DEVELOPMENT OF STEERING CONTROL SYSTEM FOR AUTONOMOUS VEHICLE

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Abstract

In this task we've evolved a steering control system for a self-riding vehicle. In-order to make the automobile steer whilst it's miles critical to influence toward the path that it's far required to influence and secure to influence. This system is implemented in a 4-wheel Electric Micro car. In order to track the path an algorithm called Pure Pursuit algorithm which is used to calculate the required steering angle. Given the general success of the algorithm over the last few years, it appears likely that it will be used again in land-based navigation issues. "Path tracking" is finished using an "Pure pursuit path tracking set of rules". Though the set of rules is used to song the direction, the records is taken from the lane tracking process that's done using photograph processing method and that very identical data is used to offer the inputs in-order to get the steerage wheel to influence at the velocity it required to receives steer so that it will turn the automobile at the speed which it is travelling.

After the required steering angle is obtained, to steer the car a closed loop stepper motor is used to persuade the steering wheel from the inputs which can be taken from the on-board micro controller. The car is tested at different speeds (of 10kmph,15kmph,20kmph,25kmph) and based on the assessments the above structures had been analysed and vital modifications have to be carried out.

Keywords—*self-riding, pure pursuit algorithm, closed loop stepper motor.*

I. INTRODUCTION

Majority of the collisions of automobiles that occur is a result of slow reaction of the driver towards the brakes and poor sensing of the environment. The driver's inaccurate judgment for braking at a safe distance is the primary reason to cause an accident in the highway traffic system. According to WHO 'Every year the lives of approximately 1.35 million people are cut short as a result of a road traffic crash. Between 20 and 50 million more people suffer non-fatal injuries, with many incurring a disability as a result of their injury'. There are many reasons that led to the commencement of collisions and primarily grounds on futility of the driver. Hence it is recognized as a Global issue and as a serious health problem. No matter what, Life is more precious hence Driver assistance systems are introduced to assist drivers in panic situations.

With advancements in information and communication and vehicle techniques, the competition to develop and commercialize intelligent Advanced Driver Assistance System (ADAS) and Autonomous Vehicles has intensified. The aim of these vehicles is to secure vehicle stability and driver ease, as well as to enhance traffic efficiency.
An autonomous vehicle has to be controlled both longitudinally and laterally. To control a vehicle autonomously different sensors and an onboard computer is required.

In order to track the path a geometric path tracking algorithm is used. The geometric path-racking method is one of the most popular methods, following pure pursuit, vector pursuit, and the Stanley method. The pure pursuit method is relatively easy to implement and is robust to large disturbances. However, this method has a problem of cutting corners at high speed, because the look-ahead distance increases along with an increase in vehicle speed. In addition, steady-state errors occur at high speed. The pure pursuit method is used to apply path tracking to an autonomous vehicle, is easy to implement, and is robust to large disturbances.

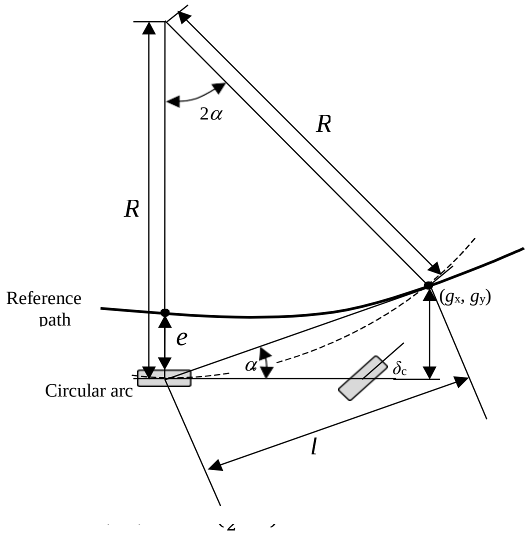
To follow the path generated by path tracking algorithm we need control the steering of the vehicle using external devices. For this a closed loop stepper motor was installed on the steering column of the vehicle where the motor is controlled by motor driver which receives a command from a micro controller.

II. PURE PURSUIT ALGORITHM

Pure pursuit is a tracking algorithm that works by calculating the curvature that will move a vehicle from its current position to some goal position. The whole point of the algorithm is to choose a goal position that is some distance ahead of the vehicle on the path.

The pure pursuit approach is a method of geometrically determining the curvature that will drive the vehicle to a chosen path point, termed the goal point. This goal point is a point on the path that is one look ahead distance from the current vehicle position. An arc that joins the current point and the goal point is constructed. The chord length of this arc is the look ahead distance, and acts as the third constraint in determining a unique arc that joins the two points. Consider the look ahead distance to be analogous to the distance to a spot in front of a car that a human driver might look toward to track the roadway.

The pure pursuit algorithm consists of geometrically calculating the curvature of a circular arc that connects the center of the rear axle to the goal point on the path ahead of the vehicle. The goal point is determined from the look-ahead distance (l). The desired steering wheel angle of the vehicle is determined using angle α between the heading angle of the vehicle and the look-ahead vector. The pure pursuit geometry is shown in below figure.



(1)

$$\frac{l}{2\sin(\alpha)\cos(\alpha)} = \frac{R}{\cos(\alpha)} \quad (2)$$

$$\frac{l}{\sin(\alpha)} = 2R \quad (3)$$

$$K = \frac{2\sin(\alpha)}{l} \quad (4)$$

where κ is the curvature of the circular arc. Applying an Ackerman model with two degrees of freedom, the steering angle is given as

$$\delta = \tan^{-1}(\kappa L), \quad (5)$$

where L is the wheel base. Using (4.) and (5), the desired steering angle can be written as

$$\delta_l(t) = \tan^{-1}\left(\frac{2L\sin(\alpha(t))}{l}\right) \quad (6)$$

The pure pursuit is influenced by the look-ahead distance, which is dynamically adjusted with the velocity. A characteristic of the pure pursuit is that a sufficient look-ahead distance will result in cutting corners while tracking a curved path. To improve this characteristic and steady-state error, we use the lateral offset (error) between the vehicle and path. The examples of lateral offset are shown in Fig.. To the left is the cutting corners phenomenon, and to the right is the steady-state error. To reduce the lateral offset, we apply proportional integral (PI) control theory, as in equation (7) below.

The desired steering angle according to the lateral offset δe (t)is the sum of the proportional term Pe (t)and integral term Q(κ(t))∫e dt where and Q(κ(t)) are the proportional and integral gains, respectively; both of which are positive values.

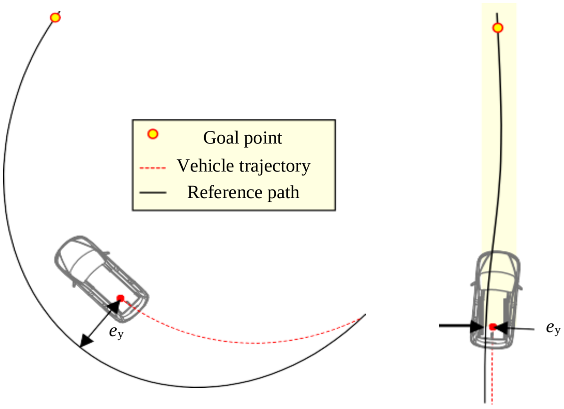
$$\delta_e(t)=P_e(t)+Q\,(\kappa(t))\int e\,dt \qquad (7)$$

The proportional term performs the role of reducing the lateral offset by reducing the target steering in the cutting corners phenomenon. On the other hand, the integral term is useful when a path has a small curvature and eliminates the residual steady-state error.

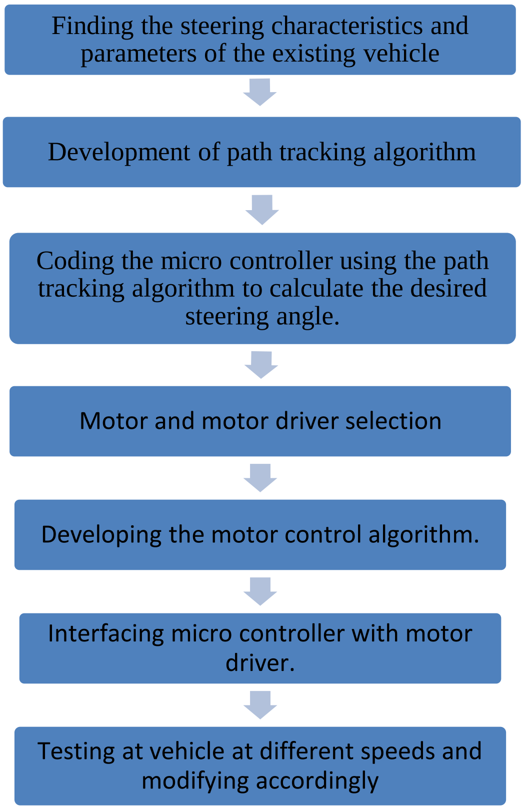
The integral gain is a function of the road curvature.The total desired steering angle, δt, is given in following equation:

$$\delta_t = \delta_l + \delta_e \qquad (8)$$

Where δl is the desired steering angle by look ahead distance.



III.METHODOLOGY



III. PROCEDURE

A. *TORQUE ON STEERING WHEEL*

Wheel Base	162 cm
Track Width	95 cm
Weight	228 kg
Weight ratio (Front:Rear)	35:65
Weight on front axle	79.8 kg
Weight on rear axle	148.2 kg
Pivot Distance	68 cm
Scrub	7 cm
Mechanical Trail	3 cm
Tie rob inclination	35 degrees
Pinion Radius	2 cm
Steering Wheel radius	15 cm

Fig.3 Specifications of Electric Micro Car

$$\text{Turning inner radius}(R_i) = \frac{\text{wheel base}}{\sin(\emptyset)} - \frac{\text{Track width} - \text{pivot distance}}{2} \quad (9)$$

$$= \frac{1.62}{0.57} - \frac{0.95-0.68}{2} = 2.70 \text{ m}$$

$$\text{Turning outer radius}(R_o) = \frac{wheel\ base}{sin(\Theta)} - \frac{\text{Track width} - \text{pivot distance}}{2} \quad (10)$$

$$= \frac{1.62}{0.5} - \frac{0.95-0.68}{2}$$

$$= 3.105 \text{ m}$$

$$\text{Average turning radius} = \frac{Ri+Ro}{2} = \frac{2.70+3.105}{2} = 2.90 \quad (11)$$

$$\text{Lateral force} = W_f \times (V^2/R) \times \text{Mechanical Trail} \quad (12)$$

$$= 79.8 \times \frac{69.4}{2.90} \times 0.03$$

$$= 57.29 \text{ N}$$

W_f – weight on front wheels

R – turning radius

V – maximum speed

Traction force = mass of vehicle × g × coefficient of traction

= 228 ×9.81× 0.7

= 1565.67N

Total torque = (lateral force × Trail) + (Traction force × scrub) (13)

$= (1909.69 \times 0.03) + (1565.67 \times 0.07) = 166.88$ Nm

$$\text{Force} = \frac{\text{Total torque}}{\text{steering arm length}} \quad (14)$$

$$= \frac{166.88}{0.125} = 1335.04 \text{ N}$$

Torque on pinion = force on rack × pinion (15)

$= 1093.60 \times 0.02 = 21.87$ Nm

Torque on steering wheel = torque on pinion

$$\text{Steering effort} = \frac{\text{Torque on steering wheel}}{\text{steering wheel raius}} \quad (16)$$

$$= \frac{21.87}{0.15}$$

$$= 145.81 \text{ N}$$

Based on these calculations it is clear that to control the steering using a motor, then that motor should have a minimum torque of **21.87 Nm .**

B. *Motor and controller selection:*

To motor should have the following specifications for controlling the steering:-

- Should be able to produce a torque upto 40Nm
- Should deliver high torque at low RPM
- Can be controlled using an Rasberry Pi or Arduino i.e, the controller should take the input signals of 5v
- Should be operated with 24v to 46v DC power source
- Should give the position feedback
- Angle should be controlled precisely
- The output shaft should have a key slot to connect to a gear or pulley

Based on the above specifications Servo motor and closed loop stepper motor are the most suitable types of motor for this application.

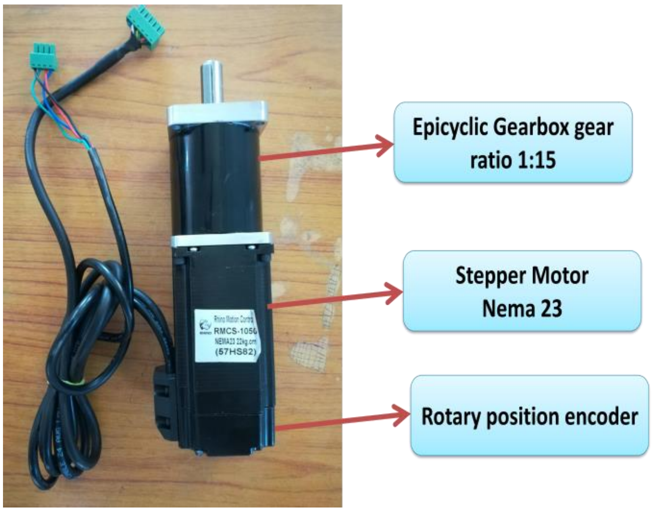


Fig.3 Stepper motor with gearbox

C. *Design of motor mount:*

- This mount has to hold the motor on the steering column.
- Mount has to be restricted in all the three directions .
- The steering column should rotate freely inside the mount.
- Vertically the motor mount is hold on the column using a radial ball bearing .
- A 5mm mild steel plates are selected for this mount.
- The maximum torque acting on the mount is 45 Nm .
- Mount is also designed to hold the motor in position with the column so as to mate the gear.

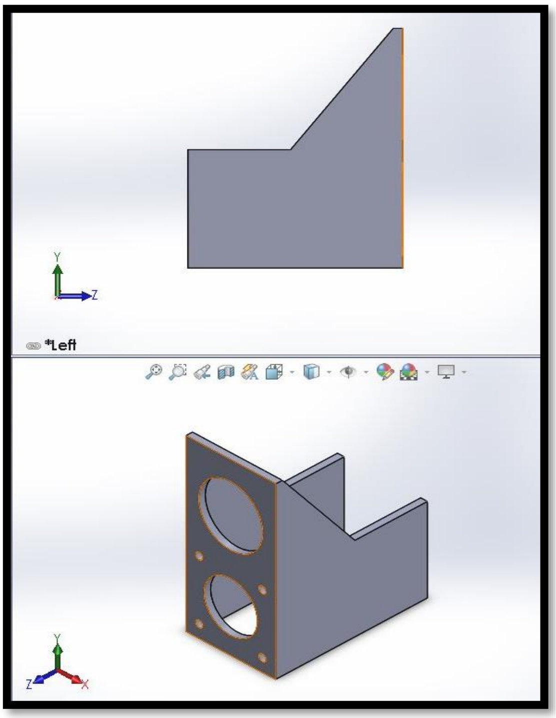


Fig.4 Side view and Isometric view of Steering mount

D. *Motor Assembly;*

In order to allow the column to rotate freely on the column a bearing is used in this assembly. The gears on the motor shaft and column shaft are hold together using keys.The motor mount is attached to the chasis of electric micro car using bolts where a special tabs are designed and joined with the motor mount using Arc welding.

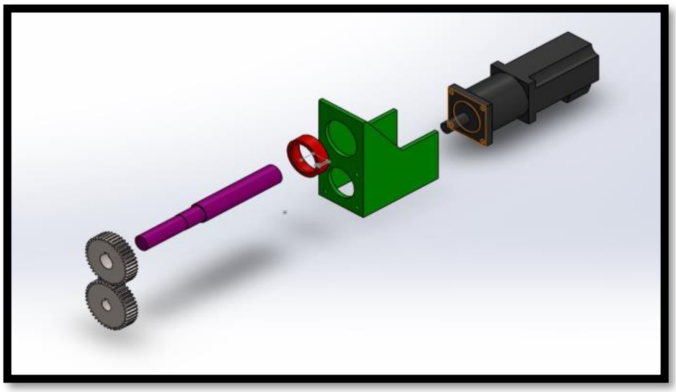


Fig 5. Exploded view of Steering motorassembly

IV. RESULTS AND DISCUSSIONS

The ultimate goal was to develop a steering control system which can be retrofitted in a 4 wheeler at lowest cost possible. This was the main reason to select closed loop stepper motor over servo motor..The stepper motor couldn't rotate more than one revolution (gearbox output). When the steps generated by the micro controller are more than one revolution then the motor out shaft would rotate one revolution only which is not suitable in steering from one end to other. Later the issue was resolved by reducing the micro stepping to 1/16 th of the previous that is set in the motor driver RMCS-1110.The driver has an inbuilt PID algorithm with well-tuned Kp ,Ki and Kd gains based on the motor characteristics .These gains are to adjusted within a range in order to obtain results as expected .The tests that are to be conducted on this vehicle couldn't be done due to the pandemic. But the expected results that we would get when tested are known from previous study. The below graphs are the expected results from this control system.

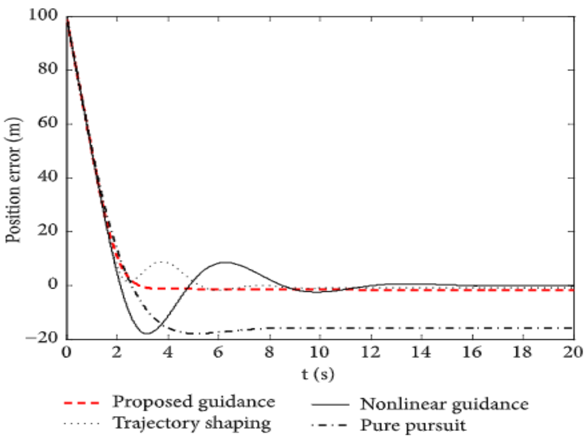


Fig 6 Path tracking in a straight line

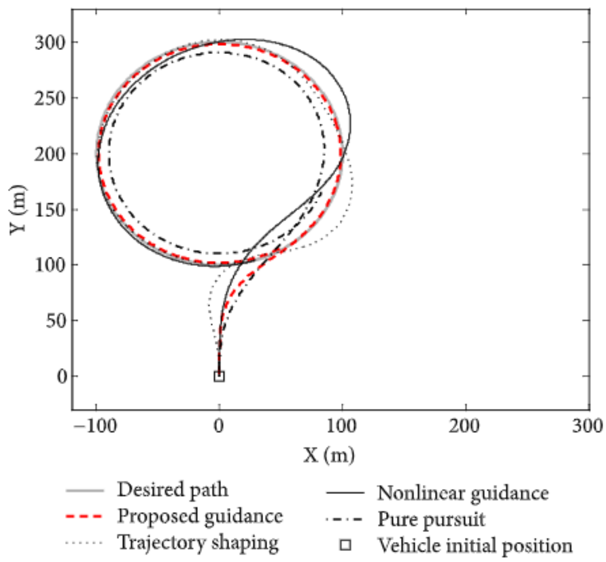


Fig 7 Path tracking a circle

V. SUMMARY AND CONCLUSION

The system is retrofitted in electric micro car so an onboard electric power can be used to control the steering. The existing steering in the electric micro car is mechanical, so it is converted to an electric power steering. The steering motor should be able to controlled precisely and easily. Based on the requirements servo motor and closed loop stepper motor were most suitable for this application. Considering cost, holding torque stepper motor was well suited rather than servo. A Nema 23 standard closed loop stepper motor with gearbox is selected and a suitable motor driver which can be controlled using an Arduino is selected.

This steering motor is to be directly attached to the steering column using gears which are directly meshed. So the column has specially designed and manufactured which holds the in position relative to the gear on the motor shaft. To hold the motor in position with the column and gear amount is designed and manufactured. The on board 48V Dc power is used to control the motor.

This entire system will give better results only when the lane data is accurate. In this system the vehicle is considered as neutral steer condition i.e, neither understeer nor oversteer .But in real conditions the vehicle is in either oversteer or under steer condition with speed. Since the vehicle is tested in low speed these conditions are neglected. This system can be retrofitted in any vehicle considering the vehicle speed and conditions. This is very suitable for the vehicles which run in a controlled environment like airports, industries which reduces human labor and thereby reducing the running costs.

REFERENCES

1) Thomas D.Gillespie Fundamentals of Vehicle Dynamics, Warrandale ,Society Of Automotive Engineers,1992.
2) R. Craig Conlter (1992) , Implementation of the Pure Pursuit Path tracking Algorithm , CMU .
3) National Instruments laboratory (2016), Understanding Servo Tune.

4) Myungwook Park, Sangwoo Lee, and Wooyong Han (June,2015), Development of Steering Control System for Autonomous Vehicle Using Geometry-Based Path Tracking Algorithm, ETRI Journal, Volume 37.
5) Vicente Milanés, Joshué Pérez and Enrique Onieva (2009), Electric Power Controller for Steering Wheel Management in Electric Cars ,Research gate .
6) Jarrod M. Snider (2009) Automatic Steering Methods for Autonomous Automobile Path Tracking, CMU-RI-TR-09-08 .
7) Chieh Chen, Han-Shue Tan (1999) Experimental Study of Dynamic Look-Ahead Scheme for Vehicle Steering Control, Proceedings of the American Control Conference.
8) Venkata Rao, Bachina Harish Babu, V. Umasai Vara Prasad, A study on effect of dead metal zone on tool vibration, cutting and thrust forces in micro milling of Inconel 718, Journal of Alloys and Compounds, Volume 793, 2019, Pages 343-351, ISSN 0925-8388, https://doi.org/10.1016/j.jallcom.2019.04.194.
9) Babu, B.H., Rao, K.V. & Ben, B.S. Modeling and optimization of dead metal zone to reduce cutting forces in micro-milling of hardened AISI D2 steel. J Braz. Soc. Mech. Sci. Eng. 43, 142 (2021). https://doi.org/10.1007/s40430-021-02861-5.
10) M. Selvamuthukumar, B. Harish babu, Sujith bobba, S. Baskar, Nivin Joy, Investigation on the lubricating behavior of cashew nut shell liquid oil as a renewable and reliable petrochemical product, Materials Today: Proceedings, Volume 44, Part 5, 2021, Pages 3583-3588, ISSN 2214-7853, https://doi.org/10.1016/j.matpr.2020.09.458.
11) Palakuru Mahesh , Sirisha Adamala , Harish Babu Bachina, Application of Space-Born Remote Sensing To Analyze Forest Cover in Chittoor (India) Area, International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887 Volume 6 Issue I, January 2018- Available at www.ijraset.com.
12) Krishna Reddy, Y.V., Sirisha Adamala and Bachina Harish Babu. 2017. Case Study on Performance Evaluation of Drip Irrigation Systems in Selected Villages of Guntur District, Andhra Pradesh, India. Int.J.Curr.Microbiol.App.Sci. 6(2): 437-445. doi: http://dx.doi.org/10.20546/ijcmas.2017.602.049
13) MAHESH PALAKURU, SIRISHA ADAMALA, & HARISH BABU BACHINA. (2020). Modeling yield and backscatter using satellite derived biophysical variables of rice crop based on Artificial Neural Networks. Journal of Agrometeorology, 22(1), 41–47. https://doi.org/10.54386/jam.v22i1.120.
14) P. Manoj Kumar , Bachina Harish Babu, S. Gowtham & K. Rajesh, Development And Study Of Tribological Properties Of Bio composite For Brake Pad Application, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P): 2249-6890; ISSN (E): 2249-8001 Vol. 7, Issue 6, Dec 2017, 263-270.
15) M Shri, B H Babu, V. Harish, Syed Riyaz Ahammed, R Hushien, Manoj Kumar, Optimized Water Pumping System Using Arduino For Home Automation, International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 8, August 2017, pp. 1412–1416, Article ID: IJMET_08_08_145 Available online at http://iaeme.com/Home/issue/IJMET?Volume=8&Issue=8 ISSN Print: 0976-6340 and ISSN Online: 0976-6359.

16) Bobba, S., Selvamuthukumar M.,, H babu, B., & Leman, Z. (2022). Solar-Based Mosquito Trap for Household Purposes. International Journal of Social Ecology and Sustainable Development (IJSESD), 13(1), 1-10. http://doi.org/10.4018/IJSESD.288536
17) Sujith Bobba, Z. Leman , B. Harish Babu, Environmental effects on the mechanical properties of E-glass and S-glass fiber epoxy composite ring specimens used in aircraft fuel pipes, Incas Bulletin, Volume 13, Issue 4/ 2021, Pp. 17 – 24 (P) Issn 2066-8201, (E) Issn 2247-4528.
18) Bobba, S., Mukkollu, S. R., Leman, Z., & Bachina, H. B. (2021). Experimental Investigation on the Effect Due to Mould Vibrations on Mechanical and Metallurgical Properties of Aluminum Alloy (A-1050). International Journal of Surface Engineering and Interdisciplinary Materials Science (IJSEIMS), 9(1), 77-86. http://doi.org/10.4018/IJSEIMS.2021010105.
19) B H Babu, Dillip Kumar Sahoo, Study of Tribological and Thermal Properties of Engine Lubricant by Dispersion of Aluminium Nano Additives. , Revue des Composites et des Matériaux Avancés, Apr2020, Vol. 30 Issue 2, p103-107.
20) Sujith Bobba, Mukkollu Sambasiva Rao, B. H Babu, Z. Leman (2020). Effect on the Mechanical Properties of Grey Cast Iron with Variation of Molybdenum and AS – Cast Alloying Elements. Universal Journal of Mechanical Engineering, 8(6), 298 - 304. DOI: 10.13189/ujme.2020.080602.
21) R Prabhu, BH Babu, M Selvamuthukumar, N Poiyyamozhi, Nanocomposites in food packaging, Int. J. Recent. Technol. Eng 2, 2277-3878.
22) Adamala, Sirisha & Srivastava, Ankur & Palakuru, Dr. (2020). Evaluation of VIC, ANN and Empirical Models for Estimating Daily Reference Evapotranspiration. Indian Journal of Ecology. 47. 29-36.
23) Palakuru, Dr & Adamala, Sirisha & BHB. (2020). Spatial Mapping of Rice Crop Evapotranspiration in Godavari Command Area, Indian Journal of Ecology. 2020, 47(2), pp. 361–364
24) Palakuru, Dr & Reddy, Venkat & Adamala, Sirisha . (2020). Hydrological Appraisal of Nariganipalli Watershed (India) using Spatial Information Technology, Indian Journal of Ecology 47(2), pp. 281–285.
25) Babu, B.H., Rao, K.V. & Ben, B.S. Modeling and optimization of dead metal zone to reduce cutting forces in micro-milling of hardened AISI D2 steel. J Braz. Soc. Mech. Sci. Eng. 43, 142 (2021). https://doi.org/10.1007/s40430-021-02861-5.
26) Babu, B.H., Ahammed, S.R., Dheeraj, S.P,Shiferaw, A.Y.(2019) Development of sensors by 3D printing technology-fused deposition modeling, International Journal of Innovative Technology and Exploring Engineering 9(1), pp. 2182-2185.
27) Dr. A. Rama Rao, Dr. Bachina Harish Babu, Dr. Mahesh Mallampati & Dr. Sujith Bobba, (2022). Fabrication and Testing of Al7075 with Hard Ceramic Particles and Solid Lubricant Particles (Sic-Gr) Using Stir Casting Process, YMER, VOLUME 21: ISSUE 10 (Oct) – 2022,1279-1292, 10.37896/YMER21.10/A8.