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DEVELOPMENT OF PROPELLER POWERED VEHICLE

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Abstract— **Many experiments have been conducted on wind-driven vehicles in the last decade, and wind-driven vehicle systems have moved faster along their paths than wind. Here, the car is powered by an aircraft propeller that is used. Therefore, we called it a "propeller-driven engine." This concept comes from merging the propulsion and automobile fields. A propeller-driven car is one type of simple power vehicle. This vehicle can be used as a ground vehicle. In the current scenario, the construction of a vehicle is a very difficult challenge because of its complex design, which requires considerable time and precaution. It cannot be constructed by a single engineer or an expert. A propeller-powered vehicle is one of the solutions to these problems. In defense, shifting a vehicle is a very complex task, and the propeller power car is the solution for which it can be easily dismantled and assembled. The propeller-powered car has a simple design. A vehicle carries 100 kg of weight, and its seating capacity is one. A propel-driven vehicle operates as a three-wheeler vehicle using aircraft propeller thrust. A propeller is placed in the rear section of the car, which gives power to the car. Propellers generate thrust by rotating an airfoil in a circle, which generates thrust by accelerating the airflow backward away from the propeller. The construction of a vehicle is less time-consuming and easier to assemble.**

Keywords— **Propeller-Powered Vehicles, Propeller engine, Thrust propulsion, Air-Powered vehicle, Thrust force, Momentum, ANSYS Fluent**

I. INTRODUCTION

An evolution in different concepts of vehicles has been changing according to needs for decades; one of them is a vehicle driven by thrust, which is produced by a propeller. Our concept is also similar, with some modifications. Our main purpose is to design and develop three-wheeled ground-based vehicles that will be powered by the thrust generated by the propeller [1]. To make the mechanism simple and cheap, we are going to use the engine in order to operate the propeller. By connecting the propeller to the back of the vehicle, thrust is generated to move the vehicle forward and avoid the effect of frictional force. Computational fluid dynamics (CFD) is widely being used to analyze the flow problem numerically rather than experimentally, as the CFD simulation provides advantages such as time and cost. [2-3].

Components of a Propeller-Powered Vehicle:

- Propeller
- Engine
- Chassis
- Transmission System

A. Propeller

A propeller uses a kind of power transmission method that converts motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blades, and the air is accelerated by the pressure difference [4]. Propeller dynamics, like those of airplane wings, can be modelled by means of Bernoulli's principle and Newton's 3rd law.

B. Engine

An engine is a machine that converts fuel's chemical energy into mechanical energy. Heat engines, including I.C. engines and E.C. engines, burn fuel to create heat, which creates motion.

C. Chassis

The fundamental framework of a vehicle is its chassis. The chassis can consist solely of the frame at times, or it can also have the wheels, the gearbox, and even the front seats. A vehicle's chassis, without which the car would lack structure, is one of its most crucial parts. Chassis are made of carbon steel and aluminum.

D. Transmission System

Transmission means the mechanism that transmits the power from the engine crankshaft to the rear wheels. In this vehicle, the power from the engine is transmitted to the propeller to produce the required thrust. Two primary categories of gearbox systems exist [5] :

(1) Manual transmission and

(2) Automatic transmission; usually, in this vehicle, a manual transmission system is used.

E. Brake Mechanism

The friction brake is the most commonly used braking method in modern vehicles. The term friction brake is used to mean shoe brakes and excludes hydrodynamic brakes, even though hydrodynamic brakes use friction. A rotating wear surface and a stationary pad are typical components of friction brakes [6]. It involves converting kinetic energy into thermal energy by applying friction to the system's moving parts [7]. The friction force resists motion, which in turn generates heat and eventually leads to zero velocity.

A report on a propeller-driven snow buggy in this propeller-driven vehicle for traversing snow and ice-covered terrain with improved steering response and stability The vehicle has a motor-driven propeller, providing motive force to sustain the forward motion of the vehicle regardless of terrain conditions [8]. Designed as a motorised propeller vehicle in which a tubular hub with a transverse axis links each thruster to the body of the vehicle, it provides signals representative of the efforts it transmits [9].

II. CALCULATION AND DESIGN

Force Calculation, estimated parameters of vehicle has been used

Weight of the Vehicle = 150 kg
Carrying Capacity = 100 kg
Velocity of the vehicle = 50 km/h = 13.88 m/s
Acceleration = 1.388 m/$s2$
Newton's 2nd Law, F = ma
Force in Newton, mass in Kg, a in m/ s^2 Fa = 347.12 N
Rotating Inertia Far = 34.71 N
Aerodynamic Drag coefficient (cd) = 0.3 Area (A) = 3.51$m2$
F drag= 391

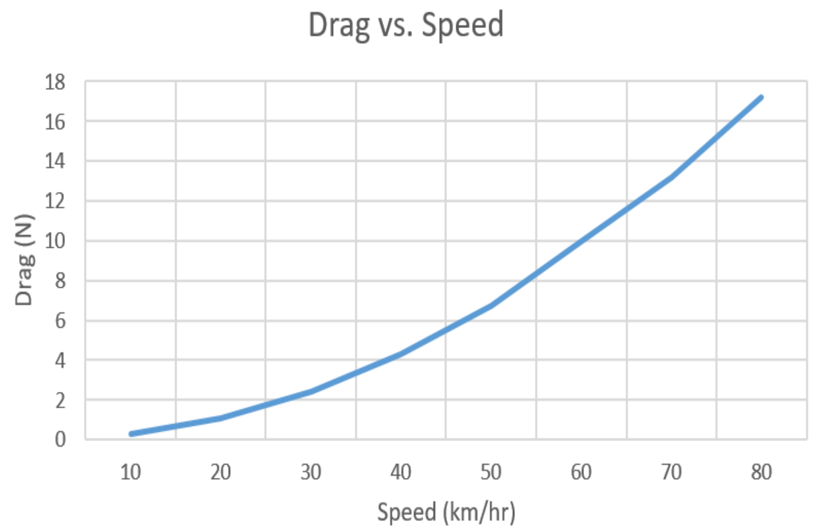


Fig. 1. Propeller Analysis

A. Total Acceleration Force

Table -2 Velocity vs. Different forces

Speed (km/hr) Force (N)	10	20	30	40	50	60	70	80
F_{a1}	**347.1**	**347.1**	**347.1**	**347.1**	**347.1**	**347.1**	**347.1**	**347.2**
F_{ar}	**34.71**	**34.71**	**34.71**	**34.71**	**34.71**	**34.71**	**34.71**	**34.71**
F_{drag}	**0.269**	**1.077**	**2.423**	**4.309**	**6.733**	**9.695**	**13.196**	**17.235**
$F_{rolling}$	**49**	**49**	**49**	**49**	**49**	**49**	**49**	**49**
F_{Totle}	**431.09**	**431.91**	**433.25**	**435.14**	**437.56**	**440.52**	**444.03**	**448.06**

B. Airfoil Selection

Due to the high Mach number, compressibility effects reduce the efficiency of the propeller. A practical way to keep the drag of an airfoil at acceptable levels is to use thinner and less cambered airfoils [10].

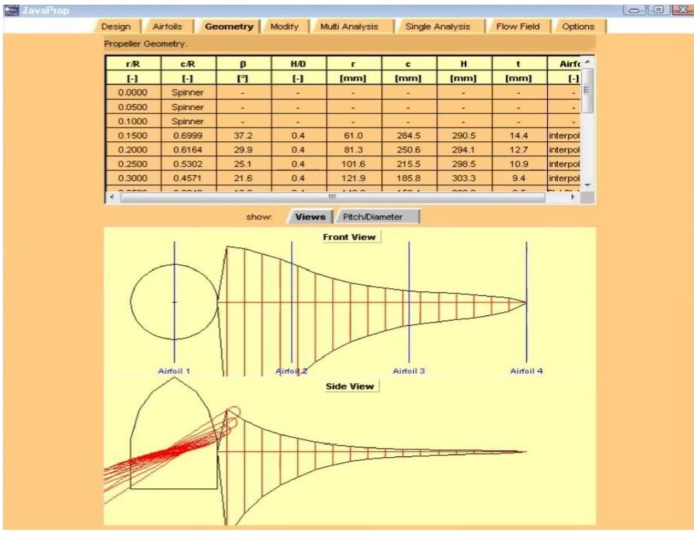
Table -3 Airfoil characteristics

Parameter	NACA 6412	NACA 9412
Thickness	**0.12c**	**0.12c**
Camber	**0.06c**	**0.09c**
Trailing edge angle	**14.2°**	**13.7°**
Lower flatness	**0.812c**	**0.318c**
Leading edge radius	**0.17c**	**0.17c**
Max C_L	**1.785**	**2.148**
Max C_L	**12.0**	**12.0**
Max L/D	**60.34**	**58.12**
Max L/D angle	**4.0**	**0.5**
Stall angle	**4.0°**	**12.0°**
Zero-lift angle	**-6.0°**	**-9.5°**

Occasionally, it could be acceptable to have a small supersonic zone at the propeller tip because reducing the diameter (to avoid supersonic tips) also reduces performance. But in general, a propeller should be designed to avoid supersonic flow by choosing the right airfoil thickness and the right diameter. Although it is impossible to fully analyse the impact of compressibility on propeller performance in this context due to its complexity, it is possible to draw some general conclusions from experimental data. The different airfoils were being selected based on their maximum allowable thickness and camber for a given Mach number, and vice versa. The airfoils selected were the NACA 6412 and NACA 9412.

C. Geometry of the airfoil

The geometry of the propeller, in the form of a table and a three-view sketch shown in Figure, also presents the distribution of the pitch-to-diameter ratio H/D over the radius of the propeller. In the figure, we show the 3D view of the propeller and also show the front and side views. The input values are used for design and analysis in Java Prop. So, by putting in the input values, we have the output of the propeller, where the propeller design is simple.



Propeller Geometry.

r/R [-]	c/R [-]	β [°]	H/D [-]	r [mm]	c [mm]	H [mm]	t [mm]	Airf [-]
0.0000	Spinner	-	-	-	-	-	-	-
0.0500	Spinner	-	-	-	-	-	-	-
0.1000	Spinner	-	-	-	-	-	-	-
0.1500	0.6999	37.2	0.4	61.0	284.5	290.5	14.4	interpol
0.2000	0.6164	29.9	0.4	81.3	250.6	294.1	12.7	interpol
0.2500	0.5302	25.1	0.4	101.6	215.5	298.5	10.9	interpol
0.3000	0.4571	21.6	0.4	121.9	185.8	303.3	9.4	interpol

Fig. 2. Propeller Analysis

D. Analysis of Propeller

The results of the multi-analysis are presented in a table and a graph showing the thrust and power coefficients depending on the advance ratio v/(nD) [11]. The percentage of blade sections where the airfoil has stalled, which is the only information about the flow conditions on the blade, indicates how many blade sections have experienced this stalling. When 100% of the blades are stalled, all airfoils operate beyond their maximum lift, which is usually the case at low speed.

Propeller

Dimension of Propeller = 81.3 cm × 6.7 cm × 3.2 cm
Pitch = 10
Diameter of Propeller = 81.3 cm

Thrust

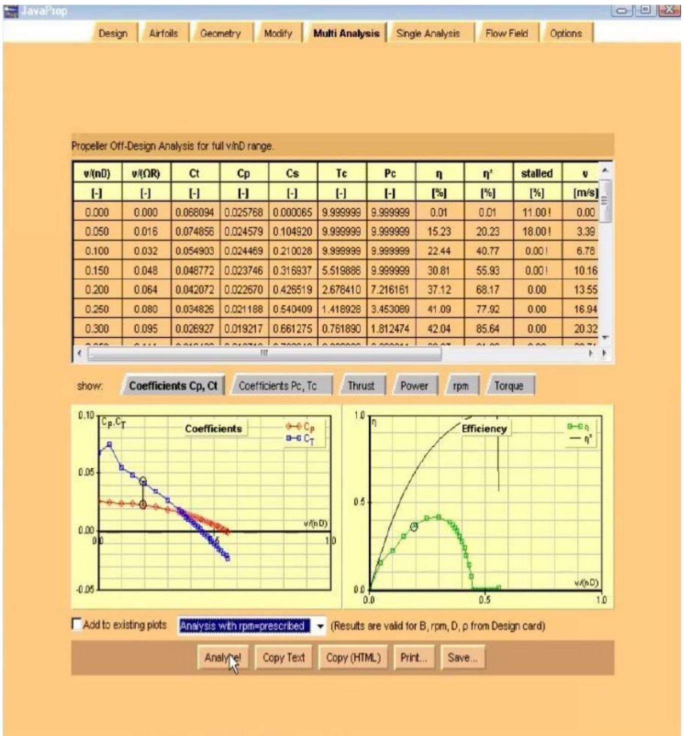
$T = 4.392399 \times 10^{-8}$
In Static Thrust V= 0 RPM = 2800
T = 85.45 N
Kinetic Honda Engine Displacement: - 110cc Engine
Type: - 2 stoke
Maximum power: - 5740watt
Maximum Torque: - 9.8Nm
Fuel Type: - Petrol

Propulsive Power

P = 3808.67Nm/s

Efficiency of propeller

η= 66.35%



Propeller Off-Design Analysis for full v/nD range.

v/(nD)	v/(ΩR)	Ct	Cp	Cs	Tc	Pc	η	η*	stalled	v
[-]	[-]	[-]	[-]	[-]	[-]	[-]	[%]	[%]	[%]	[m/s]
0.000	0.000	0.068094	0.025768	0.000065	9.999999	9.999999	0.01	0.01	11.00 !	0.00
0.050	0.016	0.074856	0.024579	0.104920	9.999999	9.999999	15.23	20.23	18.00 !	3.39
0.100	0.032	0.054903	0.024469	0.210028	9.999999	9.999999	22.44	40.77	0.00 !	6.78
0.150	0.048	0.048772	0.023746	0.316937	5.519886	9.999999	30.81	55.93	0.00 !	10.16
0.200	0.064	0.042072	0.022670	0.426519	2.678410	7.216161	37.12	68.17	0.00	13.55
0.250	0.080	0.034826	0.021188	0.540409	1.418928	3.453089	41.09	77.92	0.00	16.94
0.300	0.095	0.026927	0.019217	0.661275	0.761890	1.812474	42.04	85.64	0.00	20.32

☐ Add to existing plots
Analysis with rpm=prescribed (Results are valid for B, rpm, D, ρ from Design card)

Fig. 3. Propeller coefficient and efficiency analysis

III. VEHICLE DESIGN

The computer-aided design of the propeller power vehicle has been done using the CATIA V5 software. Figures 3 and 4 show the CAD design of the vehicle for different views, namely, side view and back view, respectively. Figure 5 shows the schematic diagram with all the measurements. After designing the model on a computer, the propeller-powered vehicle has been fabricated in the manufacturing lab of the college. Figures 6, 7, and 8 depict the fabricated model of the vehicle. The high-strength steel material described in [12] has the advantages of low cost, high strength, great rigidity, and can meet the daily working requirements of engineering machinery, so the steel pipes have been utilized in the fabrication of the outer frame of vehicles as the steel has great strength, is easily available in the local market, and fulfils the weight requirement for the vehicle. All the pipes were welded using arc welding, as arc welding is an efficient and economical method for joining metals, with advantages including high joint efficiency, simplicity, flexibility, and low fabrication costs [13–14]. A Honda kinetic engine is used to power the vehicle.

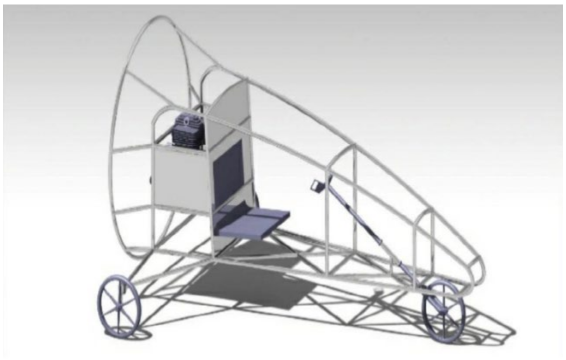


Fig. 4. CAD Model (Side view)

Fig. 5. CAD Model (Back view)

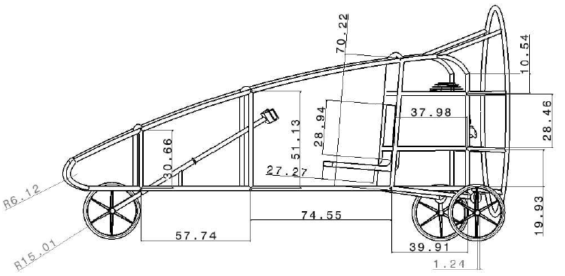


Fig. 6. Schematic Diagram (All dimension in cm)

Fig. 7. Fabricated vehicle (Side view)

Fig. 8. Fabricated vehicle (Side view)

Fig. 9. Fabricated vehicle (Back view)

IV.RESULTS AND DISCUSSION

The result comes from the Java Prop software. Some fundamental findings are shown by using a straightforward momentum theory model to illustrate the main characteristics of propeller flow. The stream tube contraction and swirl losses are included in this model. The results are presented on the flow field in the form of a contour plot of the axial velocity ratio (upper half of the graph) and the stream tube boundary (lower half). As can be seen, the propeller causes half of the flow's acceleration, and the vortices in the slipstream are responsible for the other half.

This theoretically analysed model was further tested numerically using ANSYS Fluent. In that case, the only propeller was simulated to visualise the velocity and pressure distribution on the blade. In that, the geometry was imported and the coarse mesh was created in the free stream flow, and near the region of interest, the fine mesh was created where the flow parameter needed to be captured in that region [15–16].

For the propeller simulation, pressure-based Reynolds-average Navier-Stokes equations [17] The k-ω Shear Stress Transport

(SST) turbulence model is used for propeller simulation in ANSYS Fluent [18].

Figure 9 shows the velocity distribution on the propeller blade when the air passes over it; Figure 10 shows the rotational flow on the propeller blade; and the pressure distribution on the blade has been depicted in Figure 11.

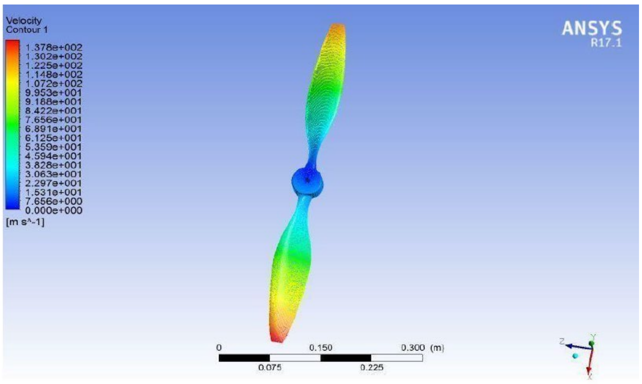


Fig. 10. Velocty distribution

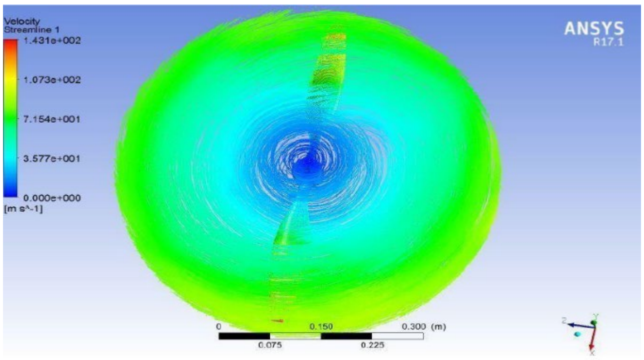


Fig. 11. Rotational flow on propeller

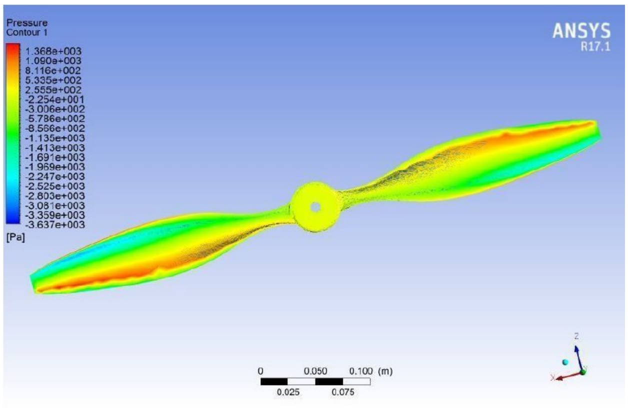
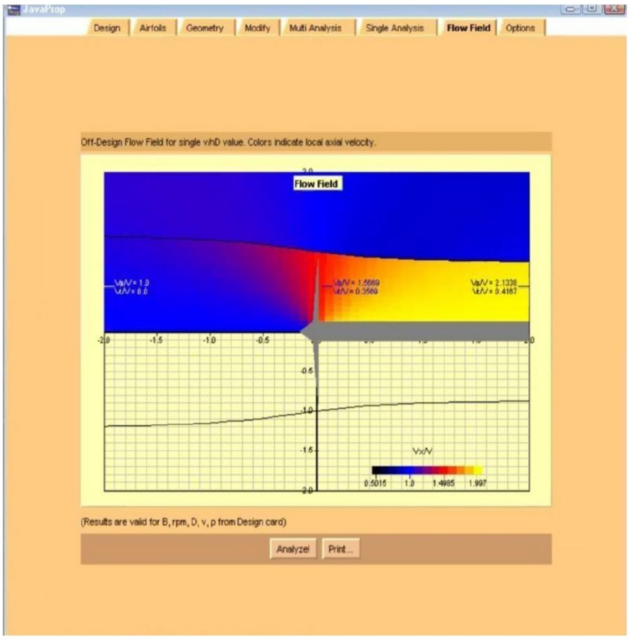


Fig. 12. Pressure distribution



Off-Design Flow Field for single v/nD value. Colors indicate local axial velocity.

(Results are valid for B, rpm, D, v, p from Design card)

Fig. 13. JAVAPROP result

V. CONCLUSION

The development of a three-wheeler propeller-powered vehicle is based upon the concept of merging the automobile system with propulsion and has been carried out and tested. The results are based on the propeller speed, which gains power through the engine, which results in less fuel consumption. The selection of propeller air foil, which is NACA6412, is carried out using Java Prop by analysing the different results of force acting on a propeller. The unique scale design and chasse model of a vehicle are done by using CATIA V5 software, which is blunt, and due to this characteristic, the drag force will decrease. From different literature surveys, the ideas of the operating system, braking system, and transmission system have been taken. Carbon steel is the material of the chassis, as it gives more strength and fulfils the weight requirement.

- There is a vehicle that can be powered by a propeller that can go in the downwind direction faster than the free stream wind speed (using a propeller in the air). The speed of the vehicle is controlled by RC. There is no definite upper limit for vehicles of this kind. As long as efficiencies are improved, velocities will also increase asymptotically.
- It is suggested to use a variable-pitch propeller so that, as vehicle speed changes, we can continue to maintain the best angle of attack (maximum lift-to-drag ratio) on the propeller blades. In order to create a better design that moves faster downwind, it is advised to conduct additional research utilising computational software to comprehend the velocity and pressure changes that take

place around the propeller. The direction of the vehicle is totally controlled by the rudder mechanism, hinge mechanism, and remote control.

- It is a pollution-free vehicle. Here, an attempt has been made by fabricating small-scale models, and we observed that it has good balancing; there is no issue with direction control, and its drifting is very good.

VI. REFERENCE

[1] Khan, Md. S. A., Sufiyan, S. A., George, J. T., & Ahmed, Md. N. (2013). Analysis of Down-Wind Propeller Vehicle. International Journal of Scientific and Research Publications, 3(4), 1–4.

[2] Wu, J., Dou, Y., Lv, H., Ma, C., Zhong, L., Xu, S., & Han, X. (2021). Thrust characteristics of ducted propeller and hydrodynamics of an underwater vehicle in control motions. Journal of Marine Science and Engineering, 9(9), 940. doi:10.3390/jmse9090940

[3] Hu, H. H. (2012). Computational Fluid Dynamics. Fluid Mechanics, 421–472. doi:10.1016/b978-0-12-382100-3.10010-1

[4] de Vries, R., van Arnhem, N., Sinnige, T., Vos, R., & Veldhuis, L. L. M. (2021). Aerodynamic interaction between propellers of a distributed-propulsion system in forward flight. Aerospace Science and Technology, 118, 107009. doi:10.1016/j.ast.2021.107009

[5] Rimpas, D., & Chalkiadakis, P. (2021). Electric vehicle transmission types and setups: A general review. International Journal of Electric and Hybrid Vehicles, 13(1), 38–56. doi:10.1504/ijehv.2021.115196

[6] Skorupka, Z. (2016). Wear in friction brakes. Journal of KONES. Powertrain and Transport, 23(2), 325–332. doi:10.5604/12314005.1213744

[7] Gaunaa, M., Øye, S., & Mikkelsen, R. F. (2009). Theory and design of flow driven vehicles using rotors for energy conversion. In EWEC 2009 Proceedings online EWEC.

[8] Ruan, H., Zhou, J., Zhao, W., Xin, G., Liu, Y., Qu, S. An all terrain vehicle integrated electric ducted propeller propulsion system. (2018).

[9] Georges, C., Olivier, C., Patrice, F. (1991). Vehicle with motorized propulsion units.

[10] Kaushik, M. (2018). Thin airfoil theory. Theoretical and Experimental Aerodynamics, 127–144. doi:10.1007/978-981-13-1678-4_5

[11] Gur, O., & Rosen, A. (2005). Propeller performance at low advance ratio. Journal of Aircraft, 42(2), 435–441. doi:10.2514/1.6564

[12] Shen, G., Tu, J., Li, H., Shen, C. (2018). High-strength steel material.

[13] Balos, S., Dramicanin, M., & Janjatovic, P. (2022). Gas metal arc welding of metal-polymer-metal sheets. Tribology and Materials, 1(2), 61–69. doi:10.46793/tribomat.2022.008

[14] Ahirwar, P., & Singh, M. (2014). The effects of welding parameters on welding qualities:review. International Journal of Innovation in Engineering Research and Management, 1(2), 1–5.

[15] Prajapati, C. R., Donga, A. P., Babariya, P. R., & Patel, A. D. (2023). Comparative analysis of turbulence models for simulating flow over a flat plate. International Journal of Engineering Applied Sciences and Technology, 8(1), 278–283. doi:10.33564/ijeast.2023.v08i01.043

[16] Prajapati, C. R., Donga, A. P., Patel, A. D., & Babariya, P. R. (2023). A review of numerical simulation and analytical calculation methods for the study of flow over a wedge. International Journal for Research in Applied Science and Engineering Technology, 11(8), 1330–1338. doi:10.22214/ijraset.2023.55353

[17] Zhang, Y., Fu, Y., Wang, P., & Chang, M. (2022). Aerodynamic configuration optimization of a propeller using Reynolds-averaged navier–stokes and adjoint method. Energies, 15(22), 8588. doi:10.3390/en15228588

[18] Selvanayagam, J., Aliaga, C., & Stokes, J. (2022). CFD simulation of ground vortex intake test case using Ansys fluent. AIAA SCITECH 2022 Forum. doi:10.2514/6.2022-0222