

THE CONTRIBUTION OF DIFFERENT COUNTRIES TO AIRPLANE DEVELOPMENT AND MANUFACTURE – PART II. HOW MANY AIRPLANES WERE THERE?

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Abstract

How many airplanes were made during 20th century in the world? What were contributions of great aviation countries? Were airplanes used for the war or peace?

What materials and aerodynamic schemes were used? And when the aviation turned from the cutting-edge to just consumer technology? That's what this report is about.

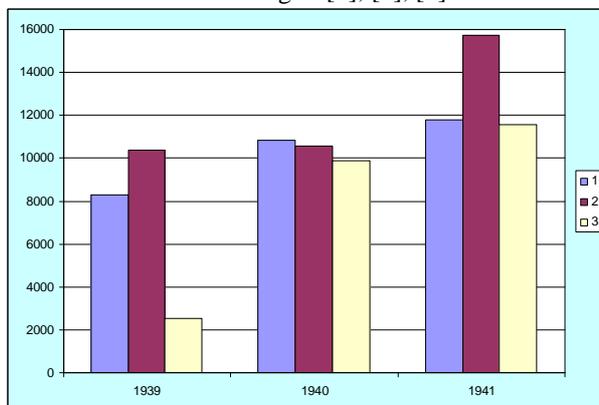
How to count airplanes?

Is there any problem? Yes.

How many airplanes were built in the world? There are a lot of figures in hundreds books, but they differs drastically.

Just one question: how many aircraft were produced in Germany in 1939 -1941? Three authoritative authors [1], [2], [3] give us very different numbers (see Fig.1).

Fig.1. Aircraft production in Germany during 1939-1941 according to [1], [2], [3]



The problem is that the method of calculations is not always evident. In my opinion the main difference between data of

[1] – [3] is not because of mistakes, but because of different methods of counting. Unfortunately it's too rare case when authors describe their calculation methods in details.

And reader should be vigilant. For example, in the great book [4] 301 Breese Penguins are counted as airplanes. But it is just ground trainers absolutely unable to fly.

Sometimes it is difficult to divide, for example, airplanes and sailplanes. In many USA books transport and trainer gliders used by USAF are added to the airplanes. For example, 253 TG-5 gliders often added to the total production of Aeronca airplanes.

And how will we count?

I've decided not to use total figures of others but to collect a data about ALL world's airplanes independently, including technical data, purpose and production year-by-year.

The preferences of this method are evident. You may get a lot of aggregated reports concerning any countries, periods, type of aircraft.

If to add (and I did) quantitative data about masses, sizes, speed, power and so on and a qualitative data about aerodynamic scheme and construction details, you may also measure and airplane evolution in any period and in any country numerically.

The lack of this approach is also evident. It is very, very, VERY time consuming. But... I've spent about 15 years and finally counted almost all airplanes.

There are about 16000 airplane modifications in my database. Only flying, powered, manned vehicles heavier than air with the lift created by fixed wings were counted.

More than 8000 bibliographic sources were used, including data from Russian archives. Only unclassified sources were applied.

Also there are data about more than 14000 events, 6000 persons, 4000 aviation engines and many more.

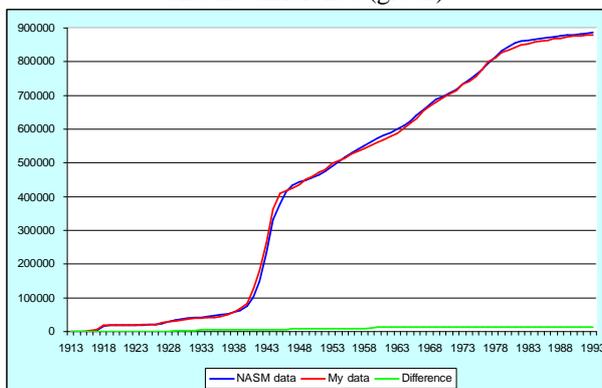
Is it accurate?

I've made a lot of checks are my calculation accurate or not. Of course, I compare a list of aircrafts with other known lists: 'Jane's all the world's aircraft' yearbooks, Boris Shavrov's books, online sources [5], [6] and others. Here is just one example: the comparison of my data with the NASM data concerning the cumulative production of airplanes in USA (Fig.2). The difference is within 1.5 %.

According to my estimates more than 96% airplanes now are counted in the database.

Data collection will be continued and I hope to present even more accurate results in nearest future.

Fig.2. Cumulative production of airplanes in USA from 1913 till 1993 according NASM data (blue), my data (red) and the difference (green)



Very few results will be presented in my report. But I'm sure they will be interesting and, may be, intriguing.

2 How many airplanes were built in the world in 20th century?

The answer is: about 2.1 million exemplars. Now let us look on this figure in details. Some data were first published by author in [7].

2.1 The contribution of different countries

Aircraft industry is very, very centralized. Only six countries manufactured more than 90% of airplanes: USA, USSR/Russia, UK, France, Germany and Japan.

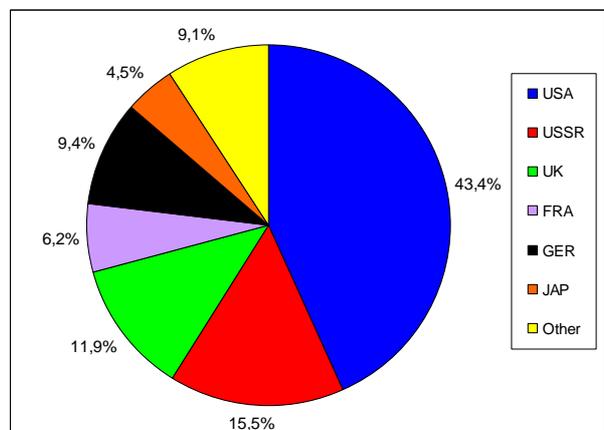
All others produced only about 9%. And there are such well known aviation countries like Brazil, Canada, China, Czech, Italy, Netherland, Poland, Sweden – and just 9%!

The greatest among other great aviation powers is USA. It's really flying country: 4/9 of all airplanes in the world were built there.

The total production in 20 century is (thousands of airplanes):

USA	907
USSR, Russia	325
UK	248
Germany	196
France	129
Japan	94
Other	190

Fig.3. Airplane production by countries in 20th century. Here and later USSR means USSR or Russia.



So the first summary is:

- only 6 countries contributed more than 90% of aircraft production;
- the greatest aviation power is USA – about 4/9 of total production.
- the second place belongs to USSR + Russia.

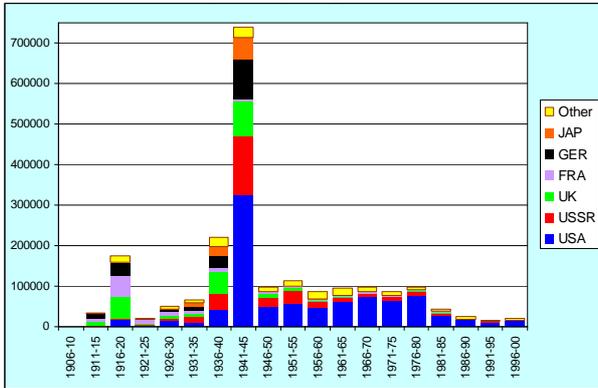
2.2 Year by year airplane production in different countries

It's sad, but the main motivation to develop and to build airplanes were wars, primarily two World Wars. In 1941-1945 740 thousands

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aircraft were built. It's more than 35% of the century production and 7 times more an average value. 8.5% more were produced during 1916-20 years (Fig.4).

Fig.4. Airplane production by countries in 20th century by five-year periods

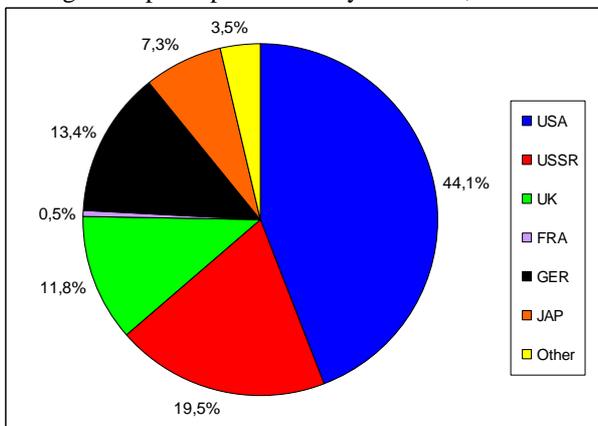


One may see the pike of the First World War and the huge reduction in the beginning of 1920th. Than the number of airplanes grows up quickly up to the World War 2.

During 1941-1945 USA produced 325.5 thousands of aircraft – it is equal to the total issue in USSR, UK and Germany together.

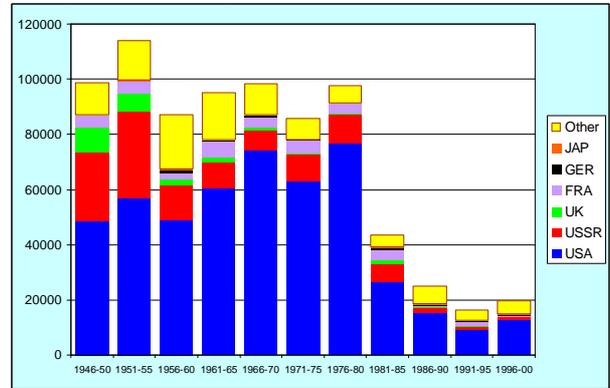
The distribution of manufacturing by countries during the war (Fig.5) is similar to Fig.3, but fractions of USSR, Germany and Japan are bigger. It shows the great stress to the economics of mentioned countries. French 0.5% are the airplanes built under German supervision and few exemplars constructed after the liberation.

Fig.5. Airplane production by countries, 1941-45



After the World War 2 aircraft production has stabilized on the level of 40000 per year up to the beginning of the 1980th.

Fig.6. Same as Fig.4 but from 1946 for better view.

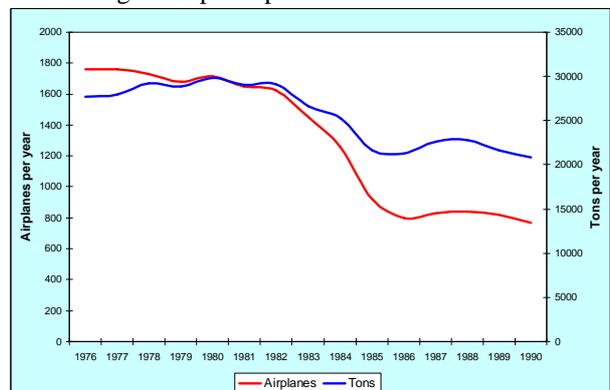


But in the 1980th the next reduction has happened. There were several reasons: the oil prices, the new law restrictions for private flying, the decreasing of combat aircraft number, the increasing of helicopter production (we speak only about airplanes – not about all aircraft)...

We just state that in 80th there was a big reduction, and only about 40000 airplanes were built in 1990th – the usual annual production for 1960-1970th.

This decrease in output has affected all aviation countries: USA, USSR and Europe. For example, let us see Fig.7 – airplane production in USSR from 1976 to 1990.

Fig.7. Airplane production in late USSR



The reduction in USSR has happened not because of 'Perestroika' but earlier, in Andropov and Chernenko's (Soviet leaders) times, in 1982 – 1985 years. Contrary to popular belief in Gorbachev's times (1986 – 1990) the

annual production was roughly on the one level. The reduction was described by author in [8].

One may say that the reduction was because of production switch to more modern and more complicated airplanes.

But in the Fig.7 there is not only quantity of produced airplanes is shown but also their total net mass: I suppose that labor content, consumption of materials and total cost is approximately proportional to the mass of airplane construction. And yes, the database permits us to build such graphs also.

You may see that both the quantity and total mass of airplanes has been reduced.

Summary:

- 35% of 20th century airplane production were done in 1941-45, 8,5% more – in 1916-20 because of the World Wars.
- The pace of aircraft production in 1950-1970 was stable: about 40000 aircraft per year. Some small grow was in the time of Korean war (1950-1953).
- In 1980th the airplane production has dropped in all countries. The reason should be studied additionally. The reduction in USSR took place earlier than ‘Perestroika’ begins.

2.3 Changing leaders

Now let us make a simple procedure: normalize a Fig.4 to the unity. So we’ll see not the total number but fractions of each country in airplane production.

In the beginning of the century France was the undisputed leader.

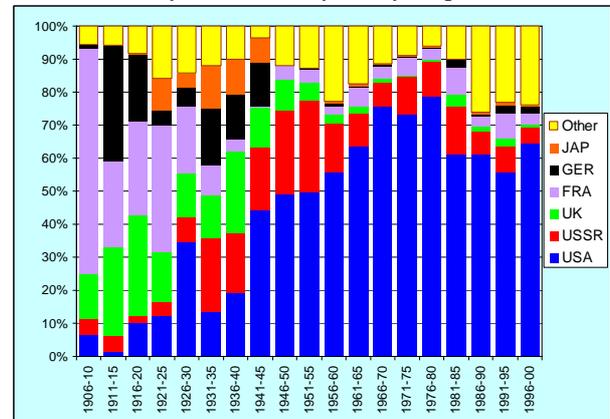
During the World War II other powers arise and the battle in the sky erupted between three main players: France, Germany and UK. The role of other participants (Austro-Hungary, Italy, Japan, Russia, USA) was not very sufficient.

In 1920th- 1930th two countries grow their national aircraft industry rapidly. It were USSR and Japan. But after the war Japan aircraft industry was destroyed and only after the long outage tries to return to the market.

The finest Hour for the Soviet aircraft industry was first decade after the World War 2.

During this time huge series of Mig-15/17, Il-28, Tu-16 and other combat aircraft were built.

Fig.8. Airplane production by different countries in 20th century (fractions) by five-year periods



But after that the ultimate success came to the USA. In 1970th about $\frac{3}{4}$ of all airplanes in the world were created in this country.

After it new players became more important: Brazil, Canada, China and others. In 21th century their shares continue to grow.

International projects including Airbus and EADS on Fig.4 and 8 belong to “others” so in fact the share of the old European aircraft countries is slightly more.

Summary

- 1900th – France is the first great airplane manufacturer;
- 1910th – World War 1, three countries: France, Germany and UK fight for skies;
- 1920-30th – the sunrise of USSR and Japan aircraft industry;
- 1940th – the huge power of USA is mobilized;
- 1950th – the peak of Soviet aircraft production;
- 1960th – decreasing production of combat airplanes in USSR and UK;
- 1970th – the amazing achievement of USA – $\frac{3}{4}$ of the world production;
- 1980th and later – new players has come. The USA role decreases both in absolute value and in fraction.

The contribution of different countries to airplane development and manufacture – Part II. How many airplanes were there?

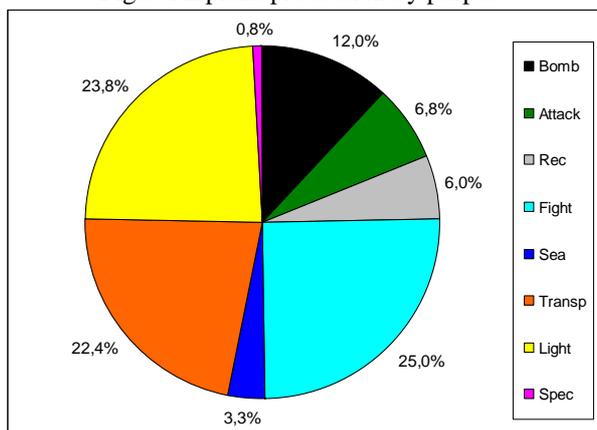
3 The purpose of airplanes

3.1 Beat swords into plowshares

What purposes airplanes were built to? Let divide all of them into eight categories:

- bombers,
- attackers (including dive bombers, fighter-bombers and trainers/ground attack),
- reconnaissance (including universal aircraft of World War 1 and of 1920th-1930th years like Breguet 19, Potez 25 and Polikarpov R-5),
- fighters,
- sea aircraft (including maritime patrol, sea and rescue, anti-submarine and so on),
- transport (commercial, military transport and general purpose aircraft),
- light (1-2 place aircraft, primary training aircraft) and
- special aircraft (all others: glider tugs, sanitary, agriculture, fire fighters, experimental, flying targets like RP-63G and so on).

Fig.9. Airplane production by purpose



On Fig.9 we see that although the aircraft industry grows quickly during wars, almost half of airplanes are civil or, at least, transport and trainers.

The strongest need is to protect against threats from skies: the most produced type of airplanes in 20th century are fighters, totally about 515 thousands of them were

manufactured (fighter-bombers are counted separately under 'attack' division).

Light aircraft and primary trainers together took second place: about 490 thousands.

Now let see how the destination of airplanes changed by the time (Fig.10, 11)

Fig.10. Airplane production by purpose, five-years periods

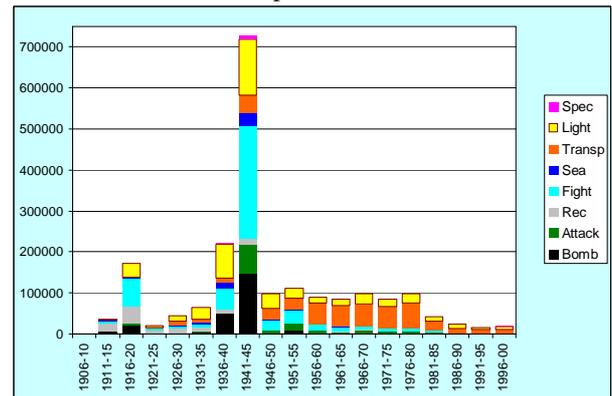
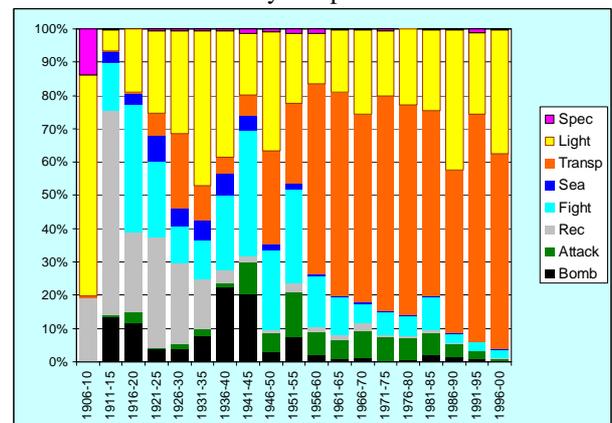


Fig.11. Fraction of different purpose airplane production, five-years periods



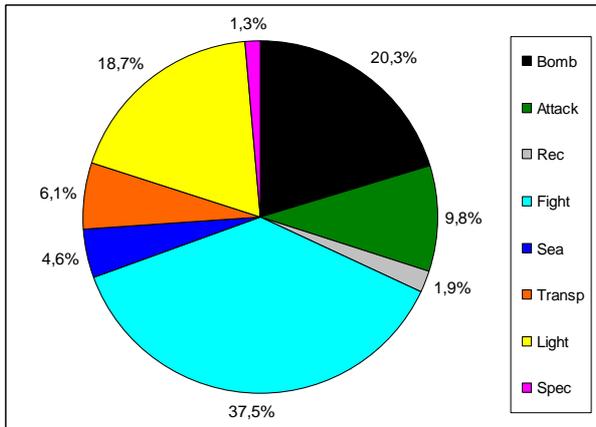
Up to the 1935 the main type of combat aircraft was an armed reconnaissance. The production of bombers was especially sufficient during World Wars.

The fraction of special sea aircrafts decreases constantly from 1920th till our days.

In the first half of 1930th almost 50% of airplanes were the light one. That's because of two different reasons: the boom of private flights in USA (despite the Great depression) and the boom of training of future military pilots in Europe.

In the second half of 1930th aircraft industry worldwide turned to war.

Fig.12. Airplanes production, 1941-1945. Light aircraft are mostly military primary trainers. The biggest groups are fighters and bombers.

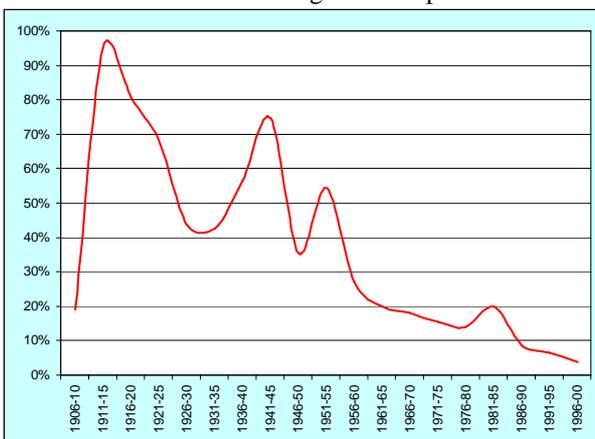


After the World War 2 more and more civil aircraft were built. Only Korean war leads to the opposite process: the fraction of combat aircraft in production was the same as in five-years before the World War 2. But, fortunately, the Korean war remained the local conflict and even during longer Vietnam war a fraction of civil airplanes exceeds 80%!

In Reagan and Andropov times the share of combat airplanes slightly grows back up to 20%, but in 1990th pacification continues.

Fig.13. Fractions of military airplanes in total airplane production worldwide. All transport and primary trainers are count as 'civil', but the trend is evident: let the peace will be in the sky.

Peaks of militarization corresponds to the both world war, Korean war and Reagan-Andropov clash.



So although the aviation remains the horrible weapon, airplanes in total becomes more and more peaceful. And it's right: let's make commerce and fun, not war!

3.2 Old and new worlds before World War 2

The database allows more in-depth analysis. Here is just one example: let us see what kinds or airplanes were produced in before-the-war five-year (1936-40) by main aviation countries. In Fig.14, 15 in contradiction with Fig.9-12 bombers and ground attack aircraft united in one category 'Attack'. 'Commerce' category includes general aviation.

Fig.14. Airplanes production in main aviation countries, 1936-1940.

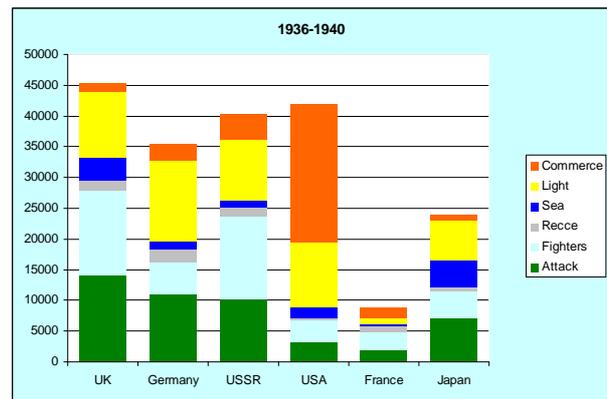
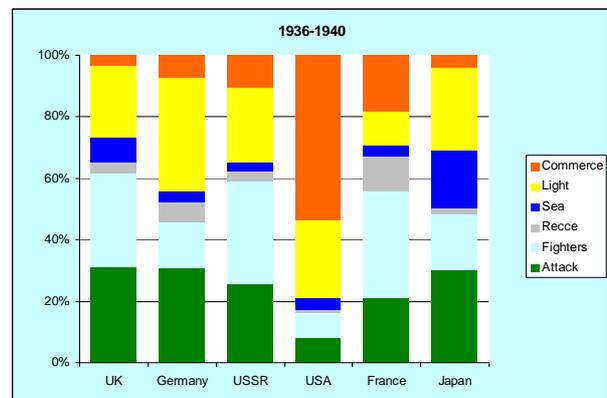


Fig.15. Airplanes production in main aviation countries, 1936-1940



This simple diagram give a lot of info to think about. We may take notice on:

- the 'defensive' strategy of future allies (UK, USA, USSR, France): the number of fighters exceeds the number of ground attack planes;
- the 'offensive' strategy of axis countries: the ratio of fighters/attackers is vice versa. Doesn't it correspond with blitzkrieg ideas?
- the sea orientation of UK and Japan
- the peaceful mood in USA. The fraction of combat airplanes is 3-3.5 times less than in the old world although the industry is powerful enough to make the great leap during the war.

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- neglect trainer airplanes in France and non-optimal resource distribution: too many commercial aircraft. Together with very small aircraft output (about 9 thousands per five years comparing with 35 thousands in Germany and 40 thousands in USA) it may partially explain the tragedy of May, 1940.

The most intriguing feature of the Fig.15, in my mind, is that profiles of future allies differ from profiles of future axis countries. The data are about 1936-1938, and it was difficult to predict at this time when the war begins and what teams will participate in. But the aircraft production shows that Germany looks like Japan and USSR is similar to France, UK and USA. It's really intriguingly.

Summary

- About 54% of all airplanes worldwide was military, another 46% – trainers, general aviation and transport aircraft.
- The share of civil airplanes grows constantly.
- The four peaks of militarization are: both World Wars, Korean war and the beginning of 1980th.
- The analysis of the aircraft production leads to interest assumptions concerning general history of 20th century.

4 The evolution of airplanes

The database includes not only airplane production figures but also data concerning aerodynamic schemes, construction materials, technical characteristics and so on.

This leads to the huge opportunities for aviation historians, but in this report I show just two examples.

4.1 From cutting-edge to consumer technology

Each technology passes several stages: from pioneer to cutting-edge, than to consumer and then to obsolete and niche one.

The cutting-edge stage means that technical characteristics are more important than

economical ones and most contemporary and advanced solutions are used.

The consumer technology oriented on “price-result” criteria and not so new but simple, cheap and reliable solutions can be claimed.

Let us look what aerodynamic schemes were used in airplanes in two biggest aviation countries: USSR/Russia and USA. Results are shown on Fig. 16, 17 (Fig.16 was calculated by author and published in [8]. Fig.17 is first published).

The descriptions are:

- TB – truss (farm) biplanes, like Farman-IV;
- FB – fuselage biplanes (usually tractor);
- RB – biplanes with retracted gears;
- BM – brace or strut monoplanes, fixed gears;
- CM – cantilever monoplanes, fixed gears;
- RM – monoplanes with retracted gears;
- SW – swept winged monoplanes;
- DW – delta winged monoplanes;
- VG – variable geometry airplanes.

Fig.16. Airplane aerodynamic schemes, USSR/Russia

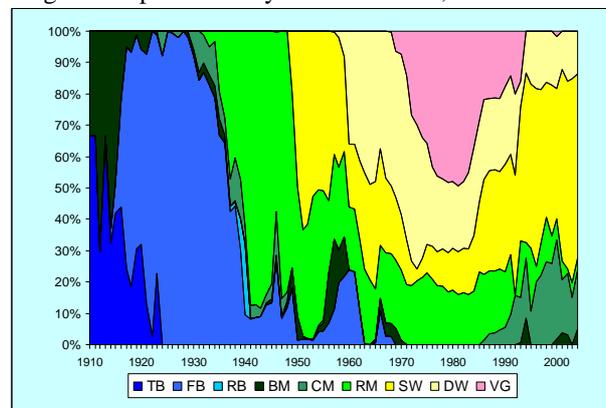
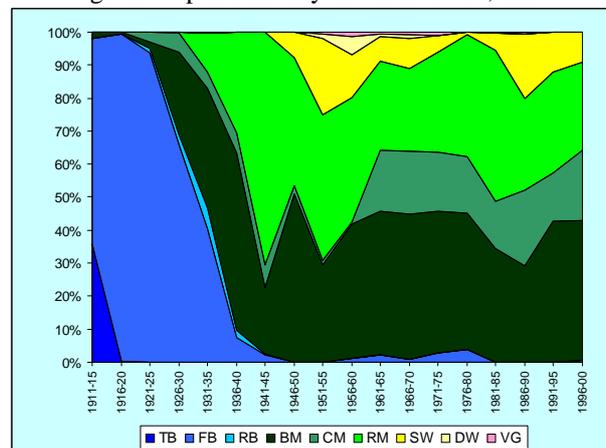


Fig.17. Airplane aerodynamic schemes, USA



Few triplanes and multiplanes are added to biplanes.

In both cases up to the some point schemes change each other from less to more progressive. But after this moment the situation becomes opposite. 'Old' schemes recapture some share from the 'modern' ones.

For USSR the technology peak in the sense of most sophisticated schemes used was reached at the end of 1970th. In USA it happened 20 years before, at the end of 1950th. The difference is because there are more private airplanes produced in the USA and they don't need swept wings and variable geometry (and often have truss wings and fixed gears).

But structures of both graphs are the same: fast technological progress is replaced by using of time-proving reliable solutions.

The cutting-edge technology has become a consumer one. It corresponds with other data: fastest aircraft (SR-71, MiG-25) were created on 1960th. The altitude record of A.V. Fedotov (37650 meters on MiG-25M) established in August,1977 is not beaten up to date.

Summary

- The quantitative studying of aircraft production gives interesting results in the philosophy of technology.
- The development paths of technology in different countries are time shifted but have a general nature.

4.2 Two worlds – two systems of airplane manufacturing

Now let us research what materials were used for aircraft frames in USSR/Russia and in USA (Fig.18 and 19).

Designations are:

T – timber;

TM – timber and metals (for example, wood wing and steel-tube fuselage frame);

Fe – steel (ferrum);

AF – aluminum and steel;

Al – aluminum;

Ti – titan or magnesium alloys are widely used;

Pl – plastics are widely used for load-bearing elements.

Fig.18. Materials used for airframes, USSR/Russia

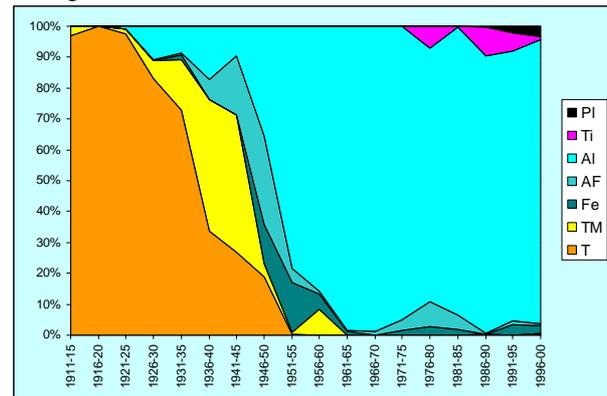
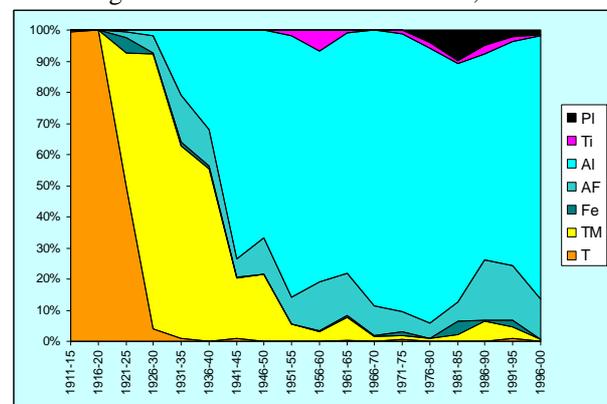


Fig.19. Materials used for airframes, USA



It's interesting to compare Fig.19 and Fig.17. The slight technological retroversion may be seen on the Fig.19 also, but the 'finest Hour time' took place not in 1950's but near 1980 year. After this an aviation industry becomes 'consumer technology' in the sense of used materials also. The technological peak in Russia was reached about 10 years later.

At the first half of century generations changes very quickly. Timber aircrafts loose it's position and were replaced by aircraft with steel-tubed fuselage. The steel-framed aircraft were short lived, and soon aluminum tubes and then profiles became to use widely. The aluminum kingdom spreads through the world and it seems that titanium and plastic masses can't shift the king from the throne.

But there is one exception. It was not easy to master an aluminum technology. In USA it required 10 years, in USSR about twenty. But if in USA only few experimental or small-scaled designs were produced, in Russia a lot of efforts and money were spent for the kolchugaluminij (Russian equivalent of

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duralumin) experiments. It took about 10% of total production.

It seems there is no sense to implant the newest technologies widely if the industrial infrastructure is not ready for this.

Summary

The history of airplane manufacturing tells as a lot non only about aviation, but about the general history, riddles of war and peace, about technology development laws.

These mysteries are opened by processing a big database with statistical methods. It's really fruitful. But very, very time consuming.

Few results of this research I just presented in this report.

Acknowledgements

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