A Case Study-Failure of Motor Shaft
Of Rotary Wagon Tippler -Reasons and Remedy

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1.0 Abstract: -

In the thermal power plants maximum requirements of fuel is a coal. The handling of this fuel is a great job. To handle the fuel i.e. coal, each power station is equipped with a coal handling plant. The coal has to size, processed, and handled which should be done effectively and efficiently. Normally, coal is brought to the unloading terminals by trains made up of either unit train cars (cars of same size and capacity) or of random cars (cars of varying sizes and capacities). If the rolling stock and infrastructure required to handle coal is to be built anew, almost invariably, unit train cars are used to achieve the required high unloading rate. Using wagon tippler carries the unloading of the coal. There are various capacities of tipplers used in coal handling of thermal power station. One of these plants is equipped with rotary type wagon tippler. The rate of coal unloading for this tippler is 12-14 coal car per hour. The breakdown to this tippler hampered major coal car unloading. The break down of this tippler occurred due to failure of drive motor shaft. Due this the tippler was out of service for 15 days. To avoid such type of failure the reason for shaft failure is discussed in this paper. And this paper also suggested necessary precautions to avoid such type of breakdown.

2.0 Introduction: -

The rotary type wagon tippler is used to dump coal in hopper from wagons. The wagons are placed in the barrel by marshalling unit and hold by clamp. By rotating the barrel the wagons are unloaded.

The BARREL must rotate up to 140 degrees to insure complete dumping of coal. Most dry coal will dump at 135 degrees. Machine apparently rotates the wagon around an axis somewhere near the center of gravity dumping the coal into an underground hopper where a conveyor system hauls it away.

The WAGON CLAMPING SYSTEM holds wagon in place as it's rotated. The clamping system is having four vertical clamps and two horizontal clamps, which are operated by oil pressure.

A CONTROLLER controls the complete system. Controller ensures smooth operation of the machine. The machine is operated at constant speed, while stopping of machine, to avoid shock s it is required to slow down the speed before stopping.

3.0 Operating Principle: -

The barrel is rotated on the support wheels. There are set of two wheels at each positions. There are four positions of wheels. The barrel is fitted with rack. This rack is driven by pinion. See figure no 1.

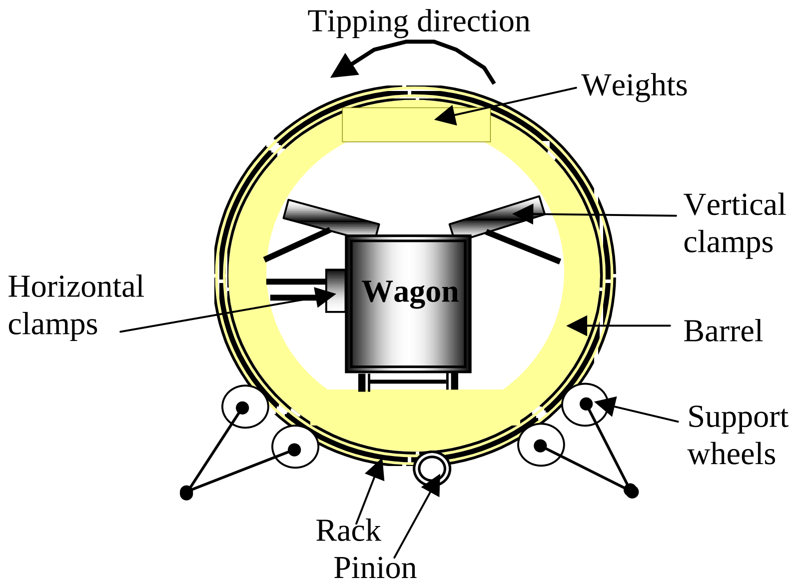


Figure No 1

The techogenerator sense the speed, which is coupled to the non drive end of the motor. The position detector is fitted to gear box, which sense the position for reduction of speed and stoping the operation. See figure no 2.

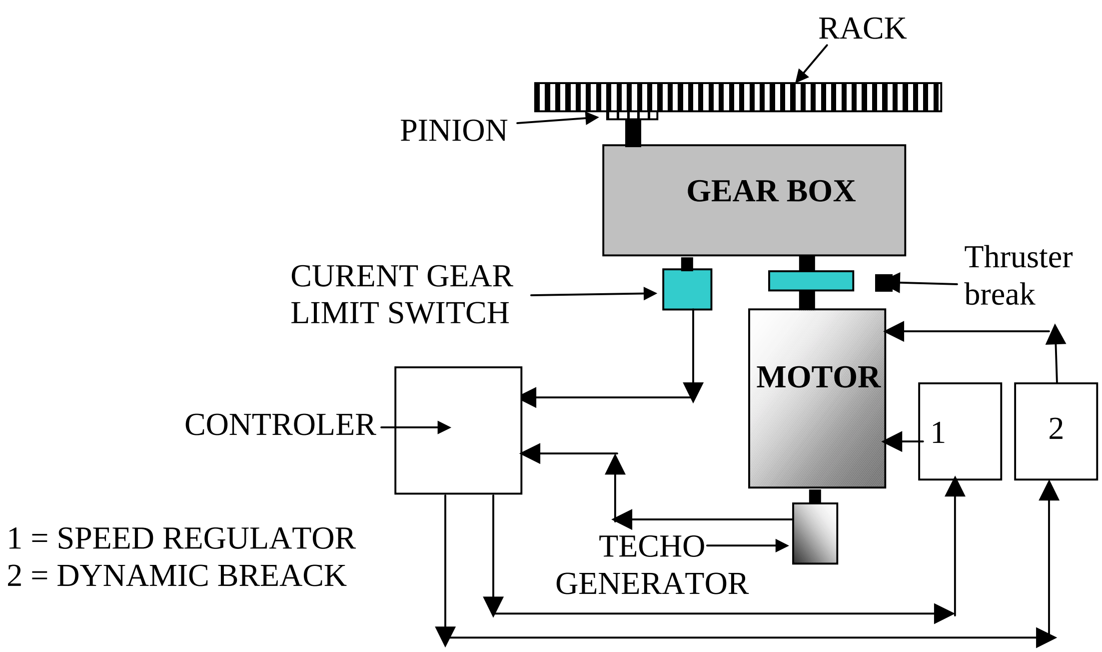


Figure No 2

The barrel is generally positioned such that the wagon can enter smoothly. This position is called rail level position and also known as 0^0 position. As soon as thruster break is released the barrel rotates in the tip direction upto neutral position because of weight, which are fixed on upper side of barrel. See figure no 3.

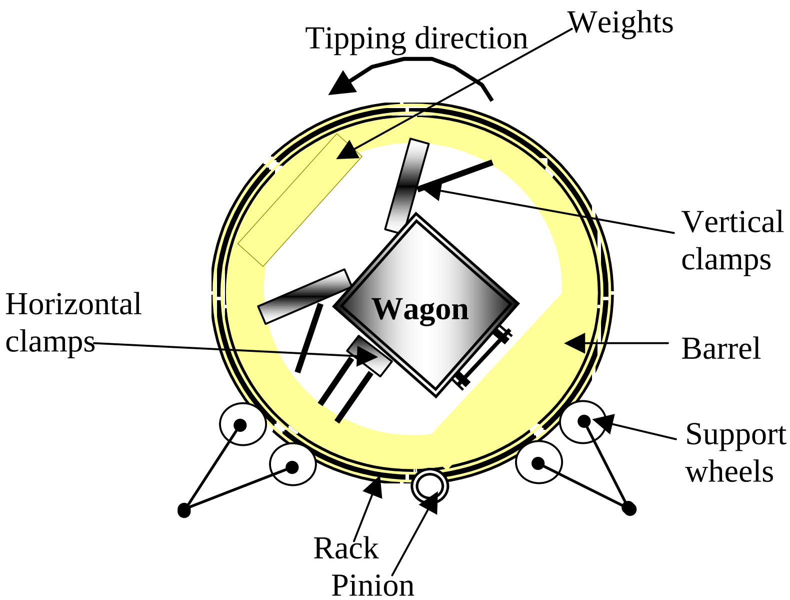
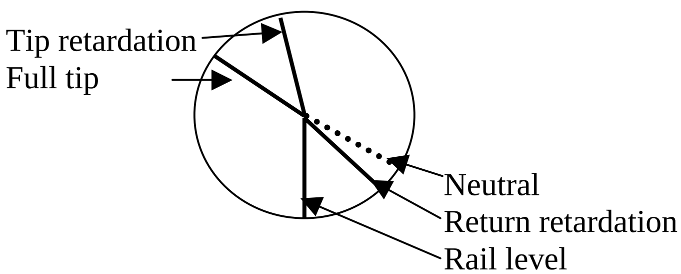


Figure No 3

The position detector shows four positions. The positions are rail level, complete tip, tip retardation and return retardation. See figure no 4.



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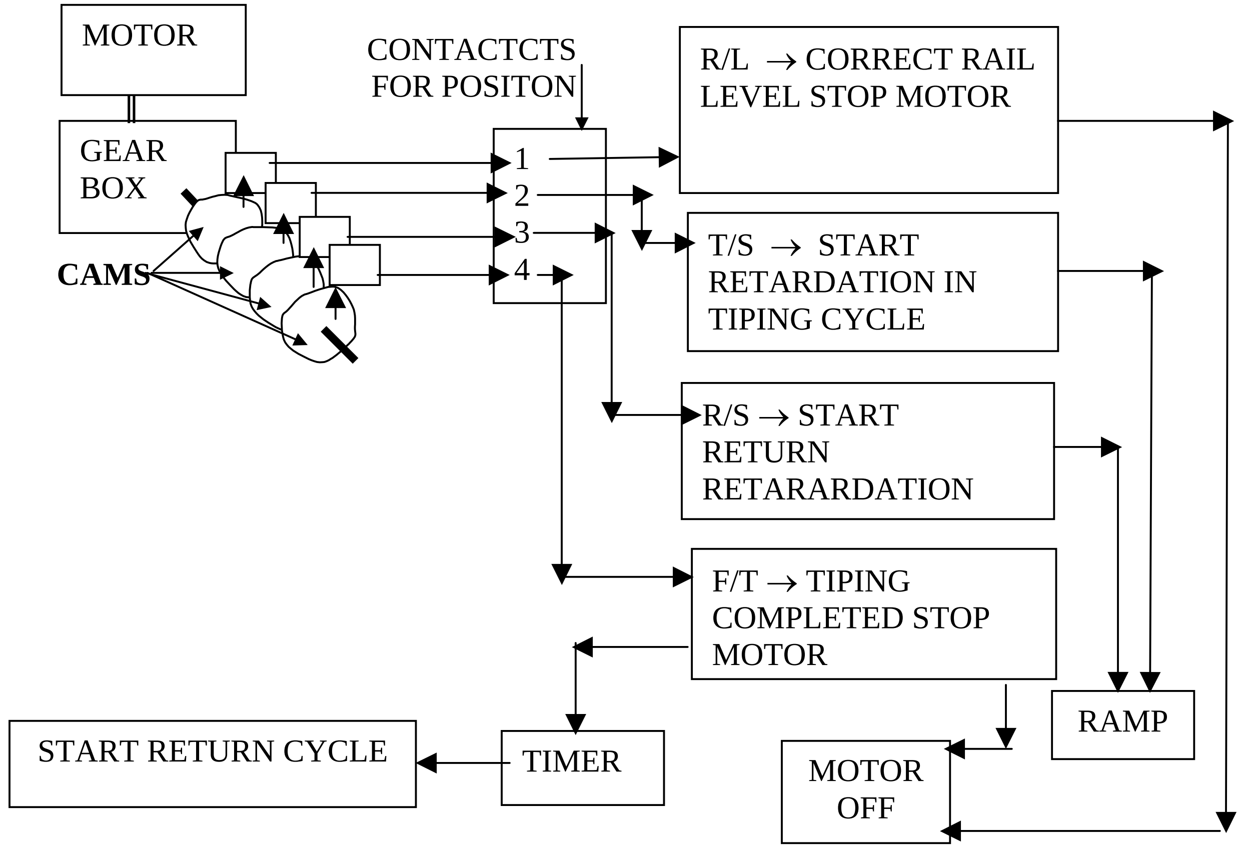


Figure No 5

While start of operation the barrel moves to neutral position after releasing of thruster, which avoids starting loading of motor. Once this motor rotates at constant speed, the feed back of this speed is obtained from techogenerator, which is at non-drive end of motor. By changing the current of armature the speed of motor is changed. Then after reaching the position of tip retardation the input to the system is ramp input. After reaching the position of full tip, the motor stops and thruster brakes operated to insure no movement of barrel. All this positions are sensed by the cams, which are mounted on gearbox. See figure no 5. After the set time the thruster break is released. Due the huge weight the barrel starts rotating to the neutral position. And at the same time motor also starts in reverse direction. But in return direction the speed of motor is difficult to control only by controlling the current as the torque on the motor is very less than in tipping cycle. See figure no 6.

Torque α (Armature current)^2
Armature current α1/spped

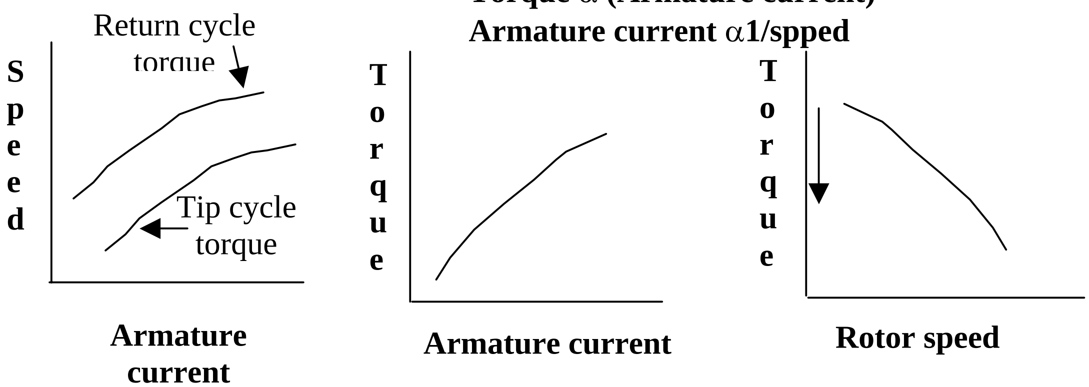


Figure No 6

Because of this, additional method of controlling the speed is used. So as the speed is increased, the motor starts functioning as generator and the load name arrester to generator act as braking. If the speed is reduced below the set level, again motor starts functioning. When it crosses the neutral position, again the torque on the motor is increased. Speed is controlled and as soon as it reaches the position of return retardation the ramp input slowly reduces the speed. The motor will stop after reaching rail level.

3.1 <u>Armature Controlled D.C. Servomotor</u>: -

In the armature controlled D.C. Servomotor, the field current is kept constant. By changing the armature current motor speed is varied [1]. See figure no 7. The regulator regulates the current of the armature as per the required speed and torque. A tachometer is connected on shaft sense the speed of motor. Let E_t = the tachometer generated voltage, K_T = the tachometer constant, $w_{(t)}$ = the speed of motor shaft.

Then $E_t = K_T \cdot w_{(t)}$. ………1.

And I_S = regulator input current, I = actual current of armature, T = torque, W= angular velocity, θ = angular position of motor shaft, S_R = Reference single, S_E = Error single, S_F = Feed back signal, S_O =Out put signal, see figure no 8.

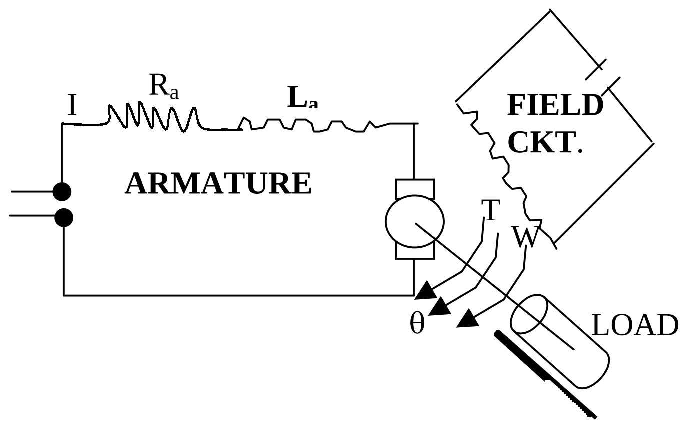


Figure No 7

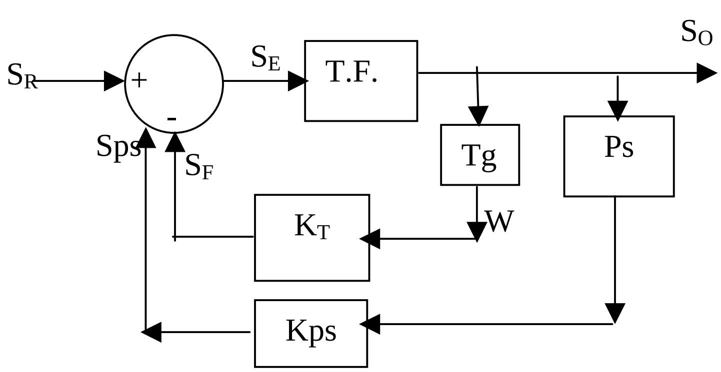


Figure No 8

$w_{(t)} = W$ ……… as the speed of motor shaft is same as of angular velocity
$S_F = E_t$ …… As the tachogenerator generated voltage is same as feed back signal.
Putting value in 1.
$S_F = K_T . W$
The position sensor Ps senses the position for ramp input.
T.F. = Transfer function, it depends on the type of regulating system
As soon as speed is reduced at angular position θ_1 the controller comes into action and speed is changed as per required speed at angular position θ_2. The difference between these two positions is depending upon system response. This is for only tipping cycle from neutral position to tip retardation and from tip retardation to full tip position same activity is carried; only retardation of speed is consider (ramp input). While return cycle the set value for input is not so useful, as torque is very less. For this reason using additional help of dynamic braking control speed is used. As speed the increase than limit motor start functioning as generator which is connected to a load named arrester. This phenomenon is upto neutral position then upto return retardation it acts as same in tipping cycle (from neutral to tip retardation).

3.2 <u>Time Response</u>: -

The time response of the system consists of transient and steady state response for a particular input. It is the variation of output variable with respect to time. In this system (step input system) a signal whose set value is fixed (between neutral to tip retardation and neutral to return retardation) for a particular speed. For other required speed the set value has to be change. And for remaining cycle i.e.tip retardation to full tip & return retardation to rail level is ramp input. The ramp is signal which starts at a some value and decreases to zero linearly with time. In the step input system slope of response is reciprocal of time constant. For getting faster response time constant should be less. See figure no 9.

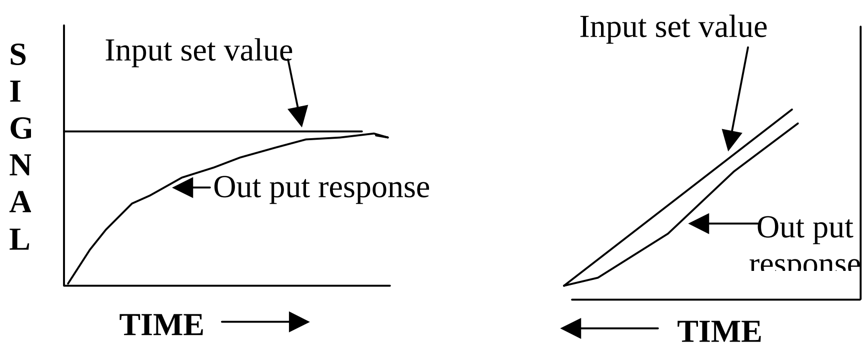


Figure No 9

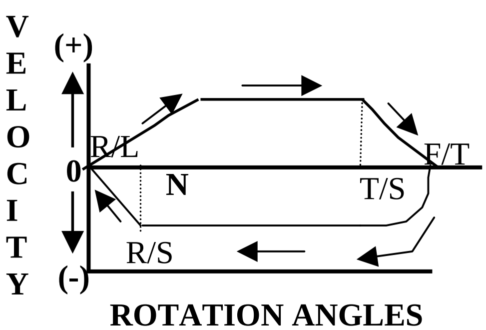
3.3 <u>Variables for the System</u>: -

There is one variable of the system. The coal quality decides full tip angle. And speed of barrel is changed within the limit to keep cycle time constant or in limit. As per these variables other set points are to be decided. The following table will show the relation of other variables.

1 Ramp input value for tip	Depend upon 7
2 Ramp input value for return	Depend upon 7
3 Tip retardation cam angle	Depend upon 1
4 Return retardation cam angle	Depend upon 2
5 **Full tip cam angle**	**As per coal quality.**
6 Rail level cam angle	It should match zero
7 Input set value for step input	Depend upon 5 and cycle time.
8 Tachometer voltage output or feed back	Depend upon actual speed of barrel
9 Output voltage signal	Depend upon 7,8
10 Motor armature input voltage	Depend upon 9
11 System response for step input	Depend upon torque
12 System response for ramp input	Depend upon torque

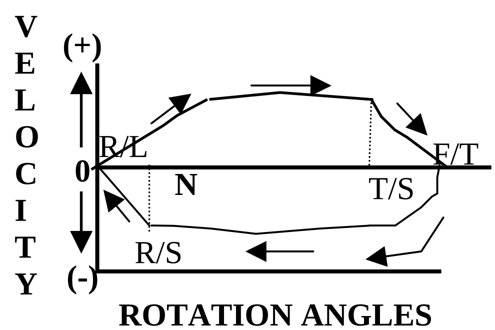
Table No 1

All these value will show the characteristic of controller. For return cycle as soon as the speed increases than input set value the dynamic braking start and will stop when it reaches the desired speed and again motor will function as per set value. The characteristic of controller is shown in figure for one set of torque value, actual values differ from these values within limit.



Velocity characteristic of system.

R/L= RAIL LEVEL
N=NUTREL POSTION
T/S=TILT RETATDATION POSITION
F/T= FULL TIP POSITION
R/S= RETURN RETATDATION POSITION



Actual velocity

Figure No 10

The figure no 10 show actual velocity characteristic of system and the actual velocity. The return cycle shows intemetiade load on motor, which is not shown in figure, is shown in figure no 11. The motor unloads when it acts as generator.

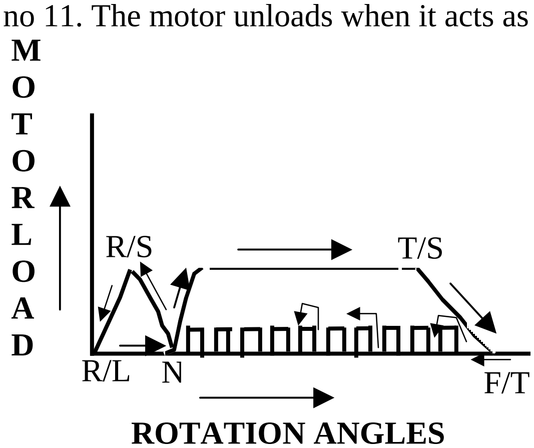


Figure No 11

4.0 <u>Observations</u>:-

The shaft failed between motor drive side bearing and coupling. And also rubbing on the seat of drive bearing. There are three probable reasons for failure of the motor shaft.

1. Failure due to high cyclic loading.
2. Failure due to poor material quality.
3. Failure due to high centrifugal force.[1]

Machine is designed for cyclic loading. If cyclic loading frequency is increased or the number of cyclic loading increases then failure can be observed. But it was observed that no such conditions have occurred.

The shaft is strongest part in the machine and the manufacturer is renowned one; the service life of the shaft was so large that the failure of the shaft due to low quality of material is not possible.

This type of failure is possible due to high centrifugal force developed [1] on shaft.

4.1 <u>Failure due to centrifugal force</u>:-

The broken shaft was checked. It was broken near drive bearing. And it was rubbed on the seat of drive bearing. When the speed of shaft increases more than limit i.e.the speed limited by the 50 m/s. See figure no 12. When return tip cycle start; there are chances of increasing shaft speed, as the shaft is rotated by barrel. Because of the increase in the shaft speed the eccentricity of shaft changes which develops the rubbing of bearing inner race on the shaft face this leads to the reduction in the bearing life and the reduced cross section of shaft concerted stresses and ultimately leads to the excessive stresses in shaft which result failure of shaft. It clearly indicates that high speed during cycle may result in failure of shaft.

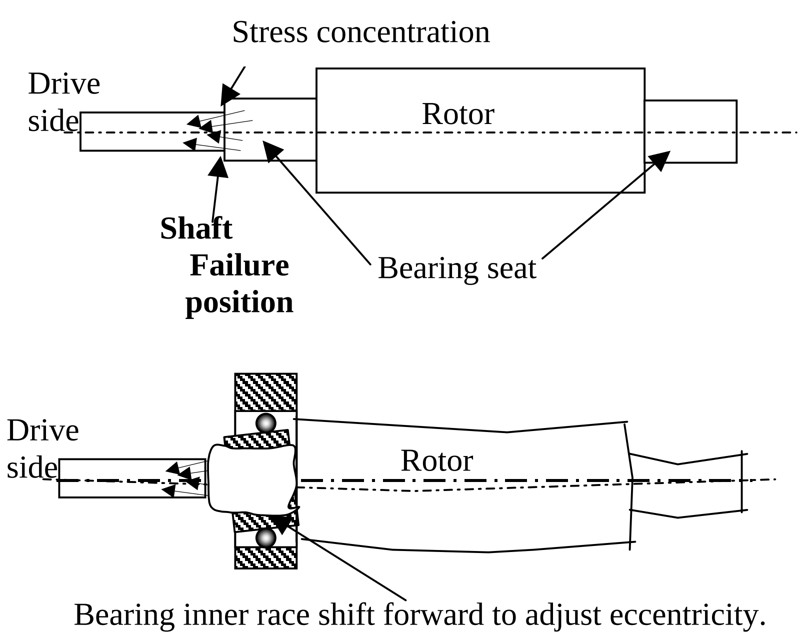


Figure No 12

4.2 <u>Reasons of high rotating speed</u> :-

The controller of the system is to take care of the speed. It should not rotate the barrel beyond the high set speed. The input set value can be change as per required speed with in the limit. Only reasons when speed can increase more than required for some periods is due to the slow response of the system.

4.3 <u>Reasons for slow response of system</u>:-

The characteristic of the system shows that the system set value is for a constant speed and constant torque. The speed of the system will change as the torque changes. For rotation of barrel a constant torque is required. In this matter instead of a constant torque, at some position it may require more torque. Only increasing the set point the problem cannot be solved. By making the system response slow, problem can be solved. Now it is necessary to sort out the reasons for excess torque than required. It was observed that in tipping cycle from approximate 45^0 to 85^0 it draws more current. This indicates the torque required is more in this region.

4.4 <u>Reasons for more torque</u>:-

To check the reasons for more torque the barrel is checked completely. On both outer sides of the rim of the barrel rubbing was observed. The maintenance record also shows frequent failure of foundation bolt of drive gearbox. Again it was checked by using mechanical comparator and observed that the barrel does not follow a smooth path in this region i.e. 45^0 to 85^0 in tipping cycle.

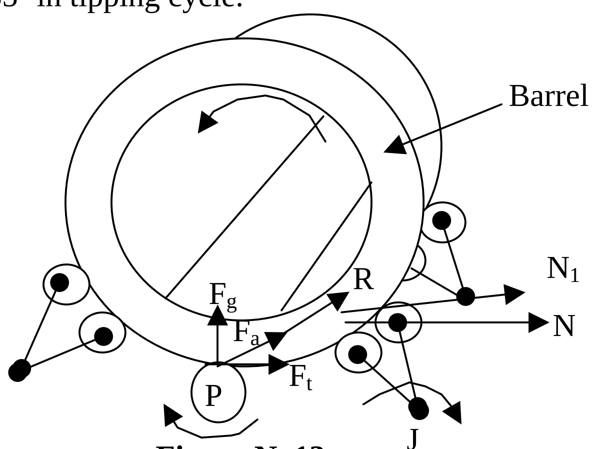


Figure No13

When pinion ‘P’ rotates a force F_t acts on rack teeth, which gives displacement of barrel towards direction ‘N’. But the rack and pinion is at only one place. Other side of barrel restricted to travel at direction ‘N’ due to gravitational force. The force F_g (force developed due to reaction of gravitational force) which result actual movement to ‘N_1’ direction. But this barrel is simply placed on support wheel, which are also rotate with having flexibility to rotate around the pin ‘J’. Due to this mechanism a very small additional force F_a required additional to resultant force ‘R’to make rotation of barrel from both end. If this force F_a is more then more torque will required. Reasons for more value force is non-free movement of support wheel around pin ‘J’. See figure no 13.

5.0 <u>Conclusion</u>: -

The reason for failure of shaft is non-free movement of support wheel around the base pin.
All the values, which are shown in table no1should, are known before setting the input set value for changing cycle time and full tip angle. And after setting the input set value it should be compare with the characteristic value of controller for deviation.
Reason for any deviation with the characteristic value should be checked to avoid further major failure.

References :-

1. Book: B.V.S. Rao: Operation And Maintenance Of Electrical Equipment.