CATALYTIC FINES

(CAT FINES) IN MARINE FUEL OIL

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AGENDA

01 **What Are Catalytic Fines?**
Origins from the oil refining process

02 **Why Cat Fines Are Dangerous**
Mechanism of engine wear and damage

03 **Regulatory Framework**
ISO 8217 limits vs engine maker recommendations

04 **The IMO 2020 Factor**
How sulphur cap rules worsened the problem

05 **Onboard Fuel Treatment**
Purifiers, settling tanks, best practices

06 **Case Study: MV CARELESS**
Engine failure due to cat fine mismanagement

07 **Key Findings & Conclusions**
Expert opinion and lessons learned

WHAT ARE CATALYTIC FINES?

DEFINITION

Catalytic fines (cat fines) are microscopic particles of **aluminium and silicon oxides** originating from catalysts used in the crude oil refining process (catalytic cracking).

KEY CHARACTERISTICS

- Size: 1 – 100 µm (mostly 5–25 µm)
- Harder than engine metal surfaces
- Density higher than fuel oil — will settle
- Hydrophilic — bind with water droplets
- Chemical composition: Al_2O_3 + SiO_2

HOW DO THEY ENTER MARINE FUEL?

STEP 1

Catalytic cracking splits heavy hydrocarbons into lighter, more valuable distillates. Catalyst particles (Al + Si) assist this process.

STEP 2

Refineries try to recover catalysts, but complete removal is not economically viable. Small quantities carry over into residual fuel.

STEP 3

Slurry oils — rich in cat fines — are used as low-sulphur blending stock for HFO, increasing cat fine concentrations.

STEP 4

Bunker fuel delivered to ships may contain up to 60 ppm (ISO limit) or more of cat fines.

WHY CAT FINES ARE DANGEROUS

MECHANISM: THREE-BODY ABRASION

Cat fines become embedded in the porous cast iron surfaces of cylinder liners and piston rings. They then act as abrasive "cutters," wearing away the harder counterpart surfaces. Since the particles are harder than engine metals, it is the engine that wears — not the particles.

Cylinder Liners

Cat fines embed in the liner surface, closing graphite pores. Wear rates can exceed safe limits dramatically. Scuffing and scoring are classic symptoms.

Piston Rings

Rings wear unevenly, develop sharp edges and break. Broken ring pieces enter the exhaust manifold and turbocharger, causing cascading damage.

Fuel Pumps (Barrel & Plunger)

Extremely tight clearances in Helix-type pumps are destroyed. Worn pumps cannot generate injection pressure — engine slows and stops.

Fuel Injectors

Nozzle holes blocked by carbon/wear debris. Poor atomisation reduces combustion efficiency and worsens wear.

Turbocharger

Wear debris from broken piston rings deforms and fractures turbine blades, severely reducing engine performance.

Piston Rods & Stuffing Boxes

Wear particles form an abrasive paste with scavenge oil, attacking piston rods and seal rings in stuffing boxes.

REGULATORY FRAMEWORK

1980s	First reports of cat fine engine damage as catalytic cracking became widespread
ISO 2005	ISO 8217:2005 — maximum cat fines in delivered fuel set at 80 ppm Al+Si
ISO 2010/12	ISO 8217:2012 — limit tightened to 60 ppm Al+Si following increase in damage claims
ISO 2017	ISO 8217:2017 — 60 ppm limit maintained; current applicable standard
IMO 2020	Sulphur cap (0.5% m/m) drives greater use of catalytic cracking, raising cat fine content in LSFO
MAN SL 2017-638	MAN engine maker recommends maximum 15 ppm at engine inlet; optimal target 7–8 ppm

⚠ CRITICAL GAP: ISO delivers fuel at up to 60 ppm — engine makers require ≤ 15 ppm at inlet. Onboard purification must bridge this 4× gap.

THE IMO 2020 FACTOR

3.5%
Max sulphur
before IMO 2020

0.5%
Max sulphur
after IMO 2020

43%
Vessels with potentially
critical cat fine levels*

≥60ppm
Cat fines found
in some bunker ports

** ExxonMobil analysis of >400,000 oil samples (Alfa Laval report)*

WHAT CHANGED AND WHY

- IMO 2020 (MARPOL Annex VI, Reg. 14.1.3) mandated a drastic cut in marine fuel sulphur from 3.5% to 0.5% m/m from 1 January 2020.
- To produce compliant Low Sulphur Fuel Oil (LSFO), refineries significantly increased the use of catalytic cracking and used slurry oil (cat fine-rich) as blending stock.
- This directly elevated the cat fine content in bunker fuel delivered to ships.
- LSFO already had higher cat fine concentrations than traditional HFO — IMO 2020 amplified this trend.
- Proactive owners issued technical circulars (e.g. MAN SL2017-638/DOJA, BIMCO/ICS/INTERCARGO guidance) warning crews of the increased risk from 1 January 2020 onwards.
- Vessels that did not update fuel handling procedures faced a substantially increased risk of engine damage.

ONBOARD FUEL TREATMENT — REDUCING CAT FINES

1	2	3	4	5	6
Bunker Storage Tank	**Settling Tank**	**Purifiers (Separators)**	**Service Tank**	**Auto Backwash Filter**	**Engine Inlet**
Cat fines settle at bottom (gravity). Storage temp ≈ 45°C max. Daily draining removes water.	Further settling by gravity. Daily draining essential. Tank cleaning at dry-dock critical.	Centrifugal force separates cat fines. 75–80% efficiency max. Temperature, flow rate and gravity disc critical.	Clean fuel held here. Overflows return to settling tank. Daily draining essential.	30 µm (ME) / 10 µm (AE) final filter. Cannot catch 5–25 µm cat fines at 30 µm.	Target: ≤15 ppm Al+Si. Optimal: 7–8 ppm. Above 15 ppm → accelerated wear begins.

PURIFIER BEST PRACTICES

- Run TWO purifiers in parallel if cat fines >25 ppm
- Fuel inlet temperature: 98°C (MAN SL recommendation)
- Flow rate: 110% of daily consumption max (55% each if dual)
- Correct gravity disc for fuel density
- Minimum 1–2 bar back pressure on light phase outlet
- Drain settling & service tanks daily

CASE STUDY: MV CARELESS — BACKGROUND

VESSEL PARTICULARS

Type:	Bulk Carrier
Owner:	Careless Shipping Ltd
Manager:	Careless Management Inc.
Flag:	Careless
DWT:	50,000 mt
Main Engine:	MAN
MCR Power:	10000 kW at 130 rpm
Voyage:	Tallinn (Estonia) → Dar Es Salaam
Cargo:	50,000 mt grain in bulk

CHRONOLOGY OF EVENTS

- **Nov 20, 2022**
  Bunkered 700 mt LSHFO in Rotterdam with 37 ppm cat fines. Owner issued specific instructions to treat carefully.
- **Dec 22, 2022**
  Vessel switched from LSMGO to Rotterdam LSHFO for the long voyage south.
- **Dec 28, 2022**
  Changed to 700 mt Rotterdam stem. Fuel rack position began to creep upward — early sign of fuel pump wear.
- **Jan 3, 2023**
  Main engine failed to start astern — crew cleaned fuel filter. Not logged.
- **Jan 7, 2023**
  Second failure to start — crew manually pushed fuel racks to fire engine. Not logged.
- **Jan 11, 2023**
  Main engine emergency stop at 01:15 hrs in an IMO-declared piracy zone.
- **Jan 16, 2023**
  Towage commenced by Tug to Duqm, Oman.
- **Jan 25, 2023**
  Vessel arrived Duqm under tow for full engine overhaul.

CASE STUDY: THE PROBLEM FUEL

Date	Port	Qty (mt)	Viscosity (cSt)	Density (kg/m³)	Al+Si (ppm)	Sulphur %	Status
20/11/22	Rotterdam	700	82.2	972.5	**37**	0.47%	**⚠ HIGH — use 2 purifiers**

KEY FACTS ABOUT THE ROTTERDAM 700 mt STEM

- Cat fine content: 37 ppm — within ISO 8217:2005 limit of 80 ppm and ISO 8217:2017 limit of 60 ppm, BUT well above the engine maker's 15 ppm inlet limit.
- Lab analysis flagged the fuel and explicitly recommended using both purifiers in parallel with reduced flow rate.
- Owner's Technical Manager e-mailed specific instructions to the vessel
- Despite these instructions, only ONE purifier was operated during consumption of this stem — the root cause of the engine failure.
- Unusual density of 972.5 kg/m³ (vs normal ~940 kg/m³) required careful gravity disc selection.

CASE STUDY: ENGINE DAMAGE FOUND AT DUQM

MAIN ENGINE

- Cylinder liner No.1 worn beyond maker's limit (504.9 mm vs max ~504 mm)
- Liners No.2 & No.5 at or near maximum wear limit
- All 6 liners showed scuffing & confirmed cat fine deposits
- Cat fine concentration on liner surfaces: ~4,000/cm² (normal: 100–200/cm²)
- Piston rings on units 1 & 5 broken; ring pieces in exhaust manifold
- All 6 fuel pump barrels & plungers: excessively worn — plungers 'just dropped in' with no resistance
- All injectors: carbon build-up, blocked nozzles, poor atomisation, leaking
- Turbocharger turbine blades: deformed with tip fractures from broken ring debris
- Piston rods 1 & 5: scuffing marks; all piston rod stuffing boxes worn

PURIFIER EFFICIENCY TEST

Parameter	BEFORE purifier	AFTER purifier
Cat fines (ppm)	48	47
Water content	2.5%	2.5%
Expected after (80% eff.)	—	~9.6 ppm

Result: Near-zero purification efficiency — cat fines passed through unchanged.

AUXILIARY ENGINES (No.1 & No.2)

- All 6 cylinder liners: scoring and scuffing marks
- No.1 AE: liners 1 & 5 exceeded maker's limits — replaced
- No.2 AE: liners 2, 3 & 6 exceeded limits — replaced
- All fuel pumps: excessive barrel/plunger clearances
- All injectors: carbon deposits, poor atomisation
- Expert opinion: AE damage consistent with ordinary wear and tear rather than direct cat fine attack (10 µm filters protective)

EXPERT FINDINGS & OPINION

CAUSATIVE FAILURES

Primary

Only ONE fuel oil purifier was operated instead of two in parallel, as required by Owner's own circular when cat fines exceed 25 ppm.

Primary

Feed rate at 110% of daily consumption — had two purifiers been used, rate per unit would have halved to 55%, dramatically improving

Contributing

Fuel inlet temperature at 88–90°C rather than recommended 98°C, though for an 82 cSt fuel this had limited impact.

Contributing

Rough weather stirred up settled cat fines in storage tanks, delivering a 'slug dose' — cat fines at purifier inlet measured 48 ppm vs 37 ppm

Exculpated

Gravity disc: Expert calculations confirm the correct 71.5 mm disc WAS fitted — service engineer's contrary finding was in error.

Exculpated

Tank draining: no evidence that settling/service tanks were not drained daily as required.

SEAWORTHINESS CONCLUSIONS

- The vessel experienced accelerated engine wear from ~29–30 December 2022 after changeover to the high cat fine Rotterdam fuel.
- The main engine failed due to excessively worn fuel pump barrels and plungers — insufficient injection pressure to maintain speed.
- Cat fine presence on cylinder liner surfaces confirmed by replica analysis at ~4,000/cm² vs normal 100–200/cm².
- The Chief Engineer admitted he failed to follow specific fuel handling instructions — he attributed this to severe personal distress during the Ukraine war.
- The Owner had adequate SMS, technical circulars, and crew training in place. The failure was in execution onboard.
- The Chief Engineer's single-purifier operation rendered the fuel treatment system incapable of reducing cat fines to the safe 15 ppm limit — the main engine failure was the direct result.

KEY TAKEAWAYS & INDUSTRY RECOMMENDATIONS

📋 Know Your Fuel

Always obtain and study bunker analysis reports before using a new stem. Identify cat fine levels relative to the 25 ppm trigger for dual-purifier operation.

⚙️ Run Dual Purifiers

Whenever cat fines exceed 25 ppm Al+Si, operate both purifiers in parallel at reduced flow rates. This is the single most effective preventive measure.

🌡️ Maintain 98°C Purifier Inlet

Lower viscosity at higher temperature aids separation. Follow MAN SL2017-638/DOJA unless fuel-specific lab instructions direct otherwise.

🔧 Gravity Disc & Back Pressure

Select the correct gravity disc for the actual fuel density. Maintain minimum 1–2 bar back pressure on the light phase outlet at all times.

🚿 Daily Tank Draining

Drain settling and service tanks daily to remove accumulated water and sludge. Rough weather can stir up settled cat fines — a particular hazard in heavy seas.

📊 Monitor Fuel Rack Position

An increasing fuel rack position at constant speed is an early warning of fuel pump wear. Act immediately — change fuel stem and investigate cause.

🏭 Tank Cleaning

Clean storage, settling and service tanks at dry-dock (or more often if dirty fuels are regularly bunkered) to prevent long-term accumulation of cat fines.

📚 Post-IMO 2020 Vigilance

LSFO and VLSFO carry higher cat fine risk than traditional HFO. Crew training and SMS must be kept current with evolving fuel quality challenges.

SUMMARY

① Cat fines are inevitable in modern marine fuel — management is everything.
② ISO 8217 permits up to 60 ppm; engines require ≤15 ppm. The gap must be closed onboard.
③ IMO 2020's sulphur mandate has materially increased cat fine risk in LSFO and VLSFO.
④ Dual-purifier operation at correct temperature and flow rate is the primary defence.
⑤ Failure to follow prescribed procedures — as in MV CARELESS — can lead to catastrophic, preventable engine breakdowns.