According to the pilots, gradual climb operation should save fuel to some extent. The optimal ROC varies with the conditions, but it is preferable to have a simple rule, such as 500 ft/min for step-up climb, or 1000 ft/min for the last 2000 ft prior to TOC. In addition, TCAS monitors climb or descent when the climb/descent rate is 500 ft/min or larger, so if the ROC is too small, other aircraft might think that the aircraft is not climbing/descending. Therefore, the ROC for 500 ft/min or greater is recommended for situational awareness. To conduct the proposed gradual climb procedure, the pilot should select V/S mode by pushing the V/S button and set an appropriate ROC. After reaching the cruise altitude, the aircraft automatically starts cruise flight and V/S mode is automatically changed. Therefore, the impact of the gradual climb procedure to the pilot workload will be limited.

As for ATC perspective, it takes longer time to reach the cruise altitude by using a gradual climb procedure. However, during the normal climb, ATC does not assign ROC of the aircraft and does not know how long it will take to reach the cruise altitude. Therefore, the aircraft are sufficiently separated horizontally from each other during climb, so no safety issue will be occurred by a gradual climb procedure. As for the ATC efficiency, ATC does not feel that 500 ft/min climb rate is slow. Since sufficient horizontal separation is set, no impact will be given to another aircraft. Also, even if the pilot applies gradual climb procedure, no report to ATC is required. However, if the aircraft conducts a 50 ft/min climb, multiple flight levels should be blocked, which might affect other flights in the vicinity.

According to these comments, the negative impacts will be almost negligible by operating gradual climb procedure. Even if the fuel saving per flight by gradual climb is not big, little negative effect is expected, so it is worth performing the gradual climb procedure.

V.   CONCLUSIONS AND FUTURE WORKS

This research considered a practical way to implement gradual climb which has theoretically been known to save fuel. Potential fuel saving was calculated considering the current ATC and pilot operation. It would be impossible to fly on the "optimal profile", but this research showed that a sub-optimal profile such as a fixed ROC could achieve fuel saving. The possible fuel saving per flight is not significant, the order of 10-100 lb. However, the proposed gradual climb procedure is applicable for all commercial aircraft flying worldwide, and so the cumulative effect will be significant. Clarification of the conditions under which the proposed operation can be applied and implemented in practice will be a subject to future work.

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