GENERATION OF SU-27 FIGHTER.

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Abstract

The history of design and development of Sukhoi Su-27 fighter family including more than 10 modifications is presented.

1 Introduction. Prehistory.

Prehistory of this paper had started from the beginning of 70th.

During some decades after Second World War only two countries - USA and former USSR were and continue to be real competitors in development of fighters. In Europe only France had active position in development and production of fighters (Mirage family). However, comparison between Mirage-family and 4th generations of US and Russian fighters: has evident result: superiority belongs F-15, F-16, F-18, Su-fighters generation (from Su-27 up to Su-37) and MiG-29.

Three decades ago Great Britain, Germany, Italy decided to joint its efforts in development of military crafts, but with contradictory requirements to aircraft. As a result of their joint efforts "Tornado" had been developed and produced (no comments about this plane).

During last years Germany, Great Britain, France, Italy, Spain elaborated "Eurofighter" with an aerodynamic scheme resembling "Mirage" with small canard. It is typical representative of 4th generation of fighters with modern airborne systems and equipment.

An original way of design of fighters had been selected by Sweden many years ago. The known aircraft "Viggen", canard, was very impressive, but potential possibilities of its aerodynamic scheme had not realized completely because of one reason: mechanical control system. The outstanding project of superlight fighter of Swedish designers had realized in "Grippen" program: modern aerodynamic scheme, fly by wire control system and other achievements had placed this aircraft in the row of outstanding fighters of the world.

As to USA and former Soviet Union in their history of design of fighters during last 50 years, there were some outstanding achievements and mistakes. For example, historical lessons have been received from aircrafts with variable sweep wing (F-111, and MiG-23) and others: F-104, F-4E, F-117, and Russian T-58D2. However, at the same time two countries had some unique aircraft: F-5E, MiG-25 and others.

At the beginning of 70th on the base of experience of local wars USA started to develop the new generation of fighters and multipurpose crafts such as F-15, F-16 and F-18 with new approaches, using in projects:

- New aerodynamic scheme, a little bit resembling MiG-25, for achievement of new level of manoeuverability with $\alpha \geq 25°$, $C_L \geq 1{,}35$ (previous generation of fighters had $\alpha < 20°$, $C_L < 1.0$);
- Fly-by-wire control system;
- New generation of avionics.

At that time Russian Ministry of Defense gave out the official order to design new generation of fighters with better characteristics in comparison with mentioned above USA projects, but with lag about 3-4 years.

Sukhoi Aircraft Design Bureau (Su-ADB) together with other aviation enterprises and

aviation research centers (Central Aero-Hydrodynamic Institute TsAGI and Sibirian Aviation Research Institute SibNIA) had developed new aerodynamic scheme (so called "integral scheme") with optimal longitudinal unstability 3%...5% of mean aerodynamic chord (at subsonic speeds) and fly-by-wire flight control system for future heavy fighters. The project was called T-10.

Su-ADB, step by step, developed the project and as the result of extensive work and closed cooperation of Sukhoi, research centers and many aviation enterprises the maiden flight of Su-27 prototype T-10-1 have been in May 1977, Fig. 1.

At first stage of aircraft design:

Some problems of stability have been solved. For example, there was guarantee the stability of "aircraft+FBW" closed loop system under great disturbances (so called "stability in large") with simultaneous minimization of hydraulic systems power. As we know, this problem has led to flight accidents with YF-22 and "Grippen". This problem was solved at the design stage with less tail deflection rate in comparison with two mentioned planes.

Very effective (from pilots opinion) limitation of normal load factor n_z and angle of attack α was realized for usual exploitation. However, we did not avoid an accident with PIO because of methodological mistake during flight tests and crash (destruction) of craft for the same reason.

Very soon, we understood, that our prospects and expectations had confirmed by flight tests; moreover, concrete data surpass our expectation. Aircraft achieved angles of attacks (in maneuver) more then 25° and C_L>1,6. After some improvements in aerodynamics of Su-family fighters the lift coefficient C_L~2,0 have been achieved in stable turn.

Therefore, we received in 1977-1978 the confirmation that the task of creation of fighter succeeding in maneuverability the fighter-competitor F-15 has been solved.

2 High maneuverability, theory and practice.

Approximately in the middle of 70th in Su-ADB and Russian research centers there were carrying out wind tunnel investigations of aerodynamics of fighter with thrust vectoring and impressive data were received and we relied for the achievement of C_L~2,5 with using thrust vectoring and increasing of aircraft negative stability margin.

But what about angles of attacks? What angles of attack after 30° will be useful for fighters, especially in closed combat?

2.1 Simulation of combat at high angles of attack.

In 1980 research teams in Su-ADB and TsAGI have started to investigate the closed combat of two fighters; one of them had possibility to realize maneuvers with achievement of α~60°, or so-called supermaneuverability. The results of simulations were very impressive [1]. These results were obtained before the well-known publication of Herbst [2] but the publication was impossible because of secrecy reasons.

These data convinced us to continue our investigations and the second topic of our researches was the investigation of fighter aerodynamics at high angles of attack and development of its mathematical model.

2.2 Fighter aerodynamics at aigh angles of attack

In order to realize supermaneuverability in flight and before training of pilots, it needs to have mathematical model of aerodynamics at high angles of attack and solve the problem of stall and spin (these regimes have to be excluded). During many years joint Su-ADB and TsAGI team investigated the aerodynamic peculiarities at high angle of attack and elaborated the mathematical model of aerodynamics with description of some effects [1][3][4]:

- Nonsymmetrical flow including nonsymmetrical breakdown of vortexes at high angles of attack, and nonsymmetrical yaw and roll moments as a result;

- Dynamic lag, static and dynamics hysteresis in lift, pitch, yaw, roll moment, side force at high angle of attack.

On the base of systematical wind tunnel investigations, flight tests in Su-ADB and Flight Research Institute (LII), the mathematical model was developed with using additional differential equations for parameters, which determine the scale of phenomena: local on profile, wing, or global, including whole plane from nose up to tail.

On the base of this investigations more detailed studying of stall and spin, requirements to effectiveness of aerodynamics and thrust-vectoring control, requirements to pitch control of airplane and requirements to characteristics of inlets and nozzles were fulfilled.

At that time, Su-ADB continued the flight tests of first copies of Su-27 fighter and discovered the possibility to fulfill maneuver with achievement angles of attack more then 60°.

Joint efforts of specialists and pilots from Sukhoi ADB, FBW control system deliver MNPK "Avionika" and TsAGI provided the modification of control system and methodology of flight tests. Intensive training of pilots was carrying out using TsAGI moving-based simulator. It has opened the "door" for in flight realization of maneuver, later called "Pugachev Cobra", Fig. 2.

3 Sukhoi Su-27 family of fighters

Role of personality in history is tremendous, not only in politics but in technology, science and engineering too.

Pavel O. Sukhoi, the first General Designer of Sukhoi ADB, was initiator of Su-27 project. After him, E.A. Ivanov made outstanding contribution in design of this plane and its modifications.

Totally, Su-ADB elaborated more than 10 modifications of Su-27 fighter, see Fig. 1. All modifications of this plane turn to only two goals: to increase the superiority of Su-fighter in comparison with leading fighters of the world (take off and landing to airfield without firm coating, expansion of the set of weapon, new airborne avionics and FBW control system, new materials etc.) and to extend the sphere of application (closed combat and interception individually and in group, ground attack, reconnaissance, medium range bomber, navy aviation with take off and landing to aircraft carrier).

In this paper only basic modification of Su-27 of plane will be mentioned, see Fig. 1:

- Su-27S/SK basic single seat configuration (typical role is interception) with neutral and small negative margin of longitudinal stability, maximal Mach number up to 2.3 and airspeed up to 1350 km/h. On this plane pilot Victor Pugachev realized maneuver "Cobra" with angle of attack up to 110°;
- Su-30MK – two seats multirole fighter, aerodynamicaly is identical to Su-27, with new airborne avionics and wide air-to-ground attack possibilities, Fig. 3;
- Su-30MKI – two seats multirole fighter with small canard and unstable aerodynamic configuration (up to 8…12% of longitudinal unstability is permissible), with three axes thrust vectoring, Fig. 4. On this aircraft C_L~2.0 is achieved and angle of attack limitation is absent.
- Su-34/32MF – two seats middle range bomber with maneuverability typical to fighter, with original scheme of pilots disposition similar to one at civil crafts (side by side), with flat and sharp-pointed nose, Fig. 5,6;
- Su-33K – single seat navy fighter, unstable aerodynamic configuration with small canard, Fig. 7;
- Su-35/37 – single seat modification of Su-30MK, multirole fighter with three axes thrust vectoring, Fig. 8.

After the demonstration of Pugachev Cobra in 1988 Su-ADB have continued the

efforts in improvement of maneuverability. For Su-30MKI (with three axes thrust vectoring) and experimental modification Su-37 (without thrust vectoring) Su-ADB realized longitudinal turn on 360° and yaw turn on 180° in some seconds by using of thrust-vectoring and aerodynamic control. It is not aerobatics, it is very effective maneuver in closed combat, to ground attack and so on.

Nine World Records were established on Sukhoi planes: four records on experimental P-42 aircraft (a modification of Su-27) and five records on Su-32FN aircraft (earlier modification of Su-32MF).

Now Su-ADB is a real leader of aviation industry of Russia. Under the leadership of Su-ADB together with aviation plants in Komsomolsk-on-Amur (KnAAPO), Irkutsk (IAPO) and Novosibirsk (NAPO) the manufacturing and modernization of Su-family multirole fighters is continuing and simultaneously Su-ADB is preparing to design the next 5th generation of fighter.

Conclusion

In spite of economical difficulties in Russia, Sukhoi DB Corporation demonstrates active position in development of Su-family fighters and does it very successfully together with aviation plants in Komsomolsk-on-Amur, Irkutsk and Novosibirsk.

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Fig. 2 Cobra maneuver at Su-33K.

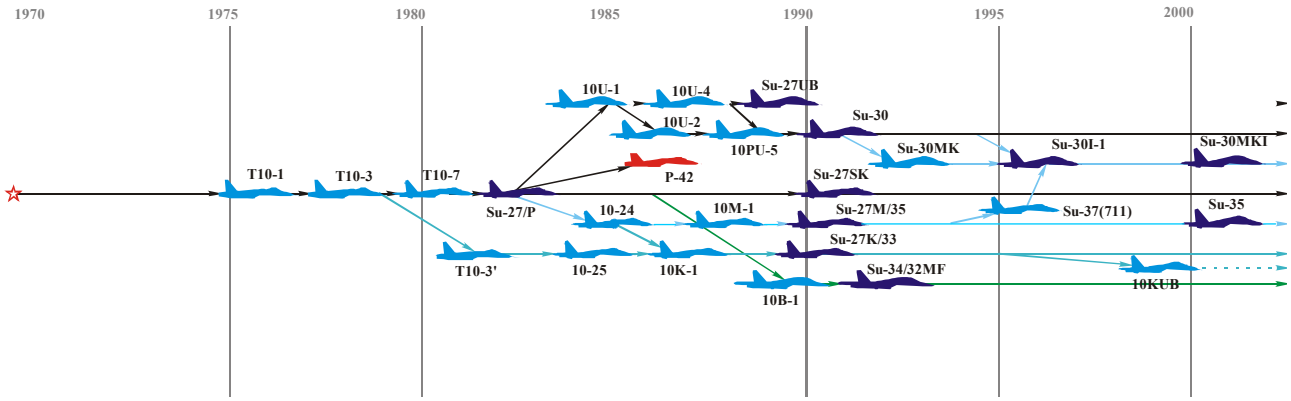

Fig. 1. The genealogical tree of Su-27 family.

Fig. 3 Su-30MK at high angle of attack.

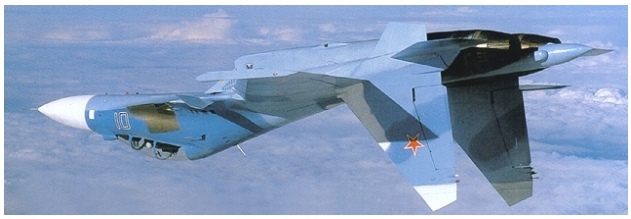

Fig. 4 Su-30MKI (top) and its deflecting nozzles.

Fig. 5 Su-32 middle range bomber with veapons in flight.

Fig. 6 Sharp-pointed nose of Su-32.

Fig. 7 Navy fighter Su-33K.

Fig. 8 Su-37(711) in flight and its deflecting nozzles.