Request 17

Furnish Ford's assessment of the alleged defect in the subject vehicles, including:

a) The causal or contributory factor(s);
b) The failure mechanism(s);
c) The failure mode(s);
d) The alleged defect's effect on safety related components;
e) The risk to motor vehicle safety that the alleged defect poses;
f) The effect that the driving situation and the state of the system play on the associated risk of the alleged defect;
g) What warnings, if any, the operator, and the other persons both inside and outside the vehicle would have that the alleged defect was occurring, or subject component was malfunctioning; and
h) The reports included with this inquiry.

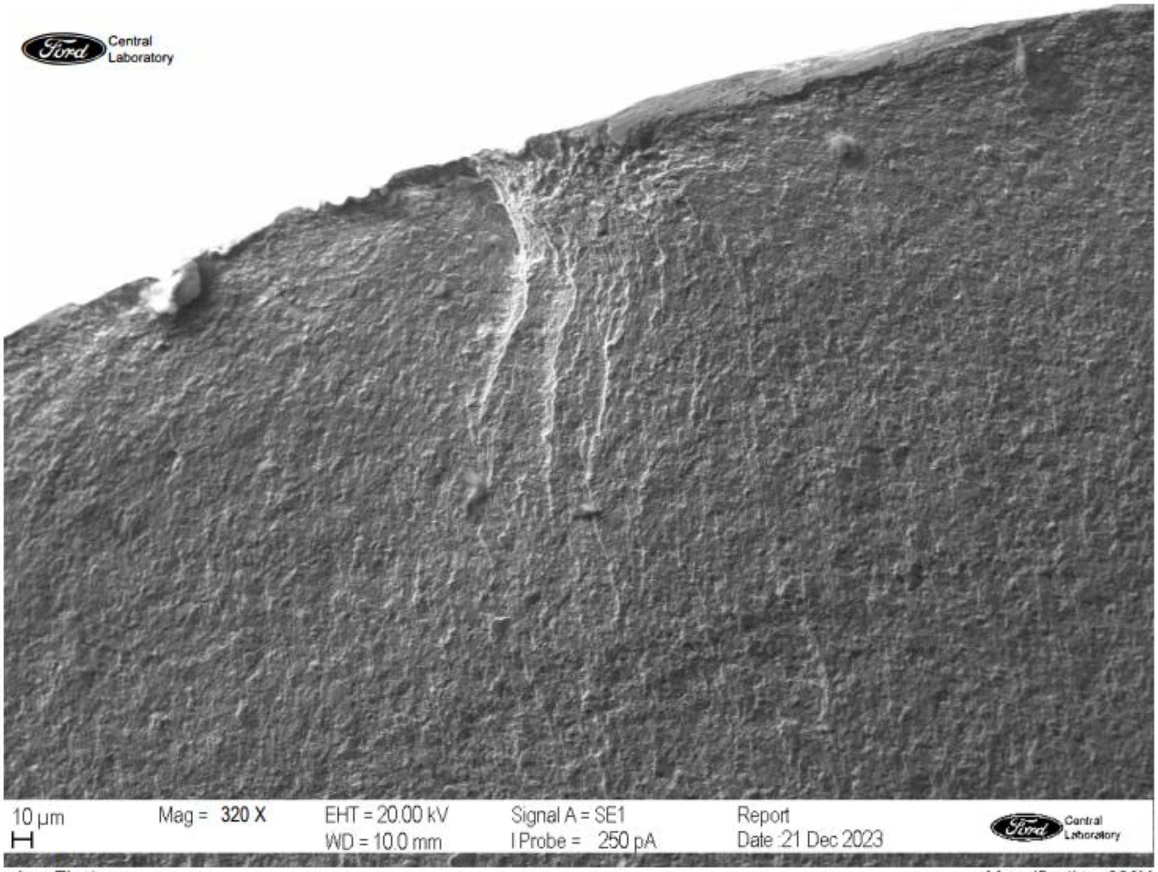
Answer

Ford believes that the alleged defect at issue here does not constitute evidence of a defect resulting in an unreasonable risk to motor vehicle safety. At this time, there has been no evidence identified to date of any related accidents, injuries, fires or loss of vehicle control. Further, the alleged defect at present does not demonstrate an actionable occurrence rate or outcome of severity (see response to request 18).

Under the Safety Act, a manufacturer's recall responsibility is limited to non-compliances with motor vehicle safety standards and defects that present an unreasonable risk to safety (see 49 U.S.C. § 30118(a)). Because there is no applicable safety standard, a recall could only be required if there is both a defect and an unreasonable risk to safety that results from that defect. Neither is present with this topic.

Throughout this investigation, Ford has maintained open dialogue and provided significant resources and materials to the agency. Since the spring of 2022, Ford has met with the agency on numerous occasions providing detailed analysis and presentations on the matter. This included a NHTSA-requested VOQ analysis. During the time in which Ford has been working with the agency on the investigation, the rate of events involving the subject vehicles has decreased and none of the events have resulted in an incident where there was a risk to motor vehicle safety. As part of the IR response to PE22-007, Ford provided an answer to this same question. Ford believes the statements and rationale in that response hold true. As more information is now known and the data has matured, Ford is providing the following information to supplement its response.

As a function of Ford's standard monitoring of field data, the company had previously initiated an investigation into reports of engine failure on these vehicles. At present, over 370 engines associated with these reports have been returned from the field and inspected. Engineering evaluation of those engines found intake valve fracture as the cause. Further investigation of the fractured valves from these engines found evidence of grinding burn and over-specification hardness, indicating the valve supplier's keeper groove grinding and heat treat processes were not within control specifications. Examples of these findings are available in the files "EA23-002 Request 17 – Ford Lab Report" and "EA23-002 Request 17 – Supplier Lab Report." In the case of the Ford lab report, these conclusions were reached by looking at the fracture surface under macrography and using Scanning Electron Microscopy (SEM) to identify the fracture initiation region, also known as the nucleation site. Figure 1 below highlights a nucleation site as observed under SEM.



Secondary Electron Magnification: 320X

Figure 1: Magnified SEM view showing nucleation site

Once the nucleation site is identified, the test sample can be sectioned longitudinally so that evidence of grinding burn on the material surface can be identified.

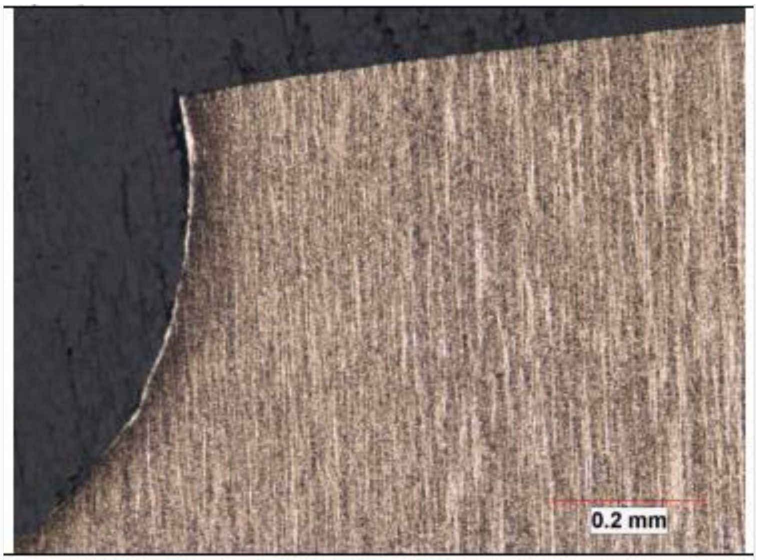


Figure 2: Excerpt from Supplier Lab Report showing white phase martensite on keeper groove

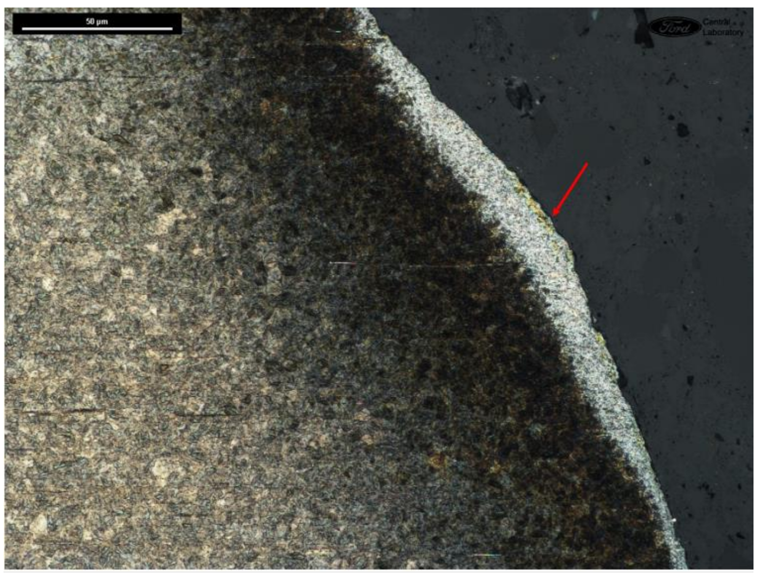


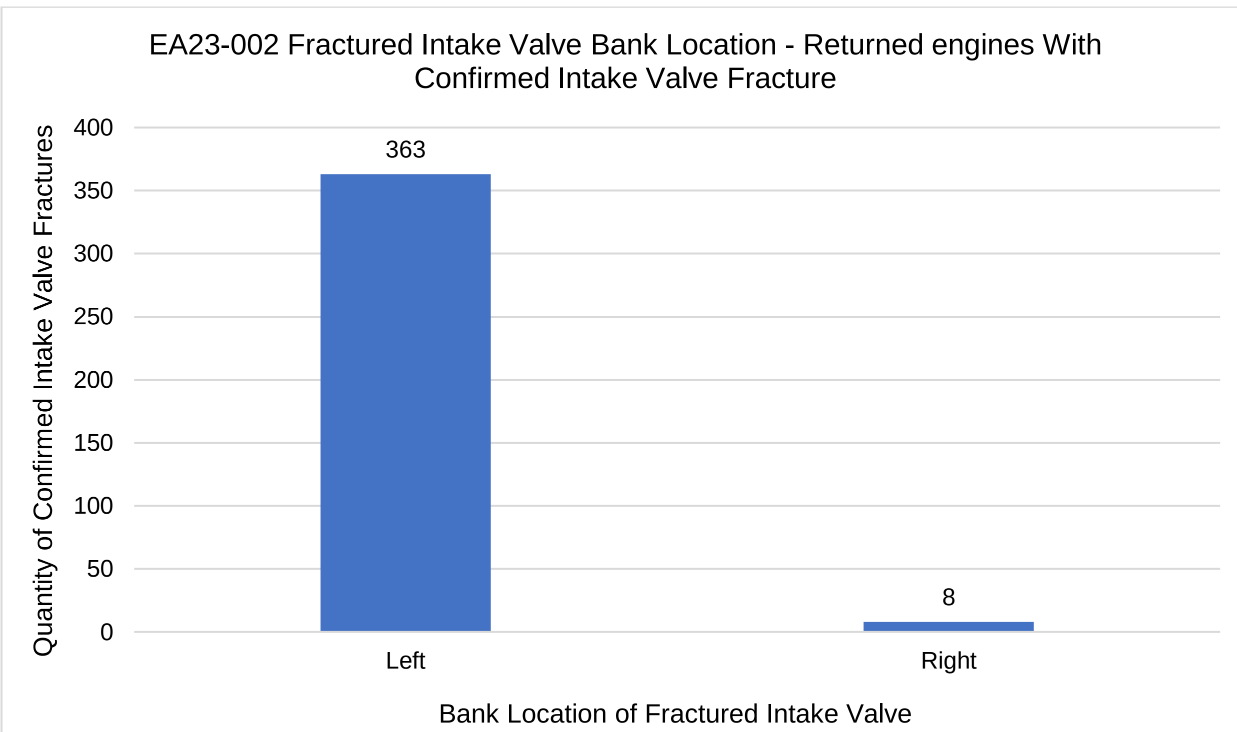
Figure 3: Excerpt from Ford lab report showing white phase martensite

One finding used to determine that fractured valves experienced grinding burn is the evidence of white phase martensite near the fracture location. Figures 2 and 3 show excerpts from both the attached Ford and Supplier lab reports which highlight the formation of white phase martensite near the valve fracture location. As discussed in response 13, this white phase martensite forms when the intake valve is subject to temperatures above the material's austenitizing temperature and then rapidly cooled. Due to the location of the white phase martensite (in the keeper grooves), Ford and the Supplier concluded that the formation of white martensite in this area of the intake valve was the result of grinding burn caused by grinding processes that were not controlled.

These out-of-specification conditions of the keeper groove grinding and heat treat processes may result in the valve fracturing at the area of highest vulnerability, which is the third keeper groove. If the valve fractures, the valve may contact the piston and may be pushed back into the cylinder head. Associated symptoms can range from reduced engine performance to engine stall depending on the final position of the fractured valve. Engine damage depends on speed and engine load when the valve fracture occurs and how long the vehicle is driven after fracture. Repair of damage caused by an intake valve fracture on these engines typically involves a full engine replacement.

Ford expects that valve fractures associated with this subject would occur at low time in service and not all valves were produced with grinding burn or out of specification hardness. Grinding burn is a result of high workpiece temperatures during grinding and produces a hard, brittle microstructure and high residual stresses toward the surface of the valve. When a valve keeper groove containing this microstructure is subjected to the application loading from normal engine operating conditions, a micro-crack initiates at low time in service at the surface and propagates in fatigue until the cross section of the valve is unable to support normal application loading and the valve fractures.

From the inspection results of engines returned from the field, Ford has determined that the intake valves on the left-hand side of the engine (cylinders 4, 5, and 6) are substantially more likely to fracture. The teardown results of engines returned to Ford as seen in the file "EA23-002 Request 12 – Engines Replaced" shows that engines that were found with a fractured left bank intake valve account for over 97% of all returned engines that were found with fractured intake valves.



Predominately left bank occurrence is to be expected and is the result of side-loading on the valve tip from the roller finger follower which is an inherent trait of a V-engine arrangement. In V-engine arrangements, such as in the 2.7L and 3.0L EcoBoost (Nano) engines, there are two banks of cylinders, a Right-Hand (RH) bank and a Left-Hand (LH) bank. To maintain symmetry of the air path between the two banks, the RH and LH bank valvetrains are mirrored across the engine centerline. The camshafts, however, are all driven in the same direction.

This mirroring of the valvetrain combined with common camshaft rotation direction results in two separate loading conditions for the valvetrain; Valve Leading (LH) and Valve Following (RH) on the 2.7/3.0L Nano V6 architecture. (Figure 17.1).

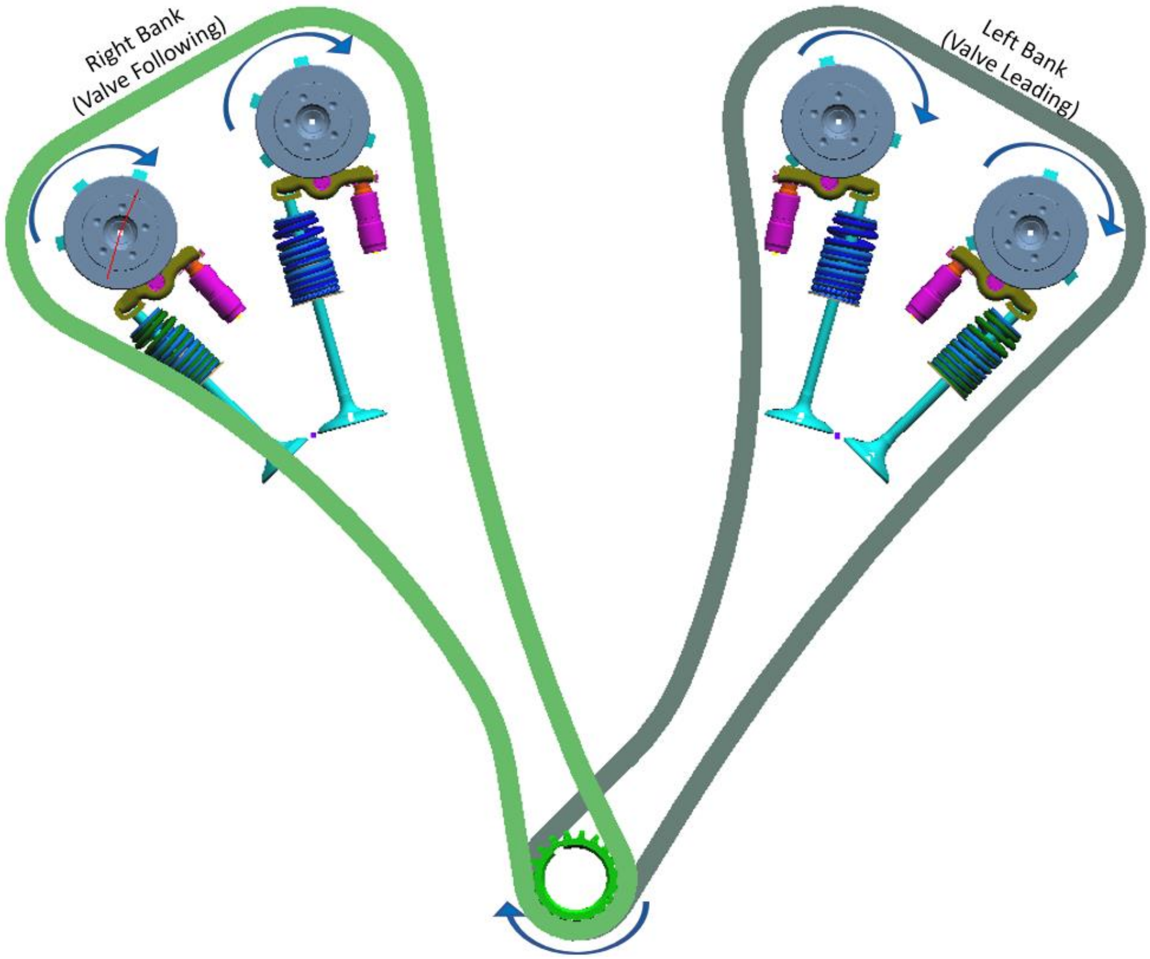


Figure 17.1: 2.7/3.0L V6 Valvetrain Layout (Front View)

Figure 17.2 below depicts the different loading conditions between the valve following and valve leading layouts. In a valve following layout, as the cam lobe transitions onto the lift event, the load from the camshaft to roller finger follower contact is pulling away from the hydraulic lash adjuster pivot point. In this arrangement, the roller finger follower axis self-aligns to the axis created between the lash adjuster pivot point and the load application point on the roller. The valve does not experience any side load or side impact from the roller finger follower. In a valve leading layout, as the cam lobe transitions on to the lift event, the load from the camshaft to the roller finger follower contact point is in front of the hydraulic lash adjuster pivot point. In this arrangement, rather than self-aligning, any misalignment between the camshaft lobe to roller contact point and the lash adjuster pivot point will create a moment in the roller finger follower, resulting in rotation around the pivot point. The roller finger follower rotation is stopped by the valve tip impact with the sidewall of the roller finger follower, inducing a side-load into the valve tip. This side-load into the valve tip is inherent to a V-engine design and the valve design is robust to the side-load. In a valve with grinding burn, the combination of brittle material, high surface residual stress, and this application loading will initiate a microcrack at the valve's surface. Analysis of failed valves indicates that this microcrack serves as a nucleation site for fatigue.

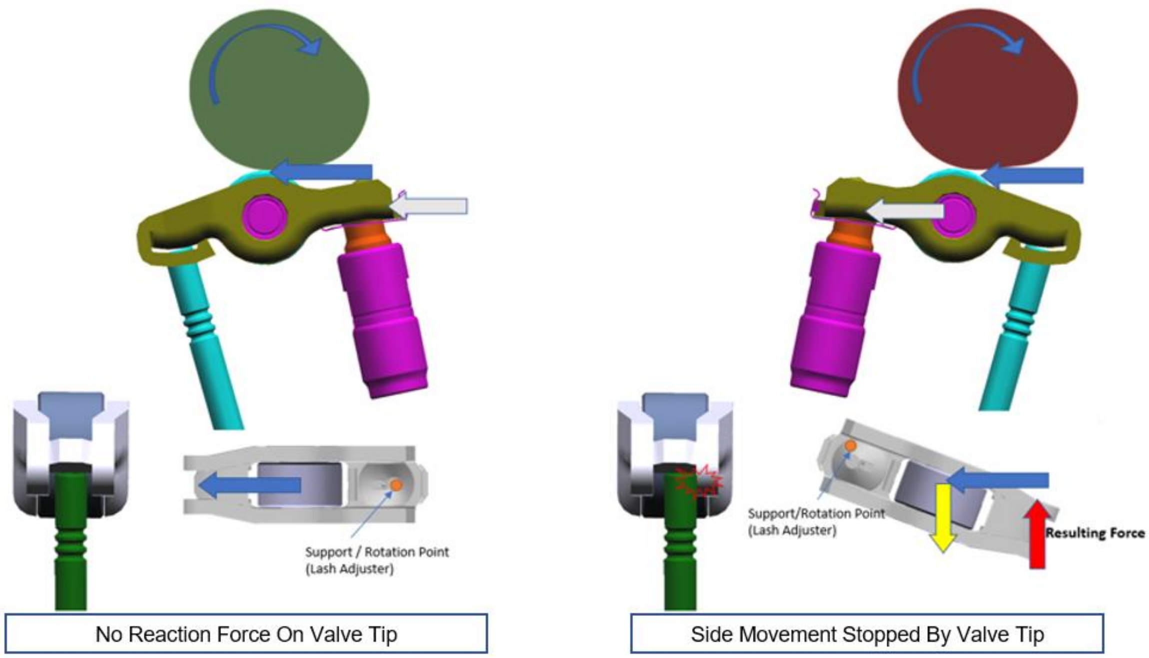


Figure 17.2: Loading conditions for valve following and valve leading layouts.

Grinding burn is typically a result of an uncontrolled grinding process. There are many grinding process parameters that can influence the creation of grinding burn, a non-exhaustive list includes: coolant quality and targeting, grinding wheel speed, grinding wheel advance rate, number of cycles per dressing of the grinding wheel and workpiece hardness. In analyzing failed valves, metallurgy shows that grinding burn is not homogeneous around the keeper groove's circumference. At the time of engine assembly, the location of grinding burned valve material is unknown, and may not align with the direction of loading, and therefore rest in a quiescent stress state.

The 2.7/3.0L Nano valvetrain is assembled with abutting valve keepers. This means that when the valve is keyed to the engine, the keepers contact one another, rather than clamping on the outside diameter (OD) of the valve. The design intention for an abutting (non-clamping) keeper is to allow valve rotation throughout the engine life. Valve rotation enables even wearing of the valve seating surface, more even valve temperature distribution and better cleaning of combustion deposits from the valve seat. Although this valve key design allows for valve rotation, there is no positive means for inducing valve rotation. The valve relies on engine vibration, and valvetrain dynamic loading conditions to induce rotation randomly. For roller finger follower type valvetrains such as the 2.7/3.0L Nano engine, valve rotation typically initiates at engine speeds above 3000 revolutions per minute (rpm) and rotation is reliably present at speeds above 5000 rpm.

With an understanding of the loading conditions required to initiate a microcrack in a valve containing grinding burn, the variability in service time until failure can be explained. As noted above, crack initiation in the third keeper groove requires three main conditions; a valve containing embrittlement and residual stress from grinding burn; stress from the side loading of the roller finger follower; and the alignment of these two contributors. With most of the customers driving at engine speeds below 3000 rpm, variability in customer drive cycles and variability in the location and extent of grinding burn there is inherently high variability in the vehicle time in service for these phenomena to align and result in crack initiation and the beginning of fatigue propagation.

Of the reports submitted in Response 3 and Response 5, over half describe symptoms other than loss of mobility while the vehicle is in motion. Some customers report that after experiencing a valve stem fracture, they are able to continue driving until they find a location to stop and request service (as stated in warranty claims). Those customers often report a message to pull over and restart the vehicle, reduced power, a check engine light, vibration and/or noise. A higher number of customers report engine failure while the vehicle is not in motion (i.e., at start-up or at a stop light/stop sign). Though engine stall due to valve stem fracture can occur while the vehicle is in motion, the vehicle will coast to a stop (the powertrain will not “lock”).

As of the time of this response, Ford is not aware of any accidents, fires, injuries or property damage attributed to valve stem fracture on subject vehicles. In addition to other warning lights and telltales, white smoke has been reported in certain circumstances and is due to the combustion process and entrance of coolant into the exhaust system.