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Study of Oxygen Blowing Lance and It's Drive Mechanism in LD Converters

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Abstract

The project deals with the Study of Basic data of converters in steel making conditions, oxygen blowing lance system characteristics and preparation, observations to be done during lance leakage test and Failure analysis for free fall of oxygen lance drive in L.D Converter. Steel plants produces steel employing three numbers of top blown oxygen converters called LD Converters. Hot metal contains different impurities above safe level which make pig iron brittle. Refining is done by blowing oxygen in LD converter charged with hot metal, scrap, flux, iron ore, etc. In this refining process, Oxygen gas, the refining agent is fed to the furnace through a water cooled lance, which is driven by a sprocket drive mechanism. But steel is nothing but refined hot metal. During this process of blowing, the lance gets with full of slag attaching to it creating jam in the thimble gate of converter while hoisting of lance, which makes the lance failure and drive sprockets mechanism.

In this paper an attempt has been made to measure the failure analysis for free fall of oxygen lance drive in L.D Converter and to point out possible reasons for the formation of slag in converter.

Introduction

Oxygen gas – the refining agent – is fed to the furnace through a water cooled lance. It consists of three concentrically arranged steel tubes with connecting branches for metal- flexible-hoses. Central pipe is for supplying oxygen, intermediate pipe is for incoming cooling water and outside pipe is for out going water. At lower part of lance there are 5 nos. Convergent-Divergent copper nozzles symmetrically arranged at 17.50 to the lance axis. Since the tip of the lance is exposed to a very high temperature, water cooling is made more effective over there by using a copper tip which is welded to the steel pipe.

The tip of the lance has five or more nozzles. In general multi hole lances are preferred because of high ability to distribute oxygen over a much larger area.

The lance is raised and lowered by an electrically operated chain drive. The movement and oxygen flow rate are controlled from the control room blowing desk.

Characteristics of OXYGEN BLOWING LANCE:

- Lance travel = 15000 mm
- Oxygen working pressure = 16 KSCG
- Water working pressure = 12 KSCG
- No. of nozzles = 5
- Water consumption = 130 cu.m/hr
- Oxygen flow rate = 400-450 NM^3/min

During blowing, LD gas is generated. This is a very poisonous gas because its main component is carbon monoxide. LD gas cooling, cleaning and controlling system comprises of tube bar-tube type skirts, gas cooling hood and stack, closed loop type gas arrangement with fin fan cooler, kimpactor, gas duct, ID fan, change over valve, flare-stack, gas holder etc.

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When the gas composition is acceptable, it is recovered and collected in gas holder.

BASIC DATA OF CONVERTERS

Steel Making Conditions

Effective volume, Cu. M 133
Converter Specific Volume, Cu.m / t 0.886
Mouth diameter inside lining, mm 2700
Drive installed capacity, KW 4 x 172
Weight of converter lining including bottom lining And other masses, t55
Thickness of working lining, mm-bottom 780 + 125 =905
Weight of lined shell with trunnion ring and bottom, t 849
Weight of lined bottom, t 60
Thickness of safety lining at bottom, mm 115
Thickness of bottom castable at centre, mm 80 – 120
Thickness of working lining in barrel (single brick), mm 700
Thickness of safety lining at barrel, mm 230
Thickness of working lining at top cone, mm 650
Thickness of safety lining at top cone, mm 125 LD I & III

230 LD II

Speed of converter tilting, rpm

------------------maximum 1.0
-----------------minimum 0.1
Oxygen flow rate through lance,
N Cum/t (max) 600
Blowing intensity, N Cum/t (min) 4.0

Lance movement speed, m/sec

----------------maximum 0.88
---------------minimum 0.2
Lance Travel, mm (approx) 15000
Converter lining life, heats 2400-2700
Duration of stoppage of converters for relining and heating, hr 180
Level of liquid steel (new lining), mm +8290
Level of liquid steel (eroded lining), mm +7630
Level of OXYGEN BLOWING LANCE thimble, mm +23000

OXYGEN BLOWING LANCE SYSTEM

Oxygen working pressure, Kgsc 15-16
Water working pressure, Kgsc 12
Oxygen consumption, cum/min 600
Water Consumption, Cum/hr 130-150
Oxygen purity 99.5 %

Slag Splashing Details

Equipment - blowing lance
Medium - nitrogen
Flow, N Cum/min (Max) - 600
Flow, N Cum/min (Normal operating value) 500
Pressure, Kgsc after PRV (Max)=15
Pressure, Kgsc (Normal) =12
Duration of splashing, minutes =4

Raw Material Conditions

Converters are being charged with hot metal of the following composition

C	4.5%	max
Si	0.5%	max average 0.4% - 0.3%
Mn	0.15%	max average 0.11
P	0.12%	max average 0.11
S	0.05%	max
Temp	1250-1420 ^{O}C	

Sized scrap is used as the basic coolant in converters while blowing. Iron ore of size 15-60 mm is being used as additional coolant. The chemical analysis of iron ore is as follows

Fe	66.9%
SiO_2	0.9%

Al_2O_3	1.6%
MnO_2	0.05%

A mixture of burnt lime and calcined dolomite is used as flux having the following composition

CaO + MgO	90-92%
SiO_2	2-2.5%
S	0.06% max
P	0.10% max
LOI	5-7%

DESCRIPTION OF CONVERTER SHOP

+ 8.5 Meters - Converter Shop

Entry to + 8.5 meters level of converter shop is by a ramp at Non-PP side at the SMS Lab end. On the right, immediately at entry of ramp is the Ferro Alloy Handling unit, served by a 10/5 Ton E.O.T crane. This level has 3 bays between row A and Row C and columns from 1 to 12. Column 1 is at the Lab end and Row C is toward CCD side. The bays are A-B , B-B/C, and B/C-C. Operator rest rooms are located on this level between columns 9 to 12 at the C-row side.

There are control pulpits beside each LD at the non-drive end of Converter. Pulpit on CCD side is called as Slagging pulpit and pulpit on Slag yard side is called as Tapping pulpit. Slagging pulpit houses control desk for LD tilt and SPTC. Tapping pulpit houses controls for LD Tilt, STC.At the tapping side of each converter at Row - C, there is a master pulpit for SCD. Blowing controls are provided at +8.5 m elevation for each individual converter control rooms.

Sampling Car:

An electrically propelled Sampling car is provided at the slagging side of each LD, for facilitating Bath Temperature measurement and collection of steel / slag bath samples.

Service Car:

An electrically propelled Service car is provided at the tapping side of each LD for tap hole replacement / repairs, gunning and other misc. activities.

Mobile Equipment:

Gunning machines and De-bricking machines are stationed on this level for lining repairs and jam removal.

Slag cut-Off Device:

Slag cut-off device for each converter is operated from this level, at the tapping side of each converter.

+18.5 Meters - Converter Shop

This is the second level of converter shop which can be accessed both by Staircase and by Freight Elevator. Following are the major sub-systems at this level:

1. Ferro-alloy charging system (FACS) for each Converter and its PDB rooms
2. GCP Recycling water pumps.
3. Skirt and Hood Transfer carriage motors.
4. FACS Telfers (5T) - 2 nos per LD.

The FACS vibro-feeder panels and jaw gate solenoid control is located in the FACS 'Macmet PDB' room. PDBs of LD-1&2 are contained in one room while that of LD-3 is separate. There are 4 FACS storage bunkers and 2 FACS Telfers for each Converter at this level. Access to Hood bottom closing device (HBCD) and its light fitting is also from this level.

+25.0 Meters - Converter Shop

Subsystems on this floor are:
Nitrogen Purging valve station, (GCP - ACDB, 1RC1 & 1RC2)
Surge Hopper Bottom Gates, Fin fan coolers, C0-120, Lime fines control room, Lime fines MCC,

+32.5 Meters - Converter Shop

The following Converter related sub-equipments are located on this Floor:

- Weigh Hopper Sector Gates (WHSG),
- Surge Hopper Top Gates (SHTG)

+38.0 Meters - Converter Shop

Sub-equipments on this level are:
1. Vibro-screens,

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2. Baffle separator,
3. Kinpactor

+44.0 Meters - Converter Shop

Important equipment on this floor are:-
1. Electromagnetic vibro-feeders of Bulk material charging system.(7 nos. per LD)
2. Vibro-feeder control panels
3. Motorized vibro-feeders and its control panels of Ladle Lime addition system.(Installed in LD-3 in Dec-2005)

+54.0 meters - Converter Shop

It is the top-most floor of converter shop with access to top of Flux Storage bunkers, catering to all 3 LD Converters. Reversible Shuttle conveyor CO -106 feeds material into these Bunkers. The drive end of CO -101 discharges material on to CO -118, which in turn discharges material on to CO -106.

Operator Access to 50T and 10T Lance handling cranes are at this level

- Water consumption = 130 cu.m/hr
- Oxygen flow rate = 400-450 NM^3/min

LANCE DESIGN :

It is known that the supersonic jet coming from the nozzle of a lance in a L.D process should penetrate the bath adequately and that the area of its impact on the bath should be maximum. These conditions are essential for efficient refining, i.e. for decarburization as well as dephosphorisation.

The static pressure in a jet from a cylindrical nozzle, as it emerges into the ambient atmosphere, is more than the atmospheric pressure. It, therefore, interacts with the atmosphere generating shock waves and the velocity of the jet decreases with damped fluctuations.

This affects the bath penetration as well as area of impact adversely.

Much of these drawbacks are eliminated if a convergent divergent shaped nozzle is used. The static pressure in a jet from a convergent divergent shaped nozzle disappears within a short distance from the nozzle tip and hence it does not interact much with the ambient atmosphere. The velocity of the jet decreases more uniformly with much less of damped fluctuations, if inside and outside

Diameters of the nozzle are properly designed. The velocity at any point in the stream is more than at the corresponding point of the stream from a similar size cylindrical nozzle under similar conditions of blowing. The resultant bath penetration is more in case of convergent-divergent shaped nozzle than that from cylindrical nozzle. The convergent-divergent shaped nozzle is, therefore, universally adopted.

Oxygen is generally blown at 8-10 atmospheres pressure through a convergent-divergent shaped nozzle so that the jet issuing at the nozzle exit is supersonic and generally has a velocity between 1.5-2.5 times the velocities of the sound (Mach). The characteristics of a supersonic jet, as emerging from a convergent-divergent shaped nozzle has characteristically a potential core, a super sonic core and a subsonic region. As the jet travels, its velocity is retarded due to the ambient atmosphere, the supersonic surrounding zone expands radially. The potential core may normally extend, to a length of about 15 times the diameter of the nozzle from the nozzle tip. The velocity of the supersonic core gradually decreases until at a distance of about 30 times the nozzle diameter from the nozzle tip, the jet becomes wholly subsonic. This point marks the end of supersonic core and the development of fully expanded jet. The velocity of the jet decreases hereafter more rapidly.

For a given size of nozzle the length of the supersonic core depends on the blowing pressure and the ratio of the densities of the jet-gas and the ambient atmosphere. Although the densities of the ambient atmosphere in the L.D process changes during the

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blow, an average value is assumed to calculate the length of the super sonic core.

During the blow the jet should be expanded to obtain maximum impact area at the bath surface. At the same time, it should also penetrate the bath surface to a maximum extent. The depth of penetration of a jet in a metal bath varies inversely with impact area at the bath surface.

In the blowing position the lance height from the still bath level has to be more than the length over which the supersonic core extends in the jet, since the jet is not fully expanded until that point. In actual practice the proper height would be around 40-50 times the diameter of the nozzle.

The depth of penetration of a jet in a bath can be assed in terms of the jet force number as:

$$JFN = \frac{\text{Gas pressure X Nozzle throat diameter}}{\text{Height of nozzle}}$$

It may be mentioned here that decarburization is faster for greater value of JFN and de-phosphorisation is faster for reverse condition.

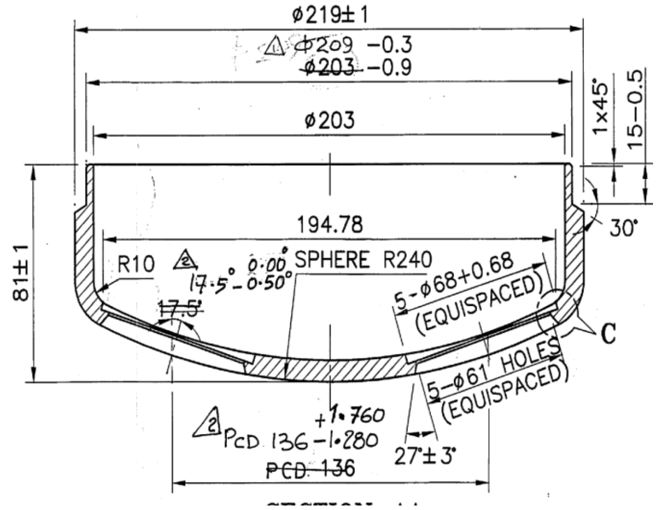
The gas flow rate from a nozzle can be calculated by assuming a frictionless and adiabatic flow through the nozzle. The jet behavior does not alter adversely even if the actual flow rate deviates by ± 20% from this nominal value.

Lance life is usually determined by the life of the nozzle. Failure of the lance may be due to faulty cooling, manufacturing defects, internal stresses differential expansion of tip and steel tubes, etc.

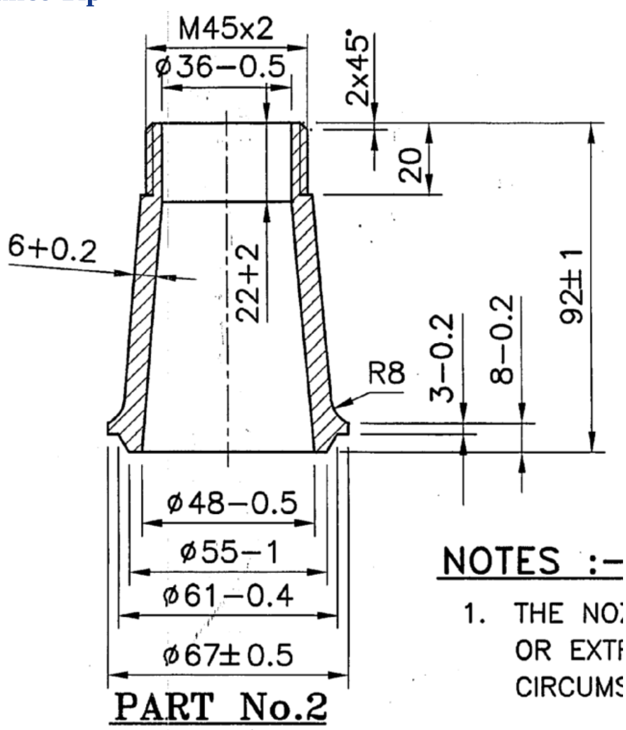
TECHNICAL DETAILS:

OXYGEN BLOWING LANCE TIP (5 - 36 DIA - 17.5 DEG) :

S.NO	DESCRIPTION	DIAMETER	LENGTH
1.	TIP (copper portion)	219	80
2.	NOZZLE	36	92
3.	COUPLING	152	91
4.	SHELL(M.S)	219	195



Lance Tip



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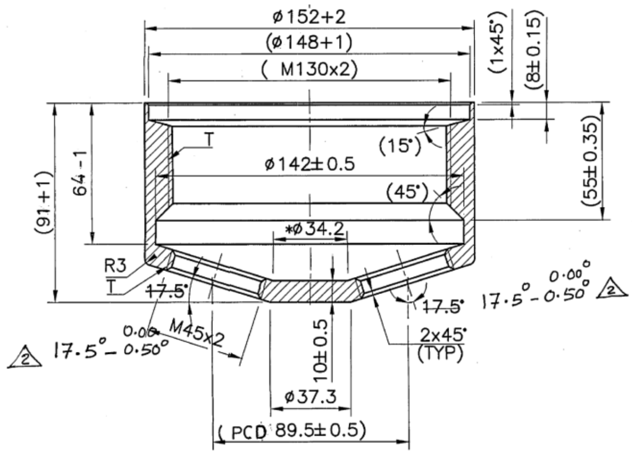
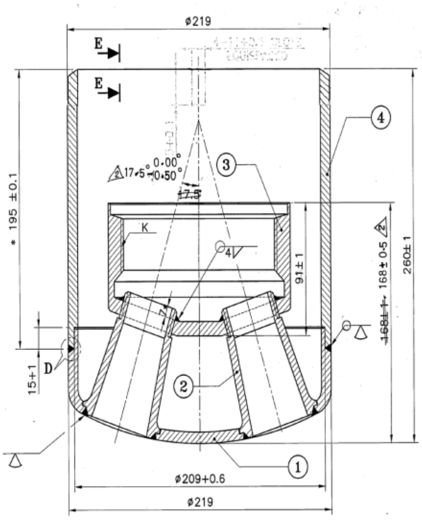
2.NOZZLE



3. LANCE COUPLING



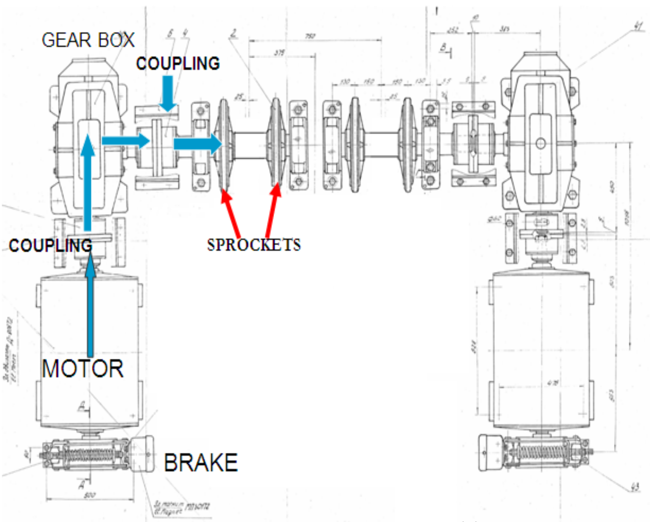
COUPLING HEAD ASSEMBLY

4. COUPLING HEAD WITH SHELL

SPARE PARTS OF OXYGEN BLOWING LANCE:

1 WATER OUTLET PIPE DIA (219X10)
2 WATER INLET PIPE DIA (180X5)
3 OXYGEN PIPE DIA (140X5)
4 STUDS (OUTER PIPE) (16X110)
5 GRAPHITE ROPE (10 MM)
6 BOLTS AND NUTS (16X90)
7 OXYGEN COUPLER
8 LANCE TIP NORMALLY 5 NOZZLE 17.5 WERE USED.SOME TIMES OTHER TIPS ARE ALSO USED ON TRIAL BASIS AS PER THE REQUIREMENT OF OPERATION.
9 COUPLER GASKET
11 OXYGEN HOSE SEGMENTS(MIDDLE)
12 WATER HOSE MIDDLE SEGMENT
13 WATER HOSE END SEGMENT CLAMPINGS
14 SLINGS (12X2 MTS)
15 OXYGEN CLAMPS
16 WATER CLAMPS
17 WATER OUTLET REDUCERS
18 CHAN WRENCH (SMALL)
19 SS ELECTRODES (2.5MM)
20 SS ELECTRODES (3.15MM)
21 MS ELECTRODES (3.15MM)
22 ELBOW END WATER INLET FLANGES
23 ELBOW END WATER OUTLET FLANGES
24 ELBOW END OXYGEN FLANGES

SCHEMATIC SKETCH OF LANCE DRIVE ARRANGEMENT:



LANCE DRIVE ARRANGEMENT

PREPARATION OF OXYGEN BLOWING LANCE:

REQUIREMENT OF SPARE PARTS

- OXYGEN PIPE seam less (140mm X 5mm)
- WATER INLET PIPE seam less (180mm X 5mm)
- WATER OUTLET PIPE seam less (219mm X 10mm)
- OXYGEN ELBOW (hot bend --152mm X 5mm)

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- WATER INLET ELBOW (fabricated - 146mm X 5mm)
- WATER OUTLET ELBOW (fabricated- 146mm X 5mm)
- OXYGEN PIPE END COUPLER(120MM)
- COUPLER GASKET(Rubber)
- LANCE TIP 195MM (5 NOZZLE 17.5 DEG)
- CHAIN WRENCH
- GRAPHITE ROPE (10MM)
- BOLTS (M16X90)
- STUDS FOR GLAND PACKING(M16X110)
- ELBOW FLANGES
- CLEATS

EQUIPMENT REQUIREMENT

- OXY ACETELENE GAS CUTTING MACHINE
- WELDING MECHINE
- EOT CRANE

PROCEDURE FOR LANCE FABRICATION:

- Welding of oxygen pipe up to length 17.64mts from sitting flange
- Welding of coupler(120mm) to oxygen pipe end
- Leakage test with water by fixing dummy to coupler.
- Welding of water inlet pipe 15-20mm more than oxygen pipe (including coupler)
- Maintaining of concentricity between oxygen & water pipe by welding of small cleats between them
- Required length of outer pipe is tobe fixed and welded
- Place the coupler gasket . oxygen coupler will have normally 23 threads. place the tip on coupler and make a marking for counting.tighten the tip on coupler by counting . ensure full tighten with help of chain wrench.
- Weld the lance tip to outer pipe.
- Pressure testing of lance is to be done for any leakages.
- Tightening of gland bolts at elbow flanges is to be done if any leakage is observed.
- Replace the gland rope ,even if leakage was not arrested after tightening.
- Final leakage test with pressurised water 12 kg/cm2.

OBSERVATIONS TO BE DONE DURING LANCE LEAKAGE TEST:

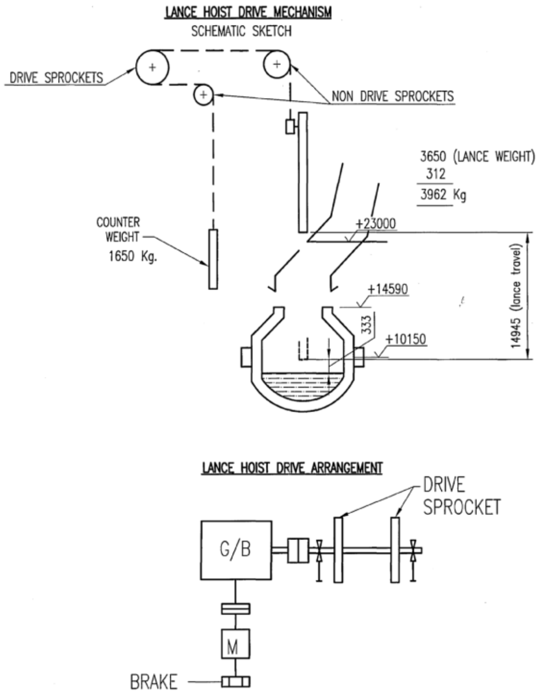
GLAND LEAK: If gland is leaking, gland collar has to be tightened further even then if it doesn't get arrested then change the gland packing.
New graphite rope (10mm) between the glands.

ELBOW PIN HOLES: Identify pin hole and weld the particular area. Replace the elbow if required.

OUTER PIPE PIN HOLES: Identify pin hole and weld the particular area.

TIP LEAK: Remove the tip and replace with new coupler gasket and lance tip

SCHEMATIC SKETCH OF LANCE HOIST DRIVE MECHANISM:



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FAILURE ANALYSIS FOR FREE FALL OF LANCE

Calculation of shearing Torque:

Considering drive shaft

Specified material EN18-40Cr4-Shear Strength I=400N/mm^2

EN24-40Ni6Cr4Mo3 Shear Strength I=550N/mm^2

Considering Coupling Key on the non-drive side

Coupling key shearing area = 110×22×2 (Considering two key way)

= 4840mm^2

Assuming key material as 45C8 IS: 5517-93

Shear strength of the key =380N/mm^2

Coupling key shearing force = 4840×380×/1000 = 1839.2 KN

Shearing Torque =1839.2× 40× 10^{-3} = 73.57 K-Nm

Assuming Single key (As original Design)

Shearing Torque = 2420 × 380 × 40× 10^{-6} = 36.78 K-Nm

Conclusion:

Torque carrying capacity of shaft at 80 diameter is the weakest link in the drive failing at 40.2KN-m

Technical Details:

Motor:

Power =34.5KW

With a maximum torque capacity of 227 %(as per data obtained from sms electrical)

Speed = 575 rpm

Voltage = 220V – 400V

Gear Box:

20.6 KW rated power

16.33 reduction ratio

3- No of start

Z2/Z1=49/3

m=10

G/B output shaft = 90mm

Sprocket shaft input coupling diameter = 80mm

Lance:

Length/height of travel =14945mm

Position of dead weight at lower position =687mm(From bottom of Guide.lower position)

Position of carriage at lower position = 325mm (from bottom of Guide)

Lance top clamp

a) When lance at Top: 40770mm level

b) When lance at Bottom :25825mm level

Lance carriage length =2180mm

Lance timple top level =2300mm level

Lance bottom when carriage at bottom =8755mm

Calculation of initial drive torque required for lance operation

F=ma

F= 3962 × 9.81

= 38514.06N

Lance Hoisting :

Considering friction loss negligible

Radius of the drive sprocket =220.315mm.

Torque required for lance hoisting

= 38514.06×220.315

= 8.485×10^6 N-mm

=8.485KN-m

Lance Lowering

F= 1650 × 9.81 = 16186.5N

Torque required for Lance lowering

=16186.5 ×220.315

=3.565 ×10^6 N-mm

=3.565KN-mm

Calculation of power requirement (During start of hoisting)

Considering Lance speed as 0.88 m/s

$V=\pi DN/60$

$N=V\times 60/\pi\times 0.44$

=38.197rpm

Power Required = $2\pi N(T_{Max})/60$

$=2\pi\times 38.197\times 8.485/60$

=33.93KW

Calculation of Running drive torque required for lance operation:

Lance lowering: (ie. Counter weight going up)

Initial drive torque = motor output torque × 16.33

Load torque = torque required to lift counter weight +frictional torque on sprocket &chain

= 3.565KN-m+frictional torque(not known)

Subsequent load torque =(3962 - 1650) × 9.81

= 22680.72N

Running torque required = 22680.72 × 220.315

= 4996.9 × 10^3 N-mm

= 4.99KN-m

Frictional torque may be = 4.99 - 3.565

= 1.425KN-m

Lance hoisting (ie. Counter weight coming down)

Drive torque = motor output torque +16.33

Torque required

= 8.485 KN-m+ frictional torque (1.425)

= 9.910 KN-m – 3.565

Running torque required = 6.345KN-m

Calculation of torque generated during free fall of the lance over carriage:

Assuming that the lance gets detached from carriage or gets folded, while lowering the lance and lance makes free fall over the carriage say 1meter fall.

F= mgh

=3560 × 9.81

=35.8×10^3 N

=35.8KN

Subjected torque on the drive pulleys transmitted to drive shaft

TDP= 35.8 × 0.22

= 7.876 KN-m

Calculation of height of free fall of lance just sufficient to break the shaft at dia 80mm:

Calculating height of fall, for a breaking torque of 40.2KN-m

$$H = \frac{40.2\times 10^3}{3560\times 9.81\times 0.22}$$

$$= 5.23m$$

Calculation of height of free fall of counter weight just sufficient to break the shaft at dia80mm:

$$H = \frac{40.2\times 10^3}{1650\times 9.81\times 0.22}$$

$$=11.3m$$

Conclusion:

The shaft is found to be designed with a afctor of safety 4.7 (for the worst case – start of hoisting) for the maximum torque generated during the operation of lance. i.e. In lowering as well as hoisting. In other words under the stall condition the torque transmitted through the shaft is well within the shear strength of the shaft and it can never break.

However shaft can break under the following two situations leading to stuck condition

- The instantaneous torque generated during the stuck situation by the free fall of lance for a mere distance of 5.23 meters is just sufficient to break the weakest link in the power transmission .ie. at diameter 80mm of the lance drive shaft with a shear torque of 40.2 KN-m (in case EN24 material is used for shaft the distance is increased from 5.23 to 7 meters).
- The instantaneous torque generated during the stuck situation by the free fall of counter weight for a distance of 11.3 meters is just sufficient to break the weakest link in the power transmission. ie. At diameter 80mm of the lance drive shaft with a shear torque of 40.2KN-m , which is very remote.

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