Case study on major fire incident due to failure of crude booster pump

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1.0 THE INCIDENT:

A major fire broke out in Crude Distillation Unit of a refinery. As per eye witness, initially the fire was around the crude booster pumps. Subsequently, the fire engulfed instrumentation & electrical cables, pipes in overhead pipe racks and heat exchangers in CDU.

At the time of the incident, 02 booster pumps (276m 3/hr. capacity each) were in operation. During site visit, it was observed that the pump casing was totally damaged and torn into two pieces; dislodged towards the suction side by about 8 inch. The impeller was found detached from the shaft. The pump casing is made up of carbon steel, A-216 WCB.

The fire lasted for about four hours and caused extensive damage to all the 03 crude booster pumps, technological structures, pipe racks with piping, insulation, electrical and instrument cables are damaged due to fire. However, there was no injury / loss of life due to the fire incident.

2.0 SITE VISIT & OBSERVATIONS:

- Prior to the fire incident, the unit was running at a normal throughput of 350 M3 / hr.
- The crude booster pumps were taking suction from the flush drum at a temperature of 179 degC. The discharge pressure of booster pump was 31.5 Kg/Cm2. The normal load of the motor was 44 – 45 A (full load 56 A).
- During the discussion with field operators on duty, it revealed that there was an explosion in the early morning hours (end of night shift).
- The shift in-charge after getting the information of fire, took action for emergency shutdown of the unit. The furnace was tripped from the control room. However, since there is no facility to isolate crude / product lines from control room, the lines were isolated manually, which is time consuming.
- The power supply to the unit was switched off from the substation by electrical personnel.
- The fire continued for more than four hours due to burning of the hold-up liquid in the flash drum, crude and product lines.
- Subsequently, fire spread to the nearby areas leading to major fire and consequential damage to pipe, fittings etc.

- The failed crude oil booster pump, at the time of the site visit, was not shifted to mechanical workshop and dismantled.

- The other observations/ inferences are as under:

    a. Casing of crude booster pump was totally damaged & torn into 02 pieces.

    b. The casing plate was cut circumferentially; there is no welding joint in the casing at the location of failure.

    c. The thickness of the casing at the detached / cut location throughout the circumference is about 1.0 mm.

    d. Such failure of the casing plate into two pieces is a clear indication of mechanical failure of the casing due to rubbing of impeller against the pump casing.

    e. No significant internal corrosion was observed in the casing plate in general.

- All the three booster pumps and motors were affected due to fire. Technological structures of piping rack were also found severely damaged (Refer to photograph in Annexure-I).

- Process piping on the overhead rack like vacuum residue, kerosene, flushing oil, safety valve discharge line and HGO lines were opened up due to impact of the fire.

- Instrumentation and electrical cables of the nearby area were found fully burnt and damaged.

Burnt Instrument & Electrical cables

3.0 DISCUSSION:

- DCS records prior to the incident indicate unit was in normal operation. The graph showing crude flow rate, pressure, temperature and level of flush drum was steady. During the fire, the instrument and electrical cables which were passing through near

the crude booster pumps got burnt & thus there was no indication to control room / DCS after the fire.

- The failed booster pump was running at a pressure of 31.5 Kg/Cm2 and 179 degC temperature; sudden release of crude to atmosphere at this condition resulted in a major fire and explosion.

- The history of the booster pump indicate the problem of high vibration and shaft jamming for which the pump was taken to mechanical work shop for repair/ maintenance. Subsequently the pump was taken on service & since then the pump was running.

- The failure / loosening of the Lock nut allowed the impeller detached; it moved towards the suction end (casing side) by the hydraulic pressure on the back of the impeller. This resulted in significant rubbing action of the impeller against the pump casing plate; the impeller acted like a cutting tool that cut the casing plate circumferentially into two pieces. This would have resulted in very high noise around the pump and high current.

Casing plate of crude booster cut circumferentially by rubbing action of impeller.

As a result, the impeller of the pump got detached due to shearing of the shaft near the lock nut. The friction between impeller and the casing is a possible source of spark generation to ignite the crude oil.

Detached Impeller from the shaft

- Failure of Lock nut of the Impeller is due to any one or combination of following :

  (a) Axial vibration resulting in Load on the Lock nut leading to its failure.
  (b) Inadequate tightening torque on the Lock nut at workshop during the overhauling.
  (c) Integrity failure of the washer of the locknut or thread damage.

- It was also gathered that there was vibration of the suction piping connected with the pump which caused significant stress on the pump and contributed for the failure.

- Incidentally, there is no record of tripping of motor. The motor did not trip on overload during rubbing / cutting action of casing plate by the impeller. This indicates that the existing trip logic of the motor and trip current setting is faulty.

4.0 **ROOT CAUSE ANALYSIS OF THE INCIDENT:**

1) The root cause of the major fire is the failure of Lock nut of the Impeller. Failure occurred due to any one or combination of following:

   (a) Axial vibration resulting in **Load on the Lock nut** leading to its failure.
   (b) Inadequate **tightening torque** on the Lock nut at workshop during the overhauling.
   (c) **Integrity failure** of the **washer** of the locknut or thread damage

   Failure of the nut caused the impeller to move towards the suction end (casing side) and touch the casing plate by the hydraulic pressure on the back of the impeller. **This resulted in significant rubbing action of the impeller against the casing plate and the impeller acted like a cutting tool to cut the casing plate circumferentially into two pieces.**

2) Vibration of the piping connected with this pump.

3) The motor also did not trip on overload during cutting action of casing plate by the impeller. Therefore, the motor trip logic and trip current setting was not proper/ faulty.

5.0 **RECOMMENDATIONS/ LEARNINGFROMTHE INCIDENT:**

1) During pump overhauling, through inspection of the locking arrangement of the impeller with the shaft must be done to check for any deterioration or abnormality. It is to be ensured that impeller locking is done with appropriate torque and the same must be properly supervised for all critical pumps.

2) Preventive /predictive maintenance of pumps to be strengthened to avoid such incidents.

3) The motor trip logic and trip current setting must be looked into so that in case of any overloading, the motor is tripped automatically.

4) Vibration of the suction piping connected with the pump must be eliminated.

5) Periodic checks and vigil by field Operator during normal shift and shift change over time is essential to take timely corrective action.

6) A detail analysis of the pump failure is to be done in consultation with the OEM and other technical experts for establishing preventive / predictive maintenance procedure and actions to avoid such failure.

7) To minimize the adverse consequences from such incident, quick isolation at the suction of such critical pump is required thru ROV operable from field / control room.