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The Continuous Pursuit of Innovation and the Reliable Dissemination of Results

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I am both honored and somewhat apprehensive at having been chosen by the membership to serve as President during the 81st term, following my tenure as President-Elect during the 80th term. The Japan Society of Mechanical Engineering is an association of highly capable experts in "machinery, machine systems, and related fields" (the fields covered by the Society having been expanded in this manner in the wake of the Second Century Committee of JSME), producing outstanding results in the areas of mechanical engineering, machine technology, the machine industry, and associated areas. I am thus honored to serve as President.

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Pattern Formation Phenomena Generated in Contact Rotating Systems

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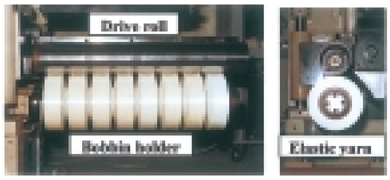
In the field of mechanical engineering, a number of contact rotating systems are used. While operating of the contact rotating systems, periodic polygonal deformation patterns are formed gradually on the peripheral surface of a roll which is a rotating body due to viscoelastic deformation, plastic deformation and cutting, grinding and wear, and hence they eventually lead to a situation where the systems become no longer operative due to strong vibrations.



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Research on Smart Structural Systems

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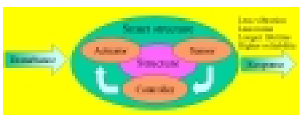
What is a smart structural system? With its concept derived from functionality of a living system, a smart structural system is expected to possess the abilities to sense the changes in its environment or internal state and to adapt itself to these changes. The realization of these abilities is based on the seamless integration of sensors, actuators and controllers, whose functions are similar to those of the nerves, muscles and brain in a living system, with a traditional structure, which has similar function to that of the skeleton of a living system.



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Autonomous Mine Detection Robot for Humanitarian Demining

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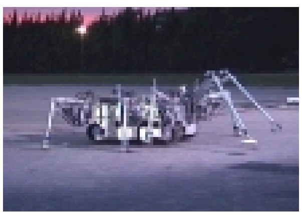
Currently, more than 100 million anti-personnel mines are under the ground all over the world. These mines not only disturb the economic development of mine-buried nations, but also injure or kill more than 2000 people a month. As a result, the removal of landmines has become a global emergency. The current method of removing mines manually is costly and dangerous. Moreover, removal of all mines by this method would require several hundred years.



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From Inaugural Address of the 81st President of JSME

The Continuous Pursuit of Innovation and the Reliable Dissemination of Results

Shigeho TANAKA
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Continued from page 1 At the same time, however, it is sobering to consider my new responsibilities in the midst of the difficult economic and social circumstances currently being faced by Japan and many other countries.

The Science and Technology Fundamental Law was recently enacted in Japan, calling for "contributions to human society as a country with creative capacity for science and technology", thereby highlighting efforts at innovation. These efforts can be summarized in terms of four desirable characteristics of society that are being sought :

(1) Environmental harmonization and sustainability in the context of resources, energy, and distribution systems.
(2) Convenience and creativity in the context of an aging society, with the integration of advanced information capabilities.
(3) Ethical consensus in which the results of life science can be applied.
(4) Attachment of importance to intellectual property.

The building of a society marked by these characteristics is not easy. Taking just the first of these as an example, Japan pledged at the 3rd Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change held in Kyoto in 1997 to reduce the average level of greenhouse gas emissions between 2008 and 2012 by 6% in comparison with the 1990 level. In order to uphold this commitment, highly efficient technology must be developed for the utilization of natural, renewable energy, and major improvements are required the efficiency and reliability of existing energy systems. Furthermore, a society endowed with the four characteristics noted above cannot be realized by leveraging any single area of science. Nevertheless, I believe that the JSME can and must play an important role in fostering progress towards such a society.

Accordingly, the underlying goals for the 81st term include the provision of high quality information, the restoration of a vibrant manufacturing sector, and the improvement of the social status of mechanical engineers. With these objectives in mind, we will be undertaking various activities in cooperation with the JSME board, and the respective divisions, branches, and centers. We will also be continuing with the flow of reforms and improvements fostered under the strong leadership Chairman Ito during the 80th term, with the activities to be implemented outlined as follows.

I. Activities for the deployment of mechanical technology through stronger linkages among industry, government, and academia
  (1) Promotion of technology consultation
  (2) Activities for the fostering of new approaches discovered at universities and industries for the revitalization of the manufacturing sector.
  (3) Promotion of national project related tasks consigned to the JSME
  (4) Reinforced public relations activities

II. Activities for the strengthening of member services and the enlarging membership
  (1) Consideration of system structuring to facilitate awareness and concrete results with respect to member participation in Society activities
  (2) Consideration of special Web information for members, and the provision of information from overseas
  (3) Enhancement of the Virtual Overseas Branch for foreign members and members living foreign countries
  (4) Establishment of editorial policies in support of a more useful and accessible Journal
  (5) Enhancement of "junior membership" and related projects involving next-generation engineers
  (6) Expansion of the stage of endeavor available to female engineers, and efforts to increase their numbers
  (7) Enhancement of the benefits and advantages accruing to members

III. Activities for the promotion of engineering education and for the maintenance and improvement of the capabilities of mechanical engineers
  (1) Cooperation with the university level educational program accreditation activities of the Japan Accreditation Board for Engineering Education
  (2) Provision of continuing education programs for engineers.
  (3) Activities in support of internationally valid engineering certification programs

IV. Activities for sound financial management
  (1) Construction of a system for the operation of independent accounting divisions, branches and centers
  (2) Establishment of standards for the calculation

of branch subsidies

V. Reinforcement of links with domestic academic societies and associations

(1) Consideration of enhanced joint research and policy statements by the "Council of Presidents" of domestic academic societies and associations related to mechanical engineering

(2) Consideration of a joint English language publication with other groups related to mechanical engineering

(3) Activities in support of greater "significance for certification" in technical fields

(4) Reinforcement of interdisciplinary linkages

VI. International development strategy (international exchange in response to increased globalization)

(1) Further promotion of cooperative relationships among mechanical engineering societies and associations within the Asian region

(2) Statements emphasizing the importance of mechanical engineering with respect to the "Basic Plan for Science and Technology"

(3) Consideration of projects and policies for an advanced information and aging society

(4) Measures aimed at advancement into new areas

(5) Consideration and recommendation of new evaluation criteria in support of increased status for engineering researchers and engineers

The most urgent issue is the continued decline in membership seen in recent years. One response consists of enhanced member services leading directly to increases in membership, but another more comprehensive approach relates to the promotion by the government of "We Like Science Schools" and "Super Science High Schools", aimed at definitive increases in academic ability in the context of educational reform. Thus, taking a longer view of the situation, I believe that we should work for the enhancement of "junior membership" for next-generation engineers, as well as greater efforts on behalf of female engineers.

Finally, I should like to express my sincere respect and gratitude to the President Yoshimi Itoh and the other officers of the Society who served during the 80th term, as well as to all leading members active at the boards, divisions, and centers. In closing my remarks, I ask for your continued cooperation and support during the 81st term.

Pattern Formation Phenomena Generated in Contact Rotating Systems

Atsuo Sueoka

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Continued from page 1 Here, we call such phenomena pattern formations. It is a matter quite interesting to us all why the polygonal pattern is regularly generated on the surface of roll. The countermeasure for the phenomena has only been taken to change the constituent parts periodically, which means that it is very difficult to clarify the growth mechanism and to take the effective measures of the pattern formations.

The pattern formations are divided into two parts. The one is the phenomenon which is generated on the outer surface of rotating rolls with periodicity of 2π mentioned above, and causes polygonization on the surface of rolls in the circumferential direction and unevenness of the gloss. This type belongs to the pattern formation of regeneration type generated in the systems with time lag, and has the relationship of $f_i \geq n \times f$, where f_i is a natural frequency of contact rotating system, f is rotating speed of roll, and n is polygonal number of polygonization generated on the rolls. The other is the phenomenon which is generated on the constituent parts besides roll in the contact rotating system, and causes wavy deformation and specific pattern. This type belongs to the pattern formation by repetition, and has the relationship of $f_i = V/\lambda$, where f_i is a natural frequency of a contact rotating system, V is traveling speed of roll, and λ is wave length resulting from pattern formation. Examples of this type include corrugation of a rail, wavy wear of an asphalted road, rifling mark in drill cutting hole, chattering of strip in a tension leveler and so on.

Now, we will introduce a few of our recent studies on pattern formation phenomena which belong to the former type.

Polygonization of roll-covering rubber of smoother rolls in paper making machine[1]: The smoother rolls are composed of a pair of rolls called top roll and bottom roll as shown in Fig.1. After a comparatively long period of rotation, the polygonal deformation occurs markedly on the hard rubber surface of top roll which is softer than that of bottom roll, and the rubber is deformed viscoelastically with the polygonal numbers of 4 to 7. As the result, not only strong vibration but also cutting of paper is generated in the plant of paper making machine. Although the large part of the rubber deformation generated immediately after passing through the nip part recovers in one revolution period of the roll, the residual deformation is fed back during reentry into the nip part.

Polygonal wear of automobile tires[2]: The polygonal wear is generated in not driver but follower wheel tires of cars traveling often on the expressway and when the toe-in of the wheel alignments is too large. The tire is deformed almost to the shape of a regular polygon independent of tread pattern of tire and to so-called diagonal wear obliquely to the axial direction of tire as shown in Fig.2. The generation mechanism of polygonal wear caused by the first natural vibration mode of the tire in the vertical direction is treated experimentally and analytically. The phenomenon is modeled as a time delay system accompanied by wear in which the amount of wear of the tire is fed back as forced displacement in the vertical direction after the time period of tire rotation. The progress of the polygonal wear of the tire is very slow and is caused by unstable vibration in the steady-state wear process generated in the limited regions.

Polygonization of elastic yarn rolls in a winder system of textile machine[3]: The winder system of textile machine is composed of two rotating machines with overhung weight as shown in Fig.3, and they are a drive roll as driver and a bobbin holder as follower. The drive roll drives the bobbin holder through the elastic yarn wounded around the paper roll set to the outer circumference of the bobbin holder. It takes about one hour and 30 minutes to wind up the elastic yarn up to final winding thickness of 30mm. The unstable vibration, that is, the pattern formation phenomenon occurs only in a limited range of rotating speed of drive roll and the thickness of the elastic yarn in the winding process, and elastic yarn is then deformed to a polygon with polygonal number of two or three viscoelastically.

Polygonal deformation of work rolls in a reversible hot plate leveler of steel making machines[4]: A hot leveler is located after a hot press rolling mill of thick plate, and corrects various irregular shapes which occur on hot rolled plates. The plates leveled by rolls with polygonal deformation become so called defective products because the profile of deformed roll is transferred to the surface of plate. Therefore, all work rolls must be replaced every three or four months. The polygonal wear patterns are parallel to the axial direction, and rolls are deformed into polygon in the circumferential direction by wear and glossy and non-glossy parts can be seen alternately as shown in Fig.4. A simple model was analyzed theoretically, regarding the polygonal deformation phenomena as unstable vibration of the hot leveler system caused by time retardation accompanied by wear on the surfaces of rolls.

It is not easy to control the pattern formation. Therefore, the constituent parts of the contact rotating system have been changed periodically as a countermeasure, and the control and delayed countermeasures of the pattern formation have not been confirmed. It is a main subject from now on for the pattern formation phenomena to make the interval changing parts longer. We will give the following measures for the pattern formation phenomena:

(1) In the case that the rotating speed of rolls are variable, the pattern formation can be controlled by changing the rotating speed opti-

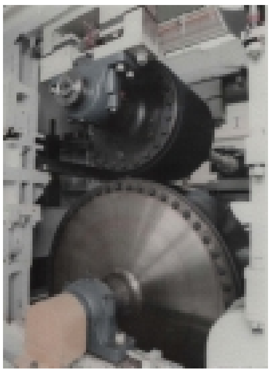

Fig. 1 A pair of rolls covering hard rubber

Fig. 2 Polygonal wear of tire

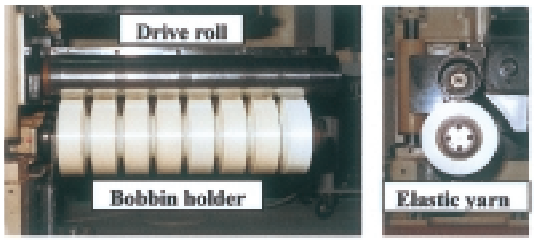

Fig. 3 Drive roll and bobbin holder of winder

Fig. 4 Polygonal wear of work roll in a hot leveler

mally, and the process that makes the pattern already formed disappear can be positively used.

(2) By setting the optimal diameter ratio of a pair of rolls, the growth of pattern formation generated in both rolls can be controlled.

(3) Since the pattern formation phenomenon is a kind of self-excited vibration, the damping is effectively arranged for its suppression. Then, it is necessary to consider that the pattern formation phenomena are easily generated in the vibration modes of higher order with out-of-phase between rolls.

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Research on Smart Structural Systems

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Continued from page 1 The concept of smart material and structural systems attracted the attention of many researchers soon after it was proposed at the end of 1980s in Japan (Figure 1). Since then studies have been performed in various aspects of this field, including structural health monitoring, development of high-performance sensor and actuator materials and devices, smart manufacturing technology for seamless integration of host structures, sensors and actuators, and smart control methods. Large-scale research projects were carried out in USA, Germany and Japan. In this article, the research on smart structural systems carried at the Intelligent Systems Laboratory, Institute of Fluid Science, Tohoku University in the past decade will be introduced.

Since mid 1990s, extensive studies were carried in the vibration control of shell structure using integrated sensors and actuators [1]. Figure 2 shows an example of a cylindrical shell composed of three layers : one polyester film in the middle and two PVDF layers, one on each side. The electrodes on the surface of the PVDF films were divided into several areas so that each area could be used independently. As shown in Figure 2, one area was used as a sensor and two areas were used as actuators for active control of the shell vibration. The amplitude of vibration was suppressed by 90% by using a hybrid control method consisting of feedback and feed-forward controls.

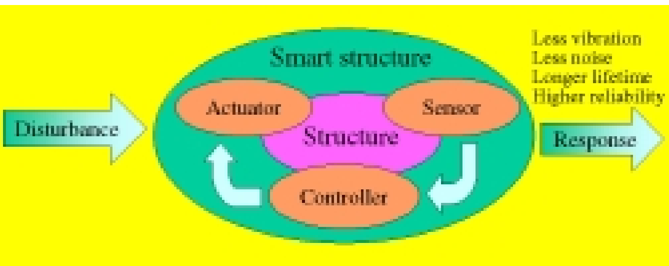

Figure. 1 A smart structural system

The concept of smart skin with actuator functions for boundary layer control was also proposed by the authors (Figure 3). A prototype of the smart skin was fabricated using a magnetic fluid, an elastic membrane and 9 electromagnets. The wind tunnel test results showed that the standing wave generated on the surface of the smart skin can effectively suppress the Tollmien-Schlichting (T-S) wave, which is one of the main reasons for the transition of the boundary layer from laminar to turbulent. Three types of surface motion of smart skins : standing transverse wave, traveling transverse wave and standing longitudinal wave, were proposed and their effectiveness in the suppression of T-S wave were confirmed by numerical simulation [2].

A multi-institutional research and development project on *Smart Materials and Structural Systems*, supported by New Energy and Industrial Technology

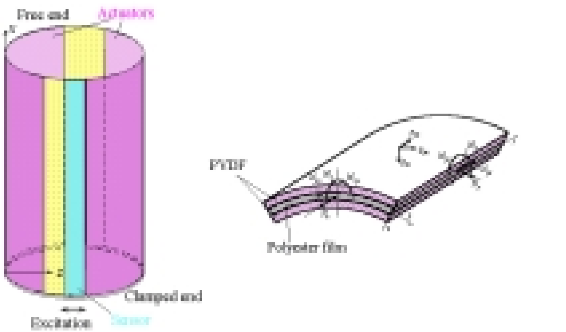

Figure. 2 A cylindrical shell with integrated sensors and actuators

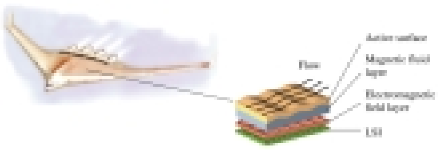

Figure. 3 Smart skin for boundary layer control

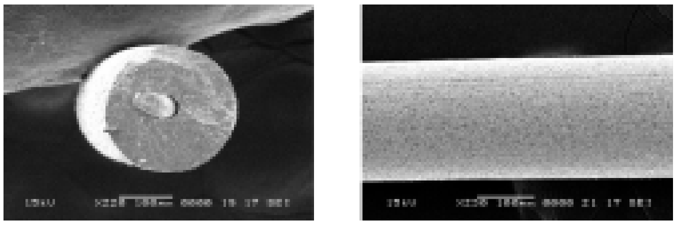

Figure. 4 Piezoelectric fiber with a metal core

Development Organization, was started in April 1998 and finished in March 2003. Seven universities, 3 national research institutes and 17 companies were involved in this research project. The project was carried on the following four fundamental research themes：1) health monitoring technology；2) smart manufacturing technology；3) active-adaptive structure technology；and 4) actuator material and devices. In the last 2 years of the two projects, two scaled aircraft fuselage structures were produced for the demonstration of the developed damage detection / suppression technology and vibration and noise reduction technology [3].

The actuator materials and devices groups, led by Tohoku University and participated by four companies and one research institute, focused on the development of high-performance piezoelectric materials and new devices as well as shape memory alloys for actuator applications. A hybrid sintering process consisting of microwave heating and hot-press was developed for the fabrication of high-performance PZT and PNN-PZT actuators. By using the new sintering process, the piezoelectric constant d_{31} of PZT was raised from 260×10^{-12} m/V to 360×10^{-12} m/V and that of PNN-PZT was raised from 310×10^{-12} m/V to 430×10^{-12} m/V, which is the highest value for piezoelectric ceramics [4].

A new process using the extrusion of a sol and powder mixture was developed for the fabrication of piezoelectric fibers. The process was applied to the fabrication of both PZT and PNN-PZT fibers [5]. It was confirmed by the measurement results that the fibers fabricated using the new process have higher performance than the fibers fabricated using the traditional process of powder and organic binder. A new type of fibers with a metal core was also fabricated by the new process. The diameter of the fibers is about 200 μm and their length can be as long as 10 cm. The photo of a fiber taken by a scanning electron microscope is shown in Figure 4. Since the metal core can be used as an electrode, a single fiber can be used a sensor or an actuator if the other electrode is coated on the outer surface of the fiber. If the coated electrode covers the whole surface of the fiber, a longitudinal deformation can be achieved. If the electrode is coated only on half of the cylindrical surface of the fiber, a bending deformation can be obtained. Moreover, piezoelectric sheets of 20－100 μm in thickness were also developed.

A new type of bending actuator, functionally graded actuator, with similar functions to the traditional bimorph actuators was also proposed and fabricated. The novel functionally graded actuator has graded material properties in its thickness direction. In the practical fabrication, a multi-layer structure was adopted. The piezoelectric constant and dielectric constant were graded with opposite gradients so that the layer with larger piezoelectric constant receives higher voltage. This means that the in-plane strain is graded in the thickness direction so that a bending deformation can be produced with a very small internal stress. It was confirmed by experimental results that the novel bending actuator has much higher durability than the traditional bimorph actuator due to its small internal stress during actuation and the high strength at the interfaces between the layers.

In the first decade of research on smart materials and structures, the studies have been focused mainly on the development of fundamental and component technologies. Recently the research on smart structures has entered the second phase, which put more emphasis on the application of the fundamental technologies developed in the first phase, such as vibration and noise control of aircraft, drag reduction of high-speed vehicles, and artificial organs. The research in this field has also become more diversified. For example, biomimetic materials and structures have also attracted the attention of many researchers in this field. The research on smart materials and structures will certainly promote the future development of technologies in a variety of areas, such as aircraft, high-speed trains, automobiles and building.

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Autonomous Mine Detection Robot for Humanitarian Demining

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Continued from page 1 There are three kinds of demining strategies. The first is a human deminier based demining. The second is a mechanical equipment based demining. The third is a advanced robot based demining. Currently, the most demining approach is the first type. Some limited mine field area are applied by the second type. The third type is now research oriented and expected in future's demining approach.

Under this ultimate environment, a walking robot might be an effective and efficient means of detecting and removing mines while ensuring the safety of local residents and people engaged in the removal work. The six-legged walking robot COMET-II with two manipulators based on the added stability, mobility, and functionality that this platform offers is introduced. Also, the latest robot COMET-III which is a full autonomous robot is presented.

The walking robot COMET-II in Fig.1 has been made. In particular, the two manipulators were developed to attach at the front of the robot. The two manipulators are used for mine detection and the colour paint marking each other. The mine detection sensor has a mixed sensor which means a metal detector and a radar sensor. And, anti-personnel mines and anti-tank mines could be detected by the mixed sensor at the end of the manipulator. The COMET-II has the fast locomotion speed and the speed is 150m/h with searching mines. The mine detecting area is about 300 m^2 per hour. When detecting a mine and a UXO's by such sensors, the GPS based mapping has been made automatically. And then, the mine avoidance walking control algorithm guards COMET-II against anti-personnel mines and UXO's. This is a very important speciality of COMET-II. Also, we have already verified the efficiency by means of walking experiments on rough surface like rough terrain using neuro-based hybrid position and force control. The six-legged walking robot with each leg having three-degree-of-freedom (3DOF) was used to ensure more stable walking on rough ground. The robot has six three-joint legs, each consisting of a shoulder, a thigh, and a shin. The leg mechanism uses a parallel link for the thigh and the ball joint of the parallel link turns the shin. The necessary power received from the power generator using gasoline for long time outdoor operation and from an external power supply for indoor operation. The total weight is about 100 kgf, the width is about 1400 mm, and the only body height is about 600 mm.

High-level motional control and external recognition will be assigned to an external high-speed host

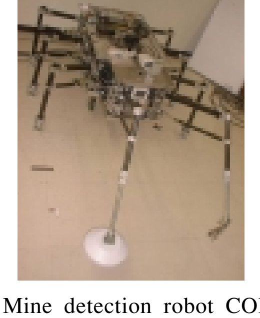

Fig.1　Mine detection robot COMET-II

Table 1 Hardware Specification of COMET-III

Hydraulic Pump	$140kg/m^2$, 17L/min
Engine	653cc, Max Output 22ps/3600rpm Max Torque 4.65kgf/m
Material	Aluminium Alloy, SUS304
Crawler	Rubber Crawler
Hydraulic Tank	40L
Gasoline Tank	20L
Control Valve	26
Thigh Cylinder	ϕ25×250st, Max Speed 280mm/s
Shin Cylinder	ϕ30×175st, Max Speed 300mm/s
Leg Turn	Max Angle ±80°, 69°/s
Weight	Frame+Crawler+Engine+Hydralic Unit=468kg, Legs=32kg×6

computer based on teleoperation. As another equipped devices, a visible-light camera, an infrared camera, an attitude control sensor, two radio transmission /reception antennas for image data, two telecommunication antennas for control commands, six force sensors, twenty four potentiometers, a ground penetrating radar (GPR) sensor and a GPS system with 2cm precision are equipped.

The latest mine detection robot COMET-III has been built. This robot is scaled up from COMET-II. The total weight is about 900Kg, the size is 4m long, 2.5m wide, 0.8m high. COMET-III has 40 litter gasoline tank to continuously work for 6 hours and 700cc gasoline engine like automobile engine to generate DC power supply. Also, COMET-III is mainly driven by the hydraulic power.

The locomotion speeds by walking mode of legs and running mode of crawler are about 600m and 4km per hour respectively. From this walking speed, the mine detection speed becomes 1800 m^2/h. The robot will be able to climb up the slope with 30 degrees using crawler and legs. The payload will be about 300kgf. Figures 2 and 3 show the running control and walking control of COMET-III

The COMET-III has a hierarchy supervisory control system shown in Fig.4. Also, the multitask cooperative control system is applied by SH4 computer systems. The embedding computer system is communicated with the host computer system simultaneously. COMET-III has the mixed array mine detector at the right arm and the marker at the left arm, and almost corresponds to a real machine to mine detection robot in actual mine field. This robot is waterproof and can be working for not only day time but also night time, also all season.

Fig. 2 Running control of COMET-III by crawler

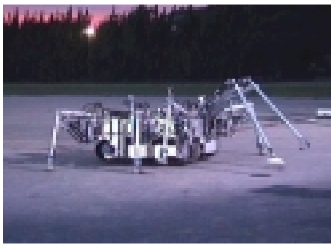

Fig. 3 Walking control with mine detection mode of COMET-III

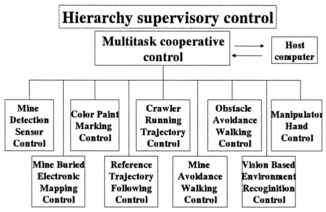

Fig.4 Hierarchy supervisory control of COMET-III

Fig. 4 Hierarchy supervisory control of COMET-III

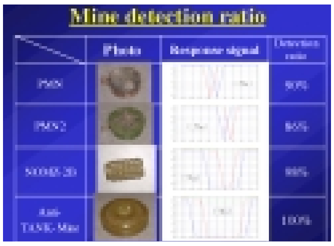

Fig. 5 Mine detection rate against several mines

Figure 5 shows the mine detection rate. We have actual mines which were imported from Cambodia. These mines were buried under the ground in Cambodia. So, we have been carrying out the mine detection test using these actual anti-personnel mines and anti-tank mines. From these results, it is found that anti-tank mines are completely detected by this mixed sensor.

It is not easy to detect anti-personnel mines with 100% reliability. Now, we have been studying to increase the detection rate using neural network learning and pattern matching after database stock. We hope it will be close to 100% for detection of anti personnel mines.

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