiraviam, F., Naveen Prabhu, V., Suresh, T. and SelvaSenthilPrabhu, C., 2015. Improved efficiency in engine cooling system by repositioning of turbo inter cooler. In Applied Mechanics and Materials (Vol. 787, pp. 792-796). Trans Tech Publications Ltd.
39. Naveen Prabhu, V. and Suresh, M., 2015. Performance evaluation of tube-in-tube heat exchanger using nanofluids. In Applied Mechanics and Materials (Vol. 787, pp. 72-76). Trans Tech Publications Ltd.
40. Prabhu, V.N. and Manigandan, N., 2014. Design and Fabrication of Solar Transport Vehicle. OSR J. Mech. Civ. Eng, 11, pp.14-19.
41. Manigandan, N., NaveenPrabhu, V. and Suresh, M., 2015. Experimental investigation of a brazed chevron type plate heat exchanger. International Journal of Science Technology & Engineering, 1(12), pp.1-7.
42. Dhiraviam, F.J., Naveenprabhu, V. and Santhosh, M., 2017. Study the Effects of Solar Assisted

Vapour Compression Air Conditioning System for Winter Applications. International Journal for Scientific Research & Development, 4(11), pp.505-508.

43. *Manigandan, N., Naveenprabhu, V. and Devakumar, M., 2014. Design and Fabrication of Mechanical device for Effective Degreasing in Roller Bearing. Procedia Engineering, 97, pp.134-140.*
44. *Pravin, V.N.D.M.K. and Swamy, V.R.S.S.A., A Review of Evaporative Cooling of Finned and Non-Finned Heat Exchanger on Condenser.*
45. *Naveenprabhu, V. and Suresh, M., 2020. Performance enhancement studies on evaporative cooling using volumetric heat and mass transfer coefficients. Numerical Heat Transfer, Part A: Applications, 78(9), pp.504-523.*
46. *Dhiraviam, F.J., Naveenprabhu, V., Satish, K. and Palanivelrajan, A.R., 2019, October. Emission characteristic in CI engines using zirconium porous medium in piston head. In AIP Conference Proceedings (Vol. 2161, No. 1, p. 020012). AIP Publishing LLC.*
47. *Naveenprabhu, V., Dhiraviam, F.J., Gowtham, K.M., Gowtham, S., Tharick, R.A. and Arunkumar, R., 2019. Smart Hot Chamber in Refrigeration System Based on Waste Heat Recovery. Indian Journal of Science and Technology, 12, p.20.*
48. *Subramaniam, B., Natarajan, B., Kaliyaperumal, B. and Chelladurai, S.J.S., 2019. Wear behaviour of aluminium 7075—boron carbide-coconut shell fly ash reinforced hybrid metal matrix composites. Materials Research Express, 6(10), p.1065d3.*
49. *Subramaniam, B., Natarajan, B., Kaliyaperumal, B. and Chelladurai, S.J.S., 2018. Investigation on mechanical properties of aluminium 7075-boron carbide-coconut shell fly ash reinforced hybrid metal matrix composites. China Foundry, 15(6), pp.449-456*
50. *N. Balaji, S.Balasubramani, V.Pandiaraj., 2021, Fabrication and Analysis of Al6061/Al_2O_3/TiC Hybrid Metal Matrix Composite, Paideuma Journal of Research., Vol 14, No 3, pp 24-35.*
51. *Balasubramani, S., Dhanabalakrishnan, K.P. and Balaji, N., 2015. Optimization of machining parameters in aluminium HMMC using response surface methodology. International journal of applied engineering research, 10(20), pp.19736-19739.*
52. *Balasubramani S, Manikandan.SPrasath.P, Suresh.D and ShanmugaSundaram.P., 2018. "Vibration Analysis of Work Holding Devices in Composite Materials" International Journal for Scientific Research & Development, Vol. 6, No 2, pp 2520-2523.*
53. *Subramaniam, B., Purusothaman, V.R., Karuppusamy, S.M., Ganesh, S.H. and Markandan, R.K., 2020. Review on properties of aluminium metal matrix composites. Journal of Mechanical and Energy Engineering, 4(1), pp.57-66.*
54. *Balaji, N., Balasubramani, S., Ramakrishnan, T. and Sureshbabu, Y., 2020. Experimental Investigation of Chemical and Tensile Properties of SansevieriaCylindricaFiber Composites. In Materials Science Forum (Vol. 979, pp. 58-62). Trans Tech Publications Ltd.*
55. *Balasubramani, S. and Balaji, N., 2016. Investigations of vision inspection method for surface defects in image processing techniques-a review. Advances in Natural and Applied Sciences, 10(6 SE), pp.115-120.*
56. *Ganeshkumar S, Sureshkumar R, Sureshbabu Y, Balasubramani S 2020, A Review On Cutting Tool measurement In Turning Tools By Cloud Computing Systems In Industry 4.0 And Iot, GIS SCIENCE JOURNAL, Vol 7, No 8, pp 1-7.*
57. *Ganeshkumar S, Sureshkumar R, Sureshbabu Y, Balasubramani S, 2019, A Numerical Approach To Cutting Tool Stress In Cnc Turning Of En8 Steel With Silicon Carbide Tool Insert, International Journal of Scientific & Technology Research, Vol 8, No 12, pp 3227-3231.*
58. *Ganeshkumar, S., Thirunavukkarasu, V., Sureshkumar, R., Venkatesh, S. and Ramakrishnan, T., 2019. Investigation of wear behaviour of silicon carbide tool inserts and titanium nitride coated tool inserts in machining of en8 steel. International Journal of Mechanical Engineering and Technology, 10(01), pp.1862-1873.*
59. *Venkatesh, S., Sivapirakasam, S.P., Sakthivel, M., Ganeshkumar, S., Prabhu, M.M. and Naveenkumar, M., 2021. Experimental and numerical investigation in the series arrangement square cyclone separator. Powder Technology, 383, pp.93-103.*

60. Kumar, S.G. and Thirunavukkarasu, V., 2016. Investigation of Tool Wear and Optimization of Process Parameters in Turning of EN8 and EN 36 Steels. Asian Journal of Research in Social Sciences and Humanities, 6(11), pp.237-243.
61. Ganeshkumar, S., Sureshkumar, R., Sureshbabu, M.Y. and Balasubramani, M.S., A Review of Performance Investigations in Hydrogen–Oxygen Generator for Internal Combustion Engines.
62. KUMAR, S.D. and KUMAR, S.S., 2021. Effect of heat treatment conditions on ballistic behaviour of various zones of friction stir welded magnesium alloy joints. Transactions of Nonferrous Metals Society of China, 31(1), pp.156-166.
63. Kumar, S.D. and Kumar, S.S., 2020. Numerical and experimental ballistic performance of welded magnesium (AZ31B) plates. Emerging Materials Research, 9(4), pp.1217-1228.
64. Kumar, S.D., Kumar, S.S. and Kumar, K.A., 2020. Investigation of forced frequency in a commercial vehicle suspension system. Mechanics and Mechanical Engineering, 22(4), pp.967-974.
65. Sundaram, S.K., 2020. Experimental ballistic performance determination of friction stir welded magnesium (AZ31B) targets. Mechanics Based Design of Structures and Machines.
66. Kumar, S.S., Kumar, S.D. and Magarajan, U., 2020. Investigation of mechanical and wear behaviour of graphene reinforced aluminium alloy 6061 metal matrix composite. KOVOVE MATERIALY-METALLIC MATERIALS, 58(5), pp.341-349.
67. Kumar, S.D. and Kumar, S.S., 2019. Investigation of mechanical behavior of friction stir welded joints of AA6063 with AA5083 aluminum alloys. Mechanics and Mechanical Engineering, 23(1), pp.59-63.
68. Magarajan, U., Arvind, D., Kannan, N. and Hemanandan, P., 2018. A comparative study on the static mechanical properties of glass fibre vs glass-jute fibre polymer composite. Materials Today: Proceedings, 5(2), pp.6711-6716.
69. Yessian, S. and Varthanan, P.A., 2020. Optimization of performance and emission characteristics of catalytic coated ic engine with biodiesel using grey-taguchi method. Scientific reports, 10(1), pp.1-13.
70. Sureshbabu, Y. and AshokaVarthanan, P., 2014. Study the emission characteristics of catalytic coated piston and combustion chamber of a four stroke spark ignition (SI) engine. Journal of Chemical and Pharmaceutical Sciences, JCHPS Special, (4).
71. Sureshbabu, Y., Ashokavarthnan, P., Balasubramani, S. and Naveenprabhu, V., 2019, October. Experimental investigation on four strokes catalytic coated spark ignition (SI) engine. In AIP Conference Proceedings (Vol. 2161, No. 1, p. 020041). AIP Publishing LLC.
72. SureshBabu, Y., Mutyalu, K.V. and Prasad, Y.S., 2012. A Relevant Document Information Clustering Algorithm for Web Search Engine. International Journal of Advanced Research in Computer Engineering & Technology (IJARCET), 1(8).

