Abstract

In supersonic flight regime, shock waves generation on aircraft wing is an important factor, and a suitable airfoil design must be considered to minimize the wave drag caused by the formation of these shock waves. Therefore, the supersonic double wedge airfoil performs quite excellent in the supersonic speed regime. But it would lead to poor performance at subsonic speed regime due to sharp edges stall. For this purpose, a theoretical and experimental study was undertaken to improve the performance characteristics of the supersonic double wedge airfoil at low speed by using passive-active flow controlling methods. The proposed passive method was a shape modification through changing the sharp leading edge and mid-section upper and lower apex to smooth curved control segment which activated during the subsonic flight regime. The airfoil returns to its standard shape at supersonic speed by using a certain mechanism, and the blowing technique was used as an active method. ANSYS FLUENT 14.5 CFD package was used to simulate the flow around the standard and modified airfoils. Experiments in low speed wind tunnel of maximum velocity ($31.1\, m/s$) and for Reynolds number ($R_e = 3.287 \times 10^5$) based on airfoil chord length tests were also conducted in order to measure the pressures and velocities chordal-wise. Four airfoil models were fabricated to accomplish these wind tunnel tests; standard airfoil, modified apex airfoil, modified apex-nose airfoil and modified apex-nose airfoil with blowing with maximum thickness of (10%) chord length, semi wedge angle of (5.71°) and a span length of (300 mm). Four values of jet to free stream velocity ratio of (1.5, 2, 2.5 and 3).

Optimization was used to find the optimum velocity, angle, size and location of jet to obtain the optimum lift with minimum boundary layer separation on the upper surface of the airfoil.

The results had proven that the proposed flow controlling methods had improved the performance of the double wedge airfoil at low speed. The best results were obtained from the modified apex-nose airfoil with blowing at jet to free stream velocity ratio equal to (3). From the theoretical results for standard double wedge airfoil at supersonic speed, (C_l) has a linear relation with angle of attack and increases with the increase of angle of attack. Which means that the performance of supersonic double wedge airfoil is excellent at supersonic speed. At low speed, the standard double wedge airfoil has a good performance at low angle of attack (0° to 10°). The modified apex airfoil led to increase the ($C_{l\,max}$) by (12.7%) in comparison with standard airfoil at angle of attack of (12°). The apex modification has no effect on the stall angle of attack. The modified apex-nose airfoil led to a significant increase in the amount of lift which increased from (0.86) to (1.059), i.e., about (23.14%) in comparison with standard airfoil. But, the angle of maximum lift remained constant.

The best results were obtained from the modified apex-nose airfoil with blowing. The ($C_{l\,max}$) increased from (0.86) to (1.15) about (33.72%) in comparison with the standard airfoil. The maximum lift angle also increased from (12°) to (18°), which means that the earlier stall is eliminated. The experimental results coincide well with the theoretical results.