Failure Analysis Of Journal Bearings Of Tyre Moulding Press

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ABSTRACT

Journal bearings of the crank pin of a few tyre moulding presses were failing frequently. A manufacturing company urgently sought for causes for the failure and suitable remedy. In order to examine the causes of failure, the units were dissembled and cleaned. The adhering grease and stored grease in the tub and can were collected for assessment of the contaminants. Macrographs of the surfaces of the failed journals and bearings were taken.

It is noticed that the bearings and journal have undergone adhesive and abrasive wear. The journals in some cases were built-in with metal and hand finished. This was not having good conformability with bearing which was causing the adhesive wear. The grease had many foreign particles ranging from steel chips, bronze chips, weld slag, sand, dust, wood chips, and waste gauge. Some of the particles were even harder than the steel surface and were causing the abrasive were. The possible causes for the entry of these particles and methods of prevention are dealt in this paper.

INTRODUTION

Tyres are being manufactured by compression moulding process. The moulding operation is performed in hot moulds and at high compacting force. For this purpose special type of press known as tyre moulding presses are used. These are mechanical presses with top movable platen operated by cranks on either side of the press. The top portion of the tyre mould is fixed to the top platen. The bottom portion of the mould is fixed to the non-movable bottom platen. The moulds are provided with heating elements and proper electrical insulation. The compression moulding operation will take considerable time during which the force has to be maintained. The top mould lifting or closing operation is done slowly and takes about 10 minutes. A typical tractor tyre moulding press requires a force of the order of 13000 kN with crank pin journal of size diameter 435 x length 200 mm. The bearing pressure as high as 73 MPa is encountered at full load.

The cranks are connected to the pins at the top platen with bush bearing. The bottom portion of the cranks carrying the bronze bush bearings engage with the journal portion of the pins which form integral part of bull gears on either sides of the press. A pinion and a two-stage gear reduction unit drive the bull gear. The power is given to the gear train from a reduction gearbox connected to an induction motor. The overall reduction is about 6000. The compression stroke will take at least 5 minutes. The crank pin and top platen pin journal portion are fine finished and the crank is provided with phosphor-bronze bushes. The bearing is having grooves inside for lubrication flow and is lubricated with grease with force feed from centralized unit located in the press. This unit also lubricates the gears and other journal bearings.

The presses after the assembly undergo several trials, before they are dismantled partially and packed off to their destination. During the dismantling of the cranks for packing, it was noticed that some of the cranks had deep scratch marks and burn marks on the bush bearing and the journal portion. These did not pass the quality requirements and had to be replaced with new components. This sort of problem was occurring recently with higher frequency. This called for urgent investigation and preventive measures. This has formed the basis for this paper.

FAILURE ANALYSIS

Methodology

The crank pins and bush bearings have undergone wear failure. This being a surface phenomenon, the examination of the surface and characterization to identify the fundamental mode of wear is essential. The process of wear also generates the wear debris, which can give the clue to the type of wear. The analysis of the lubricant and the contaminants in it gives the insight to the process of wear and ideas to control the wear.

Surface analysis

In order to carryout the surface analysis of the crank pins and the bush bearings, the cranks from the press were dismantled. The adhering grease on the pins were collected and packed separately for the analysis. The pins were then cleaned with kerosene and examined by a 5x magnifying glass. The failed surfaces wear identified for micrographic study. Using a 4.1 Mega pixel Olympus camera, the damaged surfaces were photographed.

The bushes fitted on to the crank were cleared of the adhering grease and the grease was packed separately for examination. It is cleaned with kerosene. Using a hydraulic press, the bushes were un-mounted. The grease in the lubricating groove is removed and packed. The outer surface is also cleaned with kerosene. The cleaned surface was examined with the magnifying glass and damaged surface was marked for photomicrography.

Fig.1 shows one of the crank pins journal portion showing the scratch mark. Close up view of these scratches in Fig.2 indicates that the surface has been plowed by some particles harder than steel. The scoring is found to cover part of the circumference only. Burrs adhering to the grooves can be seen at a few places in Fig.3. The mating bush bearing with the above journal is shown in Fig. 4. A deep groove corresponding to the

Fig. 1: crank pin journal portion showing scratch marks.

Fig.2: Close up view of crank pin journal showing deep scratch.

Fig. 3: Close up view of the scratch showing burrs adhering to the surface.

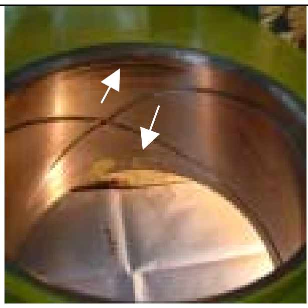

Fig. 4: Bush bearing with scratch mark at the lower end and dark adhesive wear patch at the top end.

Fig. 5: Enlarged view of the bush bearing showing deep scratch mark at the bottom edge.

Fig. 6: Enlarged view of the bush bearing showing the black adhesive marks at the top edge.

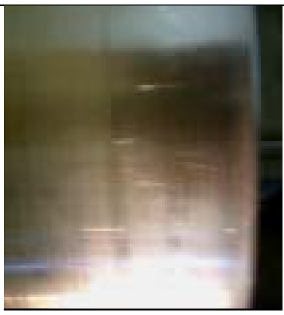		
Fig. 7: Cross marks and bronze smears.	Fig. 8: Dust particles in the grease of the LHS bearing.	Fig. 9: Dust particles in the grease of LHS journal.

one in the journal can be seen. The enlarged view of this is in Fig.5. Dark patches can be seen at some portions of the bearing in Fig.6. It was noticed that journal near the root portion was built up by welding to fill the blowholes and then hand finished. It appeared to have uneven surface. In some journals, scratch marks and smearing of bronze were seen in the axial direction (Figs. 3 & 7). This sort of cross marks can occur either during the assembly or the disassembly. If during the assembly fresh grease is used and proper care is taken, then this could have occurred during the disassembly with the bearing exposed to atmosphere partially which make it possible for the ingress of dust.

Analysis of grease samples

In order to find what has caused the abrasive wear, the grease samples are analyzed for contaminants. The grease collected from various bearings /journals were labeled to identify their location. About 20 grams of samples was spread over a watch glass. The large size particles were hand separated and cleaned with kerosene and dried on Whatman filter paper (5 micron pores) and stored for examination. The rest was dissolved in a stainless steel dish in different solvents. A numbers of solvents like acetone, carbon tetra chloride, trichloroethylene, kerosene were tried. Kerosene was dissolving the grease to some extent. However, this was not adequate for separating the contaminants. But dissolution in other solvents was very meager.

About 20 grams of grease sample was dissolved in 100 ml of TP detergent solution. The emulsion formed was diluted to make up to 250 ml in a beaker, stirred well and allowed to settle for two hour. The oil droplets floating on top of the solution was removed using a blotting paper. The balance solution along with the particles was stirred for some time and then allowed to settle. The lighter dust particles started floating at the top of the solution while the heavy particles settled at the bottom. After one hour, the upper portion of the solution containing the lighter particles was decanted over a Whatman filter paper, without disturbing the heavier particles settled at the bottom. The remaining solution was again diluted to 250ml, stirred and kept undisturbed for another one hour. The process was repeated until a clear solution was obtained with the heavy particles at the bottom. Then, the solution was filtered with Whatman filter paper to collect particles size above 5microns.

The filter paper along with the heavy particles was dried. Ferrous particles were separated using a magnet. The photographs of the particles taken with digital camera are shown in Fig.8 to 27.

Fine dust particles in agglomerate condition found in the LHS bush and journal grease are shown in Fig. 8 and 9. The dust was similar to shop floor dust. Similar dust particles were seen in the RHS bush and journal grease. However, the dust in the top bush and journal was much less. The size of the particles was between +5 and –44 µm. Various iron particles found in the grease are shown in Fig.10 to 15. Particles of droplet, curly chips, brittle chips and grinding swarf were seen. Some chips had sharp edges. All these chips were in work hardened condition. The size ranged from 44 µm to 10 mm.

Bronze particles are shown in Fig.16 to 21. Shapes ranged from globular, acicular, curly, and flaky to fine dust. Some particles were bright and shiny as seen in Fig.18 and 21. Others were in a little tarnished condition. The cleaned lubricating grooves showed some adhering machined chips and fine particles. These particles are all in work hardened condition.

The non-metallic particles such as pieces of cotton threads, plastic, grass weeds wood chips, broom chips , slag, earth, iron oxidized and silica were seen in the grease samples (Fig. 22 to 27). The shapes were globular, fibrous, rounded and acicular. The size ranged from 100 μm dust to 15 mm chips.

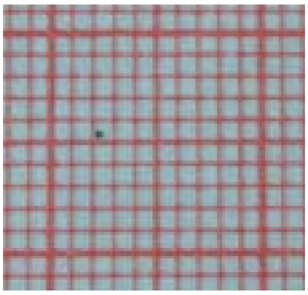

Fig. 10: Steel particle in the grease of LHS journal.

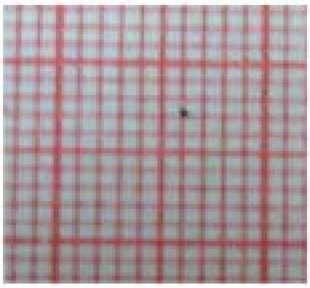

Fig. 11: Steel particle in the grease of RHS journal.

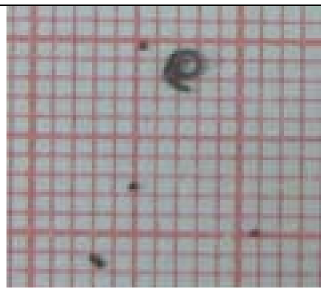

Fig.12: Steel particles in the grease of RHS bottom bush.

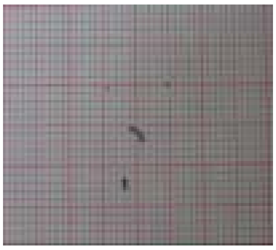

Fig.13: Steel particle in the grease of LHS bottom bush.

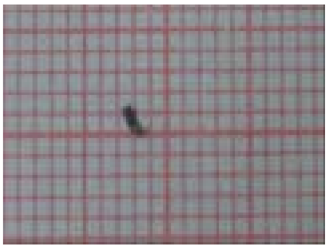

Fig.14: Steel particle in the grease of LHS bottom bush.

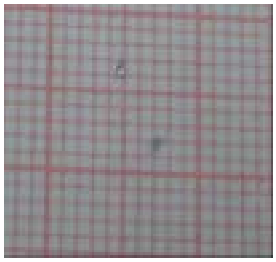

Fig.15: Steel particle in the grease of LHS bottom bush.

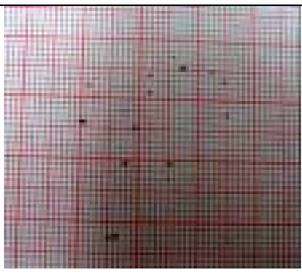

Fig.16: Bronze particles in the grease of LHS bottom journal.

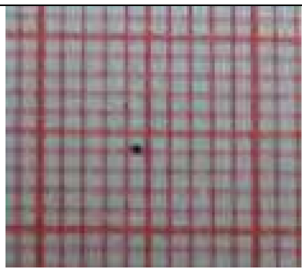

Fig.17: Bronze particles in the grease of RHS bottom journal.

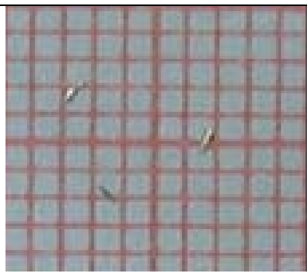

Fig.18: Bronze particles in the grease of RHS top journal.

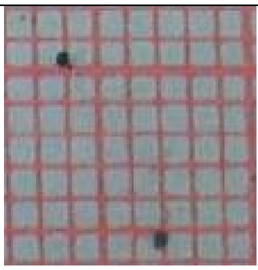

Fig.19: Bronze particle in the grease of RHS bottom bush.

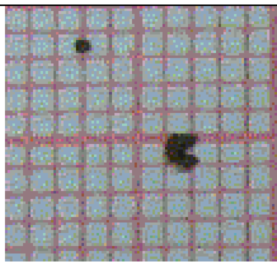

Fig.20: Bronze particles in the grease of RHS bottom bush.

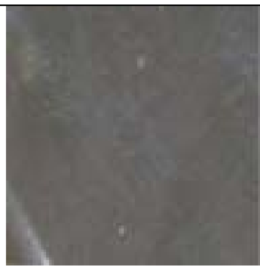

Fig.21: Shiny bronze particles in the bush grease.

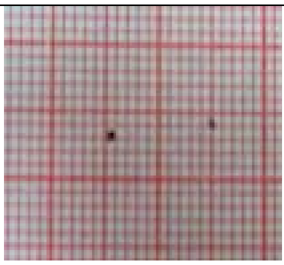

Fig. 22: Dust particles in the grease of RHS journal.

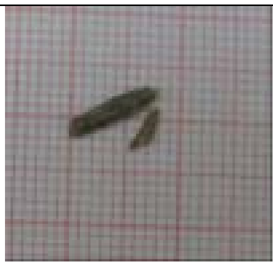

Fig.23: Wooden particles in the grease of RHS bottom bush.

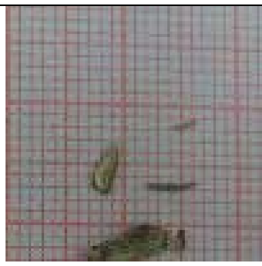

Fig.24: Wooden particles in the grease of RHS bottom bush.

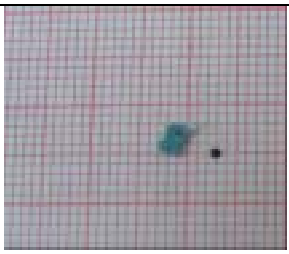

Fig.25: Thread and slag particle in the grease of RHS bottom bush.

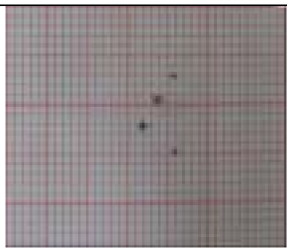

Fig.26: Nonmetallic particles in the grease of RHS bottom bush.

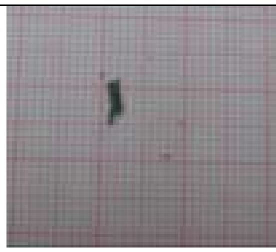

Fig.27: Particles of plastic, grass weeds and dust contained in open can grease.

DISCUSSION

The small content of dust particles which found in the grease is very fine in nature and hence they cannot bring about deep abrasive wear. They may cause polishing type of wear (mild abrasion) which can help to some extent in conforming the two surfaces. Hence they are considered harmless in the present context. However, their entry into the working surface is not advisable. The source of their entry is found to be fluidization of the floor dust during sweeping, mopping the press surface with dry clothe and while handling of the parts, and air draft cleaning of the press surface.

The deep grooves observed on bushes and journals are akin to plowing by a single point tool which is an abrasive wear. For such a damage the cutting edge has to be harder than the both the surfaces. This situation is promoted by the ingress of the particles of slag or work hardened steel chips, chilled grinding swarf or chilled molten steel material from the welding seen in the grease samples. It is likely that hard particles got embedded in the bronze bush and abraded the steel surface. During the reverse rotation, the burr formed in the crank journal surface has caused the abrasion of the bush (Fig.5). The burr has also dislodged the particle into the lubrication channel and it has not caused further damage. This is inferred from the scratch mark extending from one lubrication channel to the other and scratch formation extending only to 1/3 of the journal surface Figs. 1& 4.
The iron chips whose hardness is more than 400 VHN and slag particles whose hardness is about 1000 VHN are potential dangers from the abrasive wear considerations as the crank surface hardness was 220 to 250 VHN and bronze bush was 90 to 120 VHN.

The source of entry of iron particles is found be from the adjacent machining spot, welding region on the press after the mounting of the cranks, grinding zone on the press surface. In fact, the press was not fully cleaned and machining chips were seen in some of the pockets in the press. Air blowing of the surface of the press was the most undesirable method of cleaning, that too after mounting the crank with greased bearing. The cranks were stored in the shop floor and in adjacent area surface grinding was performed with hand grinder. Further, the crank and the bush mounting press were not cleaned before the mounting operation. The mounting press was full of dust as welding and grinding operations go on all around with giant size fans running all the time for worker's comfort. Hence, it is suggested that the cleaning operation should be done with vacuum cleaner or wet cloth which will prevent the fluidization of the particles and contamination.

The grease lines were observed closely and it was noticed that the faring operation was not followed polishing and cleaning operations. The tubes were not clean enough for lubrication lines. Cutting burrs were adhering to the edge before assembly. It is advised that the lines are thoroughly cleaned with kerosene initially to free the dust and adhering particles. Only after ensuring this, the grease tank should be filled with clean grease.

The bronze particles seen in the grease may not be harmful to the steel journal surface. Since they are work hardened and are harder than the bronze bush surface they can be potential dangers for the bush. Embedment of the particles in the bush surface may cause unevenness in the surface and improper pressure distribution. The situation can lead to adhesive wear as the contact pressure was found to be of the order of 72.7 MPa. Such an adhesive wear of the bush due to unevenness of journal surface is seen in Fig.6 due to metal to metal contact. This can be avoided by replacing hand grind finishing proper machining of the built up portion to obtain conformed surface.

It is observed that the lubrication channels, drilled holes were not cleaned properly in a hurry to assemble and complete the work. Many of the used bushes when cleaned revealed the particles adhering in the holes and channels. It is suggested that the channels be emery polished to relieve the machined burrs and cleaned with acetone or kerosene before assembly. Air blowing in a separate cleaning zone is advisable for all parts especially the lubrication lines, bushes, cranks and the press.

The other non-metallic particles such as the plastic pieces, wood pieces, grass seeds, broom stick pieces may not cause abrasive wear as they are much softer than the both the working surfaces. But they can clog the lubrication lines as the sizes seem to be quite large. The clogged lubrication can give rise to the adhesive wear.

It is observed that the dusting of the press surface was done sometimes with the broom. During this period the crank portion of the press was not covered. Grass seeds and broom pieces would have found entry in this operation. Tearing of the name stickers and pasting operation period, the pieces of the plastic would have found entry into the open working surface. The bush and the journal surfaces were cleaned with thread waste which is not a desirable method. Even if it is followed, it should be for the first cleaning operation. Final cleaning will have to be done with banian cloth. It was observed that during this process some of the waste thread adhering to the surface was noticed in surface where burrs existed. Bush groove and journal skirt region were the culprits and these regions needed the emery polishing the before assembly. The wooden logs kept at the higher decks of the press where heavy parts are unloaded for assembly, would have generated wood chips which would have found its way in to the working surface.

The grease cans and drum were left open which attracted the contaminants. Cleaning of the lid and top edges with thread waste should be avoided as it attracted thread pieces.

Some of the suggestions made and a few lecture demonstrations have brought considerable change in the attitude and work culture. This has prevented the recurrence of the wear failure.

CONCLUSIONS

The wear failure can be avoided by redrafting the assembly sequence in such a way that the crank and the bush assembly is preceded by all other operations and confining the air draft cleaning operations in a separate bay. A still better way will be performing the assembly in a bay separate from the general purpose machine shop and maintaining an air pressure of 0.1 bar above the atmosphere in the bay to prevent the entry of the air borne contaminants into the working surfaces. A transformation of work culture and attitude is the final solution to the problem which has been amply demonstrated here.
