Design and Analysis of Lifting Mechanism of Dam Gate Opening Hoist Machine

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Abstract - *An optimum design of lifting mechanism, well-equipped and efficient control system and trustable mechanism to lift the gate is important from technical point of view. If fails or not open at required speed creates a major problem to the dam & ultimately for public site. Hoist is electrically driven and fully enclosed gear reduction units, protected and interconnected shafting with flexible couplings grooved drums, and steel or stainless steel cables. Worm or spur gears are provided and are self-locking to hold the gate in position without the use of motor break. The hoist of the dam gate consists of a speed reduction gear mechanism that increases the torque & helps us to lift the gate with less effort. It is very important to know the breaking load and to design and analyse the load at which hoist can work or fail. Therefore in the present work, lifting mechanism used for lifting the dam gate is designed by using CATIA as a part & assembly modeling tool and the system is then analyzed for the given loading condition using CATIA as a FEM tool and the dam identified for research work is Arunawati Dam in Yawatmal District.*

***Keywords**: Dam gate Hoist, speed reduction gear mechanism, Analysis at different load.*

1.0 Introduction:

A hydraulic gate is a control equipment used for, controlling the flow of water through any component of the irrigation system. Generally it holds the water on the upstream side though some gates deal with a reversible water flow in special cases.

1.1 Definition:

Gates of the radial or trainer type are used as sluice gates, spillway gates, submerged intake gates and log chute gates. They consists of a curved skin plate reinforced with structural members, and radial arms transmitting the water pressure to two trunion bearings. Radial gates rotate about a horizontal axis, which passes through the centers of trunion bearings and usually coincides with the axis of the skin plate. With this arrangement, the line of action of the water pressure passes through the centers of trunion bearings and no unbalanced moments are created. Sometimes the center of skin plate curvature is placed above the trunion center line to provide a lifting moment assisting the hoist in operating the gate. This moment must be less than due to the weight of the structure by a good margin, to assure positive gate closing. The moment due to the weight of the gate may be partly balanced by a counter weight, which may be either attached to an extension of the gate. Arms on the side of the trunion opposite to the gate leaf, or may be attached to the gate structure by a wire rope or chain and made to run on sloping rails embedded in the down stream face of the pier. Radial gates have been made in sizes as large as 65ft. square and as long as 80 ft. Water pressure usually acts on the convex side of the gate and trunions are in compression. Sometimes the water pressure is applied to the concave side of the gate; trunion bearings are submerged and radial arms in tension.

1.2 Types of gates:

a) Classification on the basis of purpose and location of the gates.

1) Spill way gates.
2) Barrage or pick up weir gates.
3) Power outlet intake gates.
4) Draft tube gates.
5) Outlet/sluice/head regulator gates.

b) Classification on the basis of shape of the gates :
1) Radial gates
2) Cylindrical gates.
3) Plane rectangular gates
4) Sector or drum gates.

c) Classification on the basis mode of movement of the gates.
1) Vertical lift type: wire rope lifting (screw stem type lifting)
2)Gates rotating about a fixed trunnion point e.g. radial gates, etc.
3) Automatic functioning gates.

d) Classification on the basis of water head acting on the gates:
1)High head gates-Resisting water head greater than 30m
2) Medium head gates- resisting water heads from 15 to 30m.
3) Low head gates- Resisting water heads below 15m.

e) Functional classification:
1) Service gate: This does the main function of controlling the discharge of water .
2) Stop log;- These are barriers, which hold back the water from a certain area to enable repairs, and other operations to be performed in dry condition.
3) Emergency Gate:-This operates in place of the service gate and performs a part of its function,when servicegate is not working.

2.0 Hoisting arrangement:

A hoist is an equipment with which the gate can be lowered or lifted at the required speed of travel or held in a position at partial opening as desired .For spillway gates the hoists are installed on a hoist bridge supported by the piers. The hoist may be supported on the under deck below the road way. For an economical hoist provision, it shall be so located that the hoisting angle does not change considerable during the hoisting operation.Such a hoist is available at a location on the downstream side of the crest of the dam. This however involves larger pier sizes. An alternative of the arrangement could be upstream hoist location involving larger hoisting capacities. If the reservoir water is of corrosive nature, the hoisting cable is tied to stream side of the leaf so that it remains protected against corrosion. This arrangement makes the cable accessible for any gate position and enables inspection and repairs to the same.

2.1 Requirements:

The essential requirements of the hoist are :

- Reliable in operation.
- Smooth working (avoid any jerks while operating).
- Ability to sustain the vibrations of the gate, held at partial openings.
- Self locking arrangements.

2.2 Main components of hoists mechanism:

1)Hoist frame
2)Drive unit
3)Gear trains with wire rope drum.
4)Wire ropes, equalizer plates, lime shafts and coupling etc.

2.2.1 Drum:

The grooved drum shall be of such a size that normally there will not more than one layer of rope on the drum when the rope is in its fully covered position unless specified. The layer of the drum shall be such that each lead off rope has minimum two full turns on the drum when the gate is as its lowest position and one groove for each lead off the drum when the gate is at its highest position. The drum may be flanged at end. The flanges shall project to a height of not less than two rope diameters above the rope. A spur gear secured to the drum may be regarded as forming one of the flanges. The lead angle of the rope shall not exceed 5^0 or 1 in 12 on either side of helix angle of groove in the drum.

2.2.2 Shaft:

The shaft shall be designed for appropriate load/torque that is being transmitted. Shafts shall have ample strength and rigidity and adequate bearing surfaces. They shall be finished smoothly and if shouldered, shall be provided with fillets of large radius.

2.2.3 Bearings:

All the running shaft shall be provided with ball roller and bush bearings. Selection of bearing shall be done on consideration of duty, load and speed of the shaft.

2.2.4 Wire rope drum:

This is made of cast iron conforming to I.S. 210-1970 grade 20. The drum has machined grooves on its periphery to guide the wire rope. Before clamping to wire rope on drum, it is adjusted in such a way that a minimum of two full turns remain on the drum when the gate in its lowest position and also one spare groove remains on the drum when the gate is at its highest position.

2.2.5 Equalizer Plate:

The function of the plate is to equalize the tension in wire ropes. The equalizer plates are triangular in shape. A plate is provided at both suspension points of the gate.

2.2.6 Drive unit:

It consists of electric motor reduction gear box, electromagnetic brake, starter indicator and limit switches.

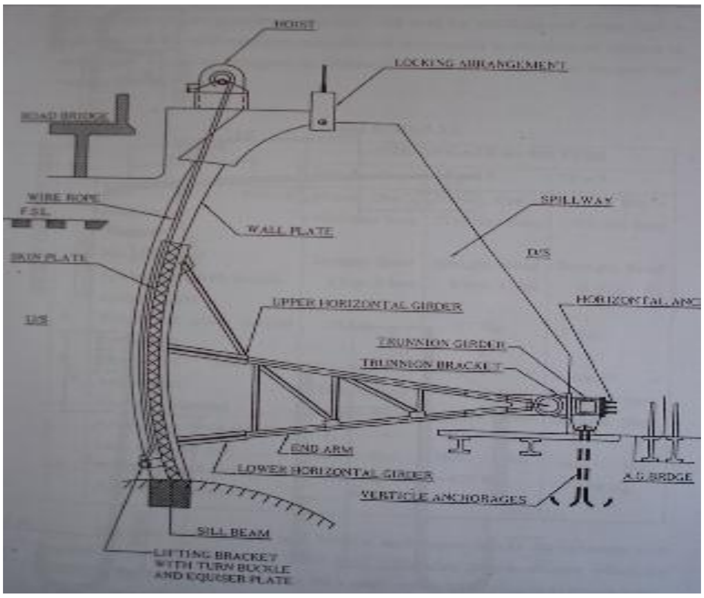

Fig.1- Componenets of Hoisting arrangement.

3.0 PROBLEM DEFINITION:

The dam identified for research work is Arunawati Dam in Yavatmal district near about 120 km from Nagpur in Maharashtra state. The size of gates are 12*5m, 12*6.5m, 12*8m and the type of hoist mechanism used to lift the gate is wire rope drum. So to get the relevant data regarding failure load as well as the load at which hoist can work efficiently ,we have to design and analyze the gear with wound rope which is a key part of hoist at different loads.

3.1 Objective:

1) To Find the optimum design of lifting mechanism ,well equipped and efficient control mechanism to lift the gate.

2) To design and analyse the load at which the hoist can work & the load at which it works.

3) To design the hoist in CATIA to get data regarding failure load as well as load at which it can work efficiently.

4) When there is electricity failure due to storms or any other natural crisis ,then it is necessary that there must be provision for opening the dam gate manually.

4.0 Design Aspect- Hoist Capacity:

The hoist capacity can be determine by taking into consideration the following forces which might be required to be overcome:

a) Weight of the gate along with all its components including the weight of wire rope and its attachments if any.

b) All frictional forces comprising of :

1. Wheel friction
2. Guide friction
3. Seal friction including friction due to initial interferences.

c) Any hydrodynamic load, like down pulley force/uplift etc.

d) Slit and ice load wherever encountered

e) Weight of lifting beam, if used; and

f) Any other consideration specific to a particular site.

The hoist capacity thus arrived at shall be increased by 20% to cater for the reserve hoist capacity unless otherwise specific by the purchaser.

The gate shall be designed for closing under its self weight (without any positive thrust to the same) and the downward forces closing the gate while lowering shall at least 20 percent higher than the frictional or the other forces opposing the downward motion. The necessary closing load shall be calculated considering the net cross sectional area of the bottom seal and maximum water pressure acting on it such that the lowering force is more than the closing pressure. However the values of the closing load shall be greater than those given below:

Type of Gate	**Minimum Seating Load**
Load head fixed wheel gates or radial gates for spillway crest	205 kN/m length of gate.
Medium Head gates	5.0 kN/m length of gate
High head sluice gate	10.0 kN/m length of gate
High head radial gate	10.0 kN/m length of gate

Table-1:-Closing Load Values.

The usual operating speed for such hoist shall be 300 to 700 mm per minute. However, higher values may be adopted depending upon the requirements.

4.1 Design of Mechanical Parts:

General Requirements:

The various components of hoist mechanism shall be so proportioned as to take the worst load coming on individual component. The stress in various components of hoist shall be checked for maximum power transmission in these components, taking into account the permissible stresses as given in relevant clauses. Various structural and mechanical components of hoist shall also be checked for breakdown torque of the motor.

i) Wire Ropes:

The wire rope shall be made from improved plough steel, galvanized(if required) Lang's lay and fiber core or normally of 6/36 or 6/37 construction and shall be conform to IS 2266:1977.

ii) Breaking Strength:

The breaking strength of wire rope, if not given by the manufacturer of rope, shall be calculated on the basis of IS 2266:1977. The minimum factor of safety based on minimum breaking strength and safe working load of the wire rope shall be as given in table:

Operation Condition	Minimum factor of Safety
Normal Operation condition	6
Break down torque condition	3
For Counter Weight Suspension	5

Table-2:-Required Factor of Safety

iii) Drums :

The grooved drum shall be of such a size that normally there will not be more than one layer of rope on the drum when the rope is in its fully wound position unless specified.

Material for drums:

The drum shall be made from one of the following materials

1) Cast iron conforming to IS 210:"1978,
2) Cast steel conforming to IS 1030:1982.
3)M.S. Plates conforming to IS 2062:1984. Use of cast iron shall be limited to small capacity hoist only.

iv) Grooves on drum:

The rope drum shall be Machine grooved and counter at the bottom of grooves shall be circular over an angle of at least 120^0 the radius of groove shall be 0.53 times the diameter of the rope rounded off to next full millimeter. The depth of groove shall not be less than 0.35 times the diameter of the rope.

The grooves of the drum shall be so pitched that there is a clearance of not less than the following values between adjacent turns of rope:

1) 1.5 mm for ropes up to and including 12mm diameter,
2) 2.5mm for ropes over 12mm and including 30mm diameter,
3) 3.0mm for ropes over 30 mm diameter.

Diameter of Drums:

The minimum pitch diameter of the drum shall be 20 times the diameter of rope 6/36 or 6/37 construction.

v) Fixing of rope:

The ends of the rope shall be fixed at the minimum two points on the drum in such a way that the fixing device is easily accessible and the rope is not subjected to undue twists and turns. Each rope shall have not less than two full turns on the drum before it is fixed.

vi) Gearing Material:

All spur gear shall be of cast steel, forged steel, Carbon steel surface harden steel or fabricated mild steel. The choice of material shall be judicious. The gear and pinion shall be made from two different grades of materials; higher strength grade shall be used for pinion and lower strength grade for spur gear.Keys in gear trains shall be so fitted and secured that they should not become loose when in service.

Items	Size of gates in meters		
	12*8	12*6.5	12*5
1st Gear train i)Module	12	12	12
ii)Face Wdth	180mm	167mm	120mm
iii)No.of teeth on pinion.	28	24	29
iv)No.of teeth on Gear.	106	106	93
v)Reduction Ratio	3.785	4.416	4.894
2nd Gear train i)Module	10	10	8
ii)Face Wdth	130mm	112mm	90mm
iii)No.of teeth on pinion.	21	18	19
iv)No.of teeth on Gear	82	70	90
Reduction ratio	3.904	3.88	4.736
3rd Gear train i)Module	6	6	
ii)Face Wdth	90mm	90mm	
iii)No.of teeth on pinion.	20	22	
iv)No.of teeth on Gear	98	81	Not required
Reduction ratio	4.9	3.681	
Total reduction in all the trains		63.07	23.177

Table-3:- Prameters for different gate sizes.

vii) Shaft:

The shaft shall be designed for appropriate load/torque that is being transmitted. Shafts shall have ample strength 7 rigidity and adequate bearing surfaces. They shall be finished smoothly & if shouldered shall be provided with fillets of large radius.

Dimensioning of Shaft:

In dimensioning the with ratio(L/D)=50, the angle of twist and the revolutions per minute shall be taken into account, in addition to simple bending, pure torsion, or the combined effect of bending and torsion. That shall be permitted is $1/4^0$ to $1/3^0$ per m. Linear deflection in the shaft shall not exceed one mm per m of length.

viii) Allowable Stresses:

The allowable stress for solid shaft shall be as follows3.

a) Maximum allowable bending stress either in tension or compression only

= 0.5 yield point or 20 percent of ultimate strength whichever is less.

b) Maximum allowable torsional shear stress

= 30 percent of the yield point stress

1) Twisting sqrt(T^2+M^2)

Where Te=equivalent twisting moment in Nm

T= twisting moment in Nm

M= bending moment in Nm.

2) Bending:

Where, Me=Equivalent bending moment in Nm.

M =Bending moment in Nm.

T =Twisting moment in Nm.

ix) Types of Bearings:

All the running shafts shall be provided with ball, roller or bush bearings. Selection of bearing shall be done on consideration of duty, load and speed of the shaft .Bearing shall be easily accessible for lubrication and /or replacement. If there is more than one bearing on shaft, every bearing shall be provided with individual lubrication arrangement.

4.2 Electrical equipments:

4.2.1 Efficiency of system

The overall efficiency of the system which is the product of individual efficiency of elements shall then be worked out. This overall efficiency of the system shall be used in calculating the capacity of the electric motor.

4.2.2 Motors:

The motor shall be totally enclosed fan cooled ,high starting torque, squirrel cage, three phase induction motor of rated capacity conforming to IS 325:1978. The motor shall be suitable for outdoor type duty. The motor shall be suitable for reversing frequent acceleration and mechanical breaking. The breakdown torque of the motor at rated voltage shall be not less than 2times (that is 200 percent) of the rated torque. During this condition, for checking the hoist components and hoist supporting structure, the starting efficiency of the systems hall be considered. Motor so located that the bush gear and terminals are readily accessible for inspection and maintenance and normal ventilation is not restricted. Motors chosen shall have rated speed not more than 1000 Rev/min.

4.2.3 Electromagnetic Break:

The electromagnetic break shall be of spring set, shoe type. It shall be solenoid operated and continuously rated. The brake shall e effective in both directions of travel and shall be capable of overcoming at least 150percent of the full load torque exerted by the motor. The brake shall set automatically when the current is cut off from the motor and it shall be electrically released when the current is applied to the motor. The brake shall be equipped with a hand operated released lever. A weather proof cover complete with heaters, if required shall be provided to prevent condensation on moving parts. In addition to electromagnetic brake, additional brake shall be also provided, if required.

Manual operation for electrically operated hoists:

The manual operation shall be provide if required for emergency operation in the event of electric supply failure.
Electrical interlocks shall be provided to prevent operation by electrical power when the manual drive is engaged.
The manual operation should be designed in such a manner that the continuous effort per man does not exceed a crank force of 100N with 400 mm of crank radius at a continuous rating of 24 rev/min. the max. Number of persons may be restricted to 4.Manual operation shall be provided with ratchet and Paul arrangement so that the gates do not fall of their own weight during manual operation.If desired by the purchased, only manual operation may be provided for small capacity hoist.

5.0 METHODOLOGY

As discussed earlier, the main purpose of hoist of dam gate is to increase the torque & helps us to lift the gate with less effort. It plays a very important role in design and construction of dam gate because if it fails ,it creates the human and wealth destruction. In existing design of hoist ,there is not relevant data regarding load at which the hoist will fail.
My aim in this project is to design and analyze the gear

with wire wound rope, which is a key part of hoist at different loads. First we have to find out various design parameters of Hoist and its components and streeses involved in it at different loads mathematically. Second phase of project is by designing the hoist in CATIA ,will get the load at which it can work effectively & then analyze using ANSYS Software.

5.1 ANSYS: The calculation of stresses condition as well as factor of safety for complex geometries having complex boundary conditions is very tedious task by means of analytical calculation. Even it is unpredictable to satisfy the governing differential equation. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimisation of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

5.2 Generic steps to solving any problem in ANSYS

1) Build Geometry.
2) Define Material Properties.
3) Generate Mesh.
4) Apply Loads.
5) Obtain Solution.
6) Present the Results.

Last phase of project is to optimize the lifting mechanism of dam gate hoist at different loads and find out correct solution.

CONCLUSION:

Various component of hoist mechanism have been made so proportional as to take the worst load coming on individual component. The various stresses induced along with manual calculation check during design procedure for safe value have also been verified by use of CATIA software so that we have checked our design successfully for all the stress induced in each & every component and the software increases accuracy and reduces chance of mistake.

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