# SHOT PEENING IN PREVENTING COAL BUNKER FAILURE

Nadkarni V S and Sharma M C
MACT (Regional Engg. College)
Bhopal, India.

## ABSTRACT

The present investigation is a case study of coal bunker failure analysis of a Thermal Power Station. Wall thickness were checked on the basis of unfired pressure vesssel design codes and wear considerations. Based on available drawings various welded joints were checked and possible modifications were suggested. Further experimental investigations were carried out in laboratory for welded joints to explore the effect of shot peening on their fatigue behaviour. Possible use of shot peening for prevention of coal bunker failure was suggested.

## KEYWORDS

Bunker and hopper welded joints, fatigue of welded joints, wear and shot peening.

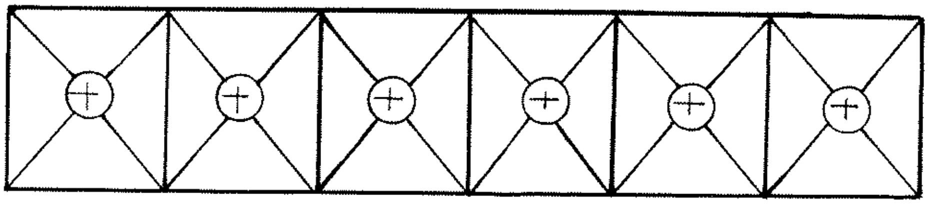
## INTRODUCTION

The coal bunkers of a Thermal Power Station were of rectangular type, bunker (shell) and hopper (cone) had assymetric circular outlet. Upper rectangular ends were open for coal inlet. Over all dimensions of one bunker were as follows :

| | |
|---|---|
| Over all length of Bunker | = 16.60 m |
| Top rectangular inlet size | = 10.5 x 8.5 $m^2$ |
| Length of rectangular shell | = 6.45 m |
| Thickness of shell plate | = 10 mm |
| Total length of Hopper portion | = 10.15 m |
| Length of Rectangular Hopper & transition piece from ground level | = 7.95 + 2.20 = 10.15 m |
| Thickness of Hopper plate | = 12 mm |
| Opening / diameter at the outlet | = 0.609 m |
| Total number of bunkers in series | = 6 nos. |

The transition piece at the outlet was rectangular at upper end while circular at lower end with 609 mm diameter opening. It was made of 5.0 mm thick S.S.

The bunker failures were noticed at the junction of shell and cone. Their transition zones were subjected to excessive wear and consequently undergone fatigue failures of middle four bunkers resulting into separation of their cones. The bunkers were hanging on columns.



Lay out of coal bunkers

## FAILURE ANALYSIS

Failure analysis of the bunkers were done on following considerations :

Shell plate thickness was checked based on IS 2825, 1957 Design of unfired pressure vessels. Side pressure on walls was taken as equal to downward pressure due to coal weight. Normally Hopper plate thickness was taken 20% higher than shell plate thickness. The rate of irrosion must be such that life of a bunker must not be less than 10 years.

Plate thickness was governed by the strength requirements and the corrosion and wear allowances but in no case it was less than a certain practical requirement, that distortion during errection must be minimised, BS2654-1973 gives the following minimum thicknesses.

| Bin Dia, m | Plate thickness, mm |
|---|---|
| Upto 15 | 5 |
| 15-36 | 6 |
| 36-60 | 8 |
| 760 | 10 |

The plate thickness determined by tensile strength consideration should be increased to take into account wear, an allowance 2 to 3 mm should be given as per technical note AWARA (1).

Therefore shell plate thickness of 10mm, and hopper plate thickness was 20% higher than the shell plate thickness (12 mm) were found to be correct.

Further as a rule, rectangular bins are constructed as stiffened plate structures. The stiffeners or ribs, are assumed to carry the loads to the top girder and the waist girder. The steel plate is assumed to resist the out of plane bending moments and in plane membrane forces. Large deflection theory is often used to achieve maximum economy.

The walls of rectangular bulk solids containers or bunkers resist the loads from the bulk solid primarily by bending action. The loads are transferred from the steel plate work into a system of ribs and ring beams, often called stiffeners. A heavy ring girder is required at the transition from vertical hopper walls to resist large forces resulting from the change in direction of the walls.

There are no hard and fast rules about preferred system of steel frame work for rectangular bins.

Using the date from ref. (1), 'Thin plate design for transverse loading' Aatami & William constrads Monograph UK'75, the plate thickness for preliminary design can be obtained from the expression :

$$t_{req} = \sqrt{\frac{K_m P_h L_1^2}{0.70 F_y}}$$

Where $K_m$ = Coefficent depending upon side ratio,

$L_2 / L_1$ = the span to thickness ratio and the load intensity, Ph should be taken as the value existing at the centre of the panel.

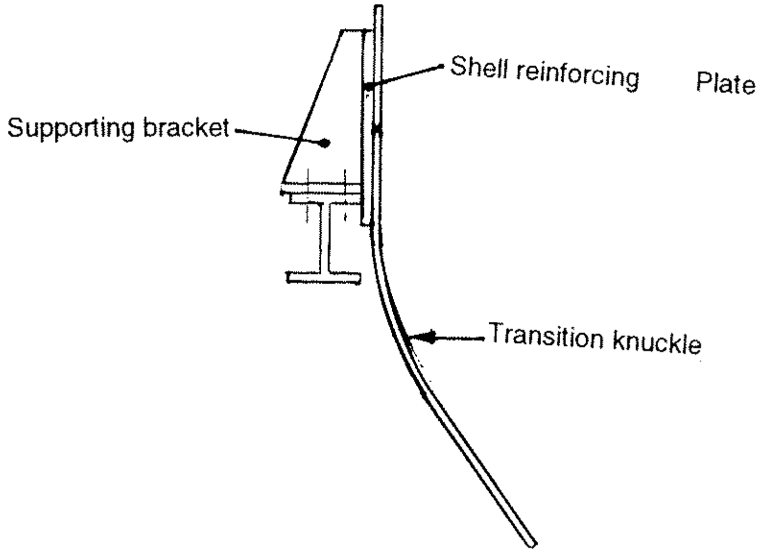
Value of Km is as follows :

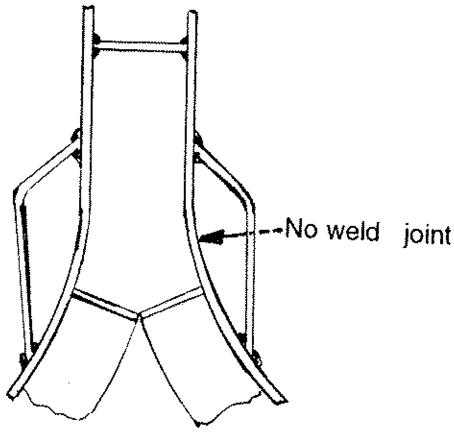
| Side ratio | | Km | Condition |
|---|---|---|---|
| L2/L1 | 1.0 | 0.28 | Plate is fully |
| | 1.5 | 0.38 | welded to the ribs |
| | 2.0 | 0.46 | and is continuous |
| | 3.0 | 0.48 | on all four sides |

However, the review of the drawings of the Mill & Bunker bay coal bunker points for due modifications.

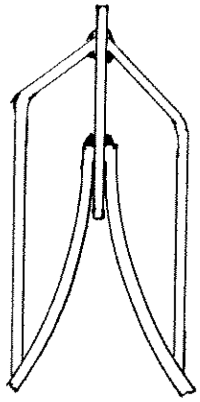
Suggested modification of welded joints

1) The joint on to a bunker and hopper should be provided by giving knuckle radius to the hopper.
2) The welded joint between bunker to hopper should always be above the knuckle which is indicated as follows :
3) Provision of Deflector / Protecting skirt inside at the transition which will deflect the descending coal to the hopper. Figures for separate plate type and single plate type are given below
4) It appears from the drawing that the hopper walls are common and the enlarged typical view shows that the knuckle was provided to the hopper cone, it was welded on to the web seperating the bunker and hopper, and precisely this could be the reason why bunker cones are getting damaged.
5) We would recommend the hopper to be welded to the web of the joint and also to the bunker.




Separate plate with stiffners
for each bunker



Single plate for two bunkers

SUMMARY OF FAILURE ANALYSIS

Failure of bunker is due to thinning down of plate at the junction of knuckle due to abression and some thermal stresses which are due to the coal sliding motion. Finally abbrasion pits will initiate fatigue crack and fracture occurs at the junction of bunker and hopper.

Recommendations for prevention of failure of the bunker (material and welding considerations)

The material used for fabrication should thoroughly checked for thermal and abbression resistance.

The design does not specify practice code of welding whereas it indicates the carbon steel to nickle chrome alloy plate. As a matter of procedure one should use an electrode which is compatible to carbon steel and stainless steel ( SS 309 grate of material will give required strength ie. High Ni alloy and prevents diffussion of carbon).

As the drawing says all weld to be continuous and intermittent welding shall not be allowed. If this welding practice to be adopted then the best procedure will be $CO_2$ MIG welding which will give continuous high deposit the wire used should be of grade 2 type having UTS 470 MPa and dia. 1.6 mm.

The material of construction suggested is Tata make grade A structural steel with low Si and low carbon, and $CO_2$ MIG wleding for good strength.

Recommendation to prevent fatigue failure of transition zone of bunker and hopper.

As reported in structural analysis of coal bins the live load is very much higher than in normal building structures. Thus fatigue failure at the transition zone is likely, for which following surface treatments were suggested :

a) Heat affected zone of welded joints at the transition zone of bunker and hopper need to be shot peened after fabrication as well as during periodical half yearly or quarterly maintenance. This will prevent or delay the fatigue failure of the transition zone. Shot peening will also retard stress corrosion cracking and corrosion. It will enhance hardness. Normally bunker were over designed with the assumption that fatigue cracking would never occur. The residual tensile stress of welded joints would also relieve themselves from the vibrations set up by flow of coal. But still post weld stress might have created fatigue cracks due to poor design on overload.

   The American Welding Society welding Handbook not only advises the elimination of tensile stresses from welding on critical components subjected to fatigue but also suggests that "it may be advantageous to induce compressive residual stress in critical areas of weldment where cyclic applied tensile stress are expected. This may be accomplished by welding sequence that controls residual stress from welding or by localized treatment that acts to place the surface in compression" (2).

   To prevent fatigue cracks in weldments proper control in grinding of concentration, drilling, and shot peening is also important. Hand held peening tools introduce a variable that could be eliminated with MIL-S-13165 C specification of shot peening equipment, where the equipment shall continuously remove broken or defective shots so that they will not be used for peening (3).

   The another important advantage of controlled shot peening is the fact that a harder, embrittled heat affected zone will be visually obvious after peening. There will be shallower dimpling in the harder area (4).

   Since fatigue strength is inversely proportional to resiudal surface stresses and shot peening provides the greatest surface stress reduction, control shot peening would offer the most effective post weld stress relief method to solve the problem of fatigue in transition zone of bunker and hopper.

## EXPERIMENTAL RESULTS

Attention to design details alone are not sufficient to ensure against failure, weld quality is also equally important. In general welding imperfections are only significant if they introduce stress concentrations which are more severe than those already present as a result of the basic weld geometry. The presence of high tensile residual stress in welded joint is also significiant in that applied compressive stresses are just as damaging as applied tensile stresses. The best solution for such problem is thermal stress relieving followed by controlled shot peening. Even manual peening gave 50% improvement in fatigue strength of welded joint for structural steel having ratio of fatigue strength to UTS equal to 0.42 following results of rotating bending fatigue study were obtained by Ojha (5).

| Test condition | Fatigue Strength MPa | Improvement |
|---|---|---|
| Virgin | 235 | 0 |
| Welded | 172 | -27 |
| Virgin Shot Peened | 288 | +23 |
| Welded Shot Peened | 203 | -14 |

## DISCUSSION

After shot peening fatigue strength of welded joints have increased from 172 MPa to 203 MPa. Further wear studies carried out by Rautaray (6) have shown that shot peening offered great potential for reducing the severity of abrasive wear. Therefore for coal bunker welding practice adopted should be $CO_2$ MIG welding with grade 2 type wire of 1.6 mm dia and UTS of 470 MPa. Welded joint should be shot peened in HAZ. This will definitely enhance fatigue and wear resistance both. Thereby life of the coal bunkers will be enhanced.

## REFERENCES


1. AWRA Technical note 14 Dec. 1984 Design and Construction of welded steel Bins - Australian Welding Research Association.
2. Welding hand book, Eighth Edition, American Welding Society.
3. "Shot Peening of Metal Parts" MIL-S-13165 C.
4. A concept for Preventing Repeated Weld Repairs of Bridge Structures - W.H. Welsch Shot Peening Theory and Application, IITT France Jack Chempaign.
5. Ojha L.N., Sharma M.C. and Janardanan P.N. Optimum shot peening parameter to improve fatigue strength of welded structural steel joints. Proc ICSP and BC Bhopal 98-103, Feb. 1996.
6. Rautaray S.K. and Sharma M.C. Shot peening reduce wear of Soil Engaging components of Tillage Machinery Proc. ICSP & BC Bhopal, 60-66, Feb 1996.