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RECREATION AND EVALUATION OF THE AGING AIRCRAFT STRUCTURE FOR THE NEED OF LIFE-TIME EXTENSION

INTRODUCTION

In this paper a method of generation a virtual model (3D-model) of an aircraft, basing only on the real aircraft structure (without the sufficient technical documentation), is shown. The first step is a precise co-axial measurement of the real aircraft structure. On this base, the models of the aircraft: Su-22 and MiG-29 were created using the UNIGRAPHICS CAD/CAM/CAE system [1, 4]. Then, the models mentioned above were utilised to design special models for the wind tunnel investigations and numerical calculations. In this way the sets of aerodynamic, and strength characteristics as well as free vibrations were obtained. In order to determine the co-ordinates *x, y, z* of the real object the following procedure was implemented:

- The aircraft was set on the jack-lift elevators according to the flight line (Fig.1), then the local grid should be set (Fig.2);
- All the linear and radial quantities were measured;
- The levelling of all the measured points was done;

Fig.1. Aircraft Su-22 set up to determine the co-ordinates x, y, z

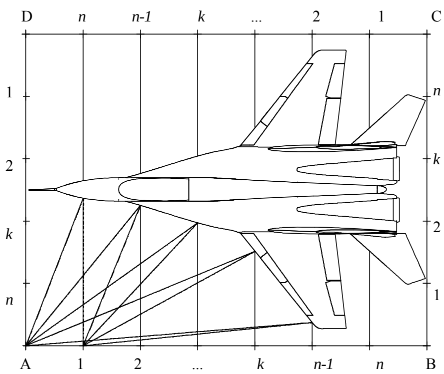

Fig.2. Local grid for high precision measurements of the co-ordinates x, y, z

The measurement procedure:

- The instrument was set consecutively at all the points of the local grid, and the angles and distances were measured (Fig.2);
- The “heights” of the considered points were determined using precise levelling method.

The set of aircraft co-ordinates: *x, y, z,* was calculated on the base of the above determined quantities.

NUMERICAL RECREATION OF AIRFRAME

Quality of the geometry recreation of the existing objects depends on: a method of the precise co-axial measurement, quality of the measuring instruments as well as CAD system used for a virtual aircraft creation aircraft.
The number of measurements, even 1000 points and more at a surface in various cross-sections of aircraft (see Fig.3) doesn’t have any impact on the recreation quality. What is more, it can be a reason of the “rippling” phenomenon of the curves, during the creation of the virtual aircraft, what it means that the measurements were done with unsatisfactory precision. In this case, the process of surface smoothening must be implemented .Technical aircraft documentation (drawings, sketches, etc.) if such exists, is a considerable convenience during recreation, mainly for verification. The wing geometry was created on the base of measurement of thirteen wing cross sections [1].

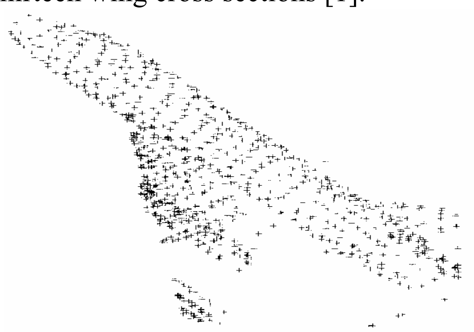

Fig.3. Grid points after determining of the co-ordinates x, y, z:, Su-22 aircraftt

Such a process of recreation of the aircraft structure is very complex and time consuming. In the case of the large structures we have to comply with the natural aircraft composition: wing, fuselage, tail unit, undercarriage. Following the procedure, component modules must be put together into complete unit, which is defined at the very beginning of the work (Fig.4).

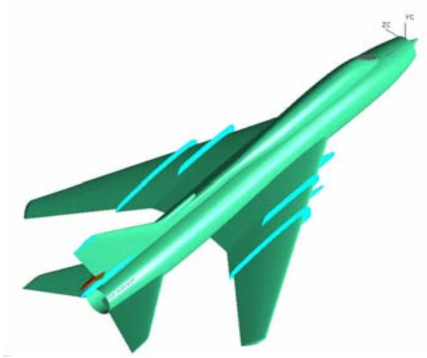

Fig.4. Virtual model of the Su-22 aircraft

To obtain a numerical model of the aircraft with a much complex aerodynamic layout, e.g. the MiG-29 aircraft (Fig.5) additional data are required; concerning the curves representing the geometry of aircraft components, such as: a strake-wing, etc. In this case the process of model generation must be preceded by selection of the aircraft elements, for which the additional precise measurements must be done.

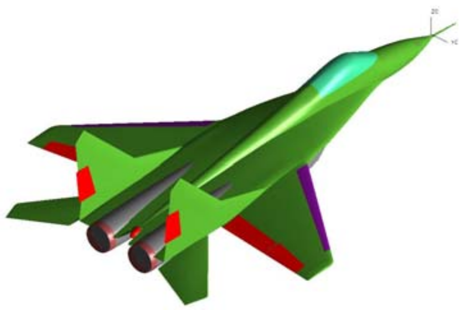

Fig.5. Virtual model of the MiG-29 aircraft

INVESTIGATIONS AND NUMERICAL CALCULATIONS OF THE SU-22 AERODYNAMIC CHARACTERISTIC

Using a CAD/CAM system a model of the Su-22 aircraft (variable geometry wing aircraft) was designed and built. The wind tunnel investigations were carried out for the model of the clean configuration aircraft without the aerodynamic fences on the wing and the armament pylons as well as for the aircraft with high lift devices and various deflections of the stabiliser. The investigations were conducted in a small velocity wind tunnel (D = 1.1 m diameter of the measuring chamber).

Fig.6. Aircraft model with the sweep angle χ_{sk} = 30° in the wind tunnel

Wing tunnel investigations as well as calculations were made for two models with the sweep angles: χ_{sk} = 30° and χ_{sk} = 63°, respectively. For the clean configuration (without external pylons) and with high-lift devices in the neutral position and retracted undercarriage investigation were carried out in scope of the angles of attack from α =-60° to α = 60° with the step 2,5°. In addition, the influence of the horizontal stabiliser, (in scope of its angles of deflection from δ_H= - 26,5° toδ_H = 10°), flaps and ailerons on aerodynamic characteristics was investigated. Moreover, the models with ailerons and stabiliser in the neutral position referring to the real aircraft (δ_ι= 6°, δ_H = - 5°), for the range α = -10° to 50° and the step 2,5°, were investigated.

AIRCRAFT EXTERNAL LOAD EVALUATION

This work must be started with determination of the aircraft service conditions. Due to the lack of the aircraft design requirements in the former Soviet Union for recreation of the external load acting upon the Su-22 aircraft, the American regulations for equivalent class of aircraft were employed.

According to [5], the velocities, which were taken for the determination of the external load acting upon an aircraft, should be related to the ultimate loads. The full spectrum of the aircraft loads required analysis of all the possible aircraft configurations, so it was time-consuming task. It was impossible to recreate all the data, but after the evaluation of the flight restriction imposed by Russian designers, it was possible to determine a critical point for Ma = 0.9 and χ =63° the sweep angle of the wing, and permissible load factor n = 7, m=14000 kg.

A manoeuvring load factor was reduced for the other aircraft configurations. So, in this case as the essential point of the curve, the following point was selected: Ma = 0.9, χ = 63°, n = 7.0, and calculations of the pressure distribution on the wing were performed with the method of the vortex grid [2, 3,].
The load growth is a result of: the backward travel of the aerodynamic centre and a considerable increase in the pitching moment. So for balance of the aircraft there is a purpose for a huge amount of the force on the horizontal stabiliser acting downward [5].
In this case an increase of the lift force on the wing must appear. Basing on the available data it can be concluded that the maximal value of the pitching moment factor (without the stabiliser and χ = 63°, x_{cg} = 38% MAC) should not exceed C_{mbu} = -0.13 (C_{mbu} = -0.188 from calculations).

STRESS ANALYSIS

The elements and nodes (FEM) for the Su-22 numerical model (see Fig.7). For the purposes of the stress analysis in the Su-22 structure the following numerical models were produced:

- Computational models of the main aircraft components for the preliminary evaluation of the aircraft as a whole;
- Verified models for more advanced research.

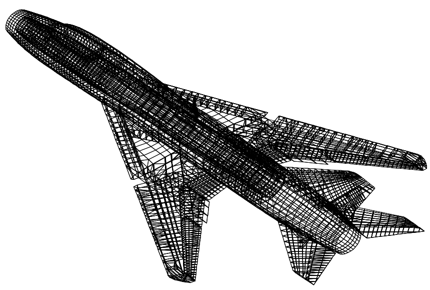

Fig.7 Model for calculations of the Su-22 aircraft

To minimise the computational time the UNIGRAPHICS processor was selected for the Finite Element Method (FEM) package NASTRAN. The grid of the nodes of the surfaces of the main aircraft components was set at points of the intersections of the theoretical lines of stingers, ribs, bulkheads and spars. The airframe skin was formed of the membrane and plate elements, frame bulkheads of beam elements, whereas the stringers of bar elements. The computations were conducted for the following flight parameters: m=14000kg, χ = 63°, Ma = 0.9, *n* = 7 and presented in Figs. 8 to 11. Fig.10 and 11 present the results for the wing spare. The maximum displacement 0.75 mm appears at the end of the wing spare, whereas the higher stress level is 472 N/mm^2 around the lower attach lug (see Fig.11).

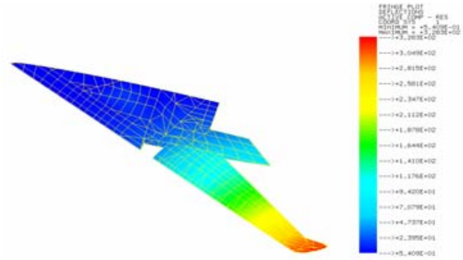

Fig.8. Wing displacements of the Su-22 aircraft

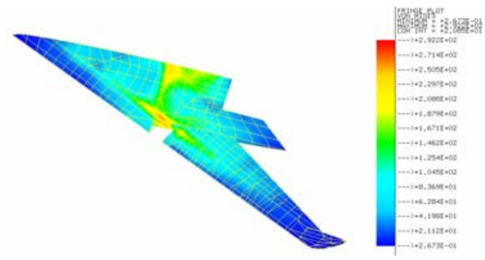

Fig.9. Von Mises stresses of the wing skin for Su-22 aircraft

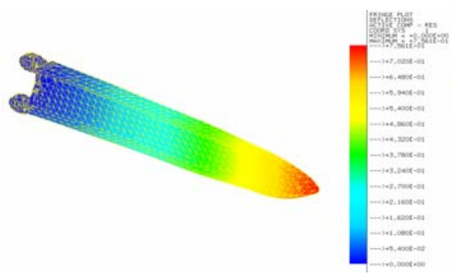

Fig.10. Wing spar displacements of the Su-22 aircraft

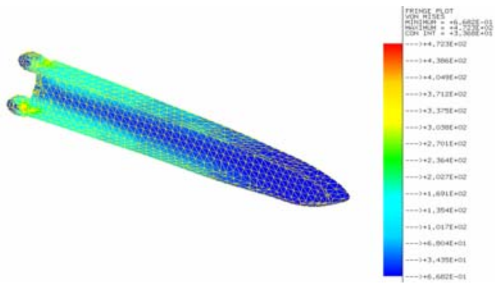

Fig.11. Von Mises stresses of the outer area of wing spar for Su-22 aircraft

6. ANALYSIS OF FREE VIBRATION

The analysis of the frequencies and modes was conducted for the Su-22 model (see Fig.7) with 65000 degrees of freedom, similar to the static evaluations. Fig.12 and 14 show the first modes of the free vibrations. Furthermore, the influence of the structure damage was detected.

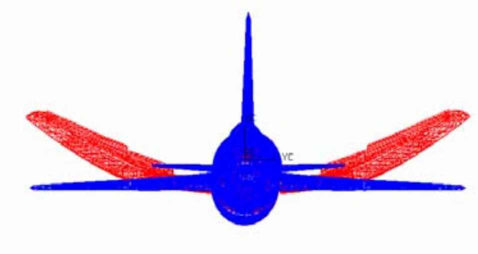

Fig.12. First symmetrical mode of the self-vibrations Su-22 aircraft, ω_1 = 8,517 Hz

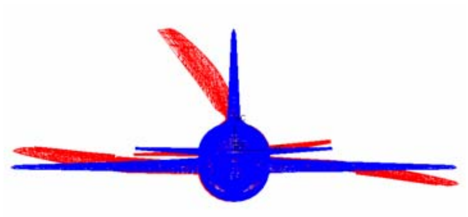

Fig.13. Second antisymmetrical mode of the self-vibrations Su-22 aircraft, ω_2 = 11,04 Hz

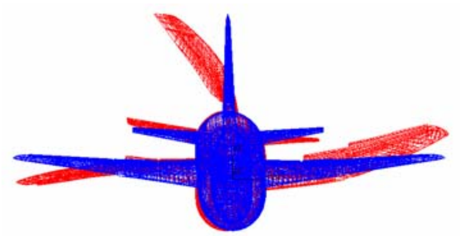

Fig.14. Third antisymmetrical mode of the self-vibrations Su-22 aircraft, ω_3 = 12,79 Hz

CONCLUSING REMARKS

Using the CAD/CAE systems the algorithm of the numerical recreation of the existing objects was presented. In this case the UNIGRAPHICS system and its processor for the FEM NASTRAN was selected.

Methodology was presented for the assessment and evaluation of the technical state of the ageing fleet of the rotary and fixed wing aircraft in service of the PAF. As a sample the Su-22 was selected. The process of the recreation was difficult due to the lack of comprehensive technical and overhaul documentation as well.

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