BY RICK DARBY

Re-Examining the Rudder

Rudder-use training is increasing, but gaps in understanding persist.

Transport airplane pilots have used, or expected to use, the rudder "in ways not always trained and in ways not recommended by the manufacturer," according to a survey conducted for the U.S. Federal Aviation Administration (FAA).[1] The survey also found that "erroneous and accidental [rudder] inputs occur" and that some pilots had to compensate for overcontrolled or wrong-direction rudder commands.

Rudder inputs became a prominent issue following the fatal accident involving American Airlines Flight 587, an Airbus A300, shortly after takeoff on Nov. 12, 2001. The flight data recorder indicated that moments before the accident there had been several rudder pedal inputs, to nearly full deflection, in opposite directions. The airplane's vertical stabilizer separated in flight, control was lost and the airplane crashed into a residential area near John F. Kennedy International Airport, New York.

"This accident focused international attention on how pilots apply rudder controls and industrywide pilot training of rudder usage in transport airplanes," the survey report says.

On Feb. 15, 2002, the FAA issued Notice N8400.28, *Transport-category Airplanes – Rudder and Vertical Stabilizer Awareness*, which directed principal operations inspectors to be certain that air carriers were aware of the danger of sequential, opposite full rudder inputs, or "rudder reversals."

The survey was developed after publication of Notice 8400.28 to ascertain pilot experience with rudder movements, as well as in-flight upsets. The survey, transmitted by the Internet to pilots of airlines belonging to the International Air Transport Association, included 52 questions about their use of rudder controls in response to upsets or unusual attitudes.[2] Among the questions were some about rudder training and unusual attitude training before and after the February 2002 notice. From the 2,179 total survey responses, 914 were selected as meeting the criteria assigned for statistical analysis.

A total of 283 pilots reported the number of upsets they had experienced in their careers. Most common was excessive bank, with a mean of 39 degrees, followed by altitude loss, with a mean of 461 ft. Pitch-up and pitch-down, with mean values of 8.4 degrees and 4.2 degrees respectively, were next in frequency among reported upsets.

Some pilots reported experiences in which rudder inputs did not produce the intended result. "Of the 118 pilots reporting an unexpected rudder characteristic, 37 percent reported an unexpected force, 31 percent reported an unexpected motion, 43 percent reported a lack of response and 40 percent reported an unexpected input sensitivity," the report says.

In response to questions concerning issues connected with rudder control inputs, pilots reported the following:

- **"Sequential opposite pilot inputs to rudder.** Thirty-seven pilots reported a total of 38 events in which they made sequential opposite-rudder pedal inputs;
- **"Pilot overcontrol or wrong-direction inputs.** One hundred forty-eight pilots reported 150 events in which they overcontrolled or made inputs in the wrong direction that had to be neutralized or reversed. Seventy-five percent of these events involved overcontrol; 25 percent were wrong-direction. Fifty-three percent of wrong-direction inputs involved yaw, 50 percent involved roll and 10 percent involved pitch;
- **"Unintentional crossed controls.** A total of 41 pilots reported they had unintentionally commanded uncoordinated rudder-pedal and control-wheel or sidestick commands; [and,]
- **"Inadvertent rudder inputs.** A total of 174 pilots reported making inadvertent, or accidental, inputs."

The inadvertent rudder inputs rarely resulted in pitch upsets, the report says. However, pilots reported 75 instances in which bank angles occurred, ranging up to 20 degrees, with 29 percent of pilots describing bank angles of more than 15 degrees. Sixty-eight pilots experienced yaw, up to 20 degrees, as a result of rudder inputs.

"One hundred eighty-eight pilots reported observing another pilot making inappropriate overcontrolling or wrong-direction inputs that had to be neutralized or reversed," the report says. Seventy-one percent of those errors involved overcontrol and 29 percent were in the wrong direction. Sixty percent of reported events involved erroneous yaw input, 58 percent involved erroneous roll input and 6 percent involved pitch.

Pilots described the phases of flight and situations when they would consider using the rudder pedals (Table 1).

"Intentions were varied for upset recovery, with 57 percent considering rudder use on takeoff, about a third in climb, cruise and descent, and 58 percent on landing," the report says. "Rudder use for engine failure was considered by at least two-thirds in all phases, almost all on takeoff, and over 80 percent for climb and landing. Intentions to use rudder to counter light turbulence were reported by many fewer respondents, with about 10 percent on takeoff and landing and less than 5 percent in other phases. Rudder use in crosswind was considered by few respondents in climb and cruise, but by 84 percent on takeoff, 18 percent during descent and 82 percent during landing."

The survey included questions about how the pilots had been instructed to use the rudder, both on the aircraft they were currently flying (Table 2) and for any aircraft they had previously flown. "Respondent perceptions of training recommendations for rudder use on their current aircraft were fairly consistent with their intentions [as shown in Table 1]," the report says.

Percentage of Pilots Who Would Use Rudder Input, by Flight Situation and Phase of Flight

	Phase of Flight				
Flight Situation	Takeoff	Climb	Cruise	Descent	Landing
Upset recovery	57%	40%	32%	34%	58%
Engine failure	96%	80%	69%	66%	86%
Counter light turbulence	10%	4%	3%	4%	11%
Counter in excess of moderate turbulence	21%	2%	10%	11%	4%
During crosswind conditions	84%	5%	3%	18%	82%
Passenger comfort	5%	4%	4%	13%	20%
Turn coordination	20%	17%	11%	14%	20%
Yaw damper hard-over/malfunction	56%	52%	49%	50%	57%
Dutch roll after yaw damper failure	30%	30%	36%	33%	30%

Source: U.S. Federal Aviation Administration

Table 1

Percentage of Pilots Reporting Training-Recommended Rudder Use on Aircraft Currently Flown, by Flight Situation and Phase of Flight

	Phase of Flight				
Flight Situation	Takeoff	Climb	Cruise	Descent	Landing
Upset recovery	36%	30%	29%	25%	35%
Engine failure	97%	79%	66%	66%	88%
Counter light turbulence	6%	3%	3%	2%	6%
Counter in excess of moderate turbulence	11%	5%	6%	11%	11%
During crosswind conditions	83%	7%	3%	5%	90%
Passenger comfort	5%	3%	3%	3%	5%
Turn coordination	15%	14%	12%	12%	15%
Yaw damper hard-over/malfunction	36%	33%	33%	32%	38%
Dutch roll after yaw damper failure	21%	21%	24%	21%	21%

Source: U.S. Federal Aviation Administration

Table 2

Pilot Rudder-Use Training, by Time Frame and Type

	Type of Training						
Time Frame	Recurrent Simulator	Recurrent Classroom	Safety Bulletin	Operations Bulletin	Aircraft Checkout	Discussion with Other Pilots	Personal Flying Experience
Pre-2002 rudder training	28%	18%	12%	12%	11%	11%	9%
Post-2002 rudder training	40%	31%	28%	28%	22%	16%	5%

Source: U.S. Federal Aviation Administration

Table 3

"For upset recovery, a quarter to a third of respondents perceived [that training recommended] rudder use; this was slightly lower than their intentions reported … . Rudder use for engine failure was perceived as recommended by at least two-thirds in all phases; almost all on takeoff and roughly 80 percent for climb and landing."

Pilots' perceptions of training recommendations for rudder use on previous aircraft flown were generally in line with intentions. "However, respondent perceptions for upset recovery recommendations were higher than their current aircraft by about 10 percent but still lower than intentions reported," the report says. "Additionally, use for turn coordination was higher, suggesting that many had flown aircraft at some point in their career in which rudder input was required to maintain coordinated flight in turns."

The report says that, in response to questions about their training on rudder use, 34 percent said that they had received additional training before February 2002, the publication date of Notice N8400.28, and 52 percent had received more training after that date. Post-2002 rudder training increased in almost every training category (Table 3).

"The number of sequential opposite-direction rudder inputs and reversed over-application of rudder reported by the respondents is important," the report says. "It implies that the [American Airlines Flight 587] Airbus accident differs in magnitude but not in fundamental misinterpretation or application error from events reported by respondents. Pilots reported a number of situations, mostly erroneous inputs requiring neutralization or reversal, which had the potential to exceed certification criteria but probably did not reach ultimate load."

Several questions were put to pilots about their monitoring of the control inputs by the pilot flying. "While the majority of respondents reported efforts to monitor the controls when acting as non-flying or monitoring pilot in a variety of phases of flight, monitoring sidestick pitch and roll was reported by many fewer respondents," the report says. No pilot expressed a preference or dislike about any particular control system design.

In their own judgment, pilots found simulators to be the most effective mode for rudder characteristics training. About half of all respondents also had received aerobatic training at least once.

"Importantly, however, the data reveal continuing inconsistency between respondent intentions, perceptions of training recommendations and published guidance," the report says. "Specific areas requiring further emphasis based upon survey responses include:

- "Avoidance of over-controlling or opposite-direction inputs, particularly involving the rudder;
- "Explanation and understanding of rudder characteristics, including forces, motions, responses and sensitivity; [and,]
- "Efforts to bring intentions to use rudder into close alignment with guidance provided in the *Upset Recovery Training Aid*."[3]

The report recommends "continued emphasis" by civil aviation authorities, manufacturers and operators on appropriate rudder use, "given the frequency of reported events in which rudder reversal was a real possibility." In addition, "future rudder designs should consider tolerance of common mistakes or inappropriate control inputs made by pilots."

Notes

1. FAA Civil Aerospace Medical Institute. *An International Survey of Transport Airplane Pilots' Experiences and Perspectives of Lateral/Directional Control Events and Rudder Issues in Transport Airplanes (Rudder Survey).* DOT/FAA/AM-10/14. October 2010.
2. Upset was defined as "unintentional conditions describing an airplane motion that a pilot believed required immediate corrective action."
3. FAA. *Airplane Upset Recovery Training Aid*, revision 2. 2008. The training aid's definition of "upset" differs from that used in the survey, and consists of a pitch attitude greater than 25 degrees nose-up, greater than 10 degrees nose-down or bank angle greater than 45 degrees.