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A Review on Design and Analysis of Bucket Elevator

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ABSTRACT

Bucket Elevators are powered equipment for conveying bulk materials in a vertical or steep inclined path, consisting of an endless belt, or chain to which metallic buckets are fixed. With the flexible belt/chain, the buckets move unidirectionally within a casing and collects bulk materials at bottom end of the equipment and delivers it at the top end.

This paper deals with the design and analysis of different parts of elevator for conveying different types of materials. The modeling of bucket elevator done using solid modeling software and analyzed using conventional finite element software (Ansys) and stresses and deflections are obtained.

This study shows that the negative influences of support of the shaft reflected through the increase in the stress concentration and occurence of the initial crack are the main causes of the shaft fracture which is occurred at the keyway of the shaft and zone of contact between shaft and gearbox.

Keywords - Bucket Elevator, Material Handling Equipment, Stress Concentration

I. INTRODUCTION

The bucket elevator is probably the oldest known form of conveyor, Its history can be traced back to the days of Babylon where wicker baskets lined with a natural pitch and fastened to ropes operating over wooden sheaves turned by slaves, were used for the elevating of water into irrigation ditches.

It consists of:
1) Buckets to contain the material;
2) A belt to carry the buckets and transmit the pull;
3) Means to drive the belt;
4) Accessories for loading the buckets or picking up the material, for receiving the discharged material, for maintaining the belt tension and for enclosing and protecting the elevator as shown in fig 1

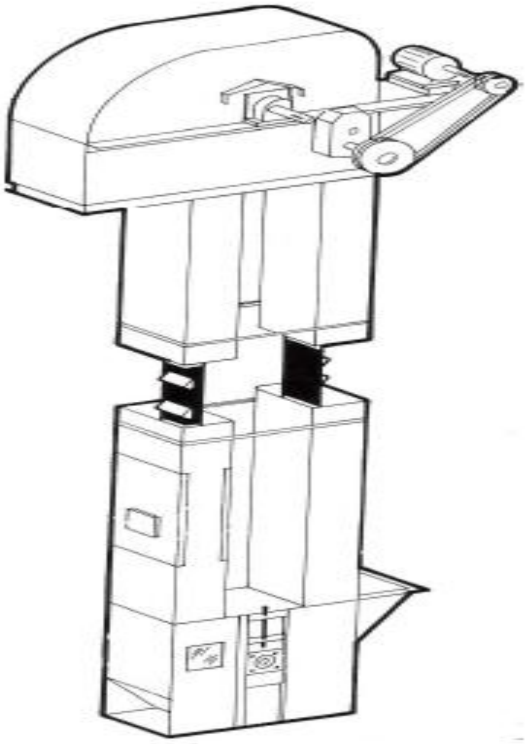

Figure 1 Schematic Diagram Of Bucket Elevator

A bucket elevator can elevate a variety of bulk materials from light to heavy and from fine to large lumps. A centrifugal discharge elevator may be vertical or inclined. Vertical elevators depend entirely on the action of centrifugal force to get the material into the discharge chute and must be run at speeds relatively high. Inclined elevators with buckets spaced apart or set close together may have the discharge chute set partly under the head pulley. Since they don't depend entirely on the centrifugal force to put the material into the chute, the speed may be relatively lower.

Nearly all centrifugal discharge elevators have spaced buckets with rounded bottoms. They pick up their load from a boot, a pit, or a pile of material at the foot pulley. The buckets can be also triangular in cross section and set close to on the belt with little or no clearance between them. This is a continuous bucket elevator. Its main use is to carry difficult materials at slow speed. Early bucket elevators used a flat chain with small, steel buckets attached every few inches. Current construction uses a rubber belt with plastic buckets. Pulleys several feet in diameter are used at the top and bottom. The top pulley is driven by an electric motor. The bucket elevator is the enabling technology that permitted the construction of grain elevators. A diverter at the top of the elevator allows the grain to be sent to the chosen bin.[1]

II. FEA ANALYSIS

A. Göksenli, I.B. Eryürek were carried out failure analysis of an elevator drive shaft. After analysis it is found that failure occurred at the keyway of the shaft as shown in fig 2

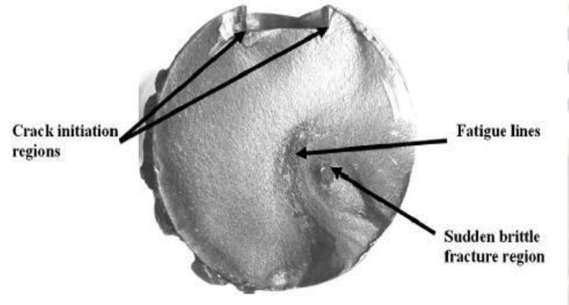

Figure 2 Fracture surface

Microstructural, mechanical and chemical properties of the shaft are determined. After visual investigation of the fracture surface it is concluded that fracture occurred due to torsional-bending fatigue. Fatigue crack has initiated at the keyway edge. Considering elevator and driving systems, forces and torques acting on the shaft are determined; stresses occurring at the failure surface are calculated. Stress analysis is also carried out by using finite element method (FEM) and the results are compared with the calculated values. Endurance limit and fatigue safety factor is calculated, fatigue cycle analysis of the shaft is estimated. By increasing radius of curvature (RC) value, stresses occurring at the keyway corner could be decreased effectively. To determine the effect of RC on stress distribution, finite element analysis is carried out.

By this examination, RC-value was increased stepwise for visual analysis of decrease in stress values, which can be seen in Fig. 3. Dramatic decrease of stress values at keyway corner can be clearly seen. For further investigation, the effect of change in RC on stress and fatigue safety factor is analyzed in detail which can be seen in Figs. 4 and 5.

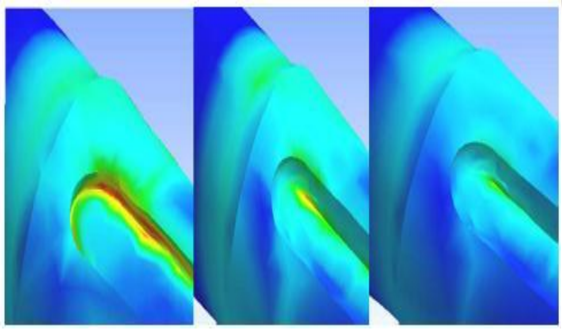

Figure 3 Effect of radius of curvature (RC) on stress distribution using FEM

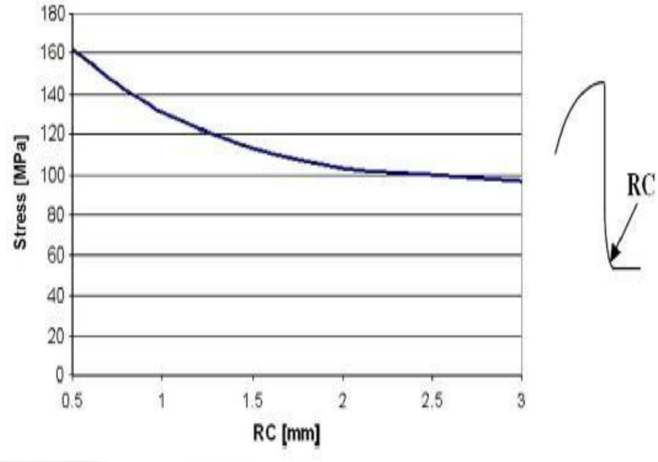

Figure 4 Effect of RC on stress distribution

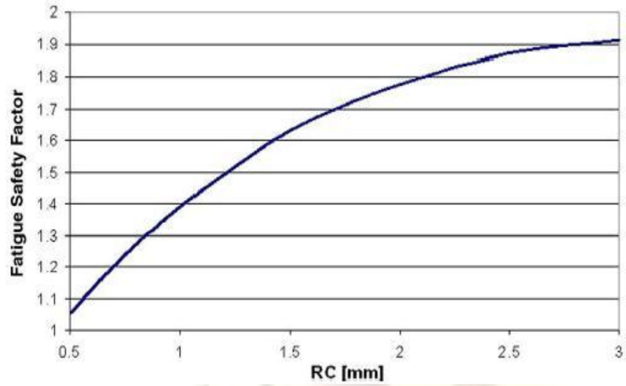

Figure 5 Effect of RC on fatigue safety factor

By increasing radius of curvature even from 0.5 mm to 2 mm would decrease stress value from 163 to 104 MPa and an increase in fatigue safety factor from 1.05 to 1.78.

Fig. 4 and 5 demonstrate that an increase of radius of curvature would probably prevent the failure of the elevator drive shaft. In conclusion it is determined that fracture of the shaft occurred due to faulty design or manufacturing of the keyway (low radius of curvature), causing a high notch effect. Fig 5 Effect of RC on fatigue safety factor. [2]

Mile Savkovic´ a[*], Milomir Gašic´ a, Miodrag Arsic´ b, Radovan Petrovic were carried out Analysis of the axle fracture of the bucket wheel excavator. They examines the causes of bucket wheel axle fractures. Experimental testing of the chemical composition and mechanical properties of the material used to make the bucket wheel axle and metallographic inspections of the fracture surfaces in the bucket wheel axle by means of electronic and light microscope carried out and also done FEM analysis of influences of disturbances on the manner of support of the bucket wheel axle on the fracture. The uniaxial stress field, according to the Huber-Hencky-von Mises hypothesis [3] of the load, is presented in Fig 6

The level of the stress state in the zone of axle fracture for the case of additional support of the hollow shaft on the bucket wheel axle is very high. The values of uniaxial stresses, at the point of support are 3.1 times higher than the stresses for the basic case of load.

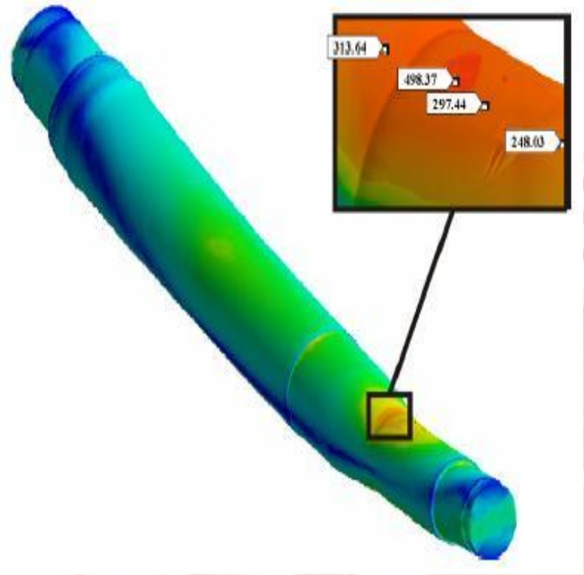

Figure 6 Distribution of the uniaxial stress of the axle

From work they concluded the metallographic examination of the fracture surface show that the fracture did not occur due to any errors in the material.

The bucket wheel axle fracture is caused by improper elimination of axis misalignment of the bucket wheel axle and thehollow shaft which resulted in:

- An increased stress concentration in the bucket wheel axle,
- A triple increase of uniaxial stresses in the axle,
- A quadruple decrease of the degree of safety of the axle [4]

Holbrow [*], G.A. Lunn [**] , A. Tyldesley [***] were carried out an experimental programme on the explosion protection of bucket elevators by venting. Two bucket elevators were used in the work—a single leg elevator and a twin-leg elevator.

Four dusts were used with *K*St values up to 211 bar m s^{-1} and dust clouds were produced by dust injection and by normal operation. Four dusts were used in the tests:

milk powder: *K*St=86 bar m s^{-1}, *P*max=7.4 bar g;
cornflour A: *K*St=147 bar m s^{-1}, *P*max=7.9 bar g;
cornflour B: *K*St=211 bar m s^{-1}, *P*max=8.0 bar g;
cornflour C: *K*St=180 bar m s^{-1}, *P*max=8.7 bar g.

In this study he shows in Fig 7 Single leg elevator how the total vent area required limiting reduced explosion pressures to 1.0 and 0.5 bar varies with the *K*St value when the value of *P*stat is 0.1 and 0.05 bar.

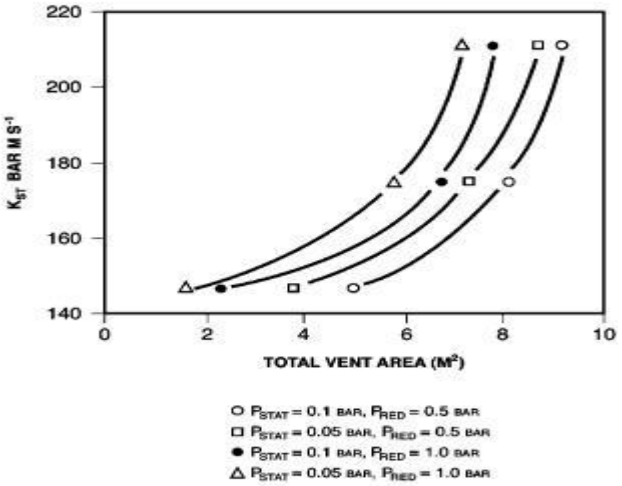

Figure 7 Total vent area vs *K*St value. Single leg elevator

The vent spacing is calculated by assuming that one vent is positioned in the boot and one in the head of the elevator, and the remaining total vent area is distributed along the elevator assuming each vent has an area equal to the cross-sectional area of the elevator.

Table 1 Vent spacing: Single Leg Elevator

Kst bar m.s^{-1}	Pstat bar g	Pref bar g	Vent Spacing(m)
150	0.05	1.0	19
		0.5	10
	0.10	1.0	14
		0.5	0.7
175	0.05	1.0	7
		0.5	4
	0.10	1.0	5
		0.5	4
200	0.05	1.0	5
		0.5	3
	0.10	1.0	4
		0.5	3

The vent spacings for several combination values of *K*St, *P*red and *P*stat taken from Fig.7 are listed in Table 1. The spacing read from Fig. 8 is rounded down to the nearest metre

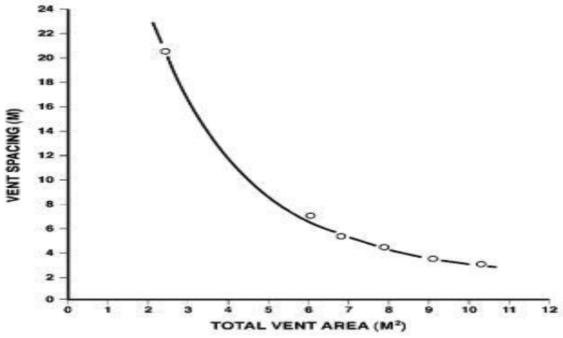

Figure 8 Vent spacing as a function of total vent area. Single leg elevator

In neither of the tests in which venting occurred did the reduced explosion pressure exceed the vent opening pressure, which was 125–135 mbar. In the two tests where venting occurred, the vent nearest the ignition position opened, along with vents approximately 10–12 m from the ignition positiona vent spacing of 14 m will limit reduced explosion pressures to the vent bursting pressure if this is no greater than 0.10 bar.

In Twin leg elevator the reduced explosion pressure data for bucket spacing of 140 or 280 mm are combined in Fig. 9. This diagram may be used to estimate vent spacing providing:

(i) the vents open at a pressure not exceeding 100 mbar;

(ii) the area of the vent is not less than the cross-sectional area of the elevator leg;

(iii) a vent is positioned at the head and a vent is located as close as possible to the boot.

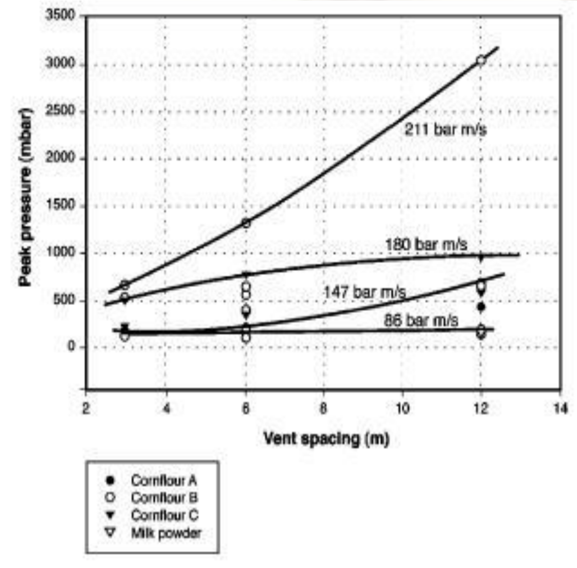

Figure 9 Explosion pressure vs vent spacing for twin leg elevator.Vent opening pressure=0.1 bar.

The data suggest that a vent spacing of 10 m will limit the reduced explosion pressure to 1 bar for dusts with *K*St values between 150 and 175 bar m s^{-1} and a spacing of 5 m is required for dusts with *K*St values between 175 and 200 bar m s^{-1}. For dusts with *K*St values between 100 and 150 bar m s^{-1}, a spacing of 14 m will limit the pressure to 1 bar. For dusts with *K*St values below 100 bar m s^{-1}, the reduced explosion pressure does not exceed the bursting pressure of the vent cover even at very high vent spacing.

After the result he conclude that in Single leg elevator Vent openings should have an area equal to the crosssectional area of the elevator leg and the minimum requirement is that vents should be fitted in the head and as close as is practicable to the boot. This generally means a vent within 6 m of

Concentration and also the other parts of elevator. So decrease in stress concentration is achieved by modified design.

the boot or within the recommended spacing, whichever is the lesser. The spacing between vents along the elevator is listed as a function of the dust *K*St value, the vent burst pressure and the reduced explosion pressure in Table 6. For dusts with *K*St values of 150 bar m s^{-1} or less, a vent spacing of 6 m will limit the reduced explosion pressure to 300 mbar, when the vent static burst pressure is 0.1 bar. For dusts with *K*St values of 100 bar m s^{-1} or less, vents installed in the head and boot of the elevator, with none intervening, will limit the reduced explosion pressure to 0.5 bar. For dusts with *K*St values of 80 bar m s^{-1} or less, a vent spacing of 14 m will limit the reduced explosion pressure to the vent bursting pressure if this is no greater than 0.1 bar. For dusts with a *K*St value of 80 bar m s^{-1}, a vent spacing of 20 m will limit the reduced explosion pressure to 250 mbar. In Twin leg elevator Vent openings should have area equal to the crosssection of the elevator leg and the least requirement is that vents should be fitted in the head and as close as is practicable to the boot. This generally means within 6 m of the boot or within the recommended vent spacing, whichever is the lesser. The static burst pressure of the vent closure should not exceed 0.1 bar.The spacing of additional vents depends on the *K*St value of the dust. (a) Although explosions are possible with dusts of low *K*St, generally the pressures developed by dusts with *K*St values below 100 bar m s^{-1} are not significant, and no additional vents are required.

(b) Dusts with a *K*St value of 150 bar m s^{-1} are able to develop significant pressures, although the likelihood of explosion propagation through the elevatoris low. Vents additional to those at the head and boot may be required on long elevators if the casing is comparatively weak. The graphs in Figs. 7 and 9 should be used to estimate the reduced explosion pressure for a given *K*St value and vent spacing.

(c) Dusts with *K*St values above 150 bar m s^{-1} will propagate explosions, and vents additional to those in the head and boot are required on elevators taller than 6 m. The graphs in Figs. 7 and 9 should be used to estimate the reduced explosion pressure for a given *K*St value and vent spacing. The strength of the elevator should then be designed appropriately.

(d) No data are available for dusts with *K*St values greater than 210 bar m s^{-1}. [5]

III. CONCLUSION

From study we concluded that there is a fracture on shaft at key way and area where abrupt change in cross-sectional area occur due to high stress

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