iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** X **Month of publication:** October 2021

DOI: https://doi.org/10.22214/ijraset.2021.38418

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

Twist Morphing: A Simulation Approach to Compare Twist Morphed Wing and Flap Configuration

Aditya Joshi[1], Avnish Surendra Rai[2]
[1, 2]Symbiosis Institute of Technology, Mechanical Engineering Department

Abstract: The aim of the work is to explore and justify an innovative concept in the niche of aerospace industry called as Wing Morphing. To narrow down the study, specifically twist morphing is taken into consideration. Wings with twist and their flap counterparts are compared in similar conditions and their aerodynamic efficiency is observed. The project implementation is done with XFLR5, a VLM solver software. The results show that this concept brings about an improvement in the aerodynamic efficiency without adding much to the drag penalty.
Keywords: Wing Morphing, Twist Morphing, C_l (coefficient of lift), C_d (Coefficient of drag), Alpha (angle of attack)

I. INTRODUCTION

All the air planes and drones we see today are inspired from bids. In fact, the concept of flying was derived from birds. The heart of flying and gliding at high altitudes lie in the wing shape. The wing also called the air foil is designed such that it maximizes lift and minimizes drag, the basic principle of flying. Modern aircrafts have designed many planes inspired from birds, but one thing that is yet to be imitated is the adaptive wing shape changes birds could perform amidst flight. This capability of changing shape dynamically and adaptively is called as wing morphing. All the modern aircrafts also called as fixed wing aircrafts, use control surfaces to control plane movement i.e., roll pitch and yaw. These surfaces known as ailerons, elevators and rudder form the basis of any aircraft movement control system. To increase the lift other surfaces known as high lift devices are used. Although these devices increase lift by significant amount but at the same time adds a significant amount of drag thus decreasing the aerodynamic efficiency. The main reason behind this is the discontinuity of flow encountered at several mechanically connected interfaces. The flow discontinuity causes uneven local pressure distribution and thus adds an extra drag. It can be clearly seen from the figure 1 that although the lift is increasing from 1.29 to 3.09, but at the same time it has decreased the aerodynamic efficiency by a great extent (7.5 to 4.1). Not only this but the mechanism used to control these surfaces is pretty bulky and significantly increases the weight of the air plane. Increase in weight leads to increase in fuel consumption, which again is a major flak for the fixed wing aircrafts. The paper titled "Wing Morphing" is aimed to explore the effects of morphing on the aerodynamic efficiency of a wing. The expected results can prove that morphing can not only significantly increase lift but also the Cl/Cd ratio. The basic idea was to simulate the project on a simulation software and interpret the results for understanding. The results would include Cl, Cd graphs. Twist morphing is a novel way of morphing wing especially used in some mission adaptive UAV's. In twist morphing the wing tip is given some degree of twist whereas the base remains intact. The main advantages of this morphing are reduced weight and stall mitigation at lower angle of attacks at low speeds. In traditional wing the stall can't be avoided but in a twist configuration by adjusting the twist, stall could be avoided.

No.	Designation	Diagram	Cl (max)	Alpha at Cl max (Degree)	CL/CD (MAX)	CL min	Reference NACA
1	Basic aerofoil Clark Y		1.39	15	7.6	-0.08	TN 459
2	.30e Plain Flap deflected 45°		1.95	12	4.0	-	TR 427
3	.30e Slotted Flap Deflected 45		1.98	12	4.0	-	TR 427
4	.30e Split Flap Deflected 45°		2.16	14	4.3	-0.250	TN 422
5	.30e Hinged at. Bo Split Flap + Deflected 45°		2.26	13	4.43	-0.300	TN 422
6	.30e Hinged at .90 Split Flap Deflected 45°		2.32	12.5	4.45	-0.385	TN 422
7	.30e Fowler Flap Deflected 40°		2.82	13	4.55	-0.660	TR 534
8	.40e Fowler flap Deflected 40°		3.09	14	4.1	-0.880	TR 534

Fig. 1 Efficiency Comparison of High Lift Devices

II. LITERATURE REVIEW

Various researches have been done on wing morphing that focused on improve the properties of wing, that can lead wing to change its shape. Various concepts have been proposed on this type of concept such as Mechanism for warp-controlled twist of a morphing wing [1]. In this, a demonstration of wing which was built based on a NACA 23012 air foil section with a span of 0.68 m and a chord length of 0.235 m. A maximum peak-to-peak twist of 27 degree was demonstrated, with excellent correlation between theory and experiment. Wind-tunnel tests showed that warping could change the lift coefficient by as much as 0.7 at maximum peak-to-peak twist. Ref [20], Effectiveness of wing twist morphing in roll control, Effect of morphing on roll control was demonstrated. The twist morphing wing was able to achieve 1.6 times roll than a conventional wing. Ref [19] an experimental validation was performed an UAV conventional and morphing wing were compared. It was found that a morphing wing resulted in better aerodynamic efficiency and better roll control. Max roll rate: 70.28 degree/s (Conventional) and 116.68degree/s (Morphed wing) Twist morphing proves to offer various advantage over conventional wing such as high aerodynamics efficiency, lightweight as well as replacing conventional control methods. Various methods of action such as, piezoelectric, SMA have been conducted for twist morphing. Ref [20] a novel morphing control surface design employing piezoelectric Macro Fibre Composite (MFC) actuators is compared to a servo-actuated system. The conformal morphing air foil geometry increases the lift-to-drag ratio over a servo-actuated flapped air foil design, showing benefits in aerodynamic efficiency. Ref [1] a wing constructed with shape changing structure from discrete lattice building block elements that are joined together that performs continuous span wise twist deformation. The main object of paper was to achieve minimum drag with better roll efficiency. Ref [2] a new concept of controlling wing twist is based on warping deformation of the wing span which got split at the trailing edge to create as open section of air foil. It was shown that at lower angles of attack, more positive twist results in higher lift to drag ratios. Ref [3] optimization of aerodynamic efficiency (Cl/Cd) has been conducted where two ways fluid structure interaction simulations and wind tunnel testing were used to solve and study the basic wing aerodynamic performance over (non-optimal) twisted morphing, membrane a rigid wing. Then, a multi-fidelity metamodel-based design optimization process was adopted to maximize the aerodynamic efficiency using Ansys Design Xplorer.

III.RESEARCH AND METHODOLOGY

For twist morphing a wing made of NACA 0012 air foil was considered. Two versions of the wing one with flaps and one with twist were compared at various AOA and various twist/flap configurations via XFLR5.XFLR5 is a basic flow simulation open-source package, for beginners which uses the VLM. solver to obtain results. It's a user friendly and beginner friendly software package. It can also provide additional results such as Cl Cd polar, which gives it an upper hand over other package. Due to meagre understanding of erudite topics such as CFD, initially the simulations were performed on XFLR5 and curves were obtained for an overall validation. The key factor followed for analysis was Reynolds no. All the analysis was performed at Re = 547486. Re was calculated as follows: - $Re = \rho v D\ /\mu$ where, $\rho\ is\ Density,\ \mu\ is\ dynamic\ viscocity\ v\ is\ velocity\ and\ D\ is\ characterstic\ dimension$. Wing made of NACA 0012 was analysed. The dimensions of wing were referenced from [. Using VLM solver various twist configurations were analysed. To show the advantages of twist over conventional control surfaces, analysis was performed for wings with flaps at different angle

A. Details of Analysis

The wing was generated as per given dimensions in the software. VLM solver was used. Velocity of flow was calculated by the software. Analysis was conducted at 500,000 Re. The analysis was performed from AOA 0° to a maximum of 30.

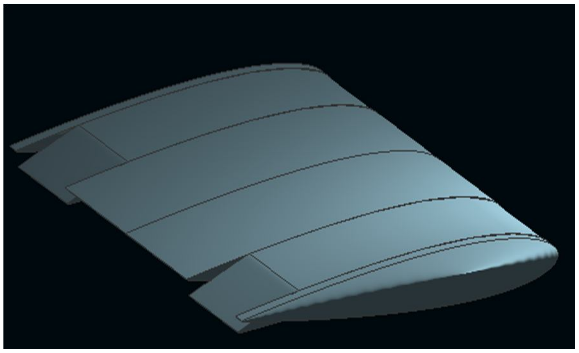
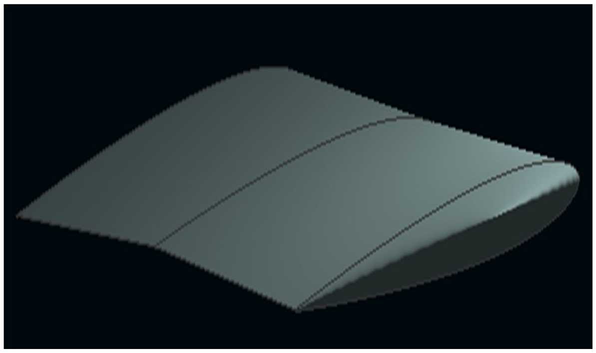
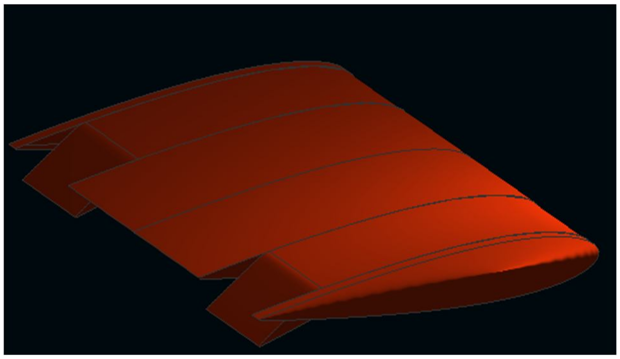
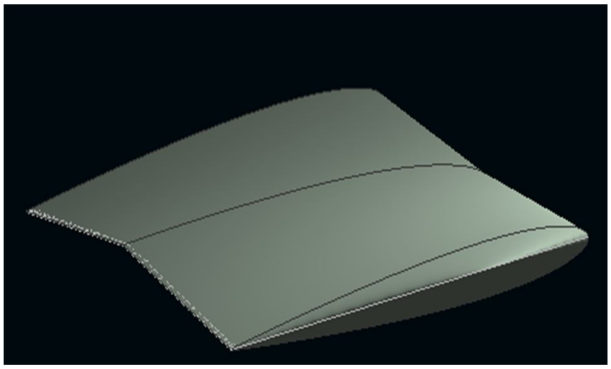
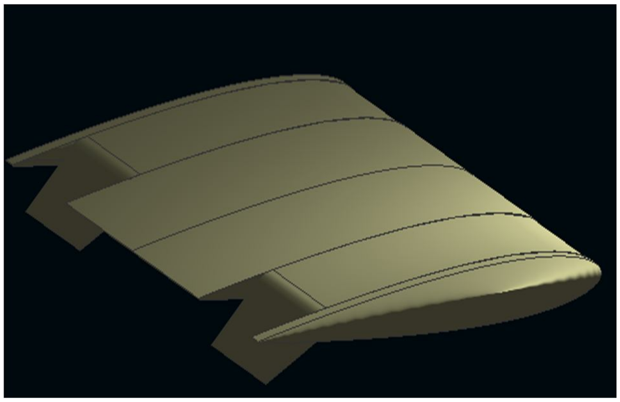
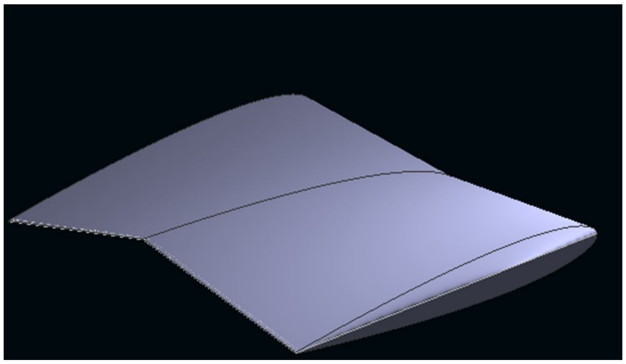
1) The Wing Span: 1.162 m2
2) Wing area: .354 m2
3) Root chord: .305 m
4) Aspect ratio: 3.810 m
5) Taper ratio: 1.0

Finally, Polars were plotted and results analysed. The results are displayed in the following manner:

a) 0012 wing without flap
b) Twist 2°
c) Twist 6°
d) Twist 10°
e) Flaps 10° down
f) Flaps 20° down
g) Flaps 30° down

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

TABLE I

Flap geometry	**Twist Geometry**
Flaps 10 ° 	Twist 2° 
Flaps 20° 	Twist 6° 
Flaps 30° 	Twist 10° 

The table shown above depicts the comparison of flap and twist geometry that is analysed in the further sections.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

B. Polars and Results Configuration of Twist Morphing

Wing based in NACA 0012 has been considered and its Polars for twist configuration for 2°, 6° and 10° are compared. The Polars considered are cl vs alpha, cd vs alpha and cl/cd vs alpha.

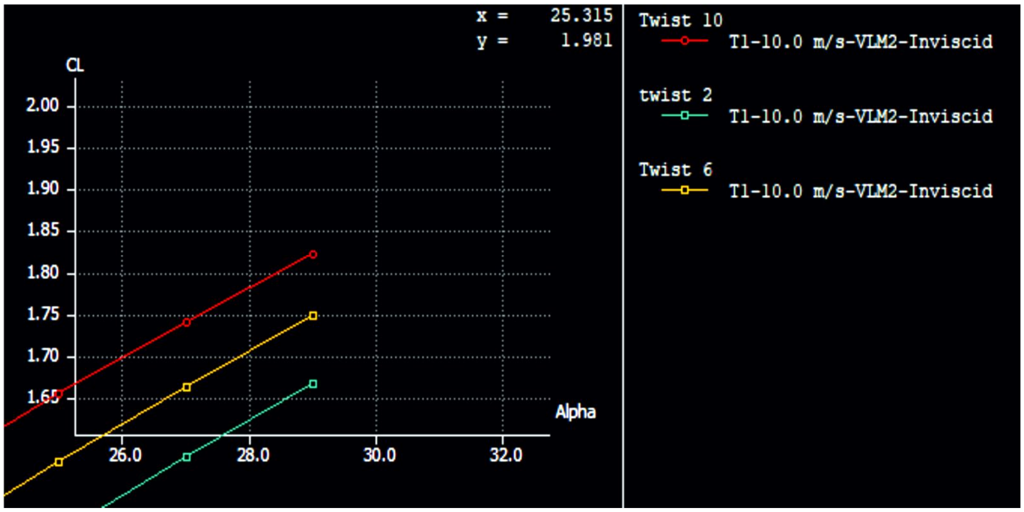


Fig. 2 Cl Vs Alpha

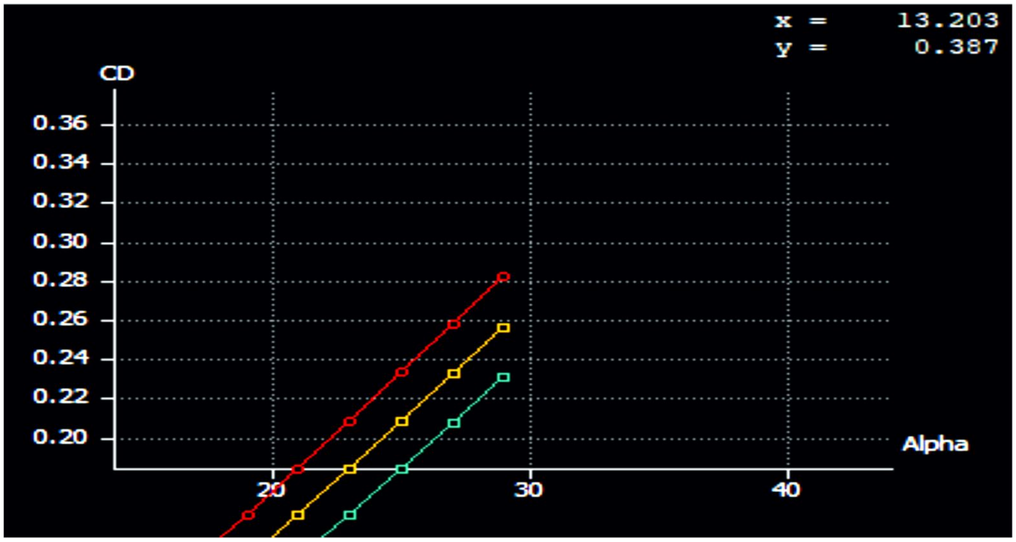


Fig. 3 CD Vs Alpha

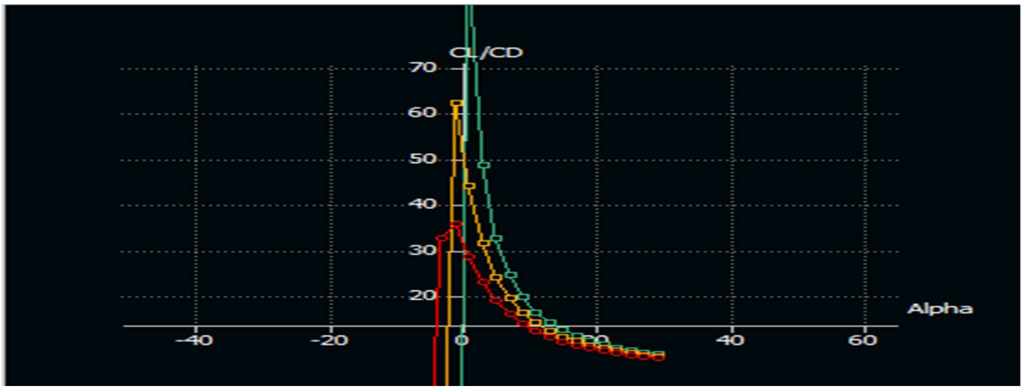


Fig. 4 CL/CD Vs Alpha

C. Observations of Twist

From figure 1(Cl vs alpha) it can be seen that with increase in twist from 2 degrees to 10 degrees there is a significant increase in Cl from 1.65 to 1.85. Figure 2 shows increase in drag from a value of .23 to .28. CL by CD value has shown a dip from 65 to 30. However, the positive side is that form a lift increase of 0.2 the drag addition is merely .06.

D. Polars and Results of Flap Configurations

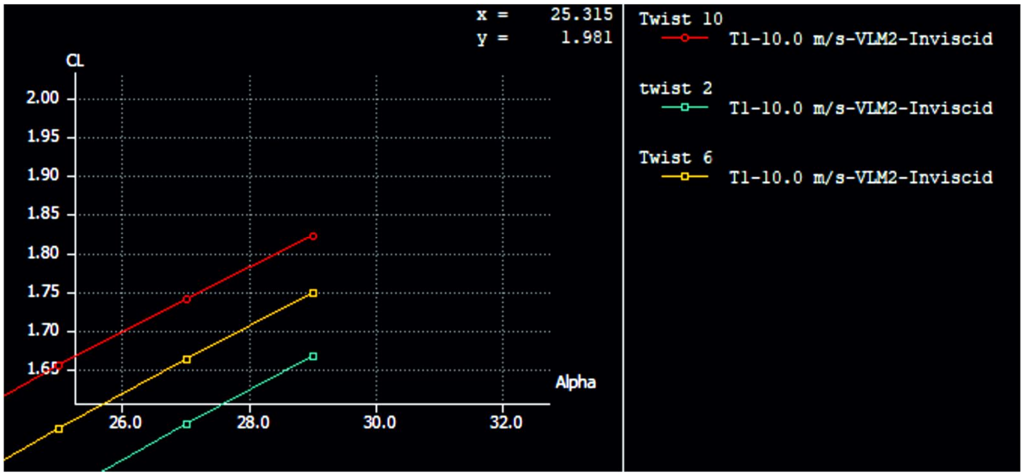


Fig. 5 Cl vs Alpha

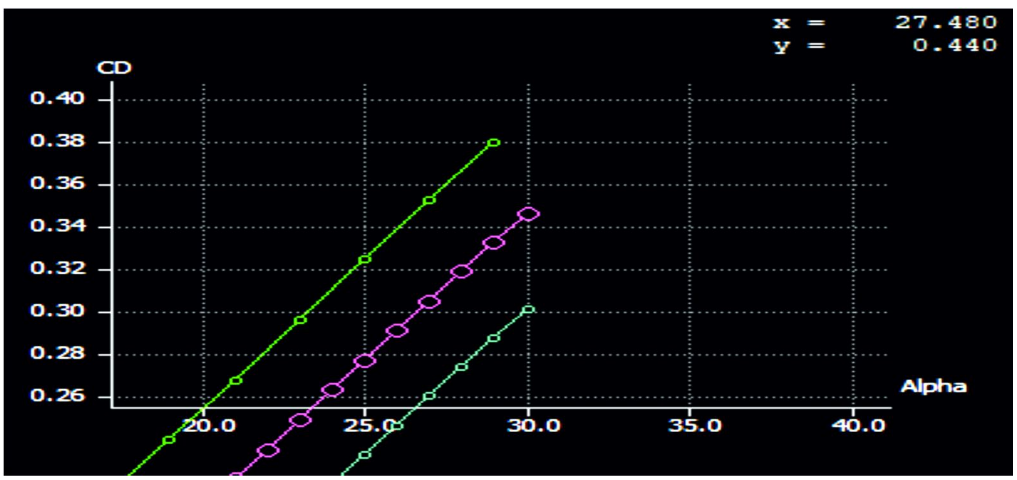


Fig. 6 CD vs Alpha

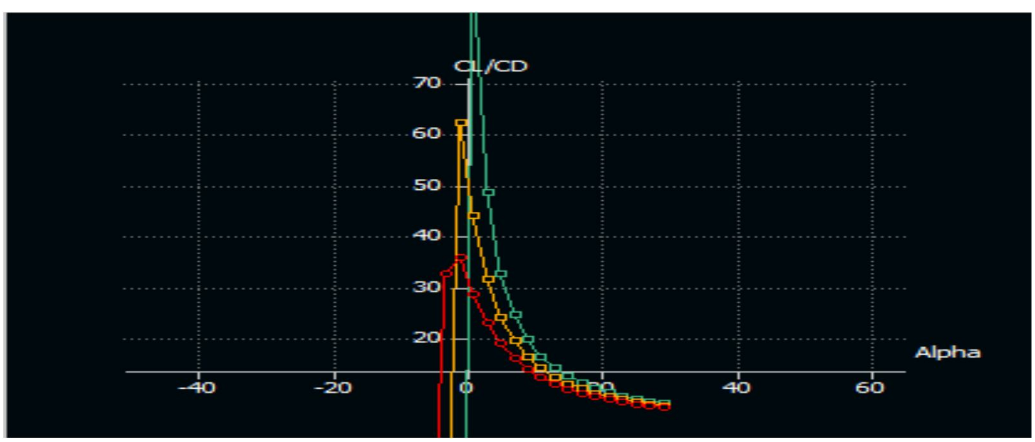


Fig. 7 CL/CD vs Alpha

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue X Oct 2021- Available at www.ijraset.com

E. Observations of Flaps

From the Cl vs alpha polar it can be observed that there is an increase in lift from 1.70 to 1.85 with 30-degree flaps reaching the maxima at a lower AOA. In the Cd vs alpha polar the drag increases from .30 to .38. The CL/CD value show a dip from 30 to 10. For a lift increase of .15 the drag increases .08

F. Relative Comparison Between Twist and Flaps

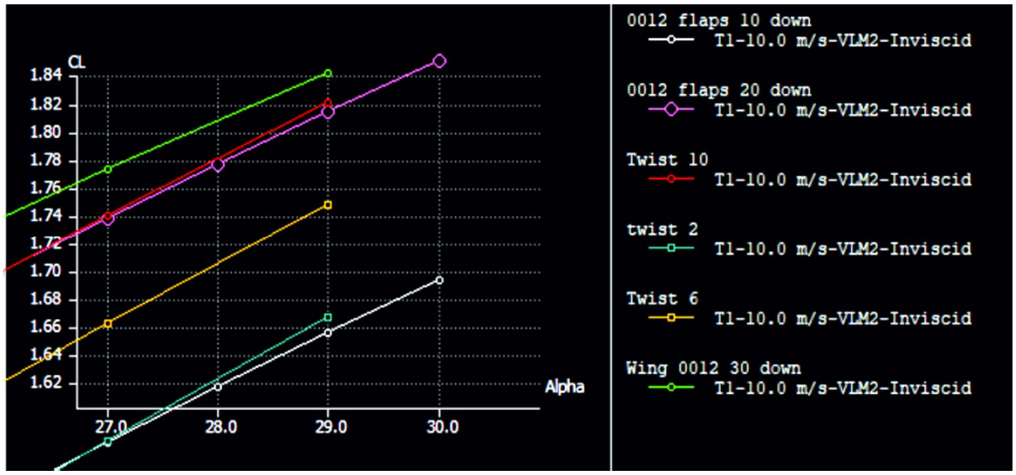


Fig. 8 Cl vs Alpha Comparison

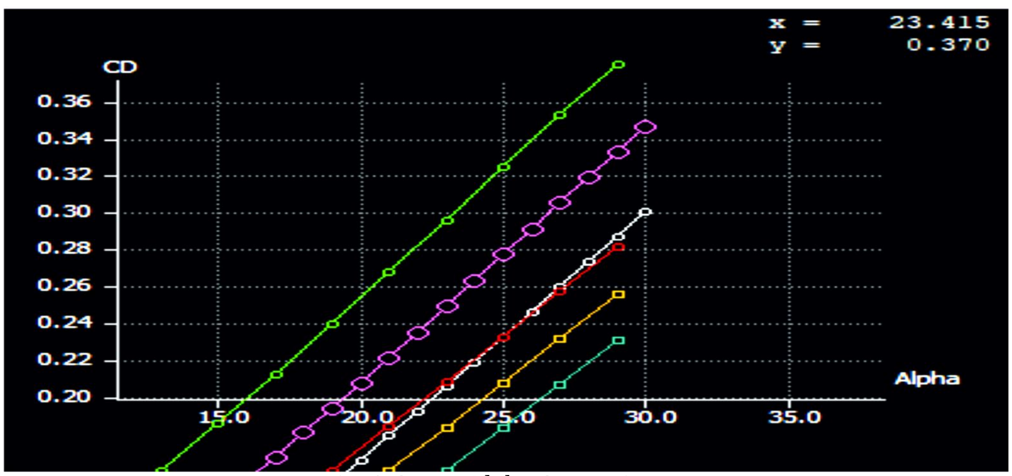


Fig. 9 CD vs Alpha Comparison

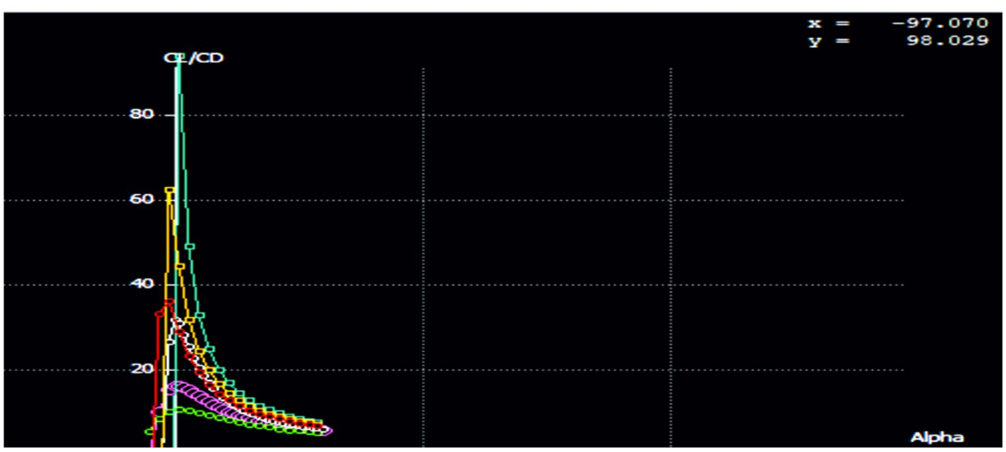


Fig. 10 CL/CD vs Alpha

TABLE II

Serial No.	Comparison of twist and flap configuration			
	Wing	Cd (Max)	Cl (max)	CL/CD (MAX)
1	0012	1.669	0.23	Infinity as CD min =0
2	0012 2° Twist	1.7	0.231	94
3	0012 6° Twist	1.75	0.256	65
4	0012 10° Twist	1.82	0.28	36
5	0012 10° Flaps	1.7	0.3	31.5
6	0012 20° Flaps	1.85	0.346	16
7	0012 30° Flaps	1.86	0.38	10.2

IV. CONCLUSIONS

It can be clearly noted that with increase in degree of twist there is increase in Cl values. From increasing twist 2° to 10° there is a significant increase in CL values: 1.7 to 1.82. Also, there is increase in CD: .23 to .28. There is a significant decrease in aerodynamic efficiency as well (due to increase in CD). From 94 to 36. The most important factor is that the aerodynamic efficiency curve (CL/CD) flattens with increase in twist which depicts increase in stability. While the flap configuration is considered there is a significant increase in CL values but at the same time CD values and aerodynamic efficiency show a decline. Twist configuration of 10° has an aerodynamic efficiency of 31.5 while the flap configuration of 30° has an efficiency of 10.5. The CL values in both cases are nearly same (CL 10° twist = 1.82; CL flap 30° = 1.86). In order to get a CL increment of .04, it's not at all desirable to drop the aerodynamic efficiency by a great amount (CL/CD twist 10° = 36; CL/CD flap 30° = 10.2). Hence it can be genuinely concluded that twist configuration is better than flap configuration. Reduced weight plus better aerodynamic efficiency proves its worth.

REFERENCES

[1] Kang, W.R., Kim, E.H., Jeong, M.S., Lee, I. and Ahn, S.M., 2012. Morphing wing mechanism using an SMA wire actuator. International Journal of Aeronautical and Space Sciences, 13(1), pp.58-63.

[2] Cheung, K., Cellucci, D., Copplestone, G., Cramer, N., Fusco, J., Jenett, B., Kim, J., Langford, A., Mazhari, A., Trinh, G. and Clinkaberry, T., 2017. Development of Mission Adaptive Digital Composite Aerostructure Technologies (MADCAT). In 17th AIAA. Aviation Technology, Integration, and Operations Conference (p. 4273).

[3] Jenett, B., Calisch, S., Cellucci, D., Cramer, N., Gershenfeld, N., Swei, S. and Cheung, K.C., 2017. Digital morphing wing: active wing shaping concept using composite lattice-based cellular structures. Soft robotics, 4(1), pp.33-48.

[4] Cramer, N., Croom, M., Cheung, K., Jenett, B., Swei, S. and Fremaux, M., 2016. Design and Testing of a Cellular Composite Active Twist Wing.

[5] Di Luca, M., Mintchev, S., Heitz, G., Noca, F. and Floreano, D., 2017. Bioinspired morphing wings for extended flight envelope and roll control of small drones. Interface focus, 7(1), p.20160092.

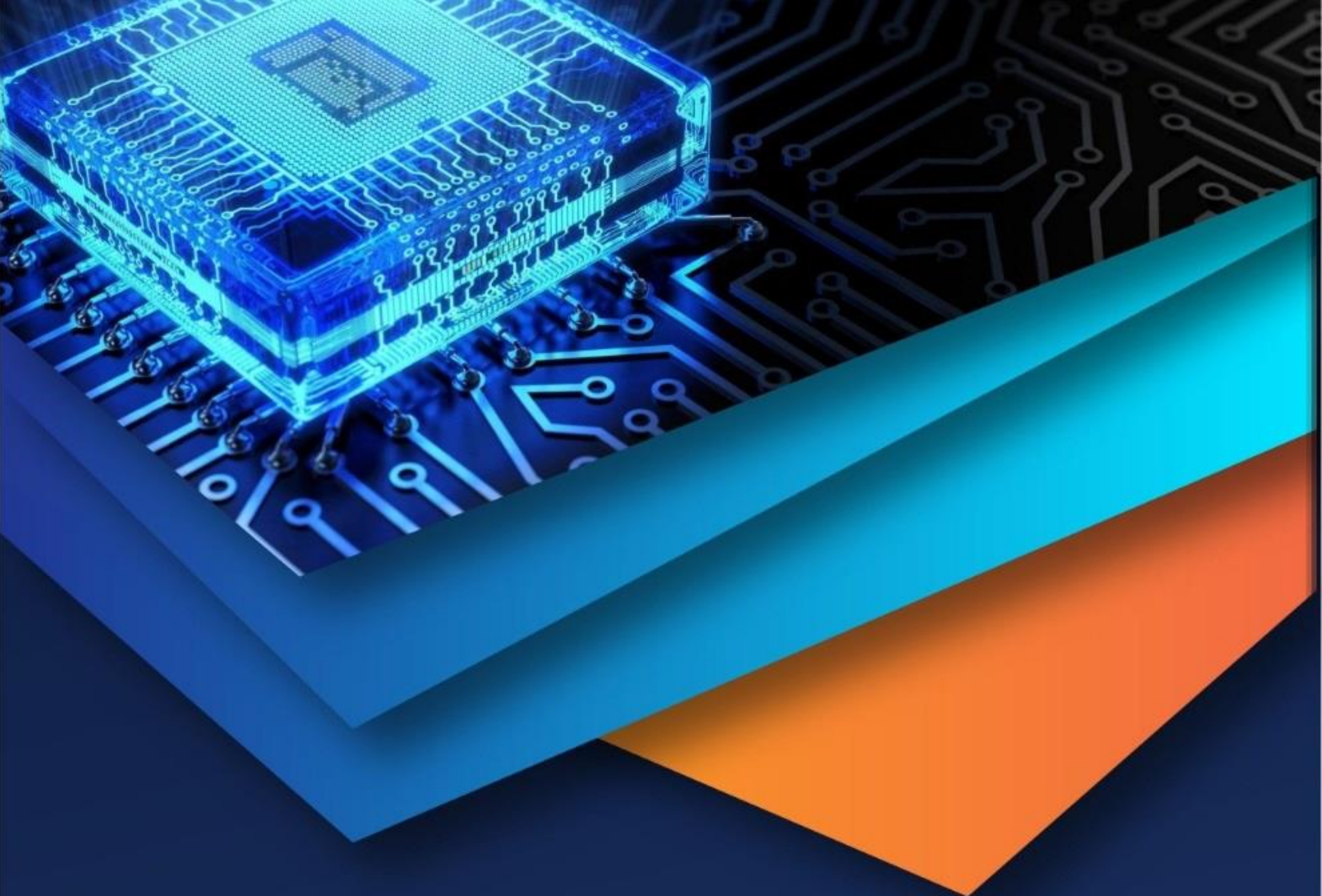
[6] Communier, D., Salinas, M.F., Carranza Moyao, O. and Botez, R.M., 2015. Aero structural modeling of a wing using CATIA V5 and XFLR5 software and experimental validation using the Price-Païdoussis wing tunnel. In AIAA atmospheric flight mechanics conference (p. 2558).

[7] Precup, N., Mor, M. and Livne, E., 2015. The design, construction, and tests of a concept aeroelastic wind tunnel model of a high-lift variable camber continuous trailing edge flap (HL-VCCTEF) wing configuration. In 56th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (p. 1406).

[8] Alsaidi, B., Akbar, M., La, S., Joe, W.Y., You, H., Kim, S. and Yun, G., 2018. Modeling and Stress Analysis of Composite Skin Structure for Camber Morphing Wing. In 2018 Multidisciplinary Analysis and Optimization Conference (p. 2934).

[9] Nguyen, N.T., Livne, E., Precup, N., Urnes, J.M., Nelson, C., Ting, E. and Lebofsky, S., 2014. Experimental investigation of a flexible wing with a variable camber continuous trailing edge flap design. In 32nd AIAA Applied Aerodynamics Conference (p. 2441).

[10] Ramrakhyani, D.S., Lesieutre, G.A., Frecker, M. and Bharti, S., 2005. Aircraft structural morphing using tendon actuated compliant cellular trusses. Journal of aircraft, 42 (pp.16141620).



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY