CS-232 Cost Reduction through Fuzzy-controlled Tunnel Ventilation System

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1. INTRODUCTION

Due to the increase of the demand for the underground developments, the tunnel technologies are becoming very important. In excavating the rock ground, it is very common that the method using the blasting and concrete spraying is adopted. Though use of blasting may largely increase the advance of the excavation with the lower cost compared with that by machines such as road header, it could degrade the circumstance inside the tunnel by generating the harmful things such as CO and dust. Concrete spraying also generates the high density of dust even though the spraying technologies have well improved. After blasting, the several machines are used in mucking and transporting the waste, and NOx and CO are generated. During the drilling of the boreholes, the working conditions are usually degraded by the high temperature and humidity from the ground. Therefore, the ventilation systems are needed. Conventional ventilation system still widely used runs with the constant fan speed. When its speed is manually fixed at the high, the working circumstance is always clean. However, the fan highly runs even when the working circumstance is already clean and it is not economically efficient. On the contrary, the low speed of fan may not sufficiently improve the working condition. In order to solve such problem, the fan has been recently invented so that its speed is changed three steps corresponding to the dust density and its efficiency has been largely improved. However, it may not be operated in the case of the high temperature and humidity under low dust density. In such circumstances a fuzzy-controlled ventilation system has been newly developed. In this paper the developed system is outlined and its validity is discussed especially from the viewpoint of economical efficiency.

2. OUTLINE OF SYSTEM

The purpose of the system is to remove the undesirable working conditions as soon as possible through operating the fan based upon the observed CO and dust densities as well as temperature and humidity real-time wise. The system configuration is shown in Fig.1. The system consists of two fans, sensors, control units and personal computer. The supplemental fan flows the contaminated air toward the excavation face and such air can be blown out of the tunnel by the main fan. Number and configuration of fans may depend on the tunnel size and construction procedure. The sensors are positioned near excavation face, since the working condition at the excavation face is generally degraded and its improvement is always desired by site workers.

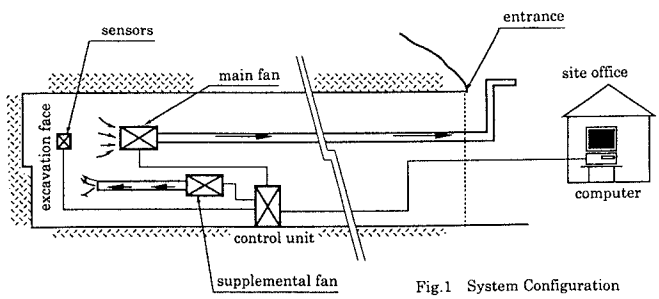

Fig.1 System Configuration

Fuzzy control, Ventilation system, Cost reduction, Improvement of working conditions
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In determining the desired fan speed, the fuzzy theory (for example [1] and [2]) is used because of the following reasons:

(1) Since four observed items are simultaneously input into the computer for determining the fan speed, usual mathematical approaches may require the complicated calculation procedure resulting in the delay in control and need of the larger computer than personal computer.

(2) How one feels may not be properly identified by the usual mathematical procedures.

(3) After installation the fuzzy-controlled system can be easily tuned without remodeling the system itself, which usually happen in the mathematical approach.

3. EVALUATION OF SYSTEM

The efficiency of the developed system was compared with that of the conventional three-step system. Fig.2 shows the convergence time that the dust density decreases within the control value ($2.5mg/m^3$). It was observed that the developed system can decrease the dust density faster than the conventional one, which is particularly clear at high dust densities. Table 1 also summarizes the comparison of the both systems in view of cost performance. The figures in Table 1 mean the time ratio that the CO or dust density is over the control value. It can be said from Table 1 that the developed system achieved the better working condition than the conventional one. As for the cost performance, the consumed electric power of the developed system was by 8% less than that of the conventional one. However, the initial investment of the developed system is about by 30% higher than that of the conventional system due to the additional sensors and equipments required. According to our experiences, the developed system is effective in view of the running cost including the initial cost in case that the length of tunnel is longer than about 2,000m.

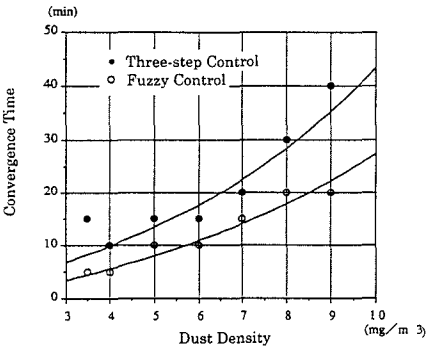

Fig.2 Recovery Efficiency of Dust Density

Table 1 Time Ratio of Over-Control Values

	Dust Density	CO Density
Developed System	33.2%	2.4%
Conventional System	37.8%	5.1%
Control Value	$2.5mg/m^3$	50ppm

4. CONCLUSION

For the purpose of improving the working conditions, fuzzy-controlled ventilation system is newly developed. This system has been already adopted in eight tunnel projects and its validity has been highly evaluated by the site engineers. It has largely contributed to the improvement of working conditions and cost reduction. The system originally developed for the tunnel construction may be easily applied to another fields such as subway and building constructions. Further applications of the system should be attempted and more accumulated data will become indispensable in improving the construction technologies for the next generation.

REFERENCES

[1] Hirota, K., Easy-understanding fuzzy system, Techno System Ltd., 1989 (in Japanese).

[2] Sugeno, M., Fuzzy control, Nikkan-kogyo News, 1988 (in Japanese).