

“Particularities and development of fly-by-wire system for light helicopters. Ansat helicopter as an example”

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In 1993 Kazan Helicopter Plant started designing a new helicopter with takeoff weight of 3.3 tons, which was called “Ansat”. While determining the helicopter configuration, it was required to choose a type of the flight control system; and initially a traditional, for that time, control system was accepted. The KAU-165 combination control hydraulic actuator assembly, which had been just developed for the Ka-226 helicopter and consisted of four single-chamber actuators, was chosen for this system. On this basis a version for Ansat helicopter was developed, this one had increased up to 450 kg rod force and separate tail rotor actuators – KAU-190 and KAU-195. According to the AP-29 aviation regulations requirements the control system must operate after any single failure in power portion. The KAU-165 design allows selecting manual control in case of pressure drop in the chamber, but heavy control forces require specifying more severe operational limitations right up to complete prohibition of operation. Therefore a decision was made to replace the single-chamber actuator by redundant double-chamber one. In Russia there was no actuator with required characteristics, so it meant new development, which would postpone the time of the helicopter production manufacturing starting and increase costs.

Approximately at the same time we were choosing a leading design bureau for development of flight and navigation system. Between candidates the Ramensky Instrument Engineering Plant, “Avionika” research and production company, “Aviapribor”, and Design bureau of Industrial Automatics (Saratov city) were under consideration. They were proposed to work over a system version based on the fly-by-wire system, but then almost all of them considered as Utopia the use of the FBW system for such light helicopter. Nevertheless the “Avionika” company mentioned in its technical proposal that there was a possibility to develop such a system for Ansat helicopter. Also this company is a leader in development of such systems in Russia, what is proved by high maneuvering characteristics of Su-27 and other aircrafts equipped with FBW system.

After long and difficult discussions in 1996 we made a decision to develop FWS and the "Avionika" company was chosen as leading designer. This decision was greatly reasoned by the fact that there had already been developed a power-by-wire hydraulic actuator for MiG-AT airplane, which was nearly good for us by its characteristics.

To save time and to check the idea it was decided to develop first three systems on the basis of the MiG-AT airplane FBW and to use components, such as stick pick-offs, angular rate sensors, power supply units, servo power amplifiers. This system has been developed.

Structurally the FBW system consists of four control channels: pitch, roll, yaw and collective-pitch. Each channel is 4-times redundant as for stick pick-offs, feedback sensors, servo power amplifiers, computers. The actuators are provided with 4-times redundant hydraulic amplifiers, feedback sensors and they are double redundant hydraulically.

The electric portion of FBW system provides roll, pitch, main rotor collective pitch and tail rotor pitch control law, which is approximation to linear law.

Initially it was planned to make cyclic pitch control stick as a side stick, as this simplifies a lot the control kinematics and it was possible to use the existing stick used for the Su-27 airplane; this stick comprises four sensors per each control channel and artificial feel unit. The design documentation was drawn up, but pilots and maintenance engineers were against this solution; as the decisive reason for using however a traditional stick was the fact that the helicopter is supposed to be used as a training one, that's why today the helicopter has usual helicopter controls.

Practically there is no actuating portion of the main rotor control system, since the actuators are installed on the main gear box and are attached directly to the swash plate in three points two along the helicopter longitudinal line and one across. The tail rotor is controlled from the actuator installed in the aft part of the tail boom. In basic configuration of the control system the hydraulic actuator will be attached directly to the tail rotor control rod and will be installed on the tail gear box.

On the 17 of August 1999 the Ansat helicopter took off for the first time and flew for 12 minutes. Doubts of many people disappeared, as the helicopter behavior was very confident and stable. Mainly, it was due to hingeless main rotor hub, which was used in Ansat helicopter for the first time in Russia, however the FBW system ensured very accurate control with minor plays, minor

insensitivity zone, and with little starting force because there is no mechanical linkage between controls and slide valve. The test-pilot of the Ansat helicopter notes high quality of control and less number of double motions in comparison with traditional helicopters. And if we take into account that with maximum takeoff weight the helicopter has rate of climb equal to 16 m/s, it is evident that today the Ansat helicopter has convenient control.

Initial tests of the Ansat helicopter were performed with angular rate sensors being off, because it was not sure that the calculations of the gear ratio of each channel are accurate, then changing the gear ratios little by little we obtained acceptable values. (картинка записи полета) The flight tests showed that at hovering flight without signals from angular rate sensors and hands-off controls the helicopter keeps its attitude for 8 seconds, and with signals supplied from the angular rate sensors it keeps the attitude for about 20 seconds. It is not bad for a helicopter without automatic flight functions.

We work together with Russian research institutes, such as Central aerodynamics institute (TsAGI), flight test institute M.M. Gromov, State scientific research institute of the civil aviation, central aircraft engine institute (CIAM), 30 central scientific research of Ministry of Defense of Russia, National institute for aircraft materials and so on, as well as with Federal Register (AR MAK). Practically everywhere when they get to know about the Ansat's FBW system, they worry about the helicopter reliability and safety: even the present day Russian and foreign helicopter airworthiness regulations do not specify any safety requirements to FBW system. While preparing First Flight Resolutions, the specialists of Gromov Flight test institute performed the reliability and fail-safe performance analysis of the helicopter systems and units. The analysis showed that the design as well as quadruple redundancy of power portion and double redundancy of hydraulic portion are enough for safe-fail performance, required by regulations and circulars. For the period of the helicopter operation on ground and in flight, which totalizes more than 200 hours, there was no one failure, related with FBW system.

Now I would like to make a digression.

Russian and foreign statistics of air crash and accidents show that about 75% of accidents are caused by human element, the most part of which is due to the crew mistakes. On our opinion, in most cases, when the investigation committee returns a verdict about wrong actions of the crew, this verdict is influenced by many non-technical reasons, such as economic interests of the country,

prestige of Designer, as well as the international level of development of aeronautical technology. The real cause is such an aircraft design defects, which result in impossibility for the pilot to act properly in emergency situations due to human physiology. For example, not long ago a collision accident was qualified as pilot or flying control officer mistake, but the use of Traffic Alert and Collision system (TCAS) excludes such a mistake. So, I am sure, that we cannot demand impossible acts from a pilot or an operator of a complicated system, but it is necessary to facilitate his work until we can make the process of the flight control completely automatic. The tragedy happened recently reconfirms the necessity in possibility of pilot's exception from a control loop in case of its errors or deliberately dangerous operations.

According to the results of the study, made by Aerospace Medicine Institute there is information, which proves that, if we consider intensity of work, conditions and work content, the helicopter pilot work is more complicated than the work of the airplane pilot. This is connected with the fact that more attention and higher training level are required to fly the helicopter. Instability of the helicopter and presence of cross-coupling effect in longitudinal and lateral motion of the helicopter demand the manipulation of all controls from the pilot. Thus to land the helicopter the pilot makes about 90 control manipulations per minute on average, this is twice more than the number of similar manipulations in airplane. The diagram shows that, for example, to recover from dive in 40% the pilot manipulate two controls simultaneously, and more than in 20% - three controls at once. At the same time due to high vibration and noise in the helicopter the capability of the pilot to detect the ground marks is reduced. All this not only intensify work, but stimulate fatigue what directly affects the flight safety, since the pilot in such a state cannot react adequately to critical situation. It appears from all this, that it is necessary to automatize much more the process of the helicopter flight control.

Having received encouraging tests results, we made a decision to develop fundamentally new digital fly-by-wire system for the 3d prototype of the Ansat helicopter, which was called integrated fly-by-wire system. In the requirements specification we specified the requirements, which should greatly simplify the pilot work and gradually, as the data of the tests will be accumulated, completely remove all the cross-coupling effects in control at all flight modes. It will allow any person to control the ANSAT helicopter without any skills of helicopter control.

Structurally the system will look similar to our initial analogue FBW system, but in fact all the hardware will be new. The most important difference is in quadruple redundant digital computer, the computation capability of which as well as interface have large margin for further development of functions. To ensure reserve for unforeseen consequences “such as Sun magnetic storm or bad weather on Mars” there is an additional quadruple redundant analogue computer similar to existing FBW system by its capabilities.

The main rotor control actuators are designed on the basis of the previous ones, but their hydraulic portion is slightly modified and they have new attachment fittings. The tail rotor actuator is new by design: first of all it is designed for less force, secondly it is divided into 2 portions. One portion is a redundant hydraulic cylinder with feedback sensors, which is installed directly on the tail gearbox; the other is hydraulic amplifiers assembly, which will be installed nearby.

The control panel, located in the cockpit, is enhanced, that is the number of the system functions is increased.

On the whole, the integrated FBW system is twice more light than the analogue one.

As I mentioned before, the integrated FBW system is an open system designed for interconnecting with other equipment and not only with flight and navigation systems. At the first stage the integrated FBW system will perform only flight functions, such as stabilization of angles, speed, absolute and pressure altitude, 20 functions in total. This configuration of the system will be certified. At the second stage, the system will be added with navigation functions such as “en-route flight to desired waypoint”, “approach” etc. This stage will require the integration with various navigation systems. This configuration is planned as option.

At the present time the Ministry of Defense of Russia carries out a tender for training helicopter and Ansat is the main contender. We proposed to consider a possibility to make a flying simulator on the basis of the Ansat helicopter. This simulator will simulate any helicopter as concerns aircraft response to controls manipulation and sensation. It is even possible to simulate co-axial helicopter with some turn rate limitations in yaw. This simulator is possible only on the helicopter equipped with FBW system. As far as we know, a similar simulator was planned to be performed on the MIG-AT and YaK-130 airplanes for Su-27 piloting training. In our case the military took the idea, because it means an

opportunity to decrease the training helicopters fleet. Of course, we understand that this task cannot be realized at the first stage.

If we look to the future, it is easy enough to develop a complete automatic flight control system on the basis of integrated FBW system and change the Ansat into drone, what tomorrow is with.

References:

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