ТРАНСПОРТ
05.22.01 – Транспортные и транспортно-технологические системы страны, ее регионов и городов, организация производства на транспорте;
05.22.08 – Управление процессами перевозок;
05.22.13 – Навигация и управление воздушным движением;
05.22.14 – Эксплуатация воздушного транспорта

UDC: 629.73.08
DOI: 10.26467/2079-0619-2021-24-1-8-15

UPSET RECOVERY TRAINING FOR CIVIL AVIATION PILOTS

V.S. DEGTYAREV[1], O.F. MASHOSHIN[1], A.V. DEGTYAREVA[1]
[1]Moscow State Technical University of Civil Aviation, Moscow, Russia

The paper is devoted to the problems of civil pilots upset recovery training. This is quite a new problem, which occurred due to the change in civil aviation pilots training programs that became possible due to the high level of modern civil aircraft automation. The upset recovery training removal negatively affected the level of flight safety both in our country and all over the world. The paper presents legal documents for flight simulations certification. Types of aircraft for civil pilots initial training used all over the world are described too. The analysis of the new types of light training aircraft that can be used as a change in the civil aviation academies was conducted. Modern upset recovery training program and its blind spots were studied in this paper in details. The problems of modern studies in upset recovery in civil aviation are the central part of this work. The paper contains information about legislative framework obsolescence, and creation of a new type of aviation simulator, that can simulate upset recovery situations concept. Current legislative framework of aviation simulators licensing is analyzed in this paper in comparison with the best international practices, regulations and recommendations. Conducted analysis showed that current certification legislative framework became obsolete and needs a revision for maintaining high standards in flight safety. Recommendations connected with the change of initial training types of aircraft in civil aviation academies are given.

Key words: initial training type of aircraft, aircraft, upset, current international practices and standards, flight safety, pilots training program, training equipment, piloting technique, civil aviation, pilots training.

INTRODUCTION

From Wright brothers up to the present time, aviation industry has become highly sophisticated, complicated and safe. Modern technologies have made operators from pilots. Nowadays aircraft are so smart and perfect, that ordinary pilot skills have become unnecessary in routine flights [1]. This situation became possible due to "fly by wire" technology, modern fly control computers and navigation equipment in "glass cockpit". This tech spread fast through the industry and made a revolution not only in the civil aviation itself, but in pilots training courses. Now upset recovery trainings are not needed. Pilots training doctrine was changed and it led to degradation in basic pilot technique skills.

As modern aircraft is protected from stall or upset by the laws of fly by wire system, new civil aviation industry says, that very expensive initial upset recovery training, on the light aircraft, now is simply unnecessary. This statement looks logically from the fist view. If a civil pilot flies the aircraft only in the flight envelope, the automatic system will give him no chance to break through restrictions neither deliberately, nor accidently. But everyday life shows us that despite all cutting-edge technology systems and protections, aircraft can sometimes be found in upset situations [2]. And if a pilot has no skills to recognize the situation and make right actions for the upset recovery, the situation always becomes a catastrophe.

ANALYSIS

One big example of wrong situation recognition and wrong pilots' actions can be an A330 crash over the Atlantic Ocean in 2009. That crash happened because of the pitot probe icing over the ocean and wrong actions of the crew. Last year Russian Air Force lost An-26 due to low altitude stall. An-148 was lost near Domodedovo, when pilots forgot to turn on electrical pitot heaters, and found themselves in the situation very similar to A330 crew over the Atlantic. In all these cases the crew could not even recognize the situation they were in and find the way out of it.

More than 1/5th of such accidents had happened due to lack of necessary upset recognition and recovery skills among pilots. Simulations showed that 90 percent of stall and upset recovery crashes could have been avoided if pilots had had necessary initial training and skills. Flight safety statistic data shows that from 2002 to 2016 lack of authority, stalls and upsets with wrong crew actions, became the reason of 16 crashes where more than 2100 passengers died, and it's still the leader in the list of air crash reasons [3]. Analysis of flight safety shows us that even in the latest models of highly sophisticated and cutting-edge technology aircraft, the main role always was, and will belong to the well-trained crew.

Civil aircraft were found in upsets before nowadays, but crew could manage the situation well more often, because they were trained for if in the walls of aviation schools. And, of course, some cases were badly investigated and could be written to a wrong graph in statistic reports. We need to say that this problem has only been found recently due to the change in pilots' generations and production of more and more automatic aircraft.

Let us see, what Boeing says about upset recovery:

"Historically, an upset was defined as unintentionally exceeding one or more of the following conditions:

- Pitch attitude greater than 25 degrees nose up;
- Pitch attitude greater than 10 degrees nose down;
- Bank angle greater than 45 degrees;
- Less than the above parameters but flying at an airspeed inappropriate for the conditions.

An upset condition is now considered any time an airplane is diverting from the intended airplane state. An airplane upset can involve pitch or roll angle deviations as well as inappropriate airspeeds for the conditions." (Boeing)[1]

Unfortunately, nowadays there is no initial pilot training for upset recovery in civil flight school programs, as there are no aerobatic flights in aviation school anymore [4]. That is why civil pilots nowadays have no idea about feelings and forces in spin, stall, steep turns, and etc. Instead of these trainings, now they only have a book, where they can read about upset recovery maneuvers. Boeing, for example divided all upset situations into two scenarios: "Nose high", and "Nose low". Let us have a look at it in Table 1 and Table 2:

Table 1

Nose High Recovery

Pilot Flying	Pilot Monitoring
Recognize and confirm the developing situation	
• Disengage autopilot. • Disconnect auto throttle. Recover: • Apply nose down elevator. Apply as much elevator as needed to obtain a nose down pitch rate.	• Call out attitude, airspeed and altitude throughout the recovery. • Verify all needed actions have been done and call out any continued deviation.

[1] QRH (Quick Reference Handbook) Boeing 747/8.

Continuation of Table 1

• Apply appropriate nose down stabilizer trim*. • Reduce thrust. • Roll (adjust bank angle) to obtain a nose down pitch rate*. Complete the recovery: • When approaching the horizon, roll to wings level. • Check airspeed and adjust thrust. • Establish pitch attitude.	

Table 2

Nose Low Recovery

Pilot Flying	Pilot Monitoring
Recognize and confirm the developing situation	
• Disengage autopilot. • Disconnect auto throttle. Recover: • Recover from stall, if needed. • Roll in the shortest direction to wings level. If bank is more than 90 degrees, unload and roll*. Complete the recovery: • Apply nose up elevator. • Apply nose-up trim, if needed*. • Adjust thrust and drug, if needed.	• Call out attitude, airspeed and altitude throughout the recovery. • Verify all needed actions have been done and call out any continued deviation.

As you can see, there is not much information about crew actions, and no information about what they are going to feel in this kind of situations. And as it was written above, modern aircraft can be found in upset or stall situation by many reasons, for e.g.: engine failure, flight control system malfunctions, loss of attitude awareness, extreme meteorological conditions, fly out of the flight envelope due to air drafts, lightning strike etc. The number of wrong crew response is growing all over the world [5].

HISTORY OF QUESTION

Before the 80^{th}, initial flight trainings in the USSR had been made on Yak-18. This aircraft was able to perform simple and complex aerobatic flights. So, all the cadets were trained to manage upset recovery situations, stall, spin and etc. That is why this question was not relevant those days.

But today we have DA-40, L-410, An-2 and Cessna-172, in Russian aviation schools for initial pilots trainings. All the above-mentioned aircraft types are not able to perform aerobatic flights, stall and spin. That is the reason, why these aircraft types are not completely satisfactory for initial civil aviation cadets training.

REQUIREMENTS FOR INITIAL TRAINING AIRCRAFT

Let us see what requirements are presented for initial training aircraft in civil aviation schools. Actually, only one requirement is made by law-it’s the presence of type certificate. But common sense shows that there are more. Initial training aircraft should:

- have modern navigation equipment, be able to train new types of approach and navigation;
- not use much fuel;

- be easy to fly;
- be easily maintained;
- cheap and reliable;
- strong for G and aerodynamic loads;
- have pilot seats side by side;
- have standard controls;
- with retractable gears, with nose gear;
- ready to use jet fuel;
- be able to take off from unpaved runways;
- be able to make aerobatic flights.

Nowadays Yakovlev design bureau can offer SM2000 and SM2000P. It is a modern aircraft, which is actually a deep modification of famous Yak-18T, and it meets all the above requirements. This aircraft can be equipped with new, cutting-edge navigation equipment and has two engine options: a piston engine for initial training, and turboprop engine for further trainings and aerobatic flights. All the weak points, which were found in the design of Yak-18T, were well corrected. This new aircraft is equipped with 3 blades fully metal propeller and modified M14-X engine that is famous for its reliability. At the same time, all the best qualities of Yak-18T were preserved. It is still easy to fly and maintain, cheap and ready to stand for cadets. All the above shows that this type can be strongly recommended to civil aviation schools.

UPSET RECOVERY SKILL MAINTAINING

To maintain basic flying and upset recovery skills, pilots need regular training exercises on the simulators [6]. Simulator training is the most efficient, rational and safe way, to practice all possible in-flight malfunctions and types of approach because:

- it is cheaper to use simulator than aircraft;
- stall and upset recovery training are safe;
- it’s a regular base training that can give strong skills for pilots;
- a lot of pilots can be trained for a short period of time [7].

Modern simulators are able to practice stalls and steep turns, but unfortunately a number of upset recovery trainings can’t be done, due to mobility restrictions of the hydro platform. It can simulate visualization, instruments readings and control forces, but it can’t simulate G loads during upset recovery, and that is why it is not certified for this kind of trainings [8, 9, 10, 11]. That means that we need to develop other simulator types, which would be able to simulate upset recovery for training purpose. And this work is already in progress. European project SUPRA (Simulation of Upset Recovery in Aviation) in cooperation with Russian Design Bureau "Dinamika" has made a lot of progress in their research [12, 13]. The greatest progress was made in the Netherlands, where simulator DESDEMONA (DESorientation DEMONstrator) was made. This new device can produce continues G loads up to ±3G, that is more than enough for upset recovery trainings [14, 15].

CONCLUSIONS

Lack of initial, as well as regular upset recovery trainings has a huge effect on flight safety [15]. To fill in this hole initial training programs in civil aviation school should be changed, and types of initial training aircraft, as well as requirements for it should be changed as well [16, 17]. Aviation society has a lot to think about on its way to safer future. All the questions that were discussed in this paper are very important for modern civil aviation and should be solved in the nearest future.

REFERENCES

1. **Biryukov, V.V.** (2013). *Vyvod samoleta iz svalivaniya: nuzhno umet, mozhno nauchit* [Upset recovery: need to know, able to teach]. Aviatransportnoye obozreniye ATO, no. 136, pp. 136–138. (in Russian)

2. **Degtyarev, V.S., Mashohsin, O.F. and Kulakov, M.V.** (2018). *Modern and future avia simulators sertification problems.* Innovations in Civil Aviation, vol. 3, no. 1, pp. 84–89.

3. **Degtyarev, V.S., Kulakov, M.V. and Degtyareva, A.V.** (2019). *The substantiation of the necessity of a complete transition from the use of qfe pressure to the use of pressure qnh*. Scientific Bulletin of the State Scientific Research Institute of Civil Aviation (GosNII GA), no. 27, pp. 28–34. (in Russian)

4. **Rukhlinskiy, V.M. and Kuminova, A.P.** (2018). *Problem of flight safety, connected with degradation of crew role in piloting, анзадачад transition to automatic flights.* Scientific Bulletin of the State Scientific Research Institute of Civil Aviation (GosNII GA), no. 22, pp. 91–101. (in Russian)

5. **Bodrunov, S.D.** (2002). *Aviatsionnoye trenazherostroyeniye v Rossii, istoriya, sovremennoye sostoyaniye, perspektivy razvitiya* [Construction of aviation simulators in Russia, history, nowadays and future]. Trenazhernyye tekhnologii i simulyatory – 2002: materialy nauchno-tekhnicheskoy konferentsii [Simulator technologies and simulators – 2002: proceedings of the scientific and technical conference], pp. 4–12. (in Russian)

6. **Aksenov, V.G.** (2005). *Otechestvennoye aviastroyeniye: realii, problemy i perspektivy* [Domestic aircraft construction: reality, problems and future]. Aerocosmicheskiy kurer, no. 2, pp. 64–66. (in Russian)

7. **Popov, O.S. and Tretyakov, A.V.** (2003). *Zadachi postroyeniya kompyuternykh system obucheniya dlya pilotov grazhdanskoy aviiatsii* [The task of education computer systems construction for civil aviation pilots]. Aerospace Instrument-Making, no. 9, pp. 38–40. (in Russian)

8. **Derevenchuk, D.M. and Derevenchuk, N.V.** (2002). *Metody avtomaticheskogo rascheta rezhimov razgona i tormozheniya v aviatsionnykh trenazherakh* [Methods of automatic accelerations and decelerations calculations in aviation simulators]. Metody i sredstva izmereniya v sistemakh kontrolya i upravleniya: sbornik trudov mezhdunarodnoy nauchno-tekhnicheskoy konferentsii [Methods and measurement means in control and operating systems: proceedings of Penza international conference], pp. 150–151. (in Russian)

9. **Derevenchuk, D.M. and Derevenchuk, N.V.** (2003). *Korrektsiya dinamicheskikh kharakteristik aviatsionnogo trenazhera na osnove algebraicheskikh invariantov* [Dynamic characteristics correction of aviation simulators based on algebraic invariants]. Trenazhernyye tekhnologii i simulyatory – 2003: materialy vtoroy nauchno-tekhnicheskoy konferentsii [Simulators technologies and simulators: proceedings of the 2nd scientific and technical conference], pp. 26–31. (in Russian)

10. **Bonder, V.A., Zakirov, R.A. and Smirnova, I.I.** (1978). *Aviatsionnyye trenazhery* [Aviation simulators]. Moscow: Mashinostroyeniye, 192 p. (in Russian)

11. **Naida, V.A. and Iablonskij, S.N.** (2013). *Organizational and methodical aspects of introduction in training process western made maintenance procedure simulators*. Nauchnyy Vestnik MGTU GA, no. 197, pp. 94–96. (in Russian)

12. **Koltsov, S.E.** (2016). *Trenazhernyy park grazhdanskoy aviatsii Rossiyskoy Fedaratsii* [Civil aviation simulators fleet in Russia]. Forum, no. 1 (17), pp. 8–9. (in Russian)

13. **Litvinenko, A.A.** (2012). *Analiz sostoyaniya rossiyskogo rynka aviatsionnykh tekhnicheskikh sredstv obucheniya* [The analysis of Russian aviation simulators market in Russia]. Aviatrenazhery, uchebnyye tsentry i aviapersonal – 2012: materialy IV mezhregionalnoy konferentsii [Proceedings of the 4th conference Aviation simulators, educational centers and aviation personal]. Moscow: Dinamika, pp. 5–8. (in Russian)

14. Proshkina, L.A. and Proshkin, V.N. (2016). *Povysheniye kachestva aviatsionnykh trenazherov na osnove ucheta chelovecheskogo faktora* [Quality improvement of simulators on the basis of human factor]. Prioritetnyye nauchnyye napravleniya, ot teorii k praktike, no. 24-2, pp. 119–126. (in Russian)

15. Mudrov, A.P. and Fazizov, M.P. (2019). *A spherical simulator motion study*. Aerospace MAI Journal, vol. 26, no. 1, pp. 182–191. (in Russian)

16. Fazizov, M.P. and Khabibullin, F.F. (2020). *Computations analysis of a four-link spherical mechanism for a spatial simulator*. Aerospace MAI Journal, vol. 27, no. 2, pp. 196–206. DOI: 10.34759/vst-2020-2-196-206 (in Russian)

17. Golovnin, S.M. (2018). *Risk of problem solution skills loss by civil aviation pilots in uncertainty conditions*. Aerospace MAI Journal, vol. 25, no. 2, pp. 184–190. (in Russian)

INFORMATION ABOUT THE AUTHORS

Vyacheslav S. Degtyarev, Postgraduate Student, Moscow State Technical University of Civil Aviation, Civil Aviation Pilot, AirBridgeCargo Airline, glider_34@mail.ru.

Oleg F. Mashoshin, Doctor of Technical Sciences, Dean of the Mechanical Department, Moscow State Technical University of Civil Aviation, o.mashoshin@mstuca.aero.

Anastasiia V. Degtyareva, Postgraduate Student, Assistant of the Transportation Organization Chair, Moscow State Technical University of Civil Aviation, tu-1542b@mail.ru.

ТРЕНИРОВКА ЛЕТНОГО СОСТАВА ГРАЖДАНСКОЙ АВИАЦИИ ПО ВЫВОДУ ИЗ СЛОЖНЫХ ПРОСТРАНСТВЕННЫХ ПОЛОЖЕНИЙ

В.С. Дегтярев[1], О.Ф. Машошин[1], А.В. Дегтярева[1]
*[1]Московский государственный технический университет гражданской авиации,
г. Москва, Россия*

Данная статья посвящена проблеме подготовки летного состава гражданской авиации к выводу воздушного судна из сложных пространственных положений. Данная проблема возникла недавно в результате изменения доктрины обучения летного состава и удаления из программы подготовки пилотов тренировки по выводу из сложных пространственных положений, что отрицательно сказалось на уровне безопасности полетов как в нашей стране, так и во всем мире. В статье рассмотрена законодательная база, применяемая в Российской Федерации и за рубежом, для сертификации авиационных тренажеров. В статье также рассмотрены эксплуатируемые на данный момент в летных училищах Российской Федерации и за рубежом самолеты первоначального обучения. Проведен анализ действующего парка, и сделаны выводы о возможной замене самолетов первоначального обучения более совершенными типами воздушных судов, способными выполнять простой, сложный и высший пилотаж и подходящими для тренировки летного состава по выводу из сложных пространственных положений. Проведены исследование проблематики тренажерной подготовки по выводу из сложных пространственных положений и анализ применяемых в учебных центрах технических средств обучения. Широко рассмотрена проблематика сертификации технических средств обучения летного состава гражданской авиации в нашей стране. Сделаны выводы о необходимости изменения программы подготовки пилотов гражданской авиации в части вывода из сложных пространственных положений для улучшения уровня безопасности полетов в стране. Даны рекомендации о необходимости приведения сертификационного законодательства к международным стандартам.

Ключевые слова: самолет первоначального обучения, сложные пространственные положения, международные стандарты обучения, безопасность полетов, программа подготовки летного состава, технические средства обучения, техника пилотирования, гражданская авиация, обучение летного состава.

СПИСОК ЛИТЕРАТУРЫ

1. **Бирюков В.В.** Вывод самолета из сваливания: нужно уметь, можно научить // Авиатранспортное обозрение АТО. 2013. № 136. С. 136–138.
2. **Дегтярев В.С., Машошин О.Ф., Кулаков М.В.** Проблематика сертификации современных и перспективных авиатренажеров // Инновации в гражданской авиации. 2018. Т. 3, № 1. С. 84–89.
3. **Дегтярев В.С., Кулаков М.В., Дегтярева А.В.** Обоснование необходимости полного перехода от использования давления QFE к использованию давления QNH // Научный вестник ГосНИИ ГА. 2019. № 27. С. 28–34.
4. **Рухлинский В.М., Куминова А.П.** Проблема безопасности полетов, связанная со снижением роли экипажа в пилотировании ВС, и переход к автоматизированным полетам // Научный вестник ГосНИИ ГА. 2018. № 22. С. 91–101.
5. **Бодрунов С.Д.** Авиационное тренажеростроение в России: история, современное состояние, перспективы развития // Тренажерные технологии и симуляторы – 2002: материалы научно-технической конференции. С-Петербург, 05–06 июня 2002 г. СПб.: Изд-во СПбГПУ, 2002. С. 4–12.
6. **Аксенов В.Г.** Отечественное авиатренажеростроение: реалии, проблемы и перспективы // Аэрокосмический курьер. 2005. № 2. С. 64–66.
7. **Попов О.С., Третьяков А.В.** Задачи построения компьютерных систем обучения для пилотов гражданской авиации // Авиакосмическое приборостроение. 2003. № 9. С. 38–40.
8. **Деревянчук Д.М., Деревянчук Н.В.** Методы автоматического расчета режимов разгона и торможения в авиационных тренажерах // Методы и средства измерения в системах контроля и управления: сборник трудов международной научно-технической конференции. Пенза, 09–10 сентября 2002 г. Пенза, 2002. С. 150–151.
9. **Деревянчук Д.М., Деревянчук Н.В.** Коррекция динамических характеристик авиационного тренажера на основе алгебраических инвариантов // Тренажерные технологии и симуляторы – 2003: материалы 2-й научно-технической конференции. С.-Петербург, 10 июня 2003 г. СПб.: Изд-во СПбГПУ, 2003. С. 26–31.
10. **Боднер В.А., Закиров Р.А., Смирнова И.И.** Авиационные тренажеры. М.: Машиностроение, 1978. 192 с.
11. **Найда В.А., Яблонский С.Н.** Организационно-методические аспекты внедрения в учебный процесс авиационных тренажеров западного производства // Научный Вестник МГТУ ГА. 2013. № 197. С. 94–96.
12. **Кольцов С.Е.** Тренажерный парк гражданской авиации РФ // Форум. 2016. № 1 (17). С. 8–9.
13. **Литвиненко А.А.** Анализ состояния российского рынка авиационных технических средств обучения // Авиатренажеры, учебные центры и авиаперсонал – 2012: материалы IV Межрегиональной конференции. Москва, 15 мая 2012 г. М.: Динамика, 2012. С. 5–8.
14. **Прошкина Л.А., Прошкин В.Н.** Повышение качества авиационных тренажеров на основе учета человеческого фактора // Приоритетные научные направления: от теории к практике. 2016. № 24-2. С. 119–126.
15. **Мудров А.П., Фаизов М.Р.** Исследование движения сферического тренажера // Вестник Московского авиационного института. 2019. Т. 26, № 1. С. 182–191.
16. **Фаизов М.Р., Хабибуллин Ф.Ф.** Анализ расчетов четырехзвенного сферического механизма для пространственного тренажера // Вестник Московского авиационного института. 2020. Т. 27, № 2. С. 196–206. DOI: 10.34759/vst-2020-2-196-206

17. Головнин С.М. Риск потери навыка решения проблем пилотами гражданской авиации в условиях неопределенности // Вестник Московского авиационного института. 2018. Т. 25, № 2. С. 184–190.

СВЕДЕНИЯ ОБ АВТОРАХ

Дегтярев Вячеслав Сергеевич, аспирант МГТУ ГА, преподаватель кафедры двигателей летательных аппаратов, командир воздушного судна, авиакомпания «AirBridgeCargo», glider_34@mail.ru.

Машошин Олег Федорович, доктор технических наук, заведующий кафедрой двигателей летательных аппаратов МГТУ ГА, o.mashoshin@mstuca.aero.

Дегтярева Анастасия Владимировна, аспирант МГТУ ГА, ассистент преподавателя кафедры организации перевозок на воздушном транспорте МГТУ ГА, tu-1542b@mail.ru.

Поступила в редакцию	28.10.2020	Received	28.10.2020
Принята в печать	28.01.2021	Accepted for publication	28.01.2021