DOI: https://doi.org/10.46632/eae/1/2/1

Electrical and Automation Engineering

Vol: 1(2), 2022

REST Publisher; ISBN: 978-81-956353-5-1

Website: http://restpublisher.com/book-series/electrical-and-automation-engineering/

A Review on Frictions Stir Welding and Its Characterization

***Kurinjimalar Ramu, M. Ramachandran, Vidhya Prasanth**

REST Labs, Kaveripattinam, Krishnagiri, Tamil Nadu, India.

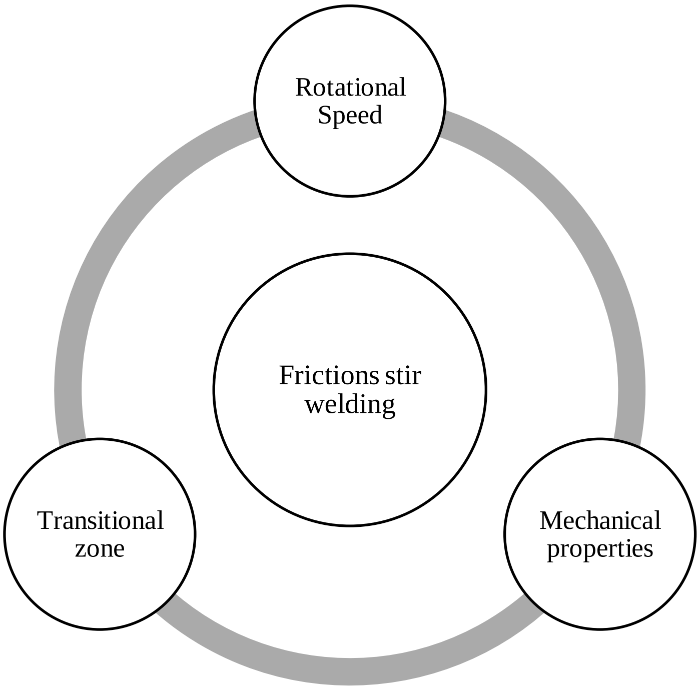
*Corresponding author Email: Kurinjimalar@restlabs.in

Abstract. Different welding speed forces and tool temperature are accurately recorded in standard welding. An arbitrary activated number is generated based on the (ALE) formula. The main feature of the numerical approach is to accurately calculate the contact and friction surface between the plate and the tool. The first study using Norton's friction model showed the high sensitivity of welding forces to the possibility of obtaining tool temperature for friction coefficients. It takes into account changes caused by small frictional variations. It is impossible to make very precise calibrations on the forces and provide an accurate instrument temperature profile. On the other hand, use the Columbine friction model to obtain realistic temperature profiles. This allows you to measure the coefficient of friction. This provides excellent agreement with experiments.

Keywords: Frictions stir welding, Rotational Speed, Transitional zone, Mechanical properties

1. Introduction

The FSW process is executed when the products are in the solid state. This prevents many metallurgical problems like corrosion, shrinkage, porosity and splatter caused by conventional fusion welding. Advanced can be achieved using these techniques. This new welding technology is being used in the automotive and aerospace industries for aluminum products due to increased demand for lightweight components and environmental protection. 2000 and 7000 grade aluminum alloy sheets were easily welded using FSW technique. It is traditionally difficult to weld by fusion welding. Papers related to the FSW process published in the past decade have focused on post-FSW weld micro structure and observations around the alloy line during FSW studied micro mechanics. Since the grain size is used to make fine grained metal products, this method is less expensive than the welding process. No need to use toxic shielding gas as shielding. Electrical arcs are harmful to the eyes and do not require electrodes that occasionally cause accidents.



2. Frictions Stir Welding

Details of the friction force welding process are available on the basis. With a specially designed rotating probe non-consumable tool, the sheets are to be welded or enter the lateral edges of the plates. Upon entry, frictional heat produces plastic deformation in the working area of the rotating tool. Important issues in evaluating friction induction welding are micro structural control and localized mechanical property differences. A serious problem in fusion welding is the complete change of microstructure and accompanying loss of mechanical properties even with a sound weld. Friction welding is a microstructure because it is a solid-state process. [15] Friction arc welding (FSW) is a relatively new technique for welding. It uses a roller pin or nipple inserted into the weld seam. The nib and shoulder to which it is attached rapidly rotates and causes severe distortion those progresses along the fold. Leaves a better even structure in the weld area. The flow of metal during FSW is studied using a fusing surface tracer and a nib frozen during welding. It has been demonstrated that matter is carried out by two processes. The material undergoes a rotational motion in the rotating zone to rotate from the front of the nipple and destroy the material in the advancing material zone first. It rotates advances and washes the threads in the nipples and exits the rotating zone. [16] It is important to distinguish between forward AS and reverse RS of the welded cross section in friction straight welding. Specifically, the welding velocity vector on the forward side obtained the same direction as the tangential velocity of the tool. Conversely, reverse side welding speed is the opposite side of the tool tangential speed. The influence of welding speed, tool rotational speed and the relationship between rotational speed and welding speed on the weld quality of joints have been studied by many researchers. [17] Process versatile loadable welding orientations and different thicknesses of microstructures and composites. [18] Thermal modeling has generally been central to the modeling of friction stir welding (FSW) since the late 1990s. One reason is that many properties of the final weld are a direct function of the thermal history of the work piece. FSW process heat is generated and is very susceptible to heat flow. From a modeling point of view the thermal modeling process FSW is considered as the basis of all other models. Be it micro-structure, computational fluid dynamics (CFD) or thermo-mechanical. [19] Some patent applications include considerable effort to avoid using the term friction welding. However the term friction welding is used for general purpose. Widely used names for spin-off processes such as friction stirrer processing and friction stirrer spot welding are acceptable, but reference to the basic friction stirrer principle should be maintained if further process variations are described. The agreed wording was established based on this document in various discussions with members of the Friction Stir Welding Licensing Association. [20] Variables including its geometry take place in FSW with a high rate of metal extraction and bonding forging. Zada and minutiae can also be measured by measuring grain size. Estimates the common deformation strain through the correlation between the temperature-compensated strain rate and the Zener Holman parameter. Frictional wave welding has been gaining popularity in recent years. These calculations follow two approaches to flow modeling. In many calculations the plasticized material is assumed to be highly viscous.

This approach uses the resistance of the work piece to quickly stop the rotation of the tool. Frictional force preserves the complex deformation field around the welding tool during welding. This is the approach used in the present study. There are many previous studies that characterize the grain structures and structures produced during friction stir welding. [22] This approach uses the resistance of the work piece to quickly stop the rotation of the tool. This is the approach used in the present study. Grain structures are produced during friction welding and there are many previous studies that characterize the structures. [23] The approach utilizes the resistance of the work piece to quickly stop the rotation of the tool and thereby protect the complex corrosion surrounding the welding tool during frictional movement. This is the approach used in the present study. There have been many previous studies characterizing grain structures and produced structures during friction stir welding. [24] The welding technique involves joining materials together using heat generated by mechanical friction between two work pieces. 1991 United Kingdom (UK) Welding Institute (TWI) Wayne Thomas and E. A solid-state friction stir welding (FSW) technique was first invented by Nichols. Burns a wide range of metals and alloys. As a result, FSW is rapidly gaining popularity in a variety of applications including aerospace, automobile, transportation, and marine engineering. [25] Many improvements in tool design have focused on the welding of low melting point and relatively soft materials. Friction welding of other materials such as steel and titanium significantly changes tool design and tool material. Another variation is the tool for generating secondary holmic heat during welding and passing current directly through the work piece. It was renamed Electrically Assisted Friction Stir Welding (EAFSW) and shipyard manufacturing and on-site maintenance. Aims to reduce the use of small machines for repairs. [26] This makes the friction welding process environmentally friendly. Non-uniform materials, low residual stresses and low distortions and joining at any weld position are other advantages of this process. Because of these advantages, FSW researchers have become popular among entrepreneurs in recent years. Bob is friction stir welding. A special type is conventional friction arc welding (CFSW) technique. The bobbin friction stir welding process is self reaction FSW (SRFSW) which is also known as self supported FSW (SSFSW) or bobbin tool FSW (BTFSW). Several properties of BTFSW are more attractive than CFSW.

3. Rotational Speed

A good surface appearance is obtained at high rotational speeds. From the macro structure up to 250 rpm, a basin-shaped moving zone with a tunnel defect was observed at the rear. The percentage of strength and elongation of the base metal and different tool rotation speeds were determined. The tensile properties of the sample processed at low tool rotation speed (250 rpm) were severely damaged. A rotation speed of 250 rpm at 50 mm/min indicates insufficient heat generation and insufficient flow of unformed plasticized material during FSP in case of tunneling defect. At the same time the tensile strength and yield strength at higher tool rotation speed were found to be better than 250 rpm but lower than the base metal. [2] NiTi rotary instruments should be operated. Rotation speed is a variable that needs to be clarified as rotating tools must be used at a rate that minimizes the occurrence of breakages while maintaining efficiency. Cyclic fatigue was the number of cycles per fracture subjected to the NiTi endothelial device test evaluating the influence of cycle speed. Morphological properties were analyzed by scanning electron microscopy (SEM) of the fractured surfaces. [3] Materialization of magnetization with opposite directions Permanent magnets is mounted around the disk to measure its rotational speed. The magnetic field is measured while rotating the disk sensor. A 90 m thick plate of yttrium territorial is cut perpendicular to the optical axis at a wavelength of 0.63 m. Illuminated by a red diode laser. [4] The macro structure of joints has three characteristics compared to other joints regardless of tool rotation speed. This trend is common to all, showing lower tensile strength and elongation compared to joints fabricated at rotational speed. [5] It is also unclear whether the fatigue properties of rotating tools made of M wire change at higher rotational speeds. The file format used in the legacy profiles tools used in that study is significantly different from the new profile cycle files. New design with triangular cross section and helical angles without intersecting radial ground. [6] Relationship between rotational speed and radial stiffness of HSK-A63 tool interface Radial stiffness decreases with increasing rotational speed. Test results are obtained with the same standard of performance. When radial force is applied to the tool shaft at high rotation speeds the HSK tool interface is over elastic to fill gaps in the narrow face at high speeds. The gap increases with the radial expansion of the vortex hole due to centrifugal force. This increases the radial displacement of the tool shaft.

4. Transitional Zone

The microstructure is compared to the cilia model. It is structurally similar to the intermediate zone of Celia. The present observations show that the membrane beads interspersed with thin plasma membranes resemble filamentous particles found in freeze-fractured membranes. The structure of the particles can be stabilized by radically connecting structures in the cross fibers. The absence of axonal capillaries in both the endothelial granules and the structural integrity of the cilia suggested that both interstitial zones were similar structures. Therefore, the micro structural probe is extended to the thin region connecting the cilia, with the aim of discovering additional features of the mid-section of the motile cilia.

5. Mechanical Properties

The residual medium-thickness micro hardness profile contrasts with that of the base metal. Reduces general softening and hardening. However, complex annealing effects resulted in the FSW zone exhibiting a minimum weak spot on the weld exterior of copper. The hardness of the base metal is in the range of 105- 110 HV. Hardness near the weld zone shows values varying from 60 HV to 90 HV. The weld center is slightly harder than the base metal despite its smaller grain size. Consequently the hardness near the weld zone was independent of grain size considering the Hall-pitch relationship. Other factors such as secondary phase and dislocation density may control the mechanical properties of the weld zone [8]. Penetration defect observed in FSW may be due to insufficient pin. Single pass FSW root defects are detected. Where the interfacial oxide layer does not effectively break down and disperse into the matrix, a significant number of these studies in recent years have focused on microstructure and mechanical properties. The published literature contains limited information on the simultaneous activation of vacuum formation in FSW. Impact of void formation and microstructure development on tool geometry and mechanical response to precipitation hardening. [9] FSW can be used to connect many products. However, the primary research and industrial interests have to do with aluminum alloys. Defective welds are made from a variety of aluminum alloys with good mechanical properties. Friction stir welds can be performed at any level, even from as little as 1 mm thick to 35 mm thick. In this remarkable process a rotating steel pin with a diameter equal to the thickness of the metal plate rotates at 300 rpm [10]. It must be mixed with other metals like copper, manganese, magnesium, zinc and silicon. Various mechanical properties can be achieved by controlling the alloying elements and the heat treatment level. Aluminum and its alloys are considered malleable on their surface and ductile due to their cubic crystal structure. It is available in fabricated and cast forms. The former can be formed by rolling (hot or cold) extrusion and forging. The latter can be made from sand casting, lost wax casting, alloy components. [11] It can be seen from the figures that the estimated values have the same trend with the experimental measurements. [12] Various constructions such as square groove butt joint, corner joint, D-butt joint and lap joint have been developed. Once the tool design and material are approved the tool rotation speed and travel speed microstructure and mechanical properties are continuously adjusted according to the basic material flow. Rotation of the tool facilitates blending of two adjacent objects and translation of the tool from the back of the tool places the smoothed object forward. High temperature due to high rotation speed and consequently high flash formation can lead to defects such as porosity and insufficient material flow in the weld plate. It is therefore necessary to identify the optimal parameters associated with appropriate tool design to produce sound ignition with desired mechanical properties.

6. Conclusion

NiTi rotary tools must be operated at rotational speed to be clarified Morphological characteristics of the fractured surfaces were analyzed by scanning electron microscopy (SEM). A rotating probe is a specially designed non-consumable tool that can enter the side edges of sheets to be welded or the rotating tool heats the friction in the work area and creates plastic deformation. The residual medium-thickness micro-hardness profile for the base metal contrasts with a general softening and reduction of hardness in the weld zone. However, as a result of complex annealing effects, the copper weld exhibited a minimum weak point outside the FSW zone. The weld center base is slightly harder than the metal. Consequently, the hardness near the weld zone was independent of grain size considering the Hall petch relationship.

Reference

[1]. Rhodes, C. G., M. W. Mahoney, W. H. Bingel, R. A. Spurling, and C. C. Bampton. "Effects of friction stir welding on microstructure of 7075 aluminum." *Scripta materialia* 36, no. 1 (1997): 69-75.

[2]. He, Xiaocong, Fengshou Gu, and Andrew Ball. "A review of numerical analysis of friction stir welding." *Progress in Materials Science* 65 (2014): 1-66.

[3]. Guerra, M., C. Schmidt, John C. McClure, L. E. Murr, and A. C. Nunes. "Flow patterns during friction stir welding." *Materials characterization* 49, no. 2 (2002): 95-101.

[4]. Costa, M. I., D. Verdera, C. Leitão, and D. M. Rodrigues. "Dissimilar friction stir lap welding of AA 5754-H22/AA 6082-T6 aluminium alloys: Influence of material properties and tool geometry on weld strength." *Materials & Design* 87 (2015): 721-731.

[5]. Deepa, N., Asmat Parveen, Anjum Khurshid, M. Ramachandran, C. Sathiyaraj, and C. Vimala. "A study on issues and preventive measures taken to control Covid-19." In AIP Conference Proceedings, vol. 2393, no. 1, p. 020226. AIP Publishing LLC, 2022.

[6]. Chakraborty, Debarun, and Wendrila Biswas. "Enlivening workplace climate through strategic human resource management initiatives: Unleashing its efficacy." Business Perspectives and Research 9, no. 3 (2021): 427-445.

[7]. Gill, Shubhnoor, Neha Sharma, Chetan Gupta, and Argha Samanta. "Attendance Management System Using Facial Recognition and Image Augmentation Technique." In 2021 International Conference on Intelligent Technology, System and Service for Internet of Everything (ITSS-IoE), pp. 1-6. IEEE, 2021.

[8]. Zhang, Y. N., X. Cao, S. Larose, and P. Wanjara. "Review of tools for friction stir welding and processing." *Canadian Metallurgical Quarterly* 51, no. 3 (2012): 250-261.

[9]. Schmidt, Henrik B., and Jesper H. Hattel. "Thermal modelling of friction stir welding." *Scripta Materialia* 58, no. 5 (2008): 332-337.

[10]. Threadgill, P. L. "Terminology in friction stir welding." *Science and Technology of Welding and Joining* 12, no. 4 (2007): 357-360.

[11]. Biswas, Wendrila, and Debarun Chakraborty. "Impact of organizational values, compassion, and well-being on industrial disputes: An empirical study." Prabandhan: Indian Journal of Management 12, no. 1 (2019): 36-51.

[12]. Jeevitha, R., M. J. Judithaa, T. Sunder Selwyn, and A. P. Srikanth. "Atalantia Monophylla Acted as Eco-Friendly Inhibitor for Mild Steel in 1N HCl Media." Oriental Journal of Chemistry 35, no. 3 (2019): 1073.

[13]. Didosyan, Yuri S., Hans Hauser, Holger Wolfmayr, Johann Nicolics, and P. Fulmek. "Magneto-optical rotational speed sensor." *Sensors and Actuators A: Physical* 106, no. 1-3 (2003): 168-171.

[14]. Elangovan, K., and V. Balasubramanian. "Influences of pin profile and rotational speed of the tool on the formation of friction stir processing zone in AA2219 aluminium alloy." *Materials Science and Engineering: A* 459, no. 1-2 (2007): 7-18.

[15]. Chakraborty, Debarun, Wendrila Biswas, and Ganesh Dash. "Marching toward “heart work”: Connecting in new ways to thrive amidst COVID-19 crisis." Conflict Resolution Quarterly 39, no. 1 (2021): 7-27.

[16]. Fegade, Vishal, Krishnakumar Gupta, M. Ramachandran, S. Madhu, C. Sathiyaraj, R. Kurinji< alar, and M. Amudha. "A study on various fire retardant additives used for fire reinforced polymeric composites." In AIP Conference Proceedings, vol. 2393, no. 1, p. 020107. AIP Publishing LLC, 2022.

[17]. Gao, Yong, Vincent Shotton, Kevin Wilkinson, Greg Phillips, and William Ben Johnson. "Effects of raw material and rotational speed on the cyclic fatigue of ProFile Vortex rotary instruments." *Journal of endodontics* 36, no. 7 (2010): 1205-1209.

[18]. SELWYN, T. SUNDER, and R. KESAVAN. "SENSITIVITY ANALYSIS OF WIND TURBINE AVAILABILITY AND ITS SUB ASSEMBLIES AT HIGH UNCERTAIN WIND." International Journal of Applied Engineering Research 10, no. 11: 2015.

[19]. Aoyama, Tojiro, and I. Inasaki. "Performances of HSK tool interfaces under high rotational speed." *CIRP Annals* 50, no. 1 (2001): 281-284.

[20]. Chakraborty, Debarun, and Wendrila Biswas. "Think love, think peace, think harmony: Rethinking on industrial tranquility." Business Perspectives and Research 9, no. 1 (2021): 92-110.

[21]. Kurinjimalar Ramu; M. Ramachandran; M. Nathiya; M. Manjula, “Green Supply Chain Management; with Dematel MCDM Analysis”, Recent trends in Management and Commerce, 2(3), (2021): 8-15.

[22]. Röhlich, Pál. "The sensory cilium of retinal rods is analogous to the transitional zone of motile cilia." *Cell and tissue research* 161, no. 3 (1975): 421-430.

[23]. Chopra, Pooja & Gollamandala, Vijay & Ahmed, Ahmed & Bala Gangadhara Tilak Babu, Sayila & Kaur, Chamandeep & Prasad N, Achyutha & Nuagah, Stephen. (2022). Automated Registration of Multiangle SAR Images Using Artificial Intelligence. Mobile Information Systems. 2022. 1-10. 10.1155/2022/4545139.

[24]. Giri, Arunangshu, Wendrila Biswas, and Jari Salo. "'Buy Luxury': Adapting the SHIFT Framework to Explore the Psychological Facets Enabling Consumers for Sustainable Luxury Consumption." Indian Journal of Marketing 52, no. 6 (2022): 59-66.

[25]. Chen, Yunhao, Xiaobing Li, Wei Su, and Yi Li. "Simulating the optimal land-use pattern in the farming-pastoral transitional zone of Northern China." *Computers, Environment and Urban Systems* 32, no. 5 (2008): 407-414.

[26]. Gupta, Krishnakumar, Vishal Fegade, Jeevan Kittur, M. Ramachandran, S. Madhu, S. Chinnasami, and M. Amudha. "A review on effect of cooling rate in fiber reinforced polymeric composites." In AIP Conference Proceedings, vol. 2393, no. 1, p. 020106. AIP Publishing LLC, 2022.

[27]. Sunder Selwyn, T., and R. Kesavan. "Vibration Analysis of a Constant Speed and Constant Pitch Wind Turbine." In Emerging Trends in Science, Engineering and Technology, pp. 429-443. Springer, India, 2012.

[28]. Lutimath, Nagaraj, and Neha Sharma. "Prediction of Heart Disease using Biomedical Data through Machine Learning Techniques." EAI Endorsed Transactions on Pervasive Health and Technology 7 (2021): e3.

[29]. Chakraborty, Debarun, Shakti Bodh Bhatnagar, Wendrila Biswas, and Ajay Kumar Khatua. "What drives people to adopt grocery apps? The moderating role of household size." Business Perspectives and Research (2022): 22785337221091640.

[30]. Ataur rahman farooqi; D R pallavi; M. Ramachandran; S. Sowmiya; Manjula Selvam, "A Brief Study On Recent Trends in Financial Literacy", Recent trends in Management and Commerce, 3(1), (2022): 40-45.

[31]. Shirke, Sanjay, Sonya C. Faber, Elissa Hallem, Helen P. Makarenkova, Michael L. Robinson, Paul A. Overbeek, and Richard A. Lang. "Misexpression of IGF-I in the mouse lens expands the transitional zone and perturbs lens polarization." *Mechanisms of Development* 101, no. 1-2 (2001): 167-174.

[32]. Fuse, Kishan, and Vishvesh Badheka. "Bobbin tool friction stir welding: a review." *Science and Technology of Welding and Joining* 24, no. 4 (2019): 277-304.

[33]. Biłozor, Andrzej, Szymon Czyża, and Tomasz Bajerowski. "Identification and Location of a Transitional Zone between an Urban and a Rural Area Using Fuzzy Set Theory, CLC, and HRL Data." *Sustainability* 11, no. 24 (2019): 7014.

[34]. Chakraborty, Debarun, and Wendrila Biswas. "Going green with green HRM practices–A strategic initiative for reinvigorating performance optimization in companies." Prabandhan: Indian Journal of Management 13, no. 10-11 (2020): 8-26.

[35]. C. Venkateswaran; D R Pallavi; M. Ramachandran; Vimala Saravanan; Vidhya Prasanth, "A Review on Promethee and Analytic Hierarchy Process with Its Application", Data Analytics and Artificial Intelligence, 2(1), (2022): 34-39

[36]. Asante, Winston Adams, Emmanuel Acheampong, Edward Kyereh, and Boateng Kyereh. "Farmers' perspectives on climate change manifestations in smallholder cocoa farms and shifts in cropping systems in the forest-savannah transitional zone of Ghana." *Land use policy* 66 (2017): 374-381.

[37]. Sunder Selwyn, T., and R. Kesavan. "Vibration Analysis of a Constant Speed and Constant Pitch Wind Turbine." In Emerging Trends in Science, Engineering and Technology, pp. 429-443. Springer, India, 2012.

[38]. Chopra, P., Gollamandala, V. S., Ahmed, A. N., Babu, S. B. G., Kaur, C., Achyutha Prasad, N., & Nuagah, S. J. (2022). Automated Registration of Multiangle SAR Images Using Artificial Intelligence. Mobile Information Systems, 2022.

[39]. Chakraborty, Debarun, Shakti Bodh Bhatnagar, Wendrila Biswas, and Ganesh Dash. "The Subtle Art of Effecting a Four-day Workweek to Drive Performance." Management and Labour Studies (2022): 0258042X221082893.

[40]. Fegade, Vishal, M. Ramachandran, S. Madhu, C. Vimala, R. Kurinji Malar, and R. Rajeshwari. "A review on basalt fibre reinforced polymeric composite materials." In AIP Conference Proceedings, vol. 2393, no. 1, p. 020172. AIP Publishing LLC, 2022.

[41]. Favorov, Oleg V., Violeta Pellicer-Morata, Amy L. DeJongh Curry, John T. Ramshur, Andrew Brna, Timothy D. Challener, and Robert S. Waters. "A newly identified nociresponsive region in the transitional zone (TZ) in rat sensorimotor cortex." *Brain research* 1717 (2019): 228-234.

[42]. Selwyn, T. Sunder, and R. Kesavan. "Reliability measures of constant pitch constant speed wind turbine with markov analysis at high uncertain wind." Procedia engineering 38 (2012): 932-938.

[43]. Biswas, Wendrila, and Debarun Chakraborty. "Impact of organisational trust, commitment and team orientation on industrial disputes-an empirical study on selected manufacturing companies of West Bengal." International Journal of Business and Globalisation 30, no. 1 (2022): 26-42.

[44]. Sharma, Neha, and Usha Batra. "A Study on Integrating Crypto-Stego Techniques to Minimize the Distortion." In International Conference on Recent Developments in Science, Engineering and Technology, pp. 608-615. Springer, Singapore, 2017.

[45]. Sathiyaraj Chinnasamy; M. Ramachandran; Kurinjimalar Ramu; Manjula Selvam: Sowmiya Soundhraj, “Exploring the Possibility of Urban Agriculture Farn”, Agricultural, Biologicals and Food Science, 1(1), (2022):1-8.

[46]. Xu, Yinyao, Hu Sun, and Xu Ji. "Spatial-temporal evolution and driving forces of rainfall erosivity in a climatic transitional zone: A case in Huaihe River Basin, eastern China." *Catena* 198 (2021): 104993.

[47]. Lee, Won-Bae, and Seung-Boo Jung. "The joint properties of copper by friction stir welding." *Materials Letters* 58, no. 6 (2004): 1041-1046.

[48]. Chandra Prakash, RC. Narayanan, N. Ganesh, M. Ramachandran, S. Chinnasami, R. Rajeshwari. “A study on image processing with data analysis. “In AIP Conference Proceedings, vol. 2393, no. 1, p. 020225. AIP Publishing LLC, 2022.

[49]. Chatterjee, Shamba, Arunangshu Giri, Wendrila Biswas, and Mukesh Kumar Bauri. "Analytical study on variation of healthcare status in Haldia city of West Bengal, India." In Contemporary Medical Biotechnology Research for Human Health, pp. 205-214. Academic Press, 2022.

[50]. Boz, Mustafa, and Adem Kurt. "The influences of stirrer geometry on bonding and mechanical properties in friction stir welding process." *Materials & Design* 25, no. 4 (2004): 343-347.

[51]. Selwyn, T. Sunder, and R. Kesavan. "Computation of reliability and birnbaum importance of components of a wind turbine at high uncertain wind." International Journal of Computer Applications 975 (2011): 8887.

[52]. Salih, Omar S., Hengan Ou, W. Sun, and D. G. McCartney. "A review of friction stirs welding of aluminium matrix composites." *Materials & Design* 86 (2015): 61-71.

[53]. Sharma, Neha, and Chinmay Chakraborty. "Evaluation of bioinspired algorithms for image optimization." Journal of Electronic Imaging 31, no. 4 (2022): 041206.

[54]. Okuyucu, Hasan, Adem Kurt, and Erol Arcaklioglu. "Artificial neural network applications to the friction stir welding of aluminum plates." *Materials & design* 28, no. 1 (2007): 78-84.

[55]. Chakraborty, Debarun, and Wendrila Biswas. "Motivating factors in a teacher’s research and developmental activities and their impact on effective quality teaching in higher education institutions." Journal of Applied Research in Higher Education (2019).

[56]. Gangwar, Kapil, and M. Ramulu. "Friction stir welding of titanium alloys: A review." *Materials & Design* 141 (2018): 230-255.

[57]. Nandan, R., Tarasankar DebRoy, and H. K. D. H. Bhadeshia. "Recent advances in friction-stir welding–process, weldment structure and properties." *Progress in materials science* 53, no. 6 (2008): 980-1023.

[58]. Fonda, R. W., J. F. Bingert, and K. J. Colligan. "Development of grain structure during friction stirs welding." *Scripta materialia* 51, no. 3 (2004): 243-248.