

Design and Analysis of A Cement Mortar Lining Machineshaft Hub and Corresponding Bolts



Engineering

KEYWORDS : centrifugal casting, shaft hub, bolts, kaizen, ansys

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ABSTRACT

For modern water supply systems ductile Iron pipe has been introduced for industry standards. Ductile iron pipe is used from more than four decades because it is as been proved with good field experience by international standard and it can resist damage of high wearing, high strength, impact loads and corrosion.

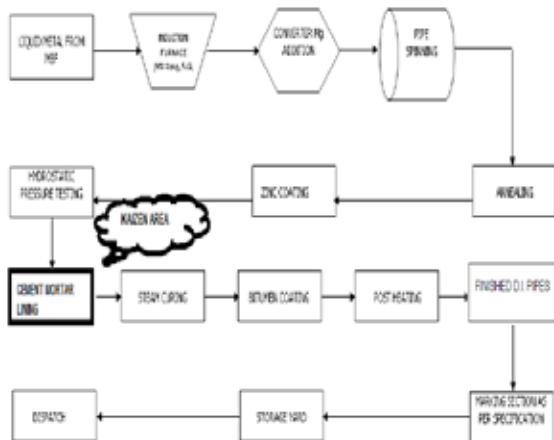
When shaft rotates at high-speeds continuously, stress builds in tires causing shearing of bolts, connecting rim to the shaft hub. Friction between tire and pipe generates heat which may blow up the tire to avoid this problem by using water as coolant. The corrosion takes places in shaft hub corresponding bolts because of water used as coolant. Production losses occur due to frequently breakdowns of shaft hub and corresponding bolts. Present work mainly focused on the methods of improving the design of the shaft hub and bolts, to overcome the above problem by using ansys software

INTRODUCTION

Ductile iron pipe as high degree for reliable is primarily due to high strength, impact forces hard wearing, and corrosion and it can resist damage likes during shipping and handling and once installed and also including water hammer, freeze ground, large ditch area of heavy traffic areas and high water channels, river crossing, pipe on support, hard ditch, area of shifting, wide area and disable soils.

Ductile iron pipe is used from more than four decades and as has been proved with good field experience by international standard because it as strength, durability and reliability and used for potable water, transporting raw water, sewage, slurries, and process chemicals. It can with stand most demanding and profit operating condition. Ductile iron pipe is designed and manufactured to the industries in most strict standards. When we compare ductile iron pipe and steel pipe both exist similar same properties and both pipe are used for transmission main project for many engineers and often flood with information related to various aspects for competitive material. Our purpose is to compare the two pipe and must show ductile iron pipe is best than steel pipe. When magnesium is added to cast iron the brittle nature is change to ductile nature. Ductile iron pipes as conservative design and case of installation make it able to decide quickly

2.MANUFACTURING PROCESS OF DUCTILE IRON PIPE ALONG WITH THE KAIZEN AREA



2.1 CENTRIFUGAL CASTING:

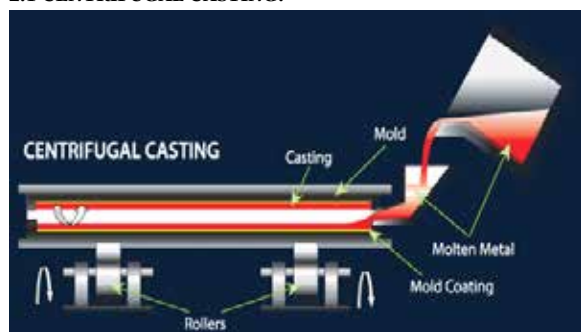


Figure1: Centrifugal casting

Centrifugal casting equipment include four water cooling metallic centrifugal casting machines and they are different machine to make different diameter of pipe like DN80-300mm, DN-400-700mm and DN800-1200mm centrifugal casting is a continuously process .when the permanent mold is rotated continuously about the axis with a high speed and the molted metal is poured continuously.

- The liquid metal from converter is brought and poured into a pre heated hopper.
- The metal is then poured into fall chute by tilting the hopper. The metal flows through the chute into runner and finally into the mold.
- The metal is poured first at the far end of the mold to the hopper.
- At the moment the metal reaches the mold, it is spun at some pre-set speed and simultaneously retracted back at some pre-set velocity. The speed and velocity depends on the diameter of the pipe.
- The hopper is tilted for per-set time so that correct amount of metal enters the mold.
- After some time (depends on the diameter of pipe) the casted pipe is removed from the mold.
- The pipe will be extracted by an extractor and then transmitted to annealing furnace.
- The metal from converter has to reach the casting machine within 13 minutes to avoid evaporation of magnesium (i.e. ductility) and also cooling

2.2. CEMENT MORTOR LINING PROCESS:



Fig2: Cement lining machine

- (1) Spinning stations rotate the pipe (1200 mm diameter) at a constant speed (190 R.P.M) for lining process.
- (2) The stopper is used to avoid side movement of the pipe. This is placed boom side of the spinning stations
- (3) To drain the excessive water inside the pipe blower system is used
- (4) Boom which moves along the axis of the pipe. This transfers the mortar from the bunker to the pipe.
- (5) Pipe end cover is located on the side opposite to the boom entry. This prevents the scattering of the mortar inside the pipe during the lining process.

3. FAILURE ANALYSIS OF A SHAFT HUB AND FASTENERS:

3.1 PROBLEM ENCOUNTERED:

The centrifugal process is applied in cement mortar lining modern practice. The necessary amount of mortar required for obtaining for lining thickness is poured by boom-nozzle system along the pipe. The pipe is rotated with the support of tires, connected with a hub to a rotating shaft of cement mortar lining machine with the help of bolts.

- (1) When shaft rotates at high-speeds continuously, stress builds in tires causing shearing of bolts, connecting rim to the shaft hub
- (2) Friction between tire and pipe generates heat which may blow up the tire. To avoid this we use water. Because of this humidity may generate inside the hub internal threading which causes corrosion. Above reasons damages the hub because of internal threading damage of the shaft hub or shank of the broken bolt jammed in the shaft hub which may not be possible to remove

3.2 STEEL FASTENERS FAILURE:

A fastener may experience either with static loading or fatigue loading. Static loading may be come across tension, shear, bending, or torsion. The static loading may occur in combination with fatigue loading and one of the example is vibrations.

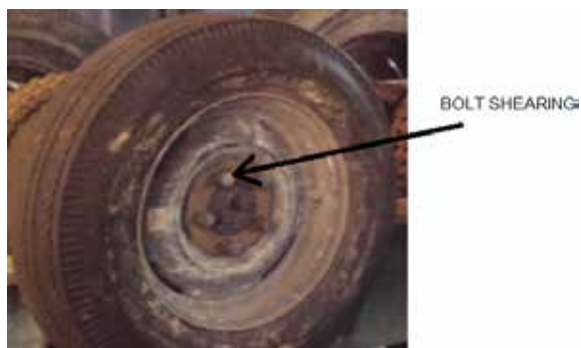


Figure3: Bolts shearing

Fatigue is common failure mode for threaded fasteners. Fretting failures can result from small movements between element surfaces. Additionally, they are many fasteners failures like atmospheric corrosion, material selection, heat treatment, cutting or rolling threads, manufacturing, assembly, and design are some of the factors that affect fastener failures. In fastener failures and primary or contributing causes of failures can be determined by failure analysis.

Threaded fasteners are considered to be temporarily elements that may be removed after assembly. Bolts and nuts are commonly used threaded fasteners. One common location is fastener failure.



Figure4: Shank and head failure



Figure5: Before modification shaft hub

Shaft hub is dismantled from current mortar lining machine



Figure6: New holes are drilled along the pitch circle diameter beside of old once



Figure7: Assembly unit shaft hub after make new tapping holes

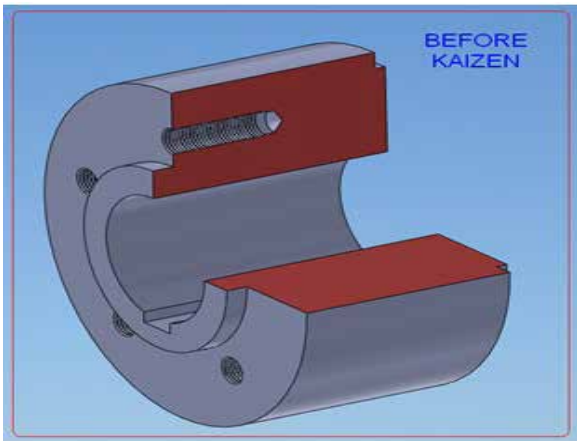


Figure8: Before modification shaft hub and bolts

4. SPECIFICATION

4.1 MOTOR DETAILS:

- 80kw
- 1440 r.p.m
- Pulley:600mm

4.2 SHAFT DETAILS:

- Shaft diameter:90 mm

- Bearing size : 2218Ek

4.3 HUB DETAILS:

- Hub length L=115mm
- Hub diameter D=200mm
- Hub material = EN8



Figure9: shaft hub

- Pcd = 140mm
- Thread hole length=40mm
- Keyway =width=20mm, depth=4mm.

4.4 BOLT DETAILS:

HEXAGONAL BOLT = M16X40 mm

PITCH=2 mm Coarse

4.5 DUCTILE IRON PIPE DETAILS:

- Pipe length = 6000mm
- Pipe diameter= 1248.8 TO 1256.0 mm
- Pipe weight = 2352 TO 2759 kgs.
- Pipe thickness= 12.8 TO 15.3 mm.

4.6 TYRE DETAILS:

- Make = MRF
- Model = twin thread 6.00-16
- Rating= 8 ply
- Pressure= 60 bar
- Index 98/94 j, 6051-1lld
- Tyre load carrying capacity=765 kgs.
- Tyre weight= 8kgs.
- Tyre O.D = 720mm

4.7Rim details:

- Frame model = 4.50
- Weight=13 kgs.
- RimO.D=400mm

Table-1 Comparing allowable stress for bolts before modification

S.no	Description	Working Stress	4.6 grade allowable stress	Bolt selection
1	Selection of 700dia pipe rotating RPM=520	31.6 N/mm ²	79.2 N/mm ²	SAFE
2	Selection of 1100dia pipe rotation RPM=250	62.71 N/mm ²	79.2 N/mm ²	SAFE
3	Selection of 1200dia pipe rotation RPM=190	81.39 N/mm ²	79.2 N/mm ²	FAIL

5. AFTER MODIFICATION SHAFT HUB AND BOLTS:

5.1 DESIGN OF NEW HUB:

The hollow shaft hub is designed by considering the same torque (T) transmitting as that of a solid shaft,

$$T = \pi/16 \times ((d_o^{4-d_i^4})/d_o)$$

5.2.1 CAUSES OF TENSION IN BOLTS

The tensile force presented into a high-strength bolt during installation can be controlled using one of the following methods:

- (1). Torque control method using a torque wrench
- (2). Turn-of-the-nut method
- (3) Direct-tension indicator method
- (4) Combined method (combination of the first two methods)

5.2.2 SCREW THREAD DESIGNATIONS:

According to Indian standards, IS: 4218 (part IV) 1976, the screw thread complex designation shall includes

- (1). Size designation of Screw thread
- (2). The size of the screw thread is designated by the letter 'M' followed by the diameter and pitch.

5.2.3 SCREW THREADS, BOLTS AND NUTS DESIGN DIMENSIONS ACCORDING TO IS: 4218 (PART III) 1976 (REAFFIRMED 1996). Designation=M16

Pitch=2mm

Major diameter of nut and bolt (d) =16.00mm

Effective bolt diameter (de)=14.701mm

Core diameter (dc) bolt=13.546 mm

Core diameter (dc) nut =13.835 mm

Depth of thread (bolt) =1.227mm

Stress area =157mm²

5.2.4 STRESSES IN SCREWED FASTENING DUE TO STATIC LOADING:

- (1) Stresses due to external forces, and
- (2) Stress due to combination of stresses.

1. Stresses due to external forces:

The bolts, studs and screws usually a load in the direction of the bolt axis which induces a tensile stress in the bolt.

External load is taken up by a number of bolts, then

$$p = \frac{\pi}{4} (d_c^2) \sigma_t \times n$$

σ_t = permissible tensile stress for the bolt material.

(1) Shear stress:

When a number of bolts are used to share the shearing load, the finished bolts should be fitted to the reamed holes.

Shearing load carried by the bolts,

$$p_s = \frac{\pi}{4} \times d^2 \times \tau \times n$$

n = number of bolts,

τ = shear stress, and

d= major diameter of the bolt.

2. Combined tension and shear stress:

Maximum Shear stress,

$$\tau_{max} = \frac{1}{2} \left(\sqrt{\sigma_t^2 + 4\tau^2} \right)$$

Maximum Principal tensile stress,

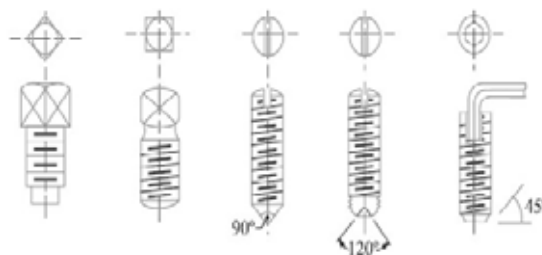
$$\sigma_{max} = \frac{1}{2} (\sigma_t + \sqrt{\sigma_t^2 + 4(\tau^2)})$$

The above stresses would not exceed the safe permissible values of stresses.

5.3 SET SCREWS:

The set screws are used to prevent relative motion between two parts. A set screw as threaded hole in one part and put against other holes it is used for connecting with key and transmitted light power between shaft and hub

Figure10: set screws



The diameter of the set screw (ds) may be obtained from the following expression:

$$ds = 0.125 D + 8 \text{ mm}$$

The set screw is pressed in surface of the shaft (D) and tangential force at the surface of the shaft is given by,

$$F = 6.6(ds) 2.3 \text{ N}$$

Torque transmitted by a set screw,

$$T = F \times \frac{D}{2} \text{ Nm}$$

Power transmitted by the shaft,

$$P = \frac{2\pi NT}{60} \text{ W}$$

Where

N = speed in r.p.m.

We know the shearing load carried

$$P_s = T/R \text{ newton.}$$

R =Pitch circle radius on bolts.

Resisting load on the bolts

$$p_s = \frac{\pi d_c^2}{4} \times \tau \times n$$

$$\tau_s = \frac{p_s}{\frac{\pi d_c^2}{4} \times n}$$

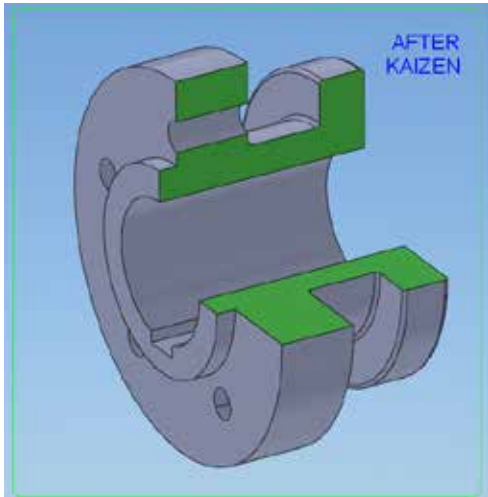


Figure11: After modification of shaft hub

Table-2 Comparing allowable shear stress bolts after modification

S.no	Description grade bolt	Allowable shear stress N/mm ²	Maximum working stress N/mm ²
1	4.6	79.2	81.39
2	8.8	198.4	
3	10.9	260	

6. COMPARISON OF 4.6 AND 8.8 GRADE BOLTS:

6.1 BEFORE KAIZEN MODIFICATION:

- Shaft hub mounting bolts was shearing frequently with affect with hub
- Shaft hub tapping hole length was short 40mm
- Shaft hub replacement time takes 3 hours
- Using 4.6 grade bolts low or medium carbon steel, fully or partially annealed
- Commercial grade bolts using M16×40mm length and 2mm coarse pitch
- Tensile strength =400MPa
- Yield stress=200MPa
- As1250-1981 maximum permissible design shear stress=79.2MPa
- Proof load stress=225MPa
Proof load of bolts=35.3KN
- Breaking load of bolts(min)=62.8KN
Recommended assembly torque=7.3Nm
- Bolts shearing due to rust and corrosion, no drain of moisture in threaded portion of shaft hub

6.2 AFTER KAIZEN MODIFICATION:

- Shaft hub mounting bolts was shearing but no affect with hub
- Provide through hole in shaft hub and increase length 50mm
- No replacement
- Selected design as 1252-1983 high strength steel bolts with associated nuts and washers for structural engineering.
- hexagonal bolt length increase M16×70 and 2mm coarse pitch
- Tensile strength=800MPa
- Yield strength=640MPa
- As 1250-1981 maximum permissible design shear stress=194.8MPa
- Proof load=580MPa
- Proof load of bolts=91.0KN

- Breaking load of bolts(min)=125KN
- Recommended assembly torque=190Nm
- Using anti corrosion bolts

7. ANALYSIS OF SHAFT HUB BEFORE AND AFTER MODIFICATION SHAFTHUB:

7.1 BEFORE MODIFICATION:

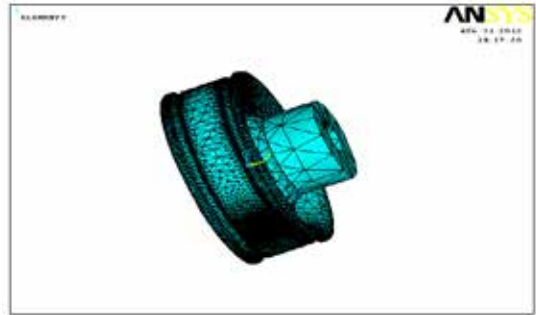


Figure12: Mesh generation of wheel and hub

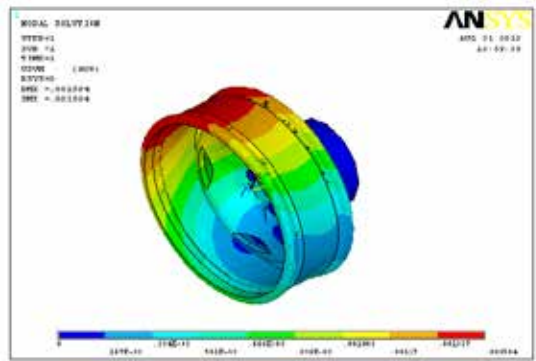


Figure13: Boundary conditions of wheel and shaft hub

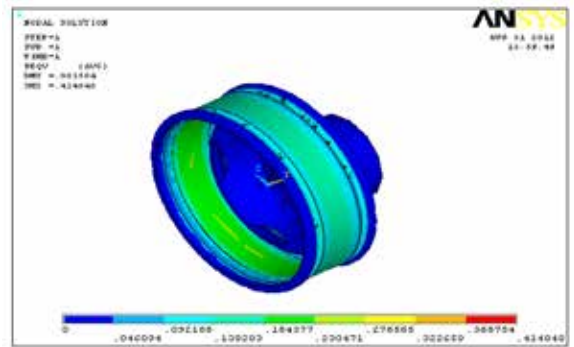


Figure14: von-mises stress of rim and shaft hub

7.2 After modification:

- 8.8 grade bolts

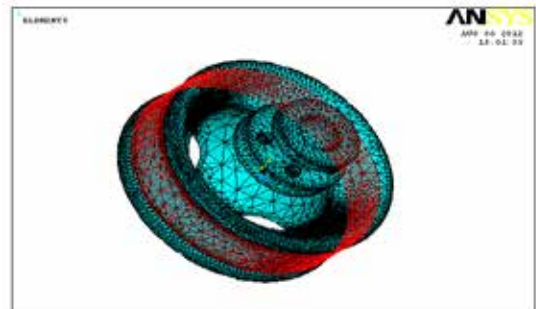


Figure15: FEA mesh and stress contours for a box girder bridge

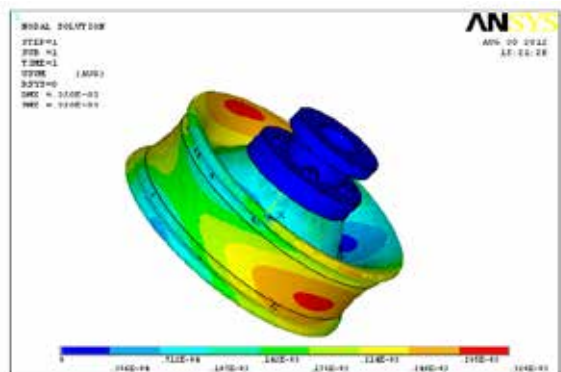


Figure16: Boundary conditions of rim and shaft hub

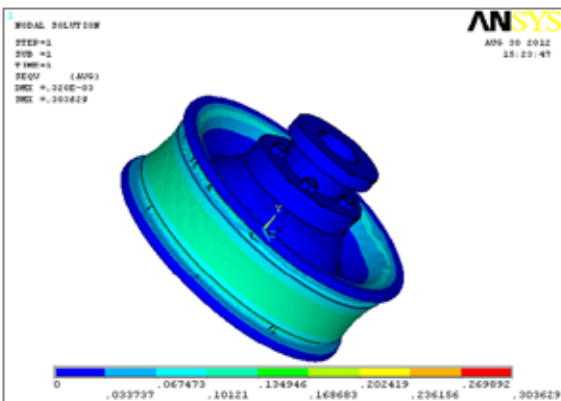


Figure17: Von-mises stress

8. COMPARE VON-MISSES STRESSES

Table-3 Von misses stresses

S.no	Description grade bolts	Von-misses stressesN/mm ²
1.	4.6	0.414848
2.	8.8	0.303629

CONCLUSIONS

Based on the results obtained after modification of shaft hub and bolts the better performance and profits are yielded as per the analysis and by the practical implementation.

The shear stress, von-misses stress and deformation have been examined for the comparison of 4.6 and 8.8 grade bolts. Among the above two it is observed that the 8.8 grade bolts minimum shear stress and minimum von-misses stress resulted

There is a good correlation between computed values and theoretical analysis.

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