Assetivo

Case Studies

Case Study: RCA on Fryer Bearing Failures.

Executive Summary

Repetitive bearing failures on Fryer 1 – particularly Stage A Tail End – have been a concern for some time at the Food Manufacturer. They have caused recurring, unplanned stoppages and lost production which increase life cycle costs for the asset. Bearing failures increased significantly from early 2016 to present day (2019). The principal failure mode of bearing failures is seizure – occurring always during normal production runs. A cause and effect study showed the principal physical and systemic causes to be an inter-connected combination of grease lubrication functional failure, corrosion, heat overload, water ingress, chemical and physical damage to seals, and a lack of a power wash / cleaning SOP. The solutions recommended were a move to AMI bearings, bearing caps, temporary bearing covers to be used when cleaning after a boil-out, and a new SOP with focus on cleaning mechanical, electrical and instrumentation assets and components. A further set of recommendations were included to address maintenance and asset management deficiencies found during the investigation. These included spares holding, maintenance strategies, CMMS functional locations, failure recording and Fryer cleaning, among others.

The Problem Statement

Table 1: The Problem Statement

The Problem	**Fryer Stage A conveyor bearing(s) seized (chronic failures)**	
When	Date	Recurring, approximate MTBF 1.1 months
	Time	Cumulative bearing failures accelerated at the end of 2015 and have maintained the high failure rate ever since. Increasing again in January 2018.
	Unique	Anytime during normal production.
Where	Facility	Food Manufacturer
	System	Line 1 Fryer Tail End Conveyor Stage A
	Component	DE & NDE Bearings
Actual Impact	Safety	N/A
	Environmental	N/A
	Revenue	N/A
	Cost	Based on an assumed average MTTR of 1 hour, Lost production: £1300, New bearing: £250, Labour: £60, Admin/SAP/MRO: £50. **Total: £1660 per failure.**
	Frequency	Chronic. Current MTBF 1.1 months.
	Company Reputation	N/A
Potential Impact	Safety	Failed bearings increase the risk of Fryer fires due to increased heat loading on bearings in the presence of carbon and oil deposits.
	Cost	Bearing failures may cause secondary damage to shafts, and drive motors.

Cause & Effect Summary

The Main Causal Paths & Themes

The cause and effect chart determined that the principal physical causes of the failure were bearing grease functional failure, corrosion of bearing surfaces, and subsequent heat overload in the bearing raceways. Refer to Appendix 1 for the full chart. The reason for functional failure was determined to be contamination of the base oil, thickener, and additives. The three driving forces that co-existed to cause the grease functional failure were the failure of the bearing seals, water contamination of the grease, and chemical contamination of the grease. The latter, however, was not thought to be a strong contributor to grease functional failure. However, chemical attack of the 'rubberised' seals in conjunction with close contact pressure washing was thought to contribute more strongly – again as physical root causes. Doubts – unconfirmed - were also raised regarding the temperature resistance of the bearings seals. From a systemic cause perspective, the cause effect chart revealed that there is no Standard Operating Procedure (SOP) available for guidance on power washing Fryer 1 - especially in terms of how to deal with mechanical, electrical and instrumentation assets and components. Evidence collection also revealed that Fryer 1 is being run at 33% above asset nameplate capacity where the Food Manufacturer line rate is 20,000 Kgs/Hour as opposed to OEM stated capacity of 15,000 Kgs/Hour.

Recommended Solutions

The following Table 2 matches root causes to solutions with costs, comments, responsibility, and due dates.

Table 2: Recommended Solutions

Cause	Solution	Costs	Comments	Responsible	Completion Date Agreed	Date Completed
Bearing Seals Failed	AMI Bearings (with high temp. inserts) and Silicone Seals as per Fryer 2	Approx. £240 per bearing + delivery costs from USA	Performance trial to be run on DE and NDE	Assetivo (quote) & Company Eng. (order & fit)	To be agreed	
Water Forced into Bearing Raceways	**Bearing Caps (twist/screw type) – where there is**	**Awaiting costs from same supplier –**	**Not on original quote – but has been requested**	**Assetivo (quote) & Company**	**To be agreed**	

During Cleaning	**sufficient space to fit them.**	**likely minimal**	**from USA supplier.**	**Eng. (order & fit)**		
Water Forced into Bearing Raceways During Cleaning	Temporary Bearing Covers (applied when Jet Washing) & mechanical scraping of bearings	Low – Can be an in-house designed solution.	This solution would require an engineering solution and collaboration between Engineering and Operations	Company Operations & Engineering	To be agreed	
No SOP Available for Cleaning with Power Wash Lances	**SOP – specific guidance on cleaning electrical, mechanical and instrumentation components. New method to be included for cleaning bearings.**	**Low – SOP is to be developed in-house.**	**Further investigation and agreement is needed on how to clean bearings of scale and grease. All Fryer operators require training on the SOP.**	**Company Operations**	**To be agreed**	

Additional Recommendations

1. Increased bearing failures on Fryer 1 since late 2015/2016 to present day - Internal company investigation required to determine trigger point for the dramatic, step change – see Appendix 5. This is deemed a high priority by Assetivo.

2. Fryer 1 running at 33% above nameplate capacity – it is recommended that an FMEA-driven maintenance strategy is developed for this asset. A strong focus on reliability-centred maintenance principles is needed due to the increased risks to asset performance and life cycle costs. This strategy can be developed via Assetivo or in-house. If the latter is preferred, then it is recommended to engage with Assetivo during the strategy development.

3. Spares holding for Fryer 2 AMI Bearings – it has been noted that the Food Manufacturer do not hold all spares for all Fryer 2 bearings and have no policy in place for re-ordering (i.e. no supplier in place). This is presently a business and operations risk. Please investigate.

4. Remove time-based replacements on Fryer 1 Tail End 4 bolt flange bearings - see comments in Appendix 2.

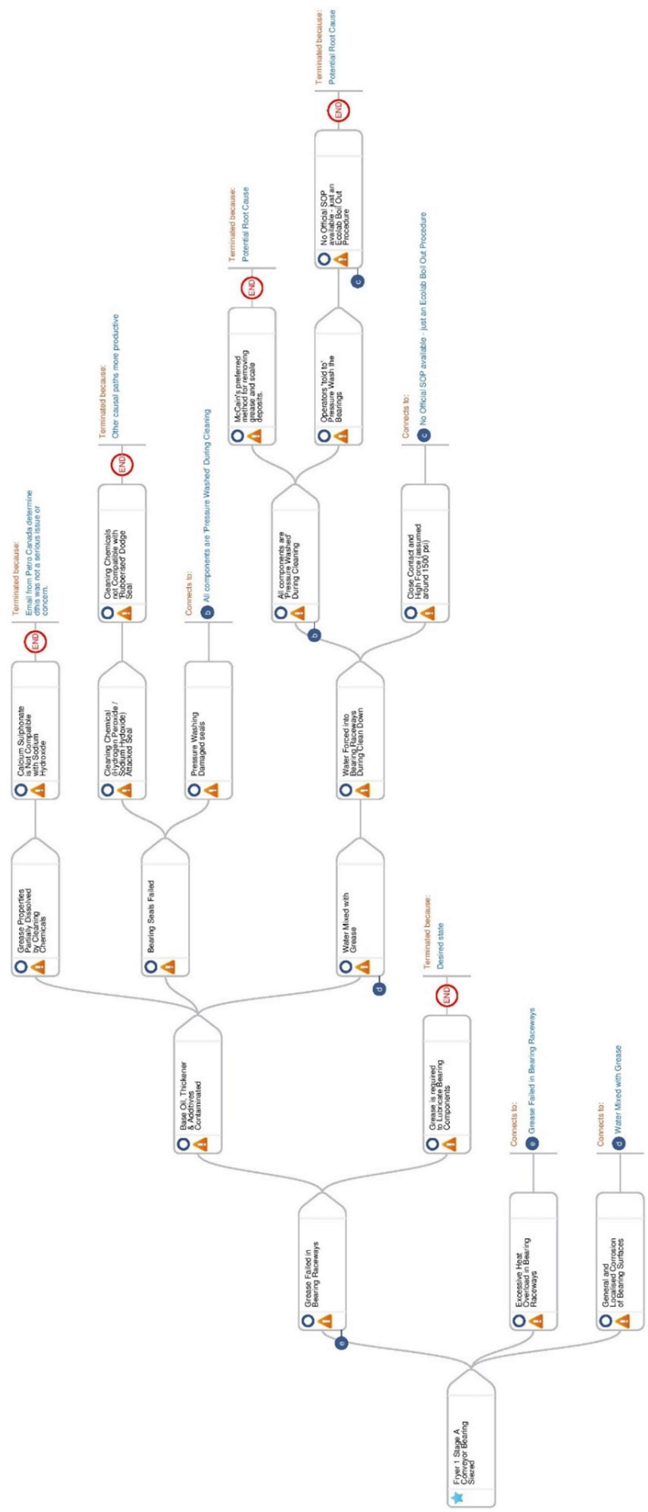
5. Improve Fryer SAP FLOCs and failure recording – in gathering data it was noted that all Fryer bearing replacements were recorded to a poor standard and at too high a level in the SAP hierarchy. This made analysis particularly challenging and will present a future risk to reliability improvement projects and defect elimination. It is strongly recommended that the Food Manufacturer considers investing in optimising the asset hierarchy to align with ISO 14224.

6. Mechanical scrapers – the OEM manual for Fryer 1 mentions scrapers can be used for cleaning the fryer. Investigate if these are a feasible alternative as part of the new SOP to be developed.

Appendices

Supporting documentation on the following pages.

Appendix 1: RCA Cause & Effect Chart



Appendix 2: Selection of Bearing Failure Photographs (corrosion & contamination)

It must be noted that the investigation and analysis indicated that the failed bearings are not genuine wear out failures. They are not reaching their natural wear out phase or anywhere near their L_{10} life (the statistical time at which 10% of these bearings would have failed under the same operating conditions). The bearings appear to be a mixture of infant mortality and random failures. This means that time-based replacements will have no effect on reliability and is not a valid strategy in this instance.

Appendix 3 Bearing Failure Analysis

3. Bearing Investigation

Bearing type:	Insert Bearing	
Bearing designation:	DODGE SC-55-MM	211
Housing designation:	DODGE F4BC	
Bearing reference name:	BRG A	
Manufactured:	USA	
Visual investigation summary:	The bearing suffered mostly from moisture contamination leading to corrosion found on the housing and bearing components. Photos below are a visual summary of the findings.	
Disposition	To be Scrapped 21-05-2019	

Fig.1 Housing Front: Corrosion

Fig.2 Housing Bore: product contamination & corrosion

Fig.3 Lubricant: Solid, hard & dry

Fig.4 IR Raceway: Lubricant starv. & discolouration

4. Application assessment

On first reception of the bearing, it was unable to rotate due to the level of corrosion on the internal components. From the inspection, it is clear that the bearing was subject to high levels of moisture contamination, evident in most of the images in section 3 of this report. Figures 7 and 8 highlight the polished rolling contact path that is slightly biased to one side of the outer ring, this indicates that the bearing is subject to an axial load component. The "orange-brown" discolouration found on the inner ring, outer ring and rolling elements is indicative of a high temperature condition.

All the lubricant found in the bearing was hard, solid and brittle, a combination of moisture contamination and high temperature being the most likely cause. Lubricant in this condition is unable to function correctly. Lubrication is a critical component in the proper functioning of a bearing. If there is insufficient lubrication or if the lubricant has lost its lubricating properties, an oil film cannot form between the bearing internal surfaces and metal-to-metal contact occurs leading to accelerated bearing damage.

Additional Assetivo comments: *The grease thickener acts like a sponge, it holds the oil in suspension , as the bearings rotates the thickener is compressed, it releases the oil which is what creates the lubricant film to support the load between the rotating and stationary elements, along with coating the surfaces to prevent corrosion. The hard deposits are what is left of the thickener with no oil present. If the seals become damaged, the oil will not remain within the bearing, so will not be recaptured by the thickener, this will then lead to lubrication failure.*

5. Conclusion & Recommendations

5.1. Damage according to ISO 15243:2004

Bearing A			
Failure Mode/most distinctive damage	Moisture corrosion	resulting from	- Presence of water - Standstill corrosion/etching causing: • Pitting • Poor lubrication conditions

- Prevent corrosion by improving protection of bearing from moisture contamination
- Ensure the bearing solution can cope with temperatures around 190°C
- Ensure correct lubrication type, quantity and relubrication intervals are employed

Appendix 4: Two-Stage Fryer Design Capacity

Capacity: 15,000 Kg/Hr
(33,000 #/Hr)

Stage One

Cook Length: 5.5 m (18')

Flow: 817.2 Cu Mtr/Hr (3600 Gpm)

Design Oil Depth (above belt): 90 mm (3.5")

No. of Zones: 2

Belt: Marcon EQ-72-18-16 Carbon Steel
½" brite steel rods with carbon drags on 3" centers

Pump: Cornell 8H-FISK
125 HP- 415V / 50Hz / 3Ph
13.5" Impeller
3600 Gpm @ 100 Ft Dth

Heater: Harris Thermal 12 Mlbtu/Hr Steam Heat exchanger
19.3 Bar (280 psig) at the vessel
199°C (390°F) out put with an 8°C (14.5°F) Delta T
.31m/s (12 Ft/s) tube speed

Filtration: Chip Chain Filter- Belt mesh EQ weave 48-51-16
Lakos CSX-2300-HL counter flow @ 6 o'clock inlet
Sweco Separator- XS48S666 for hot oil
Paper filter- 48" wide paper (Previously Supplied)

Stage Two

Cook Length: 4m (13 Ft)

Flow: 817.2 Cu Mtr/hr (3300 Gpm)

Design oil depth (above belt): 90mm (3.5")

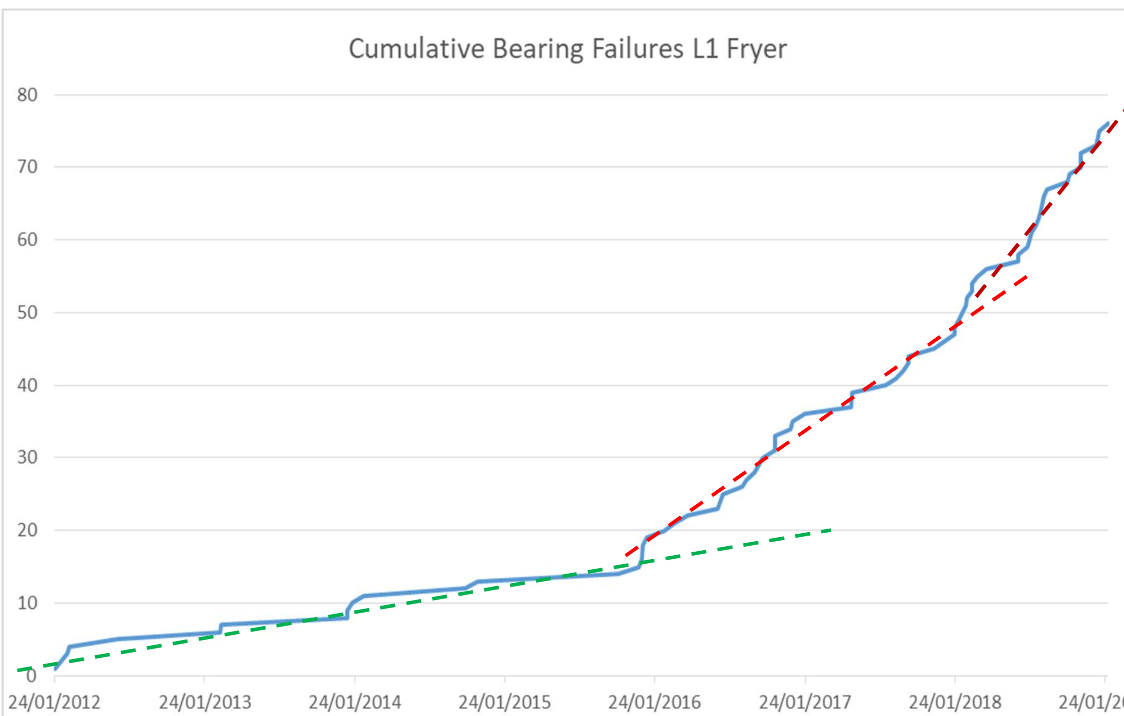
No. of Zones: 3

Belt: Marcon EQ-72-18-16 Carbon Steel
½ bright steel rods

Pump: Cornell 8H-FISK
125 HP- 415V / 50HZ / 3PH
13.5" Impeller
3300 GPM @ 110 FT DTH

Appendix 5: Bearing Failure Trends

Analysis of historical work orders on Fryer 1, clearly show a significant, step-change increase in failures around late 2015/early 2016. The rate of failure was maintained from that date. It was then seen to increase once again around January 2018. Assetivo has been unable to retrieve any robust data/information from the Food Manufacturer regarding potential reasons for this significant change (i.e. product changes, process changes, cleaning changes, projects, upgrades, etc.). In terms of asset maintenance, the Dodge bearings used have been used since initial installation in 2000, and the lubricant type was changed in early 2013 approximately – two years prior to the step change. As a point of note, historically, Dodge bearings have arrived on site with no lubricating grease. It is believed that many have been installed on Fryer 1 with no grease and therefore have failed rapidly. There is now a process in place to stop this occurring. <u>However, the larger, unresolved step change issue seen below is considered critical by Assetivo and needs further investigation by the Food Manufacturer as soon as possible.</u>



Appendix 6: Current Maintenance Strategy for Fryer 1 Tail End Bearings

Maintenance Task	Frequency	Other	Comments
Lubrication	7 days / 2 grams	Rolling Element Bearings	
PM	18 weeks		*Replace both Dodge 4 hole flange bearings on stage A at fryer in-feed end (non drive end - drive side/non drive side) (((TIME - BASED)))*
VI	7 days	'Bearing Inspection'. No issues noted from 19th Dec.2018 to 11th April 2019.	*Visually inspect all 8 DS & NDS bearings (not including the outfeed bearings) for evidence of dark, cakey or milky grease around the bearings. Look for any signs of corrosion or other deterioration of the surface, seals or obvious physical dimensional characteristics.*

Appendix 7: OEM Lubrication Recommendation

Hours Run Per Day	Suggested Lubrication Period in Weeks							
	1 to 250 RPM	251 to 500 RPM	501 to 750 RPM	751 to 1000 RPM	1001 to 1500 RPM	1501 to 2000 RPM	2001 to 2500 RPM	2501 to 3000 RPM
8	12	12	10	7	5	4	3	2
16	12	7	5	4	2	2	2	1
24	10	5	3	2	1	1	1	1

Appendix 8: RCA Solutions Chart

Cause	Solution	Effectiveness	Ease of Implementation	Return on Investment	Potential Negative Impacts	Totals
Bearing Seals Failed	AMI Bearings (high temp. inserts) with Silicone Seals as per Fryer 2	7	7	7	10	31
Bearing Seals Failed	OR SKF Bespoke Bearings (new, proprietary sleeves and seals)	7	7	3	10	27
Water Forced into Bearing Raceways During Cleaning	Bearing Caps (twist/screw type)	3	7	7	10	27
Water Forced into Bearing Raceways During Cleaning	Temporary Bearing Covers (applied when Jet Washing) & mechanical scraping of bearings	7	3	3	7	20
No SOP Available for Cleaning with Power Wash Lances	SOP – specific guidance on cleaning electrical, mechanical and instrumentation components. New method to be included for cleaning bearings.	3	7	10	7	27

Scoring Range 1 – 10, using values of 1, 3, 7, 10 only.