Loss of the deep sea remote operated vehicle (ROV), KAIKOU

May 29, 2003,About 130km South East Off the Muroto cape, Kohchi Prefecture

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Following a successful long period survey mission for acquisition of data about the Nankai Earthquake in the Nankai trough, located about 130km South-East off the Muroto cape of Kohchi prefecture, the KAIKOU, a 10,000m class deep sea ROV owned by JAMSTEC, was surfaced successfully but drifted away from the launcher vessel because the secondary cable which connects the launcher and vehicle was severed. Although a search from sea and air of a vast area was started immediately, the vehicle was not found. The severing of the secondary cable was caused by the durability deterioration of the cable. The cause of the failure to locate the vehicle was inadequacy of the recovery system such as lack of a method for confirming the position of the vehicle on the occasion that the secondary cable becomes severed.

1.Event

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2. Course

In May 29, 2003, 9:30 ,The KAIKOU was launched into the water from the deep sea research ship KAIREI at the underwater operation area (fig 1). The courses of this survey is listed below.

11:07 The vehicle was separated from the launcher and started its research survey.

13:12 The scheduled under water operation was completed, and the reeling in of the secondary cable for the docking of the vehicle to the launcher at a depth of 130m was started (fig 2).

13:22 Just before the completion of the reeling in, an abnormal condition of the secondary cable was recognized. The bell-mouth and detaining harness, which under normal conditions should be right under the rubber mold (note: they were taped rather than bonded to the outer sheath of the secondary cable), were visibly confirmed to be lower than usual. Furthermore, a material that appeared to be aramid fiber, a high tensile strength material, fluttered out from the cable, and the naked inner sheath could be seen below the outer sheath. At this point, it was judged that the aramid fiber had become severed (fig 3). The operating officer of the KAIKOU explained the condition to the captain of KAIREI, and considering the worst situation that it would be impossible to dock the vehicle with the launcher, he also informed the captain that there was the high possibility that the vehicle would become separated from the launcher at the site.

13:29 Immediately after cutting off the high power supply to the KAIKOU and confirming that docking would be impossible, the operating officer instructed the captain that the KAIREI should go

forward at 0.5kt speed and the primary cable should be reeled in at a speed of 25m/sec. The ship proceeded to move forward at 0.5 knots taking the course of 120 to 130 degrees according to the instruction. After that, the tools and operating procedure for picking up the separated vehicle and launcher were consulted. The direction finder was prepared on the beacon receiver to use in the case that the vehicle surfaced (fig 4).

16:47 The launcher was successfully retrieved. The secondary cable was recovered before the retrieval of the launcher.

16:48 The beacon from the vehicle was received three times. Although these receptions were confirmed by three operators and the volume of the sound was about the same each of the three times, after that contact was lost.

16:55 The KAIREI increased her speed, returned to the deployment point and started to search for the vehicle. Visual contact of vehicle and beacon reception were attempted. It was judged that the vehicle might have surfaced on the north side of the ship wake according to the ship speed, weather conditions, sea state and current. Therefore, the ship was directed back along the north side of the wake.

17:15 KAIREI reached the original deployment point, but the vehicle was not found nor was the beacon received. The search was continued in a three mile area, which is the twice distance from the submerging point to the lifting point, until 19:40.

20:26 Responding to instructions from the Sea Operation division of JAMSTEC, a buoy with flasher was deployed in order to determine the direction and speed of vehicle.

23:44 The buoy was recovered. The searching area was expanded to the North-East through the search points instructed by the Sea Operation division of JAMSTEC, and the search was continued until May 30th, 06:00.

The search for the vehicle was carried out in the area from the North-East of Muroto Cape to the East of Inubou cape until June 21st using the research vessels KAIREI, YOKOSUKA, NATSUSHIMA, KAIYOU, chartered airplanes, and airplanes from the Japan Coast Guard and the National Aerospace Laboratory, but no clue of the vehicle's location was found.

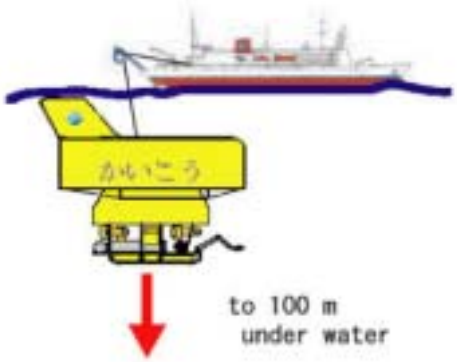

Fig1. Launch (9:30)

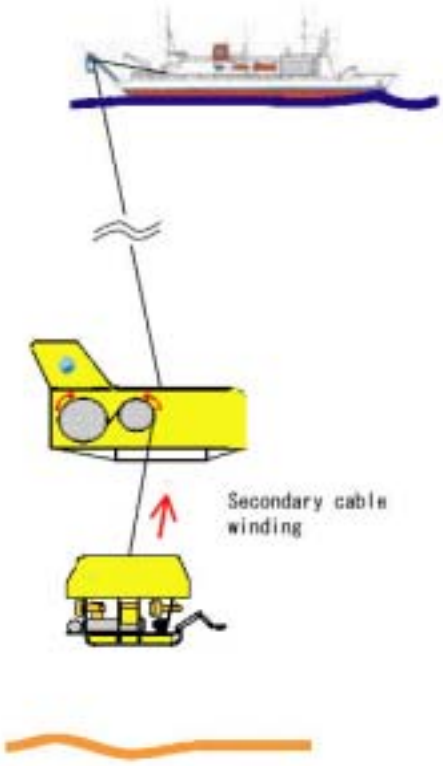

Fig2. Secodary cable winding
(13:12)

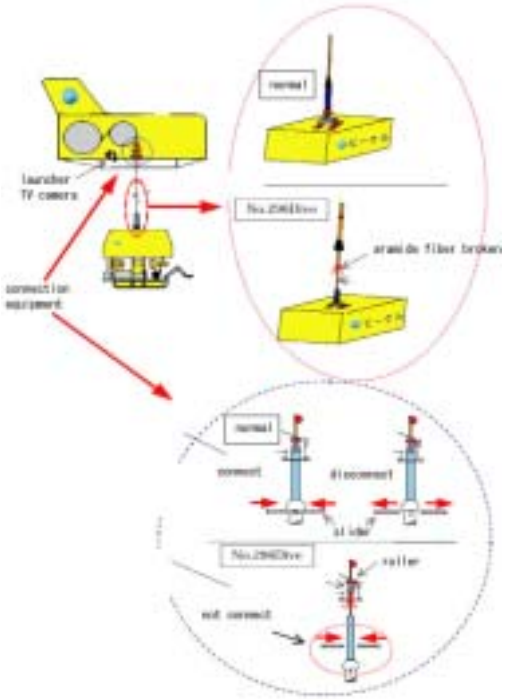

Fig3. Secondary cable annomary (13:22)

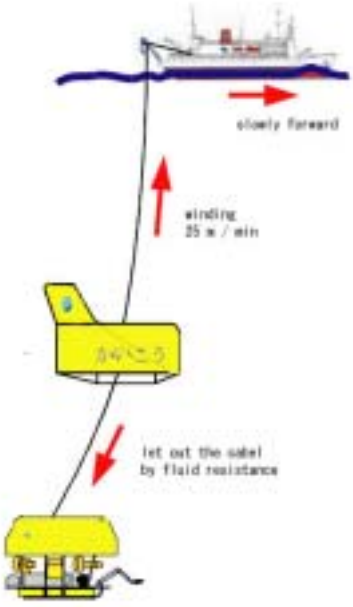

Fig4. Primary Cabel winding
(13:29 ～ 16:47)

3. Cause

1. The damage to the secondary cable
   a. The strength of the aramid fiber around the opening of the sheath near the detaining harness was deteriorated by the normal operation of separating and docking of the launcher and vehicle. It is also considered that insufficiency of the structure of the detaining harness and the high water pressure durability of the cable may have also contributed to the damage to the secondary cable.
   b. The operational blind point was the lack of clear standards for the safety and regulations in the operating manual for maintenance of the detaining harness of the secondary cable.
   c. Despite confirmation of partial damage to the braiding near the detaining harness, the No.0 cable was used without recognizing the importance of damage.

   This No.0 cable was manufactured in July 1996 and had been stored as the reserve cable after being used in 48 operations during 1999. On May 4th, 2003, the No.0 secondary cable was put back into use in order to repair the No.4 secondary cable, the cable that was being used at that time. On May 3rd, 2003, following the 123rd operation of the No.4 secondary cable, the intermediate connecting harness near the detaining harness of the vehicle side of the cable was removed and the mouth area was inspected. It was found that the polyester tape was rolled far up and that nine of the eighteen aramid fiber braids were severed. Accordingly, the No.0 secondary cable was inspected on the same day. Although it was confirmed that the one of the aramid fiber braids was severed, there was no disorder of the polyester tape and the other aramid fiber braids, and the cable seemed to be solid on the whole. Following discussion with the manufacturer, it was judged that with periodic maintenance and observation there was no problem with using the cable for a short period of time. Furthermore, investigation into the cause of the severed aramid fiber braids and establishment of a countermeasure was to be carried out separately. It was confirmed that the No.0 secondary cable was normal through measurements of the electrical and optical characteristics and external visual inspection of the full length of the cable.

   However, during the 51st operation of the cable on May 29th, the aramid fiber braids near the mouth of the detaining harness of the No.0 secondary cable were severed.

2. Inability to recover the vehicle

   Although the vehicle did surface, the operators lost sight of vehicle. The cause of losing sight was that the safety measures taken when the secondary cable was broken were only to release the ballast and deploy the radio beacon. According to the original design of the KAIKOU at the time of construction, a transponder for underwater positioning and a flasher for night operation were to be equipped. However, it was decided that vehicle would be easily spotted and recovered when the vehicle surfaced, so these equipment were excluded in order to reduce the weight of the vehicle and because of budget constraints.

4.Immediate Action

On June 17, a committee, chaired by Professor Tamaki Ura of the Institute of Industrial Science Tokyo University, was established to investigate the cause of the drifting accident of the vehicle KAIKOU resulting from the severing of the secondary cable and establish an appropriate countermeasure. The

establishment of the committee was requested by Mr. Hirano, the chairman of the board of directors of JAMSTEC, who was also the chairman of the emergency countermeasure division for the drifting accident of the vehicle KAIKOU that was established in JAMSTEC on June 2, 2003.

The following subjects were investigated by the committee.

1. The cause of the secondary cable severing.
2. The hardware system of the KAIKOU.
3. The operating procedure of the KAIKOU.
4. The loss of the vehicle KAIKOU.
5. Measures to prevent the severing of the secondary cable.
6. The improvement of the hardware system.
7. The improvement of the operating procedure.

5. Countermeasures

1. A new development procedure for the secondary cable according to the following directions.
   a. The selection of the most suitable high strength materials, including the aramid fiber.
   b. In order to assure that pressure of the high strength fiber level is equalized, the fiber should be soaked with resin.
   c. Design based on reexamination of the structure, detaining method, and other characteristics together with sufficient testing of the test manufactured secondary cable.
   d. Targeting the development of a detaining harness whose end can be processed on the ocean surface.
2. The improvement of the operation of the secondary cable.
   a. It is impossible to estimate the deterioration of the strength from the outer inspection. Therefore, together with the inspection of the detaining harness following each dive, the disassembly inspection and the strength test should be carried out regularly. These operating rules are to be established in the operating manual.
   b. It is possible that a snapping tension might be applied on the secondary cable. Therefore, the 0.2 second sampling interval should be changed to 0.1 seconds in order to obtain the accurate peak value of the tension applied on the secondary cable.
3. The strengthening of the safety countermeasures and the safety management system.

   On the assumption that the secondary cable could be severed, sufficient buoyancy should be maintained and the underwater position during the surfacing of the vehicle should be accurately measured. The following safety countermeasures should be taken in order to guarantee recovery of the vehicle after it has surfaced.

   a. The launcher and the vehicle should have independent power supplies.
   b. Taking into account the effects of breaking waves and water temperature changes, adequate buoyancy should be maintained on the sea surface. A cable cutter should be equipped to dump the pay load in case of emergency.
   c. A transponder should be equipped on the vehicle to obtain the underwater position after the power

supply for the vehicle is shut down.

d. After surfacing, the position of the vehicle should be determined by satellite.
e. The safety equipment should be doubled as much as possible in order to give complete redundancy to the system.
f. A flasher should be equipped for recovering the vehicle during the night.
g. Both a timer and an acoustic system for the emergency dumping of the ballast should be used together.

6. Knowledge

1. If an object is used, it will definitely deteriorate. Clarification of the maintenance standard is indispensable. The accident resulting in death and injury by the steam created by the breach of the cooling tube of the nuclear power plant at Mihama is a typical example.
2. Cutting the budget for safety measures will cause accidents and bring about costly damage.
3. A series of successful operations produces carelessness. The safety measures may be neglected as a result.

7. Background

The KAIKOU was the only deep sea survey system existing in the world able to explore the deepest part of the ocean, a depth of 11,000m. 296 dives were conducted after the construction of the KAIKOU, and new knowledge was obtained in the deepest parts of the ocean where little is known. From the diving explorations, priceless scientific discoveries were obtained such as the discovery of a new variety of bacteria which live under extreme high pressures and insights into the mechanisms of large earthquakes. The KAIKOU made great contributions to society. Its activities had received attention from all over the world.

8. Sequels

The equipment for safety measures was reduced to lighten the system and reduce the budget during the construction of the KAIKOU. However, more importantly proper improvements of the safety measures were not taken because the carelessness that resulted from the ten years of successful operation of the KAIKOU.

9. Reference

[1] The final report for the investigation of the drifting accident of the KAIKOU, prepared on January 19th, 2004 by the investigating committee of the KAIKOU accident