DESIGN AND ANALYSIS OF OPTIMIZED WATER PUMPING STATION

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Abstract- The main objective of this work is to design and analyze the water pumping station for Orange city water Pvt. Ltd. Gorewada. The existing pumping station is nearly out of service. This is installed in 1930, this is having many problems such as reduced water head due to leakages, rusted pipe surfaces, and also the design is outdated. The current work mainly aims at design/Analysis of pumping station. The cad model of pumping station is developed using Triflex software. Also, structural analysis is performed in the same software. On the basis of result obtained in software design modification are suggested.

Keywords- Water Pumping Station, Orange city water, leakages, rusted pipe surfaces,Design

1 INTRODUCTION

The OCW Gorewada water treatment plant collect water from Gorewada Lake & sewer filter water. Water treatment plants filter water & supply to the seminary hills or distribution network.

The components of the pumping stations as follows,

A. Centrifugal Pump: - A *centrifugal pump* is high head, high efficiency, smooth flow rate, easy in operation & maintenance. The pump existing specification are Total head: - 85 m, Discharge: - 455 m^3/s, Pump input: - 135.570 m/s, Pump efficiency: - 77.69 %, Motor: - 180 kW, Speed: - 1488 rpm, NPSH (Net positive suction head):- 2.18 m, Specific gravity: 1000 kg/cm^2 , Material constant code: - 40,Impellerdia.:- BR/497 mm, Suction size: - 200 mm, Delivery size: - 150 mm, Freq: - 50 5 %

B Butter Fly Valve: - A Butterfly Valve is used to control the flow of material through a circular pipe or tube. Its specification shown in table 1

c. Non return valve: - Non return valve prevent reverse flow & protect pump from excessive back pressure. Its specification shown in table 1

D. Gate Valve: - Gate valve either used fully closed or fully open never used to control flow of water. Its specification shown in table 1

E. Flanges: - Flanges are use to connect valves & pipes by nut & bolt. Packing is provided to prevent leakages. Its specification shown in table 2

Table 1 Butter Fly Valve and Gate Valve specification

Components	**DN (mm)**	**theoretical weight (kg)**	**material**	**Pres-sure**
Butter fly valve	300	83	DI	PN-10
Non return valve	300	230	DI	PN-10
Gate valve	300	160	DI	PN-10

Table 2 Flange specification

Table	Flange dia.	PCD	Bolts	Bolt size	Hole size	Thickness	Material
BS4505-16	840mm	770mm	20	M33	36mm	48mm	Grey CI

F. Reducer & Expander

An eccentric reducer & concentric expander are used in piping systems between two pipes of different diameters. Eccentric reducers are used at the suction side of pumps to ensure air does not accumulate in the pipe. Its specification shown in table 3

Table 3 Reducer & Expander

component	Input dia.	Output dia.	Length	Thickness
Reducer	300 mm	200 mm	175 mm	15mm
Expander	150 mm	300 mm	175 mm	15mm

The working of pumping station is usually the transport of water from storage facilities to distribution networks takes place through pressurized pipelines. The pressure is created either through gravity or through associated pumping stations. The water is moved from source (such as dams) to water treatment plants and then (usually) pumped into service reservoirs and distribution networks to homes and businesses. As shown in fig.1 typically water transmission pipelines are constructed using concrete pressure pipes, ductile iron pipes, steel pipes or GRP/GRE pipes. At the lower end of the dimensional range plastic pipes (such as HDPE) may be used.

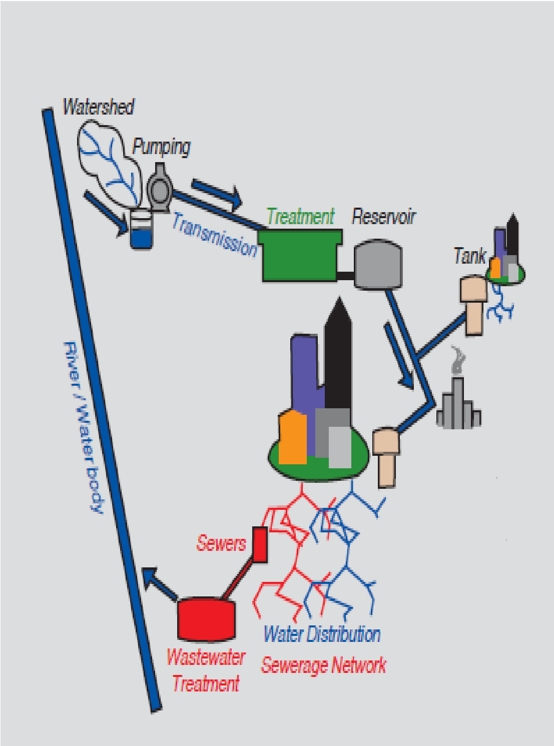


Fig 1 water transmission pipe lines

The reason of choosing this project is its pump, valves and pipelines are old, due to which required discharged pressure doesn't obtained as well as maintenance is required. Therefore we design new water pumping station pipe lines.

2 LITERATURE REVIEW

The repair cost of pipe and cost of pumping power increase as the pipe becomes older due to more frequent pipe breaks and due to the pipe wear that makes wall roughness, and thereby pressure drop, greater. Increasing the corrosion rate leads to the failure of the pipeline, low values of soil resistivity increase the corrosion rate rapidly. Technical data including the material of pipelines and operating conditions were collected. Incapability of the filling from pump to pump at design capacity is called failure. However, the system failure may be due to an unexpected rainfall event exceeding the overall design capacity of the pumps, or to the failure of one or more pumps being the inflow to the pumping station less than the design capacity. Rather than a notional factor of the mean operating pressure,True maximum loads is used to choose the suitable components. It hints to safe designs with low over-design that guarantees improved system control and permitting alternative solutions like omission of expensive protection devices. At the design stage, It discloses possible difficulties in the operation of the system, at a much lower cost than during commissioning[1-13].

3 METHODOLOGY

- 2D layout of pumping station using Auto-cad.
- Selection of components.
- 3D model of pumping station using Triflex software.
- Structural analysis of pumping station.
- 2D model of pumping station using ICEM (Ansys) software.
- Fluid flow analysis using CFD software.
- Validation of result by Bernoulli's equation.
- Result interpretation.

Suitable design of suction piping is significant to minimalize the loss of pressure and permit adequate flow into the pump. Suction piping may be small but never smaller than pump suction opening. Suction elbows is to evade great unequal zed thrust loads that overheat bearings , source the undue wear and disturbing hydraulic performance, Suction pipe slope upward to the pump connection when operating on suction lift. If discharge pipe is small, then pipe diameter is same as pump discharge nozzle. If discharge pipe is lengthy, diameter will be increased by one or two sizes depending on length. As per design principles, the pumping station layout is designed. Fig 2. Shows Details of diagram with dimensions.

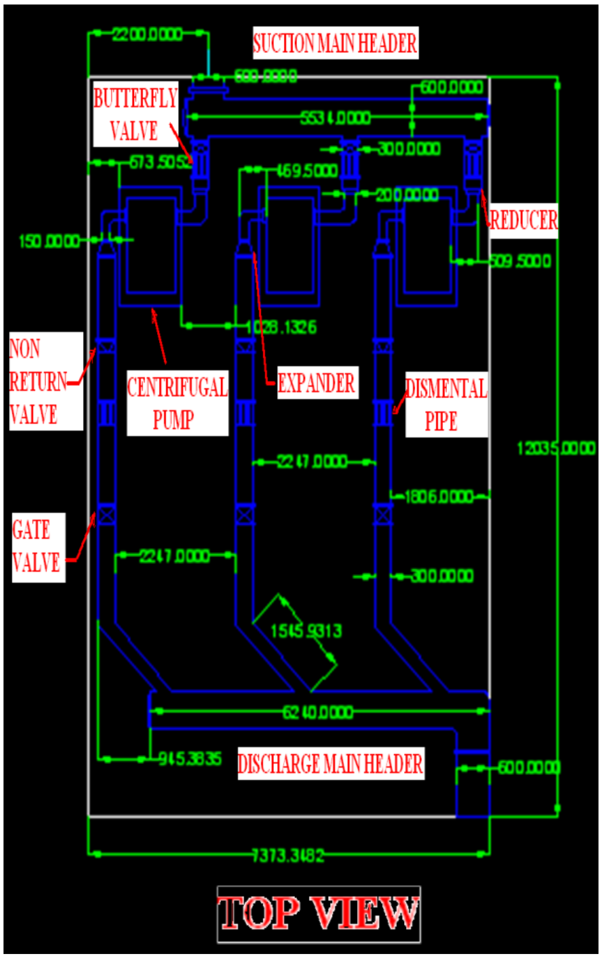


Fig.2 top view of pumping station layout

The triflex is pipe stress analysis software. Valves icon is available & graphics is good as compare to other stress analysis software. Is used for 3D layout & analysis purpose. 3D model of suction pipes as shown in fig.3. The water fetches from tank to suction main header & then flow to pump, through butter fly valve & reducer. The dia. Of Suction main header is 600 mm & pipe dia. is 300 mm.

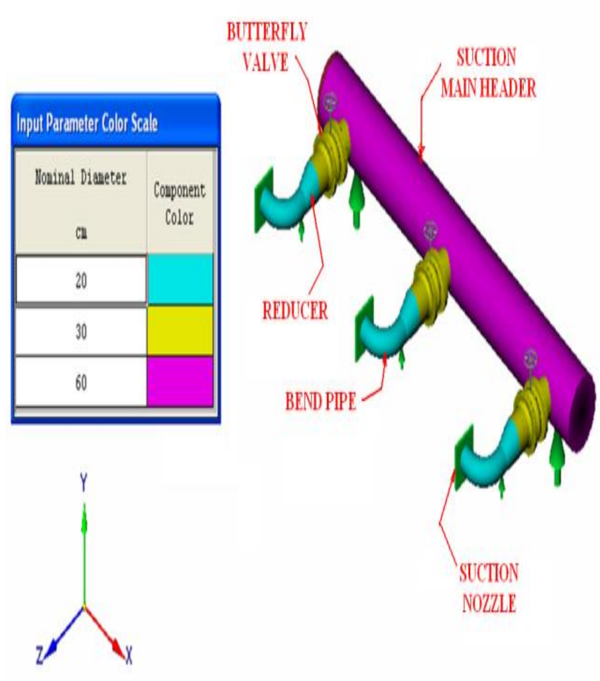


Fig.3 Geometric Plot of Suction Pipes

3D model of Discharge pipes as shown in fig.4. The water fetches from suction main header to discharge pipe by centrifugal pump & centrifugal pump to discharge main header. The dia. of discharge pipe is 300 mm & main header dia. is 600mm.

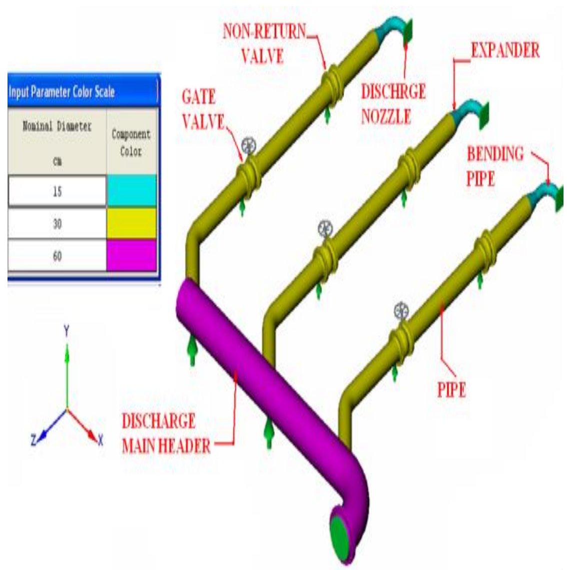


Fig.4 Geometric plot of discharge pipes

Plant specification of structural analysis of 3D model is proposed for analysis purpose selected. So as to check the viability of proposed design for static self loading condition in real time. The pipe will be selected to self weight & weight of fluid flowing inside.

Initially no support is provided along overall length of pumping station. Hence, boundary condition selected for initial analysis purpose as are follows. It is given in table 4

Table 4 Parameters

Parameter	unit	pump discharge
Fluid	-	Water
Piping code	ANSI/ASME	B31.3
Fluid temperature, t_f	^oC	28
Ambient temperature, t_a	^oC	21
Discharge pressure, p_d	KG/CM2G	7.8
Suction pressure, p_s	KG/CM2G	0.49
Material specification	ASTM	ASTM A 36

On the basis of result obtained for discharge pipes as shown in fig .5 & table 5

Table 5 Discharge pipes

stresses	allowed stress	without support	with support
Actual sustained stress (kg/cm2)	1251	5208.5	124.9
Sustained stress (%)	1876	416	10

Observing above table 5, for discharge pipes we get actual sustained stress are 5208.5 and allowed stress are 1251, it means there are more number of chances of failure. Therefore we provide support to the pipes and getting safe design stress which is lower than upper critical point.

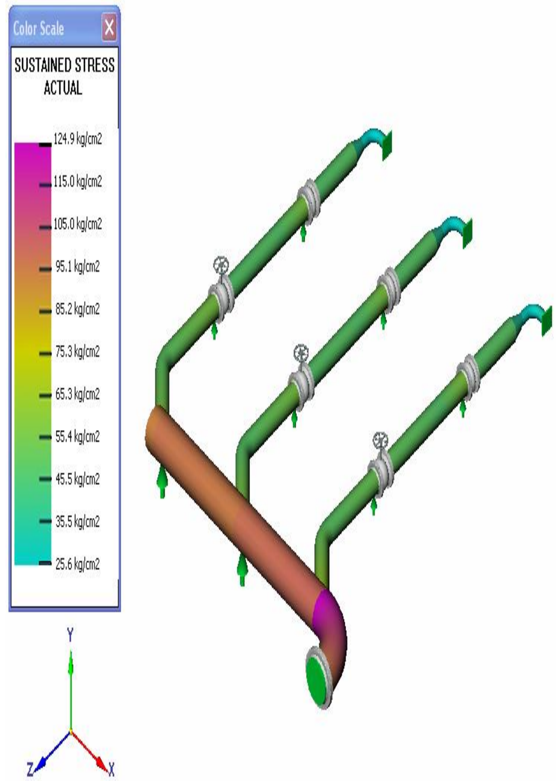


Fig.5 with support actual sustained stress for discharge pipes

The result obtained for suction pipe

Table 6 suction pipe

stresses	allowed stress	without support	with support
Actual sustained stress (kg/cm2)	1251	314.8	19.1
Sustained stress (%)	1876	25	2

Observing above table 6, for suction pipes we get actual sustained stress are 314.5 and allowed stress are 1251, it means there are no chances of failure. But for future safety, we provide support to the pipes and getting safe design stress which is lower than upper critical point. Fig.6 shows that with support actual sustained stress for Suction pipes.

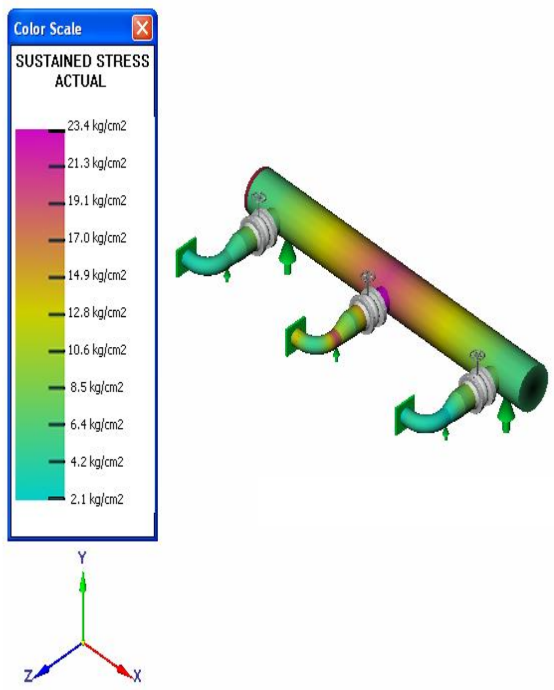
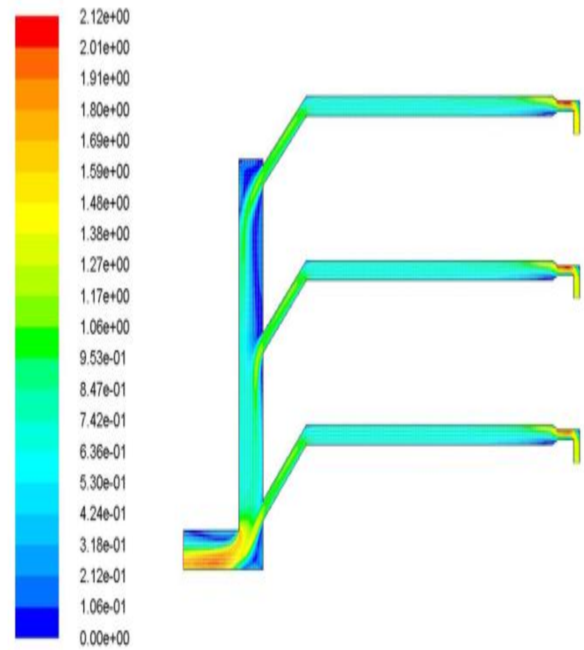


Fig.6 with support actual sustained stress for Suction pipes

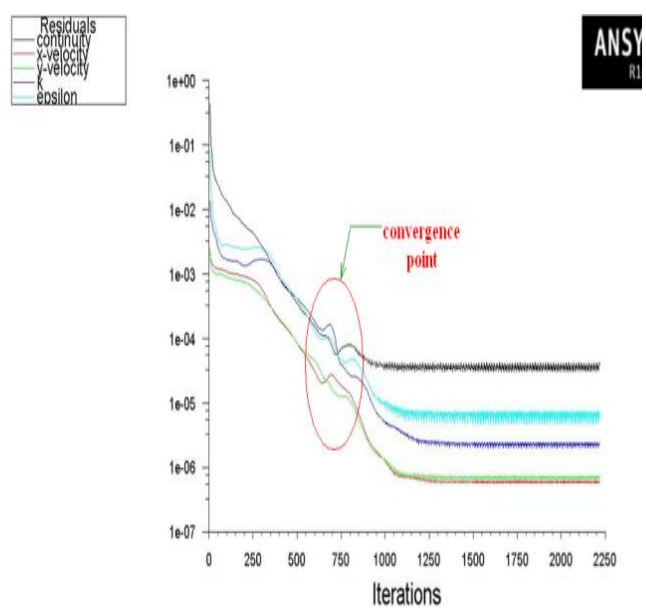
4 CFD FLUID FLOW ANALYSIS & RESULT

For Design modification CFD (computational fluid dynamics) software is been used. The purpose of modification is to increase mass flow rate by reducing friction of pipe and flow and which will therefore reduce actual head. Resultantly reduce the consumption of electricity for pump. In the system three centrifugal pumps are used. Each pump head is 85m and discharge is 455 m3/hr respectively. We need 16 MLD (million letters per day) therefore when one pump is in operation than the time required is 35 hrs. In the same way when two pumps are in operation18 hrs. Is the time required and for three pump its 12 hrs. For design modification number of parameters are considered which are changing diameter of pipes, varying bends and inclined portion of pipes. The 3D model meshing is not proper meshing and taking more time to solve these meshing therefore taking 2D models.

The discretised conservation equations are solved iteratively until convergence The conservation graph shows the iteration of x & y velocity because geometry in 2D, continuity eqn, k and epsilon. The iteration done upto 2250 & its convergence point are below $1e^{-04.}$. Fig.7 shows Conversion graph.



(a)



(b)

Fig.7 Conversion graph

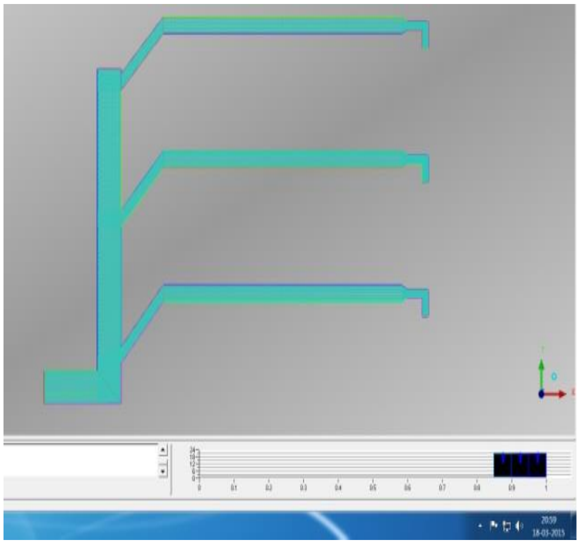


Fig.8 Mesh with quality Histogram

In geometry with curve there are three inlet and one outlet and surface. The surface is providing for fluid flow and vertical line is used to get flow of pressure. In mesh with quality histogram shows the meshing quality is above 0.85.As shown in fig.8

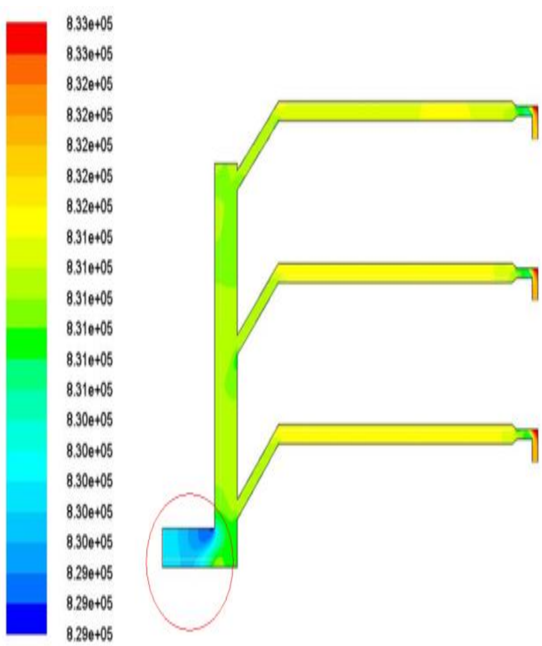


Fig.9 Static pressure

In the static pressure geometry the inlet pressure is 833000 Pascal and outlet pressure is 829000 Pascal but by default software shows in bar. The pressure drop in 0.04 bar means 0.48%.due to low length of pipe it shows small pressure drop is shown in fig. 9

In the velocity magnitude geometry shows the red color shows high velocity magnitude and blue color shows the low velocity of magnitude.

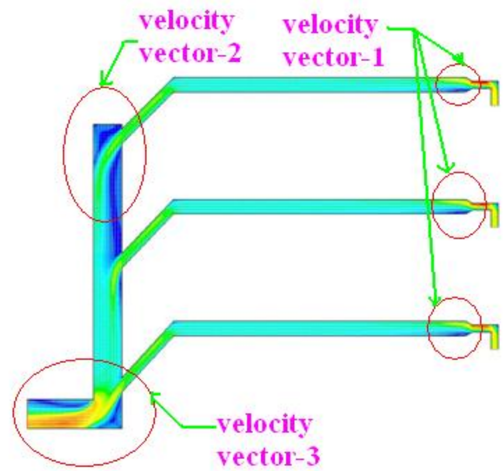


Fig.10 Velocity vector

In Velocity vector red color arrow shows high velocity, green color shows medium velocity and blue color shows back flow of water as shown in fig.10

4.1 Result Analysis of CFD Fluid Flow

1) In case-1 inlet pressure is 833000 Pascal and outlet pressure is 829000 Pascal. But by default software shows value in bar. It means pressure drop is 0.04 bar or 0.48%. Due to low length of pipes software shows small pressure drop.
2) In case-1 pressure drop is more at the end of pipe hence, to change the geometry at end of pipe in case-2.
3) In case-2 pressure drop is 0.03bar or 0.34%. Means pressure drop is reduced upto 0.01 bar.
4) In case-3 middle dia. is reduced upto 200mm. Pressure is reduced as compare to other but pressure drop is same means 0.34%
5) In case-4 middle dia. is increase upto 400mm. Pressure is increase as compare to other but pressure drop is same means 0.34%
6) The CFD result and Bernoulli's equation result are near about same & its percentage deviation upto $\pm$ 5%. Table 7 provides Result of CFD Fluid flow.

Table 7 Result Analysis of CFD Fluid

Case	Total dynamic head (m)	Length (mm)	Inlet pipe dia. (mm)	Middle pipe dia. (mm)	Last pipe dia. (mm)	Inlet pressure (bar)	Outlet Pressure (bar) BY CFD	Pressure drop (bar) By CFD	Analytical pressure drop (bar) by Bernoulli's equation	Percentage of deviation Up to ± 5%
1	**85**	**10000**	**150**	**300**	**600**	**8.33**	**8.29**	**0.04**	**7.99**	**3.73**
2	**85**	**10000**	**150**	**300**	**600**	**8.33**	**8.30**	**0.03**	**8.023**	**3.22**
3	**85**	**10000**	**150**	**200**	**600**	**8.33**	**8.30**	**0.03**	**8.0881**	**2.43**
4	**85**	**10000**	**150**	**400**	**600**	**8.33**	**8.30**	**0.03**	**8.127**	**3.34**

5 CONCLUSION

It is observed that the stress at bend of pump discharge pipe is crossing the safe limit. Hence, the design modification is suggested in which the support location are decided and reanalyzing the suggested design. It is observed that the critical areas of discharge pipe line are well below the safe stress limit. Hence it is concluded that of proposed structural design of pumping station is safe and can be implemented in real time. The CFD result and Bernoulli's equation result are near about same & its percentage deviation upto ± 5%.

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