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# Microorganic Engine

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*Abstract*: Energy systems such as fuel cells and recent combustors including internal combustion engines work at lower temperatures. Recent direct-injection gasoline and diesel engines often operate at relatively low exhaust gas temperatures around 100°C, because their lean-burn combustion process uses less fuel, resulting in burned gases of lower temperatures. The exhaust gas temperatures are close to those at which hyperthermophiles and thermophiles replicate. This situation could give rise to the possibility that thermophiles might proliferate inside the exhaust pipe of internal combustion engines. The nutrient preconditions for proliferation may be sufficient, because soot contains a lot of carbon and sulfur. Air, which is also needed by aerobic microorganisms, is taken in through the intake manifold from the atmosphere and water can be produced after combustion. Aeropyrum pernix (JCM 9820) is a species that is known to proliferate well at temperatures between 80 and 100°C, close to exhaust gas temperatures. In this paper, it is shown that Aeropyrum, a type of aerobic thermophile, proliferates well by eating soot around the temperatures in the presence of only pure water and air. This fusion of artifact and life may offer the possibility of overcoming one of the weak points of internal combustion engines.

***Keywords***: Aeropyrum, Soot, Engine, Thermophile**.**

## I. INTRODUCTION

Recent internal combustion engines with direct-injection diesel or gasoline fuel supply systems for addressing environmental problems and reducing fuel consumption often operate at relatively low exhaust gas temperatures around 100°C. This is because lean-burn operation uses less fuel than a stoichiometric condition, thus producing burned gases of lower temperatures. The lower temperature of the exhaust gas may lead to a condition of catalyst inactivity in the system with a diesel particulate filter (DPF) for trapping soot.[3] A quantum leap is necessary for overcoming the soot problem that is the principal weak point of diesel engines.

The exhaust gas temperatures are close to those at which hyperthermophiles [5] and thermophiles replicate. This situation could give rise to the possibility that thermophiles might proliferate inside the exhaust pipe of internal combustion engines. The nutrient preconditions for proliferation may be sufficient, because soot contains a lot of carbon and sulfur. Air, which is also needed by aerobic microorganisms, is taken in through the intake manifold from the atmosphere and water can be produced during combustion.

## II. AEROPYRUM PERNIX

Aeropyrum pernix (JCM 9820)[4] was isolated from a coastal solfataric vent in Japan. This species is aerobic organism. The optimum growth temperature is 90 to 95 degree Celsius at pH7.0 and a salinity of 3.5 %.[4] The isolate was grown in the standard medium referred to as JXT, containing 1g of yeast extract, 1g of trypticase peptone, and 1g of $Na_2S_2O_3$ per liter of water.[4]

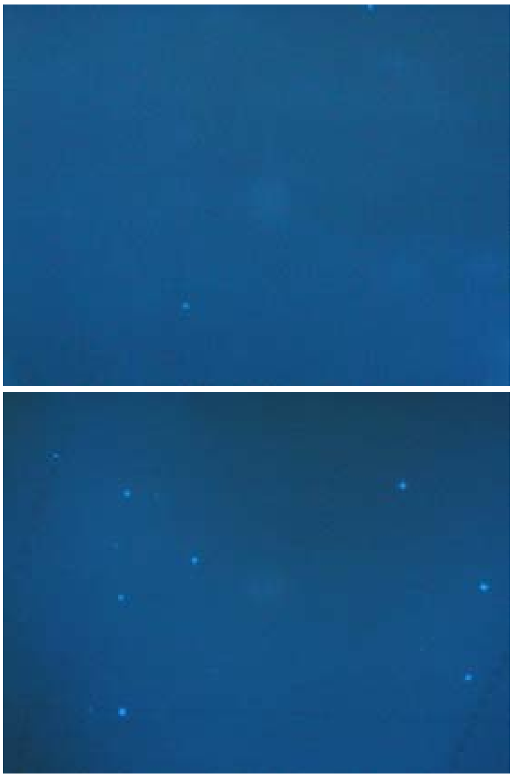
## III. AEROPYRUM EATING SOOT

In the present study, Aeropyrum pernix (JCM 9820)[4] was cultivated aerobically at temperatures over 85 degree Celsius during a period of thirteen days using soot exhausted from a conventional engine and also that from a diffusion flame burner.

The vial contained only the soot, pure water, and air in the present study, although a yeast extract and trypticase peptone are normally given as the nutrients for this species. A small amount of soot was put in 1 ml of pure water in a 10-ml vial, which was not pressurized. The pH and cultivation temperature were 7.0 and 85°C, respectively.

Figure 1 shows photomicrographs of Aeropyrum per nix cultivated during thirteen days in the vial containing only the soot, pure water, and air. The photographs wer e taken by means of DAPI staining and show densities c lose to that averaged from nine inspection points. (Photographs taken at each inspection point had dimensi ons of about 130 x 90 micrometers.)

Soot was obtained from the end of the exhaust pipe of a conventional piston engine. Several cultivation trials revealed that the density of the species after thirteen days of cultivation was about five times greater than the initial density. (Fig. 2.) Engine soot and soot taken from a methyl alcohol burner yielded approximately the same species density.



(a)

(b)

Fig.1. Microphotographs of Aeropyrum pernix cultivated during thirteen days at 85℃ in a vial containing only engine soot, pure water, and air. (a) Cultivation start and (b) after thirteen days.

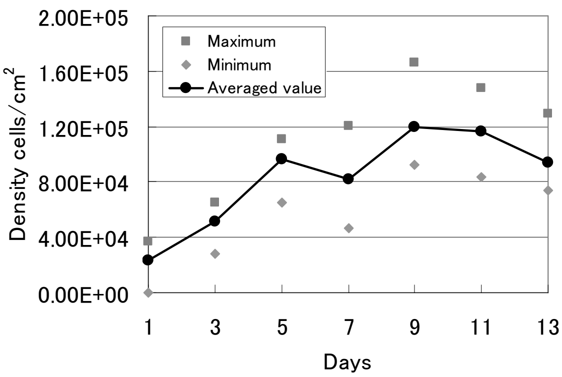



Fig.2. Time history of the density of Aeropyrum pernix cultivated during thirteen days at 85℃ in a vial containing only engine soot, pure water, and air. (The average density of the species calculated from photographs taken at nine inspection points on the glass cover was 2.55 cells per photograph at cultivation start and 10.11 cells per photograph after thirteen days of cultivation.)

## V. CONCLUSION

There is a trend toward power systems that work at temperatures close to that of living organisms.[1,2] The present fusion of artifact and life, micro-organic engine, may offer the possibility of overcoming one of the weak points of internal combustion engines. (Fig. 3)

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## REFERENCES

[1] Naitoh K, (2004) Symbiotic fusion of life and artifact, Proc. of the 9th Int. Symp. On Artificial Life and Robotics (AROB9th '04): 440－442.
[2] Naitoh K, (2004) Fundamental study on the degradation of fuel cell, Proc. of the 2004 JSAE Annual Congress, Japan Society of Automotive Engineers, No.43-04:7-11. (in Japanese)
[3] Ookubo M, Kuroki T, Miwa S, and Yamamoto T, (2 003) Soot incineration of diesel particulate filter using honeycomb nonthermal plasma, SAE paper 2003-01-1886.
[4] Sako Y, Nomura N, Uchida A, Ishida Y, Morii H, Koga Y, Hoaki T, and Maruyama T. (1996) Aeropyrum pernix gen. nov., sp. nov., a novel aerobic hyperthermophilic archaeon growing at temperatures up to 100 degrees C. International Journal of Systematics Bacteriology, 46-4: 1070.
[5] Stetter KO, (1995) Microbial life in hyperthermal en vironments. Am. Soc. for Microbiol. News, 61: 285-290.

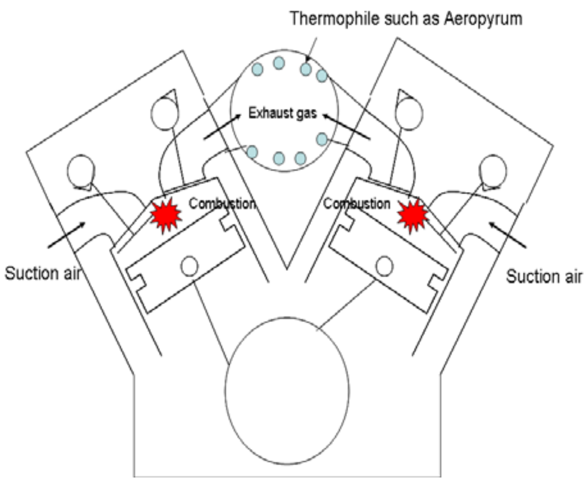


Fig. 3. Micro-organic engine including a combustion engine and thermophile.