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Execution of Nonstop Mutable Transmission Structure (NMTS) in Farming Vehicle

Ponnusamy P, Velmurugan P, Senthil Kumaran S, Kathiravan Srinivasan, Srinivasan N

Abstract: ***This paper briefly reviews the potential use of the Continuously Variable Transmission System (CVT) and its different types in a tractor. CVT is a system in which transmission is adapted automatically through continuous variable adjustment of the pulleys. The paper starts with studying the requirement of innovation in agricultural tractors through a case study and goes about discussing the results of modeling, simulation and experimental works done in this field. The paper also focuses on advantages and disadvantages of opting CVT over other transmission systems. Different efforts performed to optimize the electronic controller were also discussed. The key results that were noticed were that CVT reduces the overall fuel consumption and weight of the system. It was also noticed that it causes vehicle to show signs of improvement footing attributes, stay away from flameout, and retain vibrations and it wipes out move stun and offers smooth increasing speed. Few instances were observed where CVT implementation cannot be a commercially viable option, but overall it seems to be a very promising technology and already many heavy vehicles have started to use them. This paper also reviews all the essential factors involved in design of a transmission system for a commercial tractor which might ease the process of collecting data.***

***Keywords: Transmission system, Agricultural sector, CVT, design of transmission system, Tractors*.**

I. INTRODUCTION

The rural tractor is one of the classes of portable machines that include the 'traction' process that includes activity under what is known as 'rough terrain' conditions. The conduct of tractors' clients, concerning the presentation and selection of imaginative attributes, has gotten low consideration. Eugenio et al. [1] broke down the edge and assessment of an example of Italian clients of farming tractors, concerning a few developments, to diagram various profiles of conduct.

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***** Correspondence Author
Ponnusamy P School of Mechanical Engineering, Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, India. Email: ponnusamy.p@vit.ac.in
Velmurugan.P Department of Mechanical engineering, School of mechanical and automotive Egineering, College of engineering and Technology, Dilla university, Ethioipia.. Email: velmuruganp_1980@yahoo.co.in
Senthil Kumaran S* Department of Manufacturing Engineering, School of Mechanical Engineering, Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, India. Email: senthilkumaran.s@vit.ac.in
Kathiravan Srinivasan, Department of Information Technology, School of Information Technology and Engineering, Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, India. Email: kathiravan.srinivasan@vit.ac.in
Srinivasan N Department of Manufacturing Engineering School of **Mechanical** Engineering, Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, India. Email: srinivasan.narayanan@vit.ac.in

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The example is predicated on 228 ranchers, temporary workers and representatives, taking an interest at the International Exhibition of Agricultural Machinery. Information is investigated by Multiple Correspondence Analysis and Cluster Analysis. As can be seen in Fig. 1, The surveys tell us that about 30 % of the sample want innovation to happen in the CVT and about 40 % want innovation in maintaining good speed of the tractor.

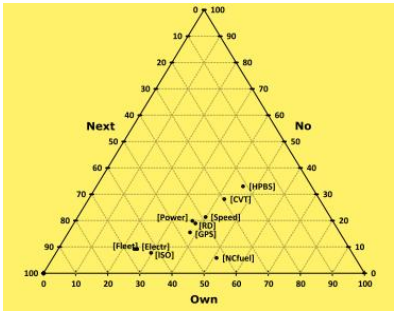

Fig. 1 Percentage distribution of people who want innovation in different sectors [1]

When contrasted with vehicles, tractor has diverse structures and furthermore needs to confront awful working conditions and the incessant outside burden variance. Subsequently it is significant that the transmission arrangement of tractors modifies the yield torque and speed consequently, which will guarantee full utilization of motor power and be of over-burden insurance with separating properties execution.

Further, the worldwide agricultural labor force is decreasing continuously year by year and at the same time the tractor market is expected to see a 3.08 % growth [22]. Therefore, there is a strong need to shift away from manual transmission system and incorporate systems which can automate the entire process.

In this paper, we shall mainly focus on the design and analysis of CVT systems for tractors and evaluate its and performance and efficiency.

2.1 Conventional transmission system

In regular transmission framework, to switch the gear the grip pedal is squeezed which switches the gear as indicated by the need of the administrator. The span where grasp pedal withdraws the gear framework from the turning motor shaft, the gear is changed and the grip pedal is discharged. The piece of the transmission known as the 'differential' has the capacity of isolating the drive to the haggles them to turn at various speeds as the tractor turns a corner. Discharging the grip pedal connects with the gear framework with the pivoting motor and the power is transmitted to the wheels through the gear framework; however the disadvantage of this framework is that the power stream is intruded on each time when the gear is changed and thus the value yield of the motor is additionally influenced bringing about more utilization of fuel as well. This framework in tractors brings about utilization of more fuel for cultivating activities expanding the costs of the ranchers.

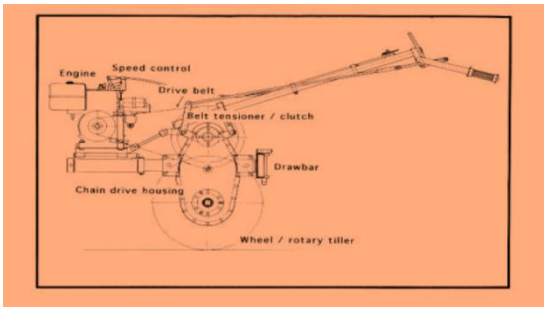

Fig. 2 A layout of continuously variable transmission system [21]

2.2 Continuously variable transmission (CVT):

In a CVT, the push belt transfers the torque from one pulley to other. The level of power transmission is adapted automatically through continuous variable adjustment of the pulleys. It is very contrasting from the mechanized transmission that envelops a set assortment of medications proportions. A CVT utilizes segments, for example, a high thickness elastic/metal belt, a driving pulley incited by water-driven chamber, a mechanical torque-detecting driving pulley, sensors and chip to play out its capacity. Fig. 2 and 4 shows a sketch of a continuously variable transmission system with a drive belt.

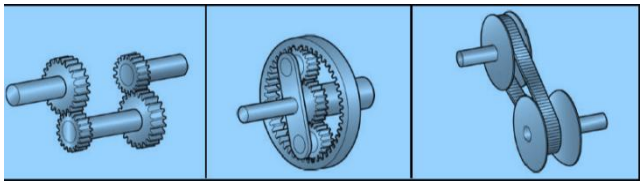

Fig 3. The first image shows Manual Transmission (MT), while the second represents Automatic transmission (AT) and third represents Continuously Variable Transmission (CVT)

Fig. 3 shows the distinction between manual transmission, automatic transmission, and a CVT.

2.3 Working of CVT

A pulley based CVT utilizes three principal parts:

- Electronically controlled and oil weight bolstered cones
- The cones structure a couple of pulleys-one of them is the 'input driving' pulley and the other is the 'yield driven' pulley.
- High-quality alloy steel belt running through the pulleys.

The pulleys can change its distance across when the cones move separated or towards one another. The cones have a point of 20° and they face one another. Belts form the main connection between these pulleys. Elastic belts in the state of 'V' go through the hole between the cones. These days, increasingly proficient adaptable metal belts are utilized to deal with more torque.

A perpetually Variable Transmission works by shifting the working distance across of the 2 principle pulleys inside the transmission.

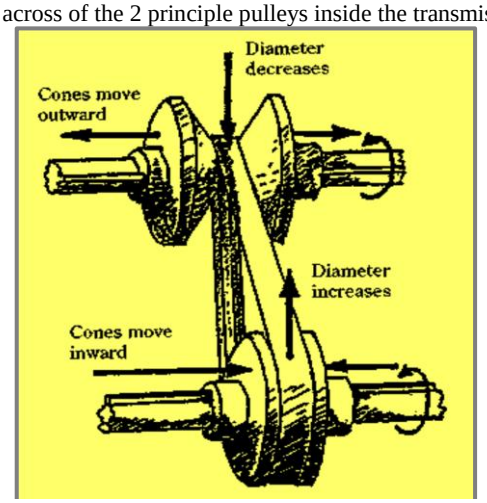

Fig. 4 CVT system sketch

The engine power is moved from the information driving pulley to the yield driven pulley by means of the belt. By shifting the hole between the cones in the pulleys, a vast number of gear proportions can be accomplished. The cones can be hydraulically worked or spring worked to change the separation between them. At the point when the cones of a pulley are far separated, the span of the belt rotating around the pulley decreases. Then again, if the hole between the cones lessons, the sweep of the belt rotating around the pulley increases.

II. LITERATURE REVIEW

Before building a suitable transmission system, it is important to analyse the types and variations in the loads that the transmission experience throughout its usage. Jung et al. [2] did this exactly through surveys and experimental data. A review was directed to research operational attributes like loads, strains and speeds by fitting torque transducers in the information shaft and radio telemetry frameworks for obtaining the data. The paper analyses the different patterns of usage of tractors across a variety of fields as shown in Fig. 5 and also gives ample data on the various load requirements successfully. The condition of the soil during such an experiment can be seen in Table. 1. This provides one a base for modeling and simulations and a benchmark for the various transmissions that could be built.

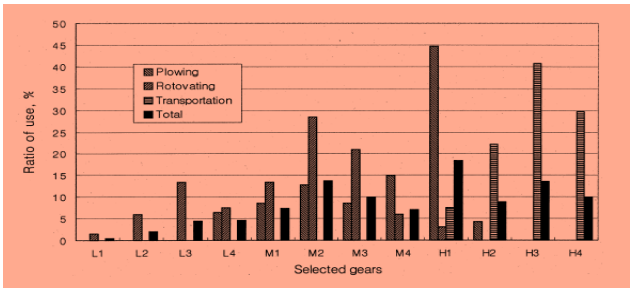

Fig. 5 The image depicts the patterns of usage of tractors across a variety of fields [2]

Contrasting the seriousness, the activities applied a heap on the info shaft of the transmission that was around multiple times more prominent than that for the transportation on the cleared street. Be that as it may, the loads for the furrowing and transportation were of a similar degree, in their seriousness, to the transmission. A huge distinction in the seriousness between the rotovating and different activities were because of huge change of torque load in the rotovating activity.

Field condition where load measurements were performed

Surface type	Soil classification	Cone index at depth of soil, kPa			Moisture content %
		0 cm	5 cm	10 cm	
Paddy field	Loamy sand	407.4	584.5	599.8	30.5
Upland I	Sand	423.3	593.7	858.5	24.2
Upland II	Sand	45.7	599.9	846.2	25.3

Table. 1 Field Conditions where load measurements were performed [2]

Aneesh et al. [24] collected the data of draft load on chassis from various experiments [25, 26, 27, 28, 29, 30, 31, 32]. The maximum force is because of mouldboard plough, as can be seen in Table. 2. By calculating the total load acting on the chassis, including the reaction forces, they performed a structural analysis over it.

Sr. No	Implement	Draft Force (Newton's)
1.	Mould Board Plough	16300
2.	Chisel Plough	15410
3.	Disc Harrow	1800
4.	Field Cultivator	3490

Table. 2 Draft force because of various implements [25,26,27,28,29,30,31,32]

Marco et al. [3] developed a theoretical model that investigated the performance of ground vehicles utilizing speeding up tests. The model takes into account the moving grating of the drive gadgets, their slip on the dirt, streamlined opposition, street incline and footing created by the motor. It was concluded that the by and large productivity is essentially affected by how the power is partitioned between the mechanical and the hydrostatic part and, in this way, by the level of commonness of one over the other. CVTs are broadly of two types: non-power split type and power-split type.

Prakash et al. [4] described different stages of installing a CVT in a manual transmission automobile. It was concluded that the CVT had reduced the weight of the system as can be seen in Fig. 6 and the fuel consumption considerably while giving a pleasant driving experience. Fig. 6 also shows the smooth variation of speed in case where CVT is implemented. We can see that there is reduction is variation of speed.

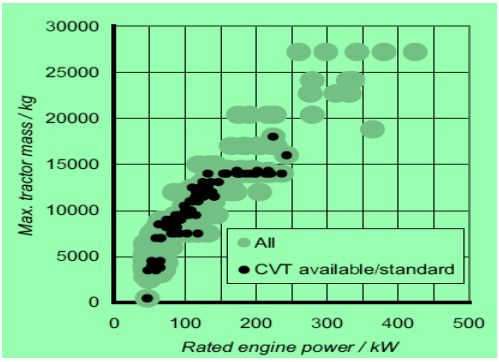

Fig. 6 The weight reduction [9] and smooth velocity variation observed when implementing CVT [8]

Sergio et al. [5] designed and tuned a control system of power-split hydrostatic CVT used in high power tractors [14]. This type of CVT inherently requires refined electronic control design, since the control and coordination of the pressure-driven and the mechanical parts of CVT can't be acquired by mechanical components as it were. The proposed design can be seen in Fig. 7.

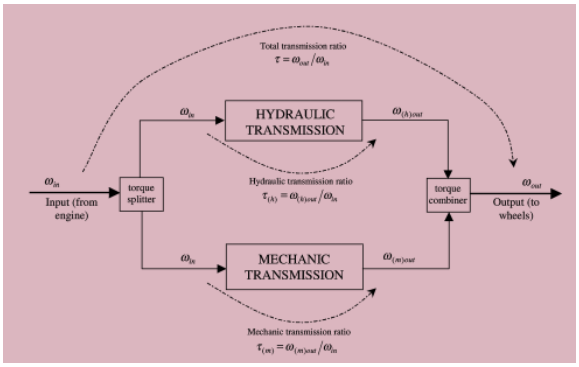

Fig. 7 Control system offered for CVT [5]

The control system proposed in work gave a near-optimal performance. However, improvements like replacing the speed sensors and pressure-driven siphon could further enhance the transmission ratio and reduce noise from the system. Zhang et al. [6] developed a control system of hydro-mechanical CVT using PID control method, which uses the motor speed and throttle numbers as control parameters. The research results demonstrate that it is a compelling strategy to refine dynamic exhibitions. Albeit all out transmission proportion is constant when multi-go HMCVT movements run, due to the speed variation when the heap of siphon engine framework is changed; there is likewise halfway effect of range move. In this manner, the range shift needs figure and composed control.

Usually, to improve the performance of a power-split CVT, the motor and transmission capacities must be synchronously controlled. Setlur et al. [7] built up a nonlinear control calculation which alters the transmission gear proportion and motor throttle edge while watching out for the motor and the wheel speeds to keep them at standard with the objective speeds.

Possibilities of implementing toroidal CVTs were also discussed by many authors. Kim et al. [8] show through testing that it can be controlled easily and maintain certain characteristics throughout its working range. The control systems respond to several pre-programmed conditions effectively but cannot cope with random and discrete disturbances that occur through daily usages. In another paper, they developed a PID controller, shown in Fig. 8, and communicate into pre-existing agricultural tractors to establish a remote-controlled and or automated tractor system. The results appeared to be safe enough for field operations but a commercial operation may not yet be viable.

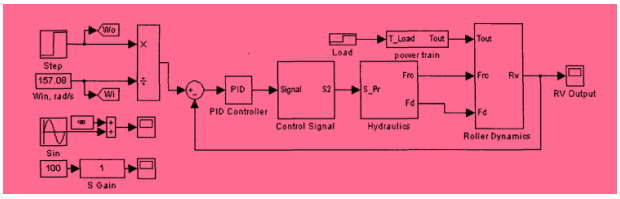

Fig. 8 PID Controller for a CVT system [8]

Attempts were also made to implement the control system in a manual transmission system. Youyu et. al [34] used an electronic control system. It was observed that the overall processing time decreased and completed with ease, greatly reducing the rough shift. The overall tractor operation efficiency and quality were improved.

Fendt Vario transmission system, a type of stepless CVT transmission in which the acceleration rates are adjustable and still gives great operator comfort. Martin et al. [9] discussed the advantages of using Frendt vario in the application of agricultural tractors. The electronification of the Frendt Vario CVT gives more freedom for automation. It also gives great stability control for tractors as described in Fig. 10. This might be very useful for high-speed tractor applications.

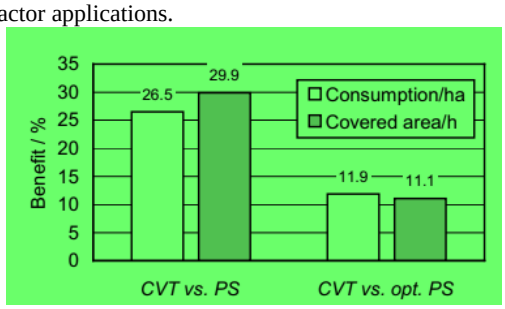

Fig. 9 Comparison between normal CVT vs. Power Shift transmission [9]

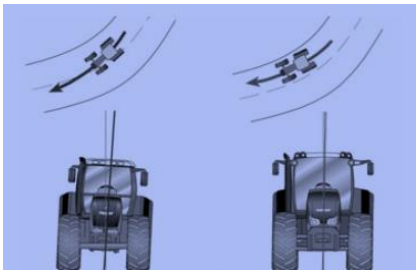

Fig. 10 Stability control in Frendt Vario CVT [9]

Fig. 9 shows that even though there is 3.4 % less benefit in using a CVT over power shift transmission, the fuel consumption benefit (about 1%) sets it apart from any other system.

John Babu et al. [10] in their paper talk about the working principle of CVT and its uses. It also covers the advantages it possesses over other transmission systems, and also the disadvantages it comes along with variable transmission (CVT) might be a transmission that may change without any steps through unbounded assortment of powerful gear proportions among most and least qualities. This diverges from option mechanical transmissions that exclusively empower various extraordinary unmistakable rigging proportions to choose. The adaptability of a CVT licenses the driving shaft to keep up a persevering rakish rate over an assortment of yield speeds. This can offer higher efficiency than other transmissions by authorizing the motor to keep running, taking care of the RPM for an assortment of vehicle speeds.

Rockwood et al. [11] in their paper talk about e-drive design and development. Dissimilar to numerous CVTs that are generally overwhelming and cumbersome, the present CVT, named "eDrive", is genuinely little and lightweight. These characteristics permit eDrive to be utilized in human-fueled vehicle gadgets, for example, bikes. The eDrive vows to expand a bicyclist's client experience, give progressively productive transformation of human vitality to motion, and by and large advance manageable urban transportation. Moreover, eDrive is structured and scaled to supply CVT reasonableness for a spread of elective vehicles and machines, similar to wind or water turbines and electric vehicles. They also talk about how CVT is an efficient solution to transmission systems.

Rahul et al. [33] talk about designing a gearbox for the transmission system of tractors with forwarding and rearward speeds of 16 using a ROMAX model.

Continuously Variable Transmission (CVT) offers a period of substances proportions between wanted breaking points. This empowers the motor to work longer inside the perfect change. Incapability, standard modified and manual transmissions have a couple of fixed transmission extents obliging the engine to work outside the perfect range. The prerequisite for gear and besides the standard of CVT has been referenced sweeping. An undertaking has been made to know the dedication of Hydraulic Actuators, which is a fundamental bit of a CVT. Additionally, the subject of regardless and why a converter has effectively superseded a standard hold has been answered. The materials used constructional points of view and stress examination of the belt has been discussed in detail.

Kim et al. [23] attempted to develop an autonomous 50 HP tractor. Electric actuators were implemented for shuttle-shifting and clutch control automatically. The outcome, as shown in Table. 3, depicts that the maximum total time and shifting shock of all shifting directions were below 2.5 sec and 0.55 G respectively.

Shifting direction	Neutral to forward	Neutral to reverse
	(avg., max.)	(avg., max.)
Shifting shock (G)	0.25,0.55	0.35, 0.47

Table 3. Shifting shock of a 50 Horse Power tractor

It is also important to note that it is not only CVT which offers efficient fuel consumption [35,36]. Naren et al. [36] talk about design and implementation of DCT. It removes shift shock and results in a much smoother acceleration.

The use and effectiveness of CVTs in agricultural fields were fairly well-established and documented. Albeit complete transmission proportion is consistent when multi-extend HMCVT movements go, in view of the speed variation when the heap of siphon engine framework is changed, there is additionally a fractional effect of range move.

CVT offers great pleasure for the driver when driving because of smooth acceleration and also reduces the overall fuel consumption.

The structural analysis of the chassis [24] concluded that the maximum deformation and maximum stress happens near the end of the axle and trumpet of housing of clutch respectively. The power losses by a 65 HP tractor compared to 50 HP is very negligible and even a 50 HP tractor's chassis can be used for 65 HP one as the factor of safety still remains above 1 when you use it.

We looked into the automation and automation of the complete tractor, with PID Controllers and other sensors, to take a look at the difference in response time and the amount of skill involved from the driver's perspective. Various degrees of human-machine interfaces (HMI) and programmed transmission control methodologies give custom-made answers for various objective markets–last clients and OEM. So, as such, it is an incomplete system and needs reactive capabilities brought together in a hybrid system before it could be used in a practical way.

In addition to this, a crucial element that was to be analyzed and documented was the different kinds of forces and loads that a transmission has to deal with. This information is highly beneficial during simulation models for the transmissions. It would help in the verification of results by extrapolating this data onto our model and then give a fair conclusion on whether the simulation is a success.

The commercial operation of Toroidal CVT may not be a viable option. Fredt Vario CVT offers more freedom in operation and is also more stable.

Continuously Variable Transmission (CVT) offers a period of substances proportions between wanted breaking points

As CVT tractors are top of the line working gear, various expansions assurance improved profitability. Headland the executives is just one of these highlights. As it decreases the quantity of activities a driver needs to take inside one turn, "TeachIn" builds the rancher's effectiveness [12].

Though DCT offers the most dynamic acceleration of any vehicle on the market at present, additional costs are involved with modifying production lines to accommodate for it.

III. CONCLUSION

The types of CVT system, and its uses were discussed in this manuscript, including its advantages and disadvantages. After extensive and careful reading of literature suggested possibility of modified transmission system. As there is a mismatch of availability of efficient agricultural labor force and its demand. This is true for India and other countries. Further, the current scanerio of tractor market is witnessing a tremendous growth of 3.08%. worldwide agricultural labor force. These are the inferences that we can draw from some of the literature articles that were reviewed, though this does not give us complete data on the CVT System that we are building, it provides a benchmark that our simulation model should achieve and help one make changes towards reaching positive results for CVT design. As a part of the future work, we would also like to extend this research by incorporating smart approaches for devising and developing intelligent CVT mechanisms.

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AUTHORS PROFILE

Dr. Ponnusamy P completed his Bachelors in Engineering from the Coimbatore Institute of Technology, Coimbatore, Bharathiar University and went on pursue his M.Tech. (Energy Technology) from Pondicherry Engineering College, Pondicherry, Pondicherry University and his PhD in Anna University,Chennai. He has over 25 years of rich & extensive experience in Teaching & Tutoring, Curriculum Designing, Strategic Planning and General Administration. Currently he is associated with Vellore Institute of Technology ,as Faculty in School of Mechanical Engineering.
He has published more than 25 research papers in Journals and Conference, written a book on Total Quality Management, has organised more than 10 Faculty Development Programmes . He is a **board member** of studies in the affiliated institutions under the Faculty of Mechanical Engineering, Anna University, Chennai.

Velmurugan P is currently working as Assisstant Professor, Department of Mechanical engineering, School of mechanical and automotive Egineering, College of engineering and Technology, Dilla university, Ethioipia. He received his B.Tech (Mechanical) degree from National Institute of Technology, Tiruchirappalli, India in 2005 and his ME (Engineering Design) from the College of Engineering Guindy, Anna University, Chennai, India in 2008. He received his PhD from National Institute of Technology, Tiruchirappalli, India. His research interests are in the field of vehicle dynamics, heavy truck ride dynamics and mechanical vibration.
He has been working for more than 7 years in various Engineering Institutions. He has guided various under-graduate, post-graduate students and 1 Ph.D. research scholars supervised in the field of electrical resistance spot welded dissimilar steel alloys. He has completed his research work in whole body vibration for tractor semi trailer drivers at the National Institute of Technology, Tiruchirappalli, and Tamil Nadu. His research interests in Advance welding process, human factors, whole body vibration, vehicle modelling, Optimization, Material characterization and Mechanical Behavior of Material, vehicle dynamics, heavy truck ride dynamics and mechanical vibration.
He has published more than 25 'Internationals' reputed Journals and conferences. He was a lifetime member of Indian Society of Technical Education (ISTE), society of automotive engineer (SAE).

Senthil Kumaran S is currently working as Associate Professor, Department of Mechanical Engineering, Vellore Institute of Technology-VIT University, Vellore, Tamil Nadu, India. He has been working for more than 10 years in various Engineering Institutions. He has guided various under-graduate, post-graduate students and 3 Ph.D. research scholars supervised in the field of quality improvement of the process in a different field such as friction welding, Tribology, Non-Traditional Machining Process, and composite materials.

He has completed his research work in Friction welding process improvement at the National Institute of Technology, Tiruchirappalli, and Tamil Nadu. His research interests in Advance solid-state welding process, Materials and Metallurgy, Composite materials and Quality Management, Unconventional machining process, Optimization, Material characterization and Mechanical Behavior of Material. He has published more than 125 'Internationals' reputed Journals and conferences. His contribution to the research work such as Genetic Algorithm, Acoustic Emission, Artificial Neural networks, fuzzy logic and optimization techniques in quality improvement of Manufacturing Process, etc.
He received Young Scientist Award from Department of Science and Technology (DST), Science and Engineering Research Board (SERB), New Delhi in the year 2014 and he has completed a research project in the year 2017 under the topic of friction welding of SA 213 tube to SA 387 tube plate using an external tool. Also, he received an outstanding reviewer award and recognized reviewer award from Elsevier journals. He was a lifetime member of Indian Society of Technical Education (ISTE), Indian Welding Society (IWS), International Association of Engineers (IAEng) and International Research Engineers and Doctors (IRED). Also, looking forward to guiding many research scholars, often developing his own interests in the field which he was expertise.

Kathiravan Srinivasan is the Professor (Associate) of Machine Learning and Artificial Intelligence in the School of Information Technology and Engineering at Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, India. He was previously working as a Faculty/Lecturer in the Department of Computer Science and Information Engineering and also as the Deputy Director- Office of International Affairs at National Ilan University, Taiwan. He has around 15 years of research experience in the area of Machine Learning, Artificial Intelligence, and its Applications. He received his Ph.D., in Information and Communication Engineering, M.E., in Communication Systems Engineering and B.E., in Electronics and Communication Engineering from Anna University, Chennai, India. He has won the Best Conference Paper Award at 2018 IEEE International Conference on Applied System Innovation, Chiba, Tokyo, April 13-17, 2018.
Moreover, he has also received the Best Service Award, Department of Computer Science & Information Engineering, National Ilan University, Taiwan. In 2017, he won Best Paper Award at 2017 IEEE International Conference on Applied System Innovation, Sapporo, Japan, May 13-17, 2017 and Best Paper Award at International Conference on Communication, Management and Information Technology (ICCMIT 2017), Warsaw, Poland. In 2016, he received the Best Service Award as the Deputy Director at the Office of International Affairs, National Ilan University. He is presently serving as the Editorial Board member and Editor of IEEE Future Directions and KSII Transactions on Internet and Information Systems (TIIS), Associate Editor for IEEE Access, IET Networks and Journal of Internet Technology, and Editorial Board Member and reviewer for various IEEE Transactions, SCI, SCIE and Scopus Indexed Journals. He is the guest editor MDPI Future Internet, Journal of Mobile Multimedia, International Journal of Distributed Sensor Networks and Recent Patents on Computer Science. He has played an active role in organizing several International Conferences, Seminars, and Lectures. He is an IEEE Senior Member and has been a keynote speaker in many International Conferences and IEEE events. His research interests include Machine Learning, Artificial Intelligence, Deep learning, Communication Systems & Networks, Multimedia, and Data Analytics.

Srinivasan Narayanan is currently working as an Assistant Professor (senior) at the Department of Mechanical Engineering in the Vellore Institute of Technology-VIT University, Vellore, Tamilnadu India. He has completed institute post-doctoral studies at IIT Madras (Chennai India), and Ph.D. in IIT Bombay (Powai India) and Monash University (Melbourne Australia). He has guided various under-graduate, post-graduate students. His research work includes metallurgy, plastic deformation, corrosion, and quality engineering. He has published lot of international journal articles of high repute and participated international conferences.