Abstract for READ/EWADE 2020

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Understanding the Aircraft Mass Growth and Reduction Factor

Background: The aircraft mass growth factor is fundamental to aircraft preliminary design. Due to the fact that mass during some aircraft design phases seems rather to increase than to decrease compared to initial estimates, the factor is called mass growth factor. However, a mass reduction factor is mathematically the same. The mass reduction factor can lead to even *substantial* mass reduction and is as such the secret to efficient aircraft design. For simplicity and tradition we may just talk about mass growth. It is usually defined as the ratio of an increase in the total mass (take-off mass) due to an arbitrary increase in local mass (empty mass) determined after a full iteration in aircraft design to achieve the original performance requirements (payload and range). The aircraft design iteration sees after each loop another increment in the take-off mass, so that an initial (local) mass increase aggravates the situation like a snow ball transforming into an avalanche. Hence the pseudonym snowball factor. The concept of the mass growth factor is probably as old as aviation. It has been discussed heavily from the 1950th to the 1970th and has continued to be mentioned until today. Nevertheless, it seems not to be well enough understood today. Maybe its importance has declined due to modern computing power providing quite accurate mass estimates in each design phase, but detaching the engineer from the feel for the numbers.

Purpose: The paper shows a literature survey, clearly defines the mass growth factor, shows a mass growth iteration, and derives an equation for a direct calculation of the factor (without iteration). Definite values of the factor seem to be missing in literature. To change this, mass growth factors have been calculated for as many of the prominent passenger aircraft as to cover 90% of the passenger aircraft flying today. The concept of avalanche-like mass reduction is explained, the "value of a pound" and the relation to Direct Operating Costs (DOC), and airline profit is pointed out.

Methodology: Calculations start from first principles. Publically available data is used to calculate a list of mass growth factors for many passenger aircraft, followed by resulting financial implications.

Findings: The mass growth factor is larger for aircraft with larger operating empty mass ratio, larger specific fuel consumption (SFC), and smaller glide ratio. The mass growth factor increases much with increasing range. The mass growth factor for subsonic passenger aircraft is on average 4.2, for narrow body aircraft 3.9 and for wide body aircraft (that tend to fly longer distance) 4.9. In contrast supersonic passenger aircraft show a factor of about 14. With a factor of only 3.1 the ATR 72 sticks out for its good performance among those aircraft sold in larger numbers.

Research limitations: The applied methodology assumes a change in the ratio of empty mass to take-off mass only to that extend as mass increases locally. This is a first order approach. E.g. wing load reduction due to additional mass, leading to smaller component mass is not considered.
Practical implications: The mass growth factor has been revisited in order to fully embrace the concept of mass growth and may lead to a better general understanding of aircraft design.