# Increasing the Accuracy of Estimation of Aircraft Basic Characteristics at Earlier Design Stages

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In the first part of the report the results of testing of three different methods for estimation of aircraft basic characteristics [1-3], further referenced as Eger method, Torenbeek method and Raymer method, are discussed.

The research was conducted according to the following plan:

1. All three methods were transformed to algorithmical form [1].
2. Tu-154, Tu-204 and Il-96 aircraft were selected as design objects.
3. External shape and characteristics of aircrafts – payload, range, take off run, landing speed and etc. were considered as initial data for estimation of specific wing loading, thrust-to-weight ratio and takeoff gross weight for each of the aircraft according to three methods (i.e. 9 projects in total).
4. The results of the redesign of the aircraft were compared with their real characteristics.
5. A new combined method was proposed, which allows to increase the accuracy of estimation for transport aircraft.

The main attention in the present research was paid to the estimation of the aircraft takeoff gross weight. High accuracy of the estimation of wing mass fraction according to weight equations [3] was noticed, while the significant disagreement in the estimation of some components of the takeoff gross weight, especially equipment, should be mentioned.

It is asserted that the high-accuracy mathematical modeling should be utilized at the earlier stages of design process, especially when unconventional external shapes are used. Statistical weight equations can't provide high accuracy in such cases in principal.

In the second part of the report a new approach to the estimation of absolute masses and mass fractions of aircraft structures is discussed. It was developed in SSAU during a long period of time and was widely used both in academical and commercial research.

The idea of this approach is the following:

1. A new criterion is introduced – load factor G, which takes in account both for internal forces in the structure and for length of their action. For frames

$$G = \sum_i |N_i| l_i \, , \qquad (1)$$

where i – rod number, $N_i$ and $l_i$ – rod force and rod length.

For thin-wall structure

$$G = \sum_i R_i S_i \, , \qquad (2)$$

where $R_i$ – equivalent forces flow in 2-D element, $S_i$ – element area.

2. Mass of the structure $m_s$ is estimated as

$$m_s = \varphi G / \bar{\sigma} \, , \qquad (3)$$

where $\bar{\sigma}$ - structural material strength-to-weight ratio, $\varphi$ - full mass coefficient, which is calculated using (3) from retrospective analysis of already available aircraft and accounts for mass of additional elements (fittings and etc.), requirements of constant element thickness and etc.

In (3) $\varphi$ expresses the perfection of detailed design of the structure, G is defined by external loads, external shapes of the aircraft and location of its structural elements, $\bar{\sigma}$ expresses of strength and density of structural material.

Load factor G can be easily found using finite element method (FEM) for the aircraft of arbitrary external shape.

In the report the application of the above-stated approach to the development of the theoretical basis for weight analysis of aircraft structures is demonstrated. This approach allows to obtain a rigorous mathematical proof for the “square-and-cube law”, relationship between wing mass and specific wing load and for some other fundamental relationships.

The practical application of the proposed approach is illustrated by estimation of wing mass for the “ECOLIFTER” project, mass estimation for the aircraft with integral fuselage, wing-in-ground-effect craft and some others.

## References

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3. Raymer, D., Aircraft Design: A Conceptual Approach. AIAA education series. USA, 1992, 745 p.