FLUID POWER TECHNOLOGY FOR REMOTE HANDLING AND DEMOLITION IN NUCLEAR FACILITIES

A. Khuperkar, P. K. Mishra, Shiju Varghese, Rites Ranjon and N. L. Soni
Refueling Technology Division

Mr. A. Khuperkar is the recipient of the DAE Young Applied Scientist & Technologist Award for the year 2008

Abstract

Fluid power technology is adopted in various applications where requirements exist for high force/torque along with simple and precise position/speed control, compact overall size etc. Remotely Operated Hydraulic Trolley Along with hydraulic Manipulator (ROHYTAM) was developed for handling some of the emergencies in Pressurized Heavy Water Reactors. Compact Integrated hydraulic circuit is implemented for controlling various actuators of manipulator and trolley. Load sensing scheme of the circuit optimizes pump pressure and flow as per instantaneous load requirement and thus it makes system highly energy efficient. In-house developed micro controller based control electronics has been used for ROHYTAM control. Remote handling of fuel bundle of 220 Mwe PHWR, manual override operation of direction control valves of fuelling machine, nut splitting and opening operation with integrating nut splitter and torque wrench with manipulator have been demonstrated. Concrete tools were also integrated with ROHYTAM. On experimental basis the developed technique was tried out on Dhruva mock-up wall. The complete system was controlled through remotely operated wireless controlled joysticks and through camera feedback.

Keywords: Integrated hydraulic circuit, Electro hydraulic controls, load sensing, nut splitter.

Introduction

Manipulators with hydraulic drives have high load carrying capabilities. Fig 1 shows photograph of remotely operated Hydraulic Trolley along with Manipulator (ROHYTAM). ROHYTAM comprises of hydraulic manipulator with six degrees of freedom is mounted on mobile hydraulic driven platform. Pay load capacity of ROHYTAM at gripper is 50 Kg and at arm end it is 500kg. Manipulator has six hydraulic drives and one linear actuator for gripper opening and closing. Trolley is driven by two hydraulic motors. Electro hydraulic controls of various hydraulic drives of ROHYTAM consist of an integrated hydraulic circuit with various types of valves interconnected in a valve block. The overall size of integrated hydraulic circuit is very compact. ROHYTAM is powered by a power pack and a battery bank mounted on trolley. Indigenously developed microcontroller based control system is used for ROHYTAM.
control. Manipulator and trolley can be wirelessly operated either by a conventional USB joy stick and steering wheel or by soft master manipulator. First time it was tried to develop such type of hydraulic powered, independent unit. Wireless controls are implemented for trolley and manipulator from control room. Different types of end effectors can be integrated with manipulator i.e. nut splitter, torque wrench, tube/pipe cutter, concrete drill, breaker, splitter etc.

**ROHYTAM Technical Specifications**

**Trolley:**

- Trolley size : 1.2 x 2.0 x 1 m. height
- Drive actuator : Two hydraulic motors for front wheels. Rear swivel passive wheels.
- Speed Range : 0 to 0.15 m/sec.
- Direction control : By controlling differential flow to motors.
- Controlling Device : Two joy sticks.
- Power : Self contained battery bank & power pack for both trolley & manipulator.

**Manipulator:**

- Load : At gripper – 50 kg and at arm end it is 500kg
- Drive : Electro Hydraulic Servo / proportional Linear & Rotary Drives.
- Reach : Vertical – ground to 4 m; Horizontal – 1 to 3 m.
- Control Device : Conventional joystick or Soft master manipulator.
- Control System : Indigenously developed micro controller based system is controlling ROHYTAM through wireless communication. Jerk free trapezoidal velocity profile for each actuator Movement,

Control chair for controlling ROHYTAM with joystick & steering wheel.

**End effectors** : By deploying various tools & attachments it can carry out nut splitting, unscrewing, cutting SS tubes, handling components i.e. fuel bundle etc. concrete tools like drill, splitter etc can also be integrated with manipulator.

**Electro Hydraulic controls of ROHYTAM**

The oil hydraulic power pack of ROHYTAM supplies oil to all the actuators of manipulator and trolley drives. The power pack consists of variable displacement axial piston pump. The pump is driven by a DC motor which is powered by a battery bank. The oil supply unit is connected to integrated hydraulic circuit of ROHYTAM through filter. From integrated hydraulic circuit, controlled oil supply goes to individual drive actuators. Load sensing signal from integrated valve block is given to pump controller of variable displacement pump. Load sensing hydraulic circuit makes the complete system an energy efficient unit.

Hydraulic Manipulator of ROHYTAM has three rotary drives and three linear drives. Three linear drives and one rotary drive are with electro hydraulic proportional controls and remaining two rotary drives are with electro hydraulic servo controls. End effector of manipulator has linear hydraulic drive with on-off control with inbuilt circuit provision against power failure. Hydraulic trolley has two rotary drives for its two front wheels with electro hydraulic proportional controls. Trolley movement direction is controlled by giving differential flow to these two hydraulic motors of front wheels. The speed of actuators can be controlled independent of loads on actuators. Further the speed range of each function can be set independently. As hydraulic circuit of ROHYTAM consists of servo valves and proportional valves, the oil cleanliness level is maintained at NAS-5 through a 3μm return line filter and 10μm pressure line filter.
Wireless communication is implemented between control chair (Ref: Fig 2) and ROHYTAM. An Embedded system has been developed in-house for interfacing USB joystick and steering wheel. In this embedded system a general purpose MCU and an IC having USB host controller capabilities has been used. The firmware has been developed to implement the USB specifications and to communicate with the remote equipment. This embedded system target HID class of USB devices. It enumerates both the USB devices, checks their capabilities and receives input control signals from them, in real time. These input signals are analyzed, parsed and converted in to an array, which is transmitted through a wireless modem using Modbus protocol for controlling ROHYTAM. The control signals are RS232 signals. This is transmitted using wireless 2.4 GHz Modem from M/s Microband systems Inc. Wireless Cameras transmitting the video signals to the control room (2.4 GHz).

Master controller of the ROHYTAM receives control data packets from the control chair. This data is parsed and send to various micro-controller based controller cards indigenously developed. Each controller card is implemented with control algorithms and trapezoidal velocity profile implementation. This gives smooth positioning of each actuators of the ROHYTAM.

**ROHYTAM Operations**

ROHYTAM was commissioned along with its hydraulic and electronic controls in fluid power lab, BARC. Trials were conducted to verify the functioning of various drives of ROHYTAM. Subsequently following operations were demonstrated using ROHYTAM.

- Handling of PHWR fuel bundle accidentally fallen during handling on fuelling machine vault floor etc. (Ref: Fig 3)
- Actuation of stuck up solenoid valve i.e. manual override operation of direction control valves of RAPS 1 & 2 type fuelling machine.
- Nut splitting operation using nut splitter to dismantle flange joints of pressure vessels; heat exchanger etc in an inaccessible area.
- Large size nut opening operation using torque wrench, e.g. fuelling machine Graylock clamp nut.

These operations were tried and demonstrated successfully in fluid power lab, BARC. Further improvements in ROHYTAM and its electro hydraulic controls are going on to make the system more sophisticated in terms of accuracy and ease in operation.
For demonstration of remote operation of concrete tools, concrete drill attachment and its hydraulic circuit was integrated with ROHYTAM. All the operations of hydraulic manipulator, trolley and attachment for concrete tools were implemented from control room. Twenty numbers of through holes were successfully drilled in the Dhruva mockup wall having a thickness of 750-800 mm in very short time as compared with manual drilling. (Ref: Fig 4).

**Conclusion**

Remotely operated hydraulic trolley along manipulator has been successfully developed for handling heavy loads and forces. Compact load sensing integrated hydraulic circuit and wireless electronic controls with conventional joystick empowers ROHYTAM to meet the intended functions. Control system of ROHYTAM is with in-built safety features. ROHYTAM has demonstrated its capability of handling anticipated emergency in fuel handling system of PHWR. Further improvements in ROHYTAM are in progress for enhancing its capabilities. Development of ROHYTAM can be extended for decommissioning activities in future for nuclear facilities.
Acknowledgement

Authors are thankful to Division of Remote Handling and Robotics for manipulator design.

References

