Analysis & Optimization of Gate Leaf Proper of Automatic Outflow Regulating Gate System: A Review

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Abstract— Automation in hydraulic gates is employed to regulate the flow of water through a water reservoir without any human interference. The Automatic outflow regulating gate is water pressure operated gate. The main objective in the "Analysis & Optimization of gate leaf of Automatic outflow regulating gate" is to achieve suitable design for Gate leaf proper. Finite element analysis of Gate leaf proper is taken for the study. Structural assembly of Gate leaf proper can be analyzed using Finite Element techniques. So firstly a proper Finite Element Model is to be developed using Cad software Creo 1.0. Then static analysis shall be done to determine the von Misses stress, shear stress & deformations etc in the present design for the given loading conditions in gate close position as well as gate open position using Finite Element Analysis Software ANSYS v 12.

Key words: Automatic Outflow Regulating Gate, Design Analysis, Optimization, Ansys Workbench

I. Introduction

Automation in hydraulic gates is employed to regulate the flow of water through a reservoir or canal, without any human interference. This is normally done to satisfy one of the following two field requirements;

- To pass out excess discharge on downstream side, while maintaining the upstream water level.
- To pass out required discharge on downstream side.

The automatic outflow regulating gate [1] is a water pressure operated gate, which does not need electricity for its operation. It is unique invention, which can decide by itself the timing as well as extent of opening & thus regulate the discharge flowing through it, by sensing water levels on Upstream &/or Downstream side.

The gate system [2] consists of 2 parts;

- Rotating gate leaf &
- A pair of supporting fulcrum assemblies & embedded parts fixed in supporting structures

- Upstream skin plate
- Downstream skin plate
- Horizontal girders

Gate leaf Proper

- End girders
- Track plates
- Sealing system

Rotating gate leaf assembly

The supporting fulcrum assemblies & embedded parts consists of rolling surfaces, link brackets, trunnion girder, seal anchors etc. The components of rotating gate leaf account for more than 60% of total weight of gate system. Hence if this portion is optimized, it will result in saving in weight as well as cost of Automatic outflow regulating gate system.

A. Operational Behavior of Automatic out Flow Regulating Gates-

The Operational behavior [3] of the Automatic outflow regulating gate is as follows;

As long as reservoir water level in below F. R.L the gate remains in fully closed position (Fig-1)

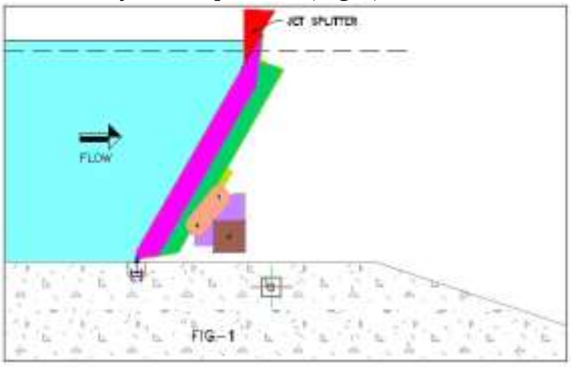

Fig. 1: Gate Remains in Fully Closed Position

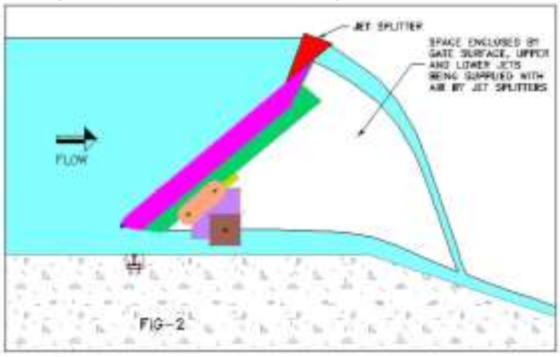

Fig. 2: Gate Stops to Move Further and Remains Stable in That Position

- As soon as the reservoir level tends to rise above F. R. L. (due to inflow into the reservoir) the gate slowly starts to open out. As soon as the outflow from the gate balances the inflow into the reservoir, the gate stops to move further and remains stable in that position (Fig-2).
- When the inflow into the reservoir increases, causing a further rise in reservoir water level, the gate automatically opens out further to the desired extent, so that the outflow matches the inflow again.
- With continuing rise in reservoir water level, the gate opens out more & more until it achieves its fully open position (Fig-3)

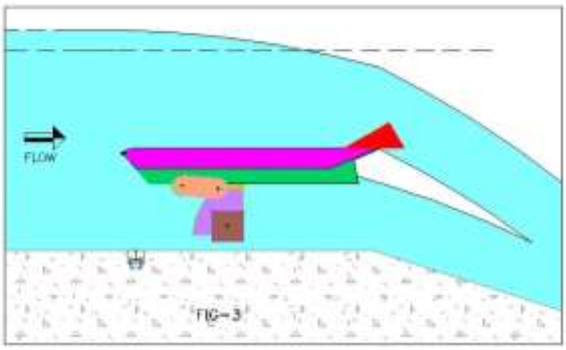

Fig. 3: Gate Opens out More & More until It Achieves Its Fully Open Position

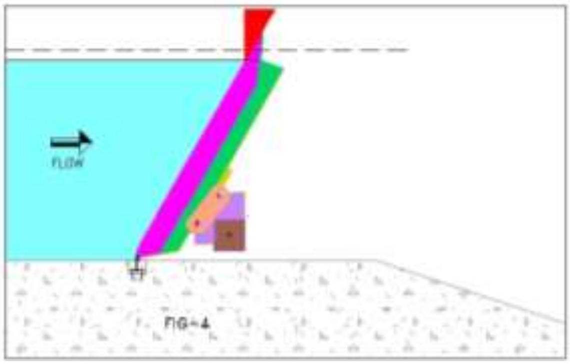

Fig. 4: Gate Closes Completely

- By this time the reservoir water level shall have risen to about 10% of gate height above Full Reservoir Level. If the inflow increases further the gate remains stable in its fully open position until the reservoir level rises to fully designed Maximum Water Level
- As soon as the inflow starts to reduce, the reservoir level starts to fall where the reservoir level falls below Full Reservoir Level + 10% gate height, the gate starts to close back slowly so as to reduce the outflow to match with reduced inflow.

When the inflow reduces to zero, the reservoir level tends to fall below Full Reservoir Level and the gate closes completely (Fig-4)

II. OBJECTIVES

The working stress method which is presently used for computing stresses is quite conservative. In view of wider availability & acceptability of FEM design software (e.g. STADD PRO, Ansys etc) methods of indeterminate structural analysis like FEM are available. It is therefore proposed to use these modern methods for design of components of rotating gate leaf for proposed work.

III. LITERATURE REVIEW

P.P. Godbole, Dr. R.N. Ingle & Dr. P.D. Porey, [4] this paper discusses, automatic tilting gate is a device used to automatically regulate outflow from the reservoir during floods. It is a unique invention, which can decide by itself the timing as well as extent of opening and thus regulate the discharge flowing through it, by sensing water levels on upstream &/or downstream side.

P.P. Godbole, [5] in this paper the system configurations of gate leaf with end girders & rubber seal assemblies are given; the gate leaf consists of horizontal members & vertical stiffeners covered by skin plates on both upstream & downstream sides. One end girder is welded at each end of the gate leaf. The end girder supports the bottom rubber seal assembly.

Xavier Litrico; Gilles Belaud; Jean-Pierre Baume; and José Ribot-Bruno [6]. This paper proposes an efficient mathematical model of an automatic upstream water-level control gate, called a Begemann or flap gate. This automatic gate controls the upstream level close to a reference level for free gate flow, using a counterweight to compensate for the hydraulic pressure on the gate. The proposed gate model is designed to be included in a hydraulic simulation model. A discharge law for the gate is first derived using simple physical assumptions.

Then a method to compute the static equilibrium is obtained by modelling the opening force exerted by the water on the gate. This mathematical model is validated on experimental data from a small-scale gate and on other data from the literature in order to show the ability of the model to simulate various gates.

Amir Khosrojerdi, [7] In this paper it is discussed that, pressure distribution around bottom outlet leaf gates and its role on the potential risk of cavitations, destructive vibrations of the gates, and to determine down pull forces have been the main importance tasks in the studies of outlet works of high dams. In this paper, regarding the importance of pressure distribution around bottom outlet leaf gates, a set of experiments were performed at Water Research Centre of the Ministry of Iran Energy to determine the effect of the geometry of gate and flow conditions on pressure distribution around the gates. Experiments were based on physical model studies of a bottom outlet gate.

Brett C. Commander, Jeff X. Schulz, George G. Goble, Bridge Diagnostics, Inc. Cameron P. Chasten, [8] In this paper it is discussed that, due to complex geometry and loading conditions, analysis and design of vertical lift gates include many simplifying assumptions. The objectives of this study was to measure the behaviour of vertical lift lock gates experimentally and to develop modeling and analysis procedures that may provide a basis for the evaluation of existing gates and design of new gates. In this study, lift gates at Mississippi River Locks 27 near Granite City, IL, and Locks and Dam 26 (Melvin Price) near Alton, IL, were investigated. The upstream lock gate of the auxiliary lock at Locks 27 and the upstream lock gate of the main lock at Locks and Dam 26 were instrumented and tested under various loading conditions in June 1992. Analytical models were developed and analyses were performed for each. The lift gate of the auxiliary lock at Locks 27 was selected for study on the following basis. This gate is identical in construction to the lift gate in the main lock chamber. The gate of the main lock will be replaced since several of its structural members have cracked. Since the auxiliary lock lift gate is in good condition, the experimental data may provide insight on the development of improved modeling and analysis procedures which will benefit the design of a replacement gate in the main lock. Furthermore, the acquired data may suggest possible causes of cracking in the main lock gate. The lift gate at Locks and Dam 26 is ideal for the verification of the testing and analysis procedures since it is a new structure in good condition. This report describes the testing, analytical modeling, and analysis procedures of each lift gate.

Mahesh P. Sharma, Denish S. Mevawala, Harsh Joshi, Devendra A. Patel [9], have done Static Analysis of Steering Knuckle and Its Shape Optimization using Creo & Ansys workbench. Shape optimization method used in this study in reducing the mass of knuckle by 19.35%. Also factory of safety is between 3 to 4. Maximum stress and displacement are within control.

Kuldeep, Arun L.R, Mohammed Faheem [10], have done analysis and optimization of connecting rod using alfasic composites. The study of said article shows that weight can be reduced by changing the material of the current al360 connecting rod to hybrid alfasic composites. The optimised connecting rod is 43.48% lighter than the current connecting rod. The new optimised connecting rod is comparatively much stiffer than the former.

Rehan H Zuberi, Dr. Long Kai, Prof. Zuo Zhengxing [11], have done Design Optimization of EOT Crane Bridge. Optimization of crane Box Bridge is a complex nonlinear problem for which a simple computational procedure has been suggested. The worksheet with solver can take more than thousand variables and very small to large scale nonlinear optimization can be performed. The results seem to be encouraging and the optimized girders are lighter than the cranes manufactured and supplied in the prevailing market.

Hirak Patel, Khushbu C Panchal, Chetan S. Jadav [12] have done Structural Analysis of Truck Chassis Frame and Design Optimization for Weight Reduction. The truck chassis design was done analytically and the weight optimization is done by sensitivity analysis. In sensitivity analysis different cross section are used for stress analysis and a 17% weight reduction in the truck chassis was observed. The stress and deformation are also compared for the different cross section.

F. Faluyi, C. Arum [13] has done Design Optimization of Plate Girder Using Generalized Reduced Gradient and Constrained Artificial Bee Colony Algorithms. This research has demonstrated how parametric optimization of a welded beam section can lead to significant reduction in weight of the beam. In particular, the GRG 2 algorithm yielded a 7.44% reduction in girder cross sectional area compared to the initial design while the ABC algorithm enabled a 7.25% reduction in the area.

IV. CONSTRUCTION OF GATE LEAF PROPER OF AUTOMATIC OUTFLOW REGULATING GATE SYSTEM

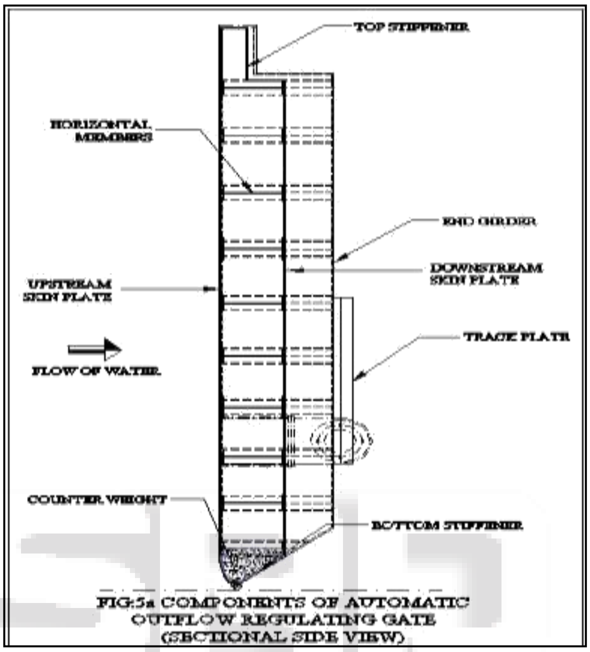

Fig. 5(a): Components of Automatic Outflow Regulting Gate (Sectional Side View)

Sr. No.	Name of component	Number of components used in gate leaf assembly	Sections used for component	Material
1	Upstream Skin plate	1	12mm plate	Structural steel
2	Downstream Skin plate	1	12 mm plate	Structural steel
3	Horizontal members	10	ISMB 600	Structural steel
4	Bottom end angle	1	ISA 90 X 90 X 12	Structural steel
5	Top end channel	1	ISMC 250	Structural steel
6	Stiffeners for bottom portion of gate leaf	8	12 mm plate	Structural steel
7	Stiffeners for bottom portion of gate leaf	8	12 mm plate	Structural steel

Table 1: Components used in gate leaf assembly

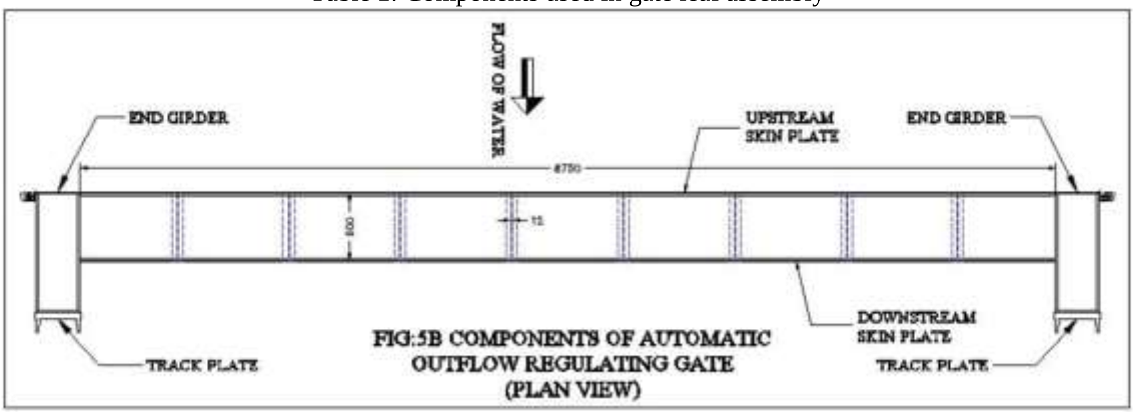

Fig 5(b): Components of Automatic Outflow Regulating Gate (Plan View)

V. CONCLUSION

The study shown there is not very significant work is done in the field of analysis & optimization of gate leaf of Automatic outflow regulating gate. Thus, need of future work in this field is necessary. The reviewed papers & articles shows how to perform an analysis & optimization of various mechanical components in different loading & boundary conditions

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