QE22 Mg Alloys Coated Using Shorter Saffil Fibres and Sic Elements: Elastic and Plastic Behaviour

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**Abstract:** The magnesium oxide alloy QE22, which has a theoretical structure consisting of 3% Ag, 3% a combination of precious metals, and an equal amount of Mg, has been strengthened using 20% particle size of SiC as well as 6% saffil fibres. The squeeze-and-cast method was used to create the hybrid material. The technique of scanning electron microscopy was used to examine the monolithic metal and composite's composition. The modulus of elasticity was calculated using the Halpin-Tsai-Kardos mathematical framework and tested at ambient temperature. The experimental results were compared to the estimated reinforcing impact of fibers and particles. The primary words for improvement have been determined. Using the scanning electron microscope, the fractured areas were analysed. The breakdown caused by the combination was transcrystalline, whereas the matrix of the alloy fractured mostly along intercrystallite lines.

**Keywords:** Elastic; Plastic behaviour; Magnesium alloy; Short saffil; Intercrystallite.

# Introduction

Although the physical properties of cast aluminium alloys built upon the Mazuz–Mn combination quickly degrade at high temperatures, such alloys are intended for use at room temperature. Of alloys intended for use at extremely high temperatures, industrial QE22 represents one of the most commonly used. Appropriate heating could improve hydraulic properties; alternatively, varied reinforcement with different physical and mechanical specifications may improve thermal endurance. Mg matrix composites have improved their durability, resistance to degradation, and resilience to creep. These also maintain high manufacturing and low density [1]. Porcelain such as oxides of n-borides, diamonds, carbon nanotubes (CNT), or intermetallic elements are good choices for the reinforcement stages [2]. The composition, form, and physical and electrical properties of the reinforcement components determine how composites behave. Long-fibre metal matrix composites (MMCs), which were first used to fortify inflatable metal hybrid matrices, have a number of drawbacks, including excessive anisotropy and poor mechanical stability because the fibres separate from the backing material when the matrix is loaded. Highly anisotropic alloys supplemented with whisker or short fibres exhibit significant suppression of anisotropy [3]. In polymers that have particulate reinforcement, this asymmetry could disappear. However, as compared to composites made with fibres, the mechanics of particle-reinforced composites are not as good as composites made with fibres.

Combining fibres with particulates has proven to be a workable middle ground. Reinforcing fibres or particles gives the whole thing greater rigidity, enhances its strength and creep qualities, and reduces its expansion when heated. Over the past decade, a great deal of research has been done on nanotechnology that has a strengthening phase with a wavelength of as much as 100 nm [4]. In recent times, magnesium-alloy-based nanocomposites have come to be regarded as materials best suited for medical use. Particles of silicon carbide (SiCp), as well as Al2O3 ceramic saffil fibres, are frequently used as magnesium-based reinforcement. Compared to a simple fibre-reinforced laminate with Mg matrices, an amalgamation of both materials—where Saffil fibres are substituted with less expensive SiC particles—may provide a substance with exceptional power, tolerable flexibility, better creep qualities, and increased durability. The material's roughness affects both the physical and mechanical properties of composites made using the hot extruded process. The characteristics of metal-metal composites are mostly influenced by the connection that exists between the metal substrate and the phase of reinforcement [5]. Throughout the manufacture of the combination, precipitation mechanisms in the metal matrices may potentially be influenced by the existence of fibres or nanoparticles. The alloy's chemical makeup may be selected based on the desired durability of the compound matrix-like structure, taking into account the increasing effects of reinforcing fibres or grains. The incorporation of elements made from rare earths (RE) makes magnesium alloys stronger at extreme temperatures, reducing casting leakage and weld fracturing.

Ag may be added to the Mg-RE-Zr alloy to remedy its rather poor tensile qualities. This opens up more options for heating and aging the alloys, as well as their ultimate combination. The commonly used magnesium-ag cast alloy QE22 has less than 2% silver, which enables the creation of magnesium-Nd precipitates that resemble magnesium-RE alloy while also refining its precipitate thickness. In order to get a deeper understanding of the procedures and variables impacting the final composite characteristics, this intricate research examined the modulus of elasticity as well as the plastic and fracturing characteristics of a QE22 hybrid composite, including saffil fibres and particles made of SiC [10-13]. Furthermore, in this study, the monolith QE22 metal was also examined as an alternative substance.

# Experimentations

## Materials and methods

The combination matrix component was readily accessible for casting QE22 magnesium alloys with a minimum concentration by weight percentage of 2 Ag, two mischmetal, mostly Nd-0.3 zinc, and the rest magnesium. Utilising a mould made of fibres, parts, and an adhesive structure, the metal was strengthened with 6% Saffil fibres as well as a 20% particle size of SiC [14-19]. The fibers in the preform were randomly oriented in the plane direction, exhibiting an even alignment. Fluid magnesium alloy was introduced onto the perform, which had been warmed to 1200 °C, using the squeezing cast method. To make sure that there were no holes in the final hybrids combined, two stages of pressure—80 and 150 MPa—were used. Tested after squeezing the casting process, saffil fibres had a standard length that was 78 ± 16 µm as well as a median diameter of 3 µm [20-25]. The irregularly shaped, almost equiaxial substance had an average dimension of around 9 µm.

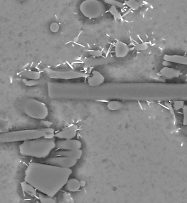
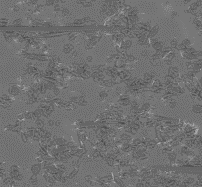
## Characterization

A dispersive X-ray spectroscopy (EDS)-equipped scanning electron microscope, or SEM, was employed to analyse and characterise the tiny structures of the produced composite's fractured surface. The evaluation protocol and specimen shape were in compliance with EN ISO 6892-1 [26-31]. The specimens weren't given any preliminary heat treatment. The specimens for distortion testing have been removed from the poured piece with its stress axis aligned perpendicular to the fibre plane. The actual width, breadth, and depth for the flattened samples utilised in the tensile test were 30 mm, 8 mm, and 3 mm, respectively. For the purpose of conducting compressive examinations, cylinders measuring 8 mm in width and 12 mm in height were developed. Molybdenum was applied to the testing device's gripping tips prior to the compression test. Three specimens were utilised for the compressive and tensile examinations. The structural testing was done at the ambient temperature.

# Result and discussions

## Microstructure Analysis

In this investigation, 2.58 weight percent Ag as well as 1.46 weight percent mischmetal were present in the QE22 aluminium alloys. The α particles within the QE22 magnesium steel seen in the images are made up of a solid state of combining elements such as Mg. According to the elemental determination analysis (EDS) data shown in Figure 1, Mg structures the tiny particles at the borders of the grains [6, 32-36]. The pictures indicate the mixed composite's microstructure. It is clear that there are small groups of particles of SiC along the fibres, indicating that the arrangement isn't equal. The outer edges of the insulating SiC fragments that were bombarded by protons while imaging were evident in the form of an unreported phrase little needle in Figure 1. According to Kiehn et al., the QE22 alloy augmented by Al2O3 fibres had an altered chemical structure in the base material as a result of a greater quantity of Al that was added from the artificial binders in the preform during manufacture. In the forms of precipitates that remain disintegrating within the matrix, Al takes the place of Ag. The projected particle size in the QE22 metal was 45 µm, while the mixture had an average grain size of 7 µm. A quadratic intercepting approach was used to determine the grain dimensions based on lighting photographs [7, 37-40].



1. (b)

**Figure 1**. Microstructural analysis of hybrid composites with SiC particles

## Elastic Properties

Fibre-reinforced MMCs that are unilaterally constant demonstrate a gradual increase in their Young's modulus as the fibre percentage of volume increases in whichever direction the fibers go. While there is not much elastic rise in the transverse guidance, the Young's module rise in the fibre axis is consistent with the rule of mixing. The modulus is far less affected by particles in MMCs than is implied by the law of mixes. Figure 2 presents the results of the empirical determination of Young's modulus estimates for the hybrid Li-sample, E L H (ex) = 74.5 GPa, and the hybrid Tr-sample, E T H (ex) = 71.3 GPa. As we may see, the observed moduli are considerably lower and show some anisotropy when we contrast the measured elasticity ones to those determined by applying the formula of mixing. Compared to the T-sample, the modulus of friction determined using the L-sample is considerably greater [8, 41-45].

It is evident that the match is much greater than in the instance of the norm of mixes when comparing the estimated modulus of the combined, E L H (th) and E T H (th), to the empirically observed numbers, E L H (ex) as well as E T H (ex). The actual combined is not entirely consistent with the conceptual presumptions: fragments are not frequently sent in the the matrix, the length of the fibre is not homogeneous, and fibres don't line up in a single direction (fibres have only flat isotropic in nature shipping). As a result, the match between the results of measurements and the predictions made by theory is not ideal. On the other hand, the model accurately captures the mixed asymmetry found in experiments. Overall, it can be believed that the incorporation of reinforcement fibres has less of an impact on the perpendicular permeability than the continuous permeability. This outcome is consistent with Chawla's findings on Al-Li materials augmented with shorter fibres.



**Figure 2.** Tensile strain of pure and Mg based hybrid alloy

## Plastic Deformation

The first figure 3 displays the tension-measured true stress-true stress ratios for the hybrid composites and monolith QE22 alloys. Compared to the monolith alloys, a much greater stress is required for the hybrid material to plastically deform. It was discovered that both the metal and the mixture under stress had very little plasticity—a property that is often seen in cast metals. Additionally, take note of the anisotropy shown in both substances, since the amount of yield stress due to the two states is distinct. The CYS in the hybrid material is greater compared to the TYS, despite the fact that the CYS anticipated for the alloy of the matrix is less [46-51]. These variations might be explained by the various strengthening and deformation processes at work in the matrix metal and compound under stress [9]. The magnesium alloys typically exhibit the imbalance noticed in the TYS and CYS computed for the structure of the metal. Máthis et al. investigated the sound emission patterns that occurred when specimens of mg with varying sizes of grains underwent bending [10]. A significant imbalance in sound emission was discovered at temperatures below 200 ◦C, which is consistent with twin creation activities. Researchers came to the conclusion that distinct deformation processes operate in tension and compression conditions [11]. In bending, physical pairing at the onset of plastic distortion acts as the regulating system, whereas in anxiety, dislocated glide mostly aids the breakdown of plastic. This imbalance is likewise dependent on the structure, becoming less pronounced as grain size increases [12]. Twin limits were impassable barriers to the movement of dislocations that easily developed throughout compression testing. As a result, twin creation helps materials subjected to compression undergo improved stress stiffening. The heating ratio (CTE), α, of the ceramic backing and the metal substrate often varies significantly [13]. Thermal strains Report Phrase are created in the mixture during the production process as it cools down to ambient temperatures. In this way, additional thermally unstable circuits are drilled, and a matrix's stress response may be reached [14]. Movements that are mathematically required for flexible deformation are produced due to a clash between the metal matrices and the material of the ceramic reinforcement stage, which also adds to the increased dislocated frequency [15].



**Figure 3.** Compressive strain of pure and Mg based hybrid alloy

# Conclusion

At the ambient temperature, the flexible, plastic, and fracture characteristics of a magnesium-alloyed medium (MMC) supplemented by saffil fibres and particles of silicon carbide (SiC) made of QE22 were examined. The data collected allows for the drawing of the subsequent findings: The 2D fibre arrangement caused anisotropy in the modulus of young tests. Young's modulus of asymmetry has been effectively modelled using the Halpin-Tsai-Kardos independent approach; the simulation report phrase is in good alignment with the through-experimentation obtained data. The flow-induced stresses resulting from tensile and enlargement stretching increased significantly with the inclusion of strengthening fibres and particulates.

# References

1. Zapletal, Josef, Zuzanka Trojanová, Pavel Doležal, Stanislava Fintová, and Michal Knapek. "Elastic and plastic behavior of the QE22 magnesium alloy reinforced with short saffil fibers and SiC particles." *Metals* 8, no. 2 (2018): 133.
2. Kelagadi et al., (2024). An Analysis on the Integration of Machine Learning and Advanced Imaging Technologies for Predicting the Liver Cancer. In 2024 4th International Conference on Pervasive Computing and Social Networking (ICPCSN) (pp. 1082-1086). IEEE. <https://doi.org/10.1109/ICPCSN62568.2024.00180>
3. Oakley, R., R. F. Cochrane, and Ron Stevens. "Recent developments in magnesium matrix composites." *Key Engineering Materials* 104 (1995): 387-416.
4. Ahmad et al., (2024). IoT-Enabled Smart E-Healthcare System with Predictive Prescription Algorithm for Automatic Patient Monitoring and Treatment. In *2024 4th International Conference on Pervasive Computing and Social Networking (ICPCSN)* (pp. 1076-1081). IEEE. https://doi.org/[10.1109/ICPCSN62568.2024.00179](https://doi.org/10.1109/ICPCSN62568.2024.00179)
5. Padalka, Oksana. "On the Relation Between Properties and Microstructure of New Mg Based Alloys and Composites for Advanced Structural Applications." (2008).
6. Mondal, A. K., and S. Kumar. "Extruded Mg based hybrid composite alloys studied by longitudinal impression creep." *arXiv preprint arXiv:1704.06563* (2017).
7. Chhaparwal et al., (2024). Numerical and experimental investigation of a solar air heater duct with circular detached ribs to improve its efficiency. *Case Studies in Thermal Engineering*, *60*, 104780. <https://doi.org/10.1016/j.csite.2024.104780>
8. Hu, Bin, Liming Peng, and Wenjiang Ding. "Dry sliding wear behavior of Saffil fiber-reinforced Mg-10Gd-3Y-0.5 Zr magnesium alloy-based composites." *Journal of composite materials* 45, no. 6 (2011): 683-693.
9. Kainer, Karl Ulrich. "Basics of metal matrix composites." *Metal Matrix Composites: Custom‐made Materials for Automotive and Aerospace Engineering* (2006): 1-54.
10. Mariya Louis et al., Multiresponse optimization and network-based prediction modelling for the WEDM of AM60B biomedical material. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, *238*(20), 10045-10066. [https://doi.org/10.1177/09544062241264](https://doi.org/10.1177/09544062241264939)
11. Zhang, Xin. "Squeeze casting of magnesium matrix composites reinforced with alumina short fibers." (2004).
12. Masannan et al., (2024). Experimental investigation on the drilling characteristics of kenaf/PLA-based laminates. Engineering Proceedings, 61(1), 9. <https://doi.org/10.3390/engproc2024061009>
13. Kaliappan S et al., (2024). Impact of Kenaf Fiber and Inorganic Nanofillers on Mechanical Properties of Epoxy-Based Nanocomposites for Sustainable Automotive Applications (No. 2023-01-5115). SAE Technical Paper.<https://doi.org/10.4271/2023-01-5115>
14. Anita et al., (2024). Energy Trading and Optimum Scheduling for Microgrids Using Multiple Agents Based DL Approach. Electric Power Components and Systems, 1-19.  <https://doi.org/10.1080/15325008.2023.2300329>
15. Niveditha, V. R., Nadh, V. S., Srinivas, C., Dhanraj, J. A., & Saravanan, A. (2024). Application of response surface and artificial neural network optimization approaches for exploring methylene blue adsorption using luffa fiber treated with sodium chlorite. Journal of Water Process Engineering, 58, 104778. <https://doi.org/10.1016/j.jwpe.2024.104778>
16. Yuvaraj, K. P., Reddy, V. K., & Ali, H. M. (2024). Evaluating the Wear and Mechanical Properties of Cotton Fabrics for Women’s Summer Clothing. Engineering Proceedings, 61(1), 15. <https://doi.org/10.3390/engproc2024061015>
17. Rajendran et al., (2024). Development of Intelligent Power Quality Management in Renewable Energy System in Smart Grid using Deep Learning. In 2024 International Conference on Inventive Computation Technologies (ICICT) (pp. 1178-1182). IEEE. <https://doi.org/10.1109/ICICT60155.2024.10544835>
18. Parashar et al., (2024). Time series analysis and random forest techniques for prediction of sales for retail grocery. In 2024 IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT) (Vol. 5, pp. 531-535). IEEE. <https://doi.org/10.1109/IC2PCT60090.2024.10486802>
19. Kaliappan et al., (2024). Thermal and Mechanical Properties of Abutilon indicum Fiber-Based Polyester Composites under Alkali Treatment for Automotive Sector (No. 2024-01-5031). SAE Technical Paper.<https://doi.org/10.4271/2024-01-5031>
20. R. Venkatesh Effects of ramie fiber/boron nitride exposure on the mechanical characteristics of injection-moulded polypropylene composites for automated structural applications. International Journal of Automotive Science and Technology. 2024; 8 (4): 451-456. <http://dx.doi.org/10.29228/ijastech..1528281>
21. R. Venkatesh Fabrication and Functional Behavior Studies of Polypropylene Composite Containing Hybrid Reinforcements, SAE Int. J. Mater. Manf. 18(2), 2025, <https://doi.org/10.4271/05-18-02-0015>.
22. R. Venkatasubramanian et al. Thermal characteristics and dryer performance analysis of double pass solar collector powered by copper and iron oxide. J. Thermal Sci. Eng. Appl. (2025) 1-20. https://doi.org/10.1115/1.4067258
23. Kamal, M. R., Manivannan, K. K., & Sunil, G. (2024, January). Machine Learning and Data Mining Approaches for Infectious Disease Surveillance and Outbreak Management in Healthcare. In 2024 International Conference on Advancements in Smart, Secure and Intelligent Computing (ASSIC) (pp. 1-7). IEEE. <https://doi.org/10.1109/ASSIC60049.2024.10507990>
24. Raskar, Sandeep, Gulshan Dhasmana, M. Lakshminarayana, and Harshal Patil. Enhancing Energy Efficiency in Wireless Sensor Networks using Deep Learning. In 2025 International Conference on Multi-Agent Systems for Collaborative Intelligence (ICMSCI), pp. 1515-1520. IEEE, 2025.
25. Natarajan, Gobu, et al. Influence of heat treated Manihot Esculenta Biosilica on friction stir welded AA 6065-Al2O3 metal matrix composite and microstructural, mechanical, and fatigue analysis. Materials Research 28 (2025): e20240473.
26. Senthilkumar et al., (2024). Maximizing Power Utilization through Machine Learning and IoT based Power Flow Strategies in DC Micro Grids with Renewable Energy Resources. In 2024 International Conference on Inventive Computation Technologies (ICICT) (pp. 1166-1171). IEEE.  https://doi.org/10.1109/ICICT60155.2024.10544791
27. Sreethar et al., (2024). Implementation of cross layer design with localization techniques in wireless sensor networks using deep learning. In 2024 International Conference on Expert Clouds and Applications (ICOECA) (pp. 607-613). IEEE. <https://doi.org/10.1109/ICOECA62351.2024.00111>
28. Chaturvedi, Abhay, S. Suhas, JL Divya Shivani, Ch Raja, Umang Soni. Enhancing IoT Network Security: A Double Decker Convolutional Neural Network with Brown-Bear Optimization for Intrusion Detection. In 2025 International Conference on Inventive Computation Technologies (ICICT), pp. 1903-1908. IEEE, 2025.
29. . Mohanavel et al. Investigation of Al/Mg composite behaviour by the adaptation of SiC and Al2O3 nanoparticle via electromagnetic stir cast route. Materials Science and Technology. 2025;0(0). doi:10.1177/02670836241306686
30. Kaushal et al., (2024). Fault prediction and awareness for power distribution in grid connected res using hybrid machine learning. Electric Power Components and Systems, 1-22. <https://doi.org/10.1080/15325008.2024.2337217>
31. Murthy, HS Niranjana, Shirish Kulkarni, Syed Mohd Uzair Iqbal, and Umang Pancha. Enhancing Video Captioning: A Bayesian Normalized Attention-based Multi-Dimensional Graph Network with Moss Growth Optimization. In 2025 5th International Conference on Pervasive Computing and Social Networking (ICPCSN), pp. 1688-1694. IEEE, 2025.
32. K. Logesh et al. Injection mould processing and characteristics measures of hybrid epoxy composites with jute fiber/boron nitride. J Mech Sci Technol. 39(1), 2025. <https://doi.org/10.1007/s12206-024-1219-1>
33. Singh et al. Natural fiber-ceramic filler configured polypropylene hybrid composite made via hot compression technique: Characteristics evaluation. J Mech Sci Technol. 39(1), 2025. <https://doi.org/10.1007/s12206-024-1216-4>
34. S. Prabagaran et al. Texturing of silicon nitride passivation layers on functional behaviour study of polycrystalline silicon (p-Si) made with plasma enhanced chemical vapour deposition. J Mater Sci: Mater Electron 36, 73 (2025). <https://doi.org/10.1007/s10854-024-14135-6>
35. V. Rathinavelu et al. Optimal performance of poly-hybrid nanocomposites promoted with carbon fibers and nano silicon carbide particles via compression associated with hot pressing: characterization study. International Polymer Processing, 2025. <https://doi.org/10.1515/ipp-2024-0152>
36. M.E.M. Soudagar et al. Exploration and thermal characteristics analysis of hybrid TiO2/SiO2 nanofluids passing through heavy-duty automotive radiators for intensive cooling system. J Therm Anal Calorim (2025). <https://doi.org/10.1007/s10973-025-14305-6>
37. S. Ravi et al. Processing and SiC content on functional behaviour of aluminium alloy composite. J Mech Sci Technol (2025). <https://doi.org/10.1007/s12206-025-0723-2>
38. M. A. Babu et al. Effect of Surfactants and Hybrid Filler on Microstructural and Mechanical Properties of Al7075/TiC/Graphene Alloy Composite via Additive Manufacturing. J. of Materi Eng and Perform (2025). <https://doi.org/10.1007/s11665-025-11873-4>
39. A. Sharma et al. Semisolid stir casting and effect of hybrid fillers on functional properties of aluminium alloy composites. J Mech Sci Technol (2025). <https://doi.org/10.1007/s12206-025-0620-8>
40. V. V. Upadhyay et al. Hexachloroethane fluxing mechanism and actions of hybrid fillers on functional behaviour of AZ31B alloy composites. J Mech Sci Technol (2025). <https://doi.org/10.1007/s12206-025-0622-6>
41. V. Mohanavel et al. Exploration of photovoltaic thermal collector performance enhancement by the accumulations of hybrid nanofluid and phase change material. J Therm Anal Calorim (2025). <https://doi.org/10.1007/s10973-025-14427-x>
42. K. K. Ilavenil et al. Enrichment of monolithic aluminium alloy characteristics by nano ceramic: Solid state process. J Mech Sci Technol (2025). <https://doi.org/10.1007/s12206-025-0513-x>
43. N. Basavegowda et al. Influence of Silver Nanowire Concentration on Electrical and Optical Properties of Polyaniline for Transparent Conductive Sensors. J. Electron. Mater. (2025). <https://doi.org/10.1007/s11664-025-12174-1>
44. A. Sharma et al. Featuring of Formamidinium lead halide and enrichment of optoelectronic behaviour of SnO2/FAPbI3/NiOx with PCBM layer. J Mater Sci: Mater Electron 36, 1124 (2025). <https://doi.org/10.1007/s10854-025-15203-1>
45. G. Deepana et al. (2025). Synthesis and machining characteristics study of agro-waste coconut shell powder incorporated aluminium alloy composite via the squeeze cast technique. International Journal of Cast Metals Research, 1–11. <https://doi.org/10.1080/13640461.2024.2447101>
46. Venkatesh, R., Chaturvedi, R., Umamaheswari, D. et al. Featuring of Fiber-Ceramic Combination on Behavior Studies of High Density Polyethylene Composite: Hot Compression Mould. Mech Compos Mater (2025). <https://doi.org/10.1007/s11029-025-10305-7>
47. R.P. Singh et al. Influence of a Copper Layer on the Functional Behaviour of a Cadmium Telluride Solar Cell Processed via Thermal Evaporation. J. Electron. Mater. (2024). <https://doi.org/10.1007/s11664-024-11669-7>
48. Tuluwengjiang et al., (2024). Dendritic cell-derived exosomes (Dex): Underlying the role of exosomes derived from diverse DC subtypes in cancer pathogenesis. Pathology-Research and Practice, 254, 155097. <https://doi.org/10.1016/j.prp.2024.155097>
49. Kaushal et al,. (2024). Navigating Independence: The Smart Walking Stick for the Visually Impaired. In 2024 5th International Conference on Mobile Computing and Sustainable Informatics (ICMCSI) (pp. 103-108). IEEE. https://doi.org/10.1109/ICMCSI61536.2024.00022
50. Chhaparwal et al., (2024). Numerical and experimental investigation of a solar air heater duct with circular detached ribs to improve its efficiency. Case Studies in Thermal Engineering, 60, 104780. <https://doi.org/10.1016/j.csite.2024.104780>
51. Kumar et al., (2024). Optimized forecasting approach for scheduling wind generation plants and maximizing renewable energy utilization. Electric Power Components and Systems, 1-17. <https://doi.org/10.1080/15325008.2024.2337218>