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Analysis on the Aerodynamic Efficiency of Modified Blended Wingtip

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Abstract: ***As aircrafts fly, a lot of lift needed to ensure maximum thrust can be generated. However, as lift increase, induced drag also will increase. One of the problems due to drag usually happen at the wingtip. Vortices will be formed at the wingtip and create pressure above the wing. Therefore, reduce lift. In order to overcome this problem, various wingtip shapes are being applied at the wingtip. The purpose of this analysis is to analyse the aerodynamic efficiency of modified blended wingtip. This analysis consists of blended wingtip and modification of the wingtip itself based on different speed and angle of attack. From this analysis, the lift and drag ratio from the coefficient of lift and drag obtained for the blended wingtip and all the design will be compared and therefore, analyse the efficiency of the applied modification. The analysis involving wing of NACA 4415 with four different types of wingtip; the original blended wingtip, modification 1 with 15° plane added, modification 2 with 30° plane added and modification 3 with 45° plane added, four different speed and so do four different angle of attack (AOA). All of these designs will be analysed by using Computational Fluid Dynamic (CFD) software. From the analysis, the efficiency can be determined by comparing the lift and drag ratio. The result from the analysis has been proved that modification of blended wingtip with 45° plane added has the highest lift and drag coefficient that is 2.16 X 10^{-1} at highest angle of attack at 30 m/s compared to blended wingtip and design modification of blended wingtip with 15° and 30° added plane.***

I. BACKGROUND

This research is a continuation from past researches[1-17] that have been completed in UniKL MIAT regarding improving aviation engineering technology significantly. Hopefully, this research will succeed and the design modification on blended wingtip can be proved in order to assist in wingtip efficiency. With this, it can reduce the vortices at the tip of the wing and helps improve the lift produced while reducing the induced drag. The analysis is explained thoroughly by using Solidworks and XFlow. This was adopted as the best approach to gather the results need for this analysis. From this methodology, the objectives of this analysis can be achieved.

II. METHODS

The aircraft design itself plays an important role to ensure the aerodynamic of the design to produce the maximum thrust and minimum drag. The performance of an aircraft is determine based on the lift and drag ratio. In another word, the higher the lift and drag ratio, the better the performance of the aircraft. Better aircraft performances will save the fuel consumption and lead to a higher rate of productivity. There are a lot of key factors that related to an aircraft performance. One way to increase the efficiency of the aircraft is by reducing the amount of vortex produced at the tip of the wing. In order to reduce the amount of production of vortex, a barrier at the tip of the wing is being added. This barrier is called aircraft wingtip. Various shapes of wingtips were designed to increase the aircraft efficiency. Nowadays, the common wingtip that are being use by the majority of all the aircraft are blended wingtip. However, to get higher lift and drag ratio, the analysis on the design modification of blended wingtip are being done. For this modification, a small plane was added at the end of the wing. The main purpose of this plane is to reduce the vortices created at the tip of the wing of an aircraft when flying. Parameters that were used to test the blended wingtip and its design modification are speed and angle of attack. The value of the speed and angle of attack being used are as follows:

Table. 1 Parameter

Speed (m/s)	15, 20, 25, 30
Angle of Attack (°)	0, 5, 10, 15

Because of this analysis is a test to analyse the new design modification of blended wingtip, a random range of speed and angle of attack are being used. Three modification of blended wingtip has been created and the added plane at the tip of the blended wingtip will having an angle of 15°, 30° and 45°.

Table. 2 Type of Design Modification

Type of Modification	Added Plane at The Tip of Blended Wingtip
Modification 1	15°
Modification 2	30°
Modification 3	45°

There will be two parts of analysis throughout the process. The first analysis being done is between all of the

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three design modifications of blended wingtip. The second analysis is being done between the blended wingtip itself and the modification of blended wingtip with 45° angle added plane. The analysis is categorized as follows:

Table. 3 Categories of Analysis

Part I	Modification 1 vs Modification 2 vs Modification 3
Part II	Blended wingtip vs Modification 3

All of the speed used are categorized as follows:

Table. 4 Categories of Speed

Speed 1	15 m/s
Speed 2	20 m/s
Speed 3	25 m/s
Speed 4	30 m/s

III. RESULTS

From the XFlow calculation, lift and drag ratio on each of wingtip modification shapes has been obtained. From the lift and drag ratio, the most efficient wingtip shapes will be determined. Lift and drag ratio calculated by using Excel are collected as follows:

Part I - Speed 1

Table. 5 Coefficient of Lift, Coefficient of Drag and Lift & Drag Ratio between Modification 1, Modification 2 and Modification 3 (Speed 1)

Type of Wingtip	Angle of Attack	Coefficient of Lift	Coefficient of Drag	Lift and Drag Ratio (Cl/Cd)
Modification 1	0	3.23 X 10^{-1}	3.22	1.00 X 10^{-1}
	5	6.66 X 10^{-1}	9.84	6.77 X 10^{-2}
	10	1.06	9.89	1.07 X 10^{-1}
	15	1.84	1.02 X 10^{1}	1.80 X 10^{-1}
Modification 2	0	4.61 X 10^{-1}	4.03	1.14 X 10^{-1}
	5	6.62 X 10^{-1}	7.18	9.22 X 10^{-2}
	10	1.33	8.99	1.48 X 10^{-1}
	15	1.82	9.33	1.95 X 10^{-1}
Modification 3	0	9.96 X 10^{-1}	6.90	1.44 X 10^{-1}
	5	1.15	9.38	1.23 X 10^{-1}
	10	1.77	9.53	1.86 X 10^{-1}
	15	2.51	11.59	2.17 X 10^{-1}

Part 2 - Speed 2

Blended wingtip with a design modification of 45° added plane has the highest lift and drag ratio compared to the other two modification.

At 0° angle of attack, the lift and drag ratio of design modification of 15° added plane has a value of 1.00 X 10^{-1} while for the 30° added plane modification, it has a value of 1.14 X 10^{-1}. For the third modification, it has the highest reading of 1.44 X 10^{-1}.

There is a slight decrease at 5° angle of attack for all of the design modifications but as the angle of attack keep increasing up to 15°, the lift and drag ratio shows an increment.

At the highest angle of attack of 15°, the value of lift and drag ratio for the first modification is 1.80 X 10^{-1} and 1.95 X 10^{-1} for the second modification. As for the third design modification, it scores a value of 2.17 X 10^{-1}, the highest lift and drag ratio at the speed of 15 m/s.

Speed 2

Table. 6 Coefficient of Lift, Coefficient of Drag and Lift & Drag Ratio between Modification 1, Modification 2 and Modification 3 (Speed 2)

Type of Wingtip	Angle of Attack	Coefficient of Lift	Coefficient of Drag	Lift and Drag Ratio (Cl/Cd)
Modification 1	0	4.84 X 10^{-1}	4.27	1.13 X 10^{-1}
	5	7.67 X 10^{-1}	9.94	7.72 X 10^{-2}
	10	1.55	1.04 X 10^{1}	1.49 X 10^{-1}
	15	1.89	1.08 X 10^{1}	1.75 X 10^{-1}
Modification 2	0	5.54 X 10^{-1}	4.22	1.31 X 10^{-1}
	5	6.67 X 10^{-1}	7.14	9.34 X 10^{-2}
	10	1.42	9.11	1.56 X 10^{-1}
	15	1.92	9.34	2.06 X 10^{-1}
Modification 3	0	1.00	6.86	1.46 X 10^{-1}
	5	1.14	9.39	1.21 X 10^{-1}
	10	1.81	9.54	1.90 X 10^{-1}
	15	2.51	1.16 X 10^{1}	2.16 X 10^{-1}

Based on the above graph, blended wingtip with a design modification of 45° added plane has the highest lift and drag ratio compared to the other two modifications.

At 0° angle of attack, the lift and drag ratio of design modification of 15° added plane has a value of 1.13 X 10^{-1} while for the 30° added plane modification, it has a value of 1.31 X 10^{-1}. For the third modification, it has the highest reading of 1.46 X 10^{-1}. There is a slight decrease at 5° angle of attack for all of the design modifications but as the angle of attack keep increasing up to 15°, the lift and drag ratio shows an increment.

At the highest angle of attack of 15°, the value of lift and drag ratio for the first modification is 1.75 X 10^{-1} and 2.06 X 10^{-1} for the second modification. As for the third design modification, it scores a value of 2.16 X 10^{-1}, the highest lift and drag ratio at the speed of 20 m/s.

Part 3 - Speed 3

Table. 8 Coefficient of Lift, Coefficient of Drag and Lift & Drag Ratio between Modification 1, Modification 2 and Modification 3 (Speed 3)

Type of Wingtip	Angle of Attack	Coefficient of Lift	Coefficient of Drag	Lift and Drag Ratio (Cl/Cd)
Modification 1	0	4.13 X 10^{-1}	4.12	1.00 X 10^{-1}
	5	6.66 X 10^{-1}	9.84	6.77 X 10^{-2}
	10	1.07	1.00 X 10^{1}	1.07 X 10^{-1}
	15	1.86	1.02 X 10^{1}	1.83 X 10^{-1}
Modification 2	0	4.58 X 10^{-1}	4.03	1.14 X 10^{-1}
	5	6.65 X 10^{-1}	7.10	9.36 X 10^{-2}
	10	1.53	1.05 X 10^{1}	1.45 X 10^{-1}
	15	2.27	1.18 X 10^{1}	1.92 X 10^{-1}
Modification 3	0	1.01	6.84	1.47 X 10^{-1}
	5	1.12	9.40	1.19 X 10^{-1}
	10	1.85	9.55	1.94 X 10^{-1}
	15	2.51	11.62	2.16 X 10^{-1}

IV. CONCLUSIONS

Wingtip added can reduce vortex produce at the tip of the aircraft wing. Thus, it will increase the aircraft performance by reducing induced drag due to the production of vortices. Varies wingtip shapes are designed and different wingtip shapes will have a different performance.

A wing, together with blended wingtip and another 3 modifications are designed and tested, in order to choose which, the most efficient design modification is. Efficiency of the wingtip shapes are determined by calculating the lift and drag ratio tested by using XFlow software.

By comparing lift and drag ratio of all four types of wingtip shapes tested, modification 3 has the highest lift and drag ratio up to 2.16 X 10^{-1} at highest angle of attack at 30 m/s. Lift and drag ratio will determine the efficiency of wingtip shapes.

Therefore, blended wingtip with the design modification of 45° added plane is the most efficient wingtip shapes. This can be proved as modification of blended wingtip with 45° added plane has the highest lift and drag coefficient at all speed during the test. For further study on this topic, several recommendations be made for improvement. Some recommendations made are as follow:

- Ensure that the design drawing for the wing and wingtip shapes is smooth in order to increase the lift and reduce drag. From this analysis, the value of coefficient of drag is higher compared to lift. The main significant causes are because of the blended wingtip and other three design modifications are not so smooth.
- Add more variation of wingtip design in order to choose which is more efficient. In other word, there are a lot of wingtip shapes available and not all wingtip shape available being used throughout this project analysis.
- Add the experimental analysis by using wind tunnel test. Fabricate the design and test it inside the wind tunnel. Then, compare it with the result from CFD instead of only rely on the result from a simulation software only.
- Applying this modification to a prototype aircraft and compute the analysis for a flight test for a better result.

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