Engineering Assessment of a Dual-Clutch Transmission Failure

Roar File Number: 16R11004 **Date:** November 29, 2016

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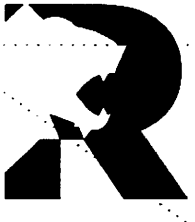
1.0 INTRODUCTION

It has been reported that certain Ford Fiesta and Ford Focus vehicles have demonstrated consistent and ongoing issues with the function of their transmissions. Specifically, the Ford Fiesta (including model years 2011 to 2017) and the Ford Focus (including model years 2012 to 2017) equipped with the "PowerShift" dual-clutch transmission option are affected. Complaints related to these transmissions include, but are not limited to; vehicles lurching forward, shuddering during acceleration, delayed acceleration, vehicle rolling back, and sudden loss of propulsion.

On November 2, 2016, Roar Engineering was retained to conduct an independent assessment of these complaints. Roar Engineering was asked the following questions:

- Is there a common design and/or manufacturing defect which impacts the safety of the 2012 – 2016 Ford Focus vehicles equipped with the Powershift dual-clutch transmission (the "Focus Vehicles")?
- Is there a common design and/or manufacturing defect which impacts the safety of the 2011 – 2016 Ford Fiesta vehicles equipped with the Powershift dual-clutch transmission (the "Fiesta Vehicles")?
- Is there a common design and/or manufacturing defect which impacts the performance of the Focus Vehicles?
- Is there a common design and/or manufacturing defect which impacts the performance of the Fiesta Vehicles?
- Is there a design and/or manufacturing defect(s) impacting safety and/or performance which is common to both the Focus and Fiesta Vehicles?
- If there is a common design and/or manufacturing defect(s) impacting the safety and/or performance of the Focus and/or Fiesta Vehicles, is Ford capable of permanently repairing those design and/or manufacturing defect(s)?

The following preliminary analysis is based on a review of the Statement of Claim, a database of complaints submitted by the complainants, a sample Customer Satisfaction



Program letter from Ford Motor Company of Canada Limited, service records submitted by the complainants, and a report authored by Mr. Neil J. Bigelow dated November 9, 2015.

2.0 QUALIFICATIONS OF THE AUTHORS

Mr. Darryl Schnarr has practiced Forensic Engineering for over five years, primarily engaged in the reconstruction of vehicle collisions and vehicle component failures. Mr. Schnarr graduated from University of Waterloo's Faculty of Engineering and is a licensed Professional Engineer. In addition to his experience as a Forensic Engineer, Mr. Schnarr has experience working in the automotive manufacturing field and is the owner of a motorcycle repair shop in Kitchener, Ontario. He has been qualified as an expert witness in both the Ontario Court of Justice and the Ontario Superior Court of Justice. A copy of Mr. Schnarr's Curriculum Vitae has been enclosed as Appendix A.

Mr. Vincent Rochon has practiced forensic engineering since 1986, and formed his own forensic engineering company in 1990. During his career, Mr. Rochon has been involved in various investigations, and mentored many engineers through their forensic engineering training. Mr. Rochon is a licensed Professional Engineer with a Consulting Engineer designation, and has qualified as an expert witness numerous times. A copy of Mr. Rochon's Curriculum Vitae has been enclosed as Appendix B.

3.0 REPORTED CIRCUMSTANCES

3.1 COMPLAINT DATABASE & SERVICE RECORDS

A database was provided which summarized the issues experienced by the vehicle owners related to the PowerShift transmission. This database (the "Complaint Database") contained entries related to 514 Ford Fiesta vehicles and entries related to 1115 Ford Focus vehicles, for a total of 1629 vehicles. Service records were provided for more than 50 of these involved vehicles.

The Complaint Database includes answers to the question "Have you experienced any performance and/or safety issues with the PowerShift dual clutch transmission?" and the follow-up request "If so, please describe the nature of the performance and/or safety issues you experienced with the PowerShift dual clutch transmission."

The vocabulary used by the complainants vary somewhat, but most commonly the shifting of the transmission is described including the words "shudder" or "shuddering", "jerk" or "jerking", "pulsation", "harsh", "rough", or "jumping". In addition, complainants describe the vehicles as accelerating "poorly" or having "sluggish" acceleration. Others complain of "sudden", "harsh", or "sped up" acceleration, often accompanied by squealing tires. The transmission's behaviour was described by one complainant "like a teenager learning how to drive a manual vehicle."

Some owners have described the "Check Engine Light" coming on and losing engine power completely. Others experiencing the vehicle stalling or felt that it was about to stall. One complainant even described its vehicle's episode as a "seizure".

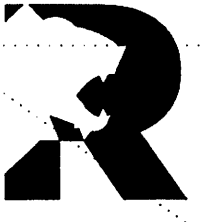
Though the language used by each complainant varies, the symptoms being described are extremely consistent. The Complainant Database contains 1629 reports of transmissions shuddering while driving and accelerating inconsistently, from all involved

model years, in every province in Canada. The complainants' experience a very low performing vehicle which inevitably places the driver in unsafe situations.

The Complainant Database also includes the questions "Do you consider it safe to drive the vehicle?" and "Have you been involved in a motor vehicle accident as a result of a problem with the transmission in your vehicle?" Of the 1,629 vehicles in the Complainant Database, 1,286 (79%) believe their vehicles are not safe to drive. 51 vehicles were reportedly involved in collisions as a result of a problem with their transmission. Many owners have decided that they will no longer drive the vehicle, as they have determined their safety is at risk.

The bulk of the 1629 complainants described these symptoms returning shortly after having their clutch replaced. In all cases in which service records were available, after the clutches were replaced, these same symptoms returned. Complainants describe having their clutches replaced multiple times, with the problem persisting. Some clutches were replaced as quickly as 5,000 km after they was installed, while others were able to travel 17,000 – 23,000 km before requiring a clutch replacement. The majority of complainants report their clutches requiring replacement between once every four months to once per year, and the majority of complainants are on at least their third clutch.

Transport Canada is investigating similar complaints as a part of TC File No. 3280-09-24 described as a "Loss of Propulsion in Vehicles Equipped with the DPS6, Dual-Clutch PowerShift Six-Speed Automatic Transmission", opened in November 2016. The author has been informed that a Freedom of Information (FOI) request has been submitted to Transport Canada. However, no information has been provided, as Transport Canada has requested more time in light of the volume of data.



3.2 TECHNICAL SERVICE BULLETINS & CUSTOMER SATISFACTION PROGRAMS

A Technical Service Bulletin (TSB) is a notification provided by an Original Equipment Manufacturer (OEM) to its dealership's service departments communicating information regarding the repair of a specific issue. TSBs are often issued when a repair is difficult (in order to help the technician with the repair), when there are known concerns (so different dealerships can manage the issue in the same manner), or to assist with diagnostics and/or troubleshooting (to improve efficiency).

TSBs are not recalls, and as such, the OEM is not required by law to perform these repairs free of charge, or to call customers who are effected by the content of the TSB.

Several TSBs have been issued as a result of the reported issues with these transmissions. TSB 13-4-5 outlines the clutch shudder issues, while TSB 16-0109 (and its predecessors, including TSB 15-0120) outlines the procedure to diagnose and test for "erratic shifts and driveability concerns". In each model year, the TSBs related to these transmission issues is updated. In all included model years, the TSBs associated with the PowerShift transmission apply.

In response to the transmission issues, Ford has created at least two "Customer Satisfaction Programs", titled "14M01" and "14M02". These programs include the previously defined Fiesta Vehicles and Focus Vehicles equipped with the dual clutch transmission. 14M01 extends coverage of the "DPS6 Transmission input shaft seals, clutch, and transmission software calibration" warranty to seven (7) years and 100,000 miles (160,000 km). 14M02 extends coverage on the "DPS6 Automatic Transmission Control Module (TCM) to 10 years of service or 150,000 miles (240,000 km)."

4.0 SYSTEM DESCRIPTION & VEHICLE EXAMINATIONS

4.1 SYSTEM DESCRIPTION

The Ford Fiesta and Ford Focus vehicles described above are all equipped with the Ford PowerShift "automatic" transmission. More specifically, these vehicles are equipped with a PowerShift 6DCT250 dual-clutch 6-speed transmission manufactured by Getrag. This transmission is electro-mechanically actuated, and is outfitted with two dry clutches.

The task of a transmission (also called a transaxle) is to transmit power from the engine to the differential, which in turn transmits that power to the wheels. In North America, the bulk of automotive transmissions are hydraulic automatic transmissions[1], with most of the remainder outfitted with manual transmissions. An image depicting the location of a transmission (blue) as part of a typical front-wheel drive drivetrain is depicted as Figure 1.

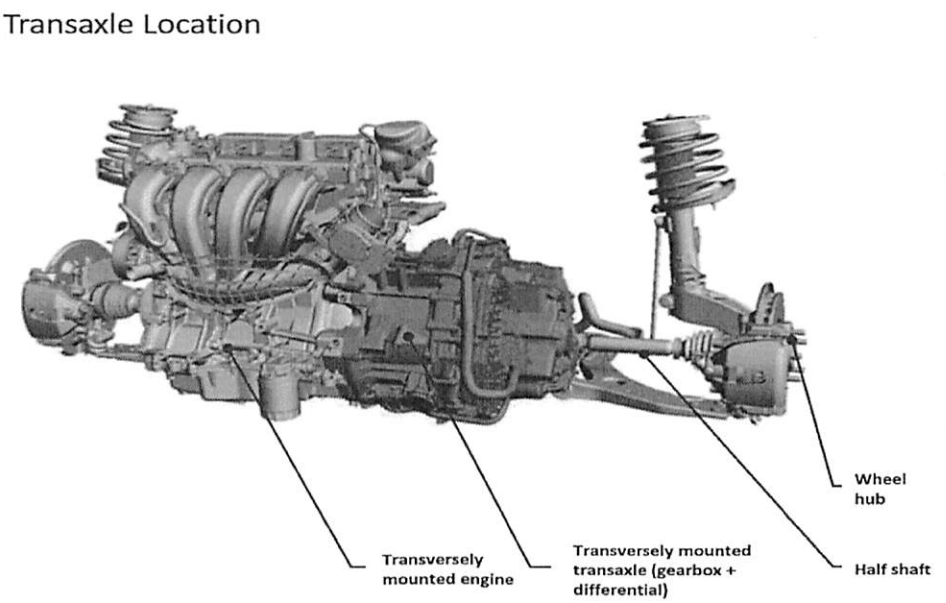


Figure 1: Transmission (blue) and front-wheel drive drivetrain.

[1] *Data on this subject varies, but all sources indicate between 90 – 95% of North American vehicles have hydraulic automatic transmissions.*

A manual (often referred to as a "standard" or "stick-shift") transmission transmits power to the differential by way of a single dry clutch engaged by spring force. This clutch, operated by a foot pedal located to the left of the brake pedal (intended to be operated by the driver's left[2] foot), is engaged and disengaged manually. With the vehicle stopped, the clutch is disengaged, allowing the engine to rotate freely. To launch the vehicle forward, the driver must engage the clutch by letting out the clutch pedal while simultaneously applying throttle. The smoothness of this launch is defined by the precision of the clutch operation and the application of the throttle. If a driver is inexperienced or is not paying full attention, launches can be abrupt, the vehicle may shudder and shake, or the vehicle may stall and need to be restarted.

To shift gears, a gear shift lever (most commonly located to the driver's right), is manipulated manually with the clutch disengaged, such that a different set of gears are selected. The clutch can then be engaged (let out) and driving can continue in the newly selected gear. Images of a manual transmission clutch and manual transmission are depicted in Figure 2 below.

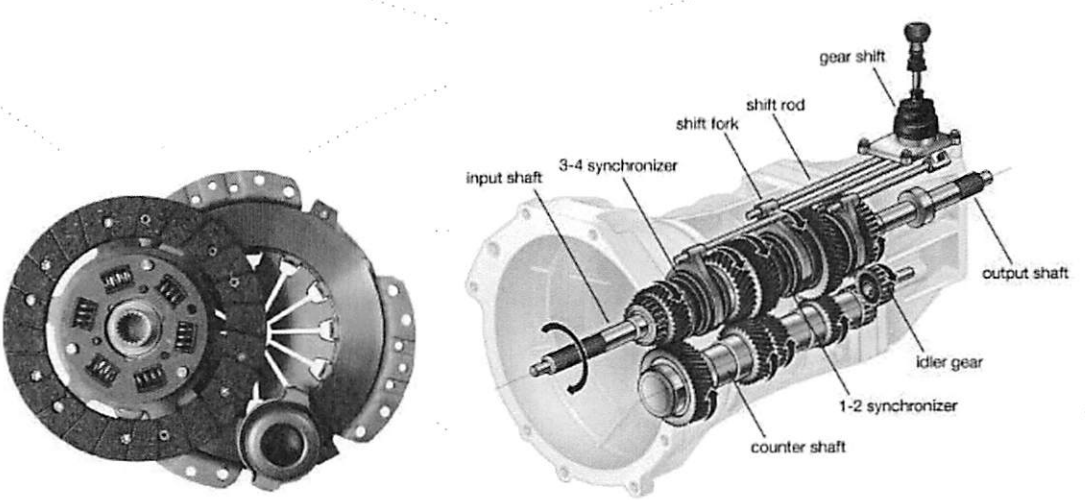


Figure 2: Manual transmission clutch (left) and manual transmission (right).

[2] *For the purposes of this report, references made to the left or right are made from the driver's perspective.*

A hydraulic automatic transmission transmits power to the differential through a torque converter. A torque converter uses hydraulic fluid (light oil) to transfer power smoothly from the engine to the transmission. As the engine rotates, a turbine attached to the engine forces fluid outward, toward the transmission. A pump, attached to the transmission, interacts with this moving fluid and is rotated as a result of the fluid's motion. This is similar to having a fan blowing air onto an unpowered fan facing it: The air blown by the primary fan will cause the second fan to rotate. Figure 3 depicts a torque converter and the fan analogy described above.

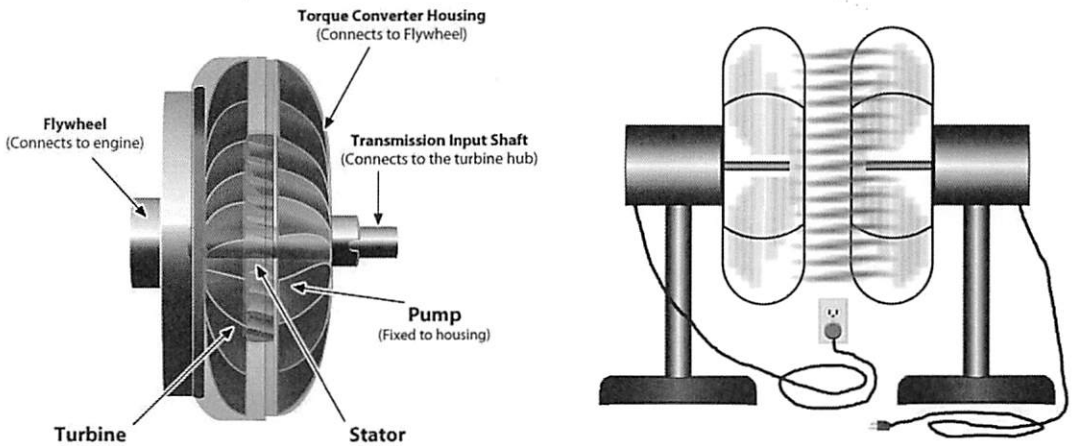


Figure 3: Torque convertor (left) and fan analogy (right).

Power is transmitted through a hydraulic automatic transmission through a series of planetary gear sets and wet clutches. A planetary gear set is comprised of an outer ring gear, a central sun gear, and a set of planetary gears which rotate around the sun gear (hence the nomenclature). The result is a gear set which can produce relatively high gear ratios in a small footprint. One of the reasons planetary gears are chosen for automatic transmissions is their ability to be linearly cascaded (several gear sets placed in a line), forming the ability for an automatic transmission to "shift" similar to a manual transmission.

Figures 4 and 5 on the following page depict planetary gear sets and a cutaway view of an automatic transmission.

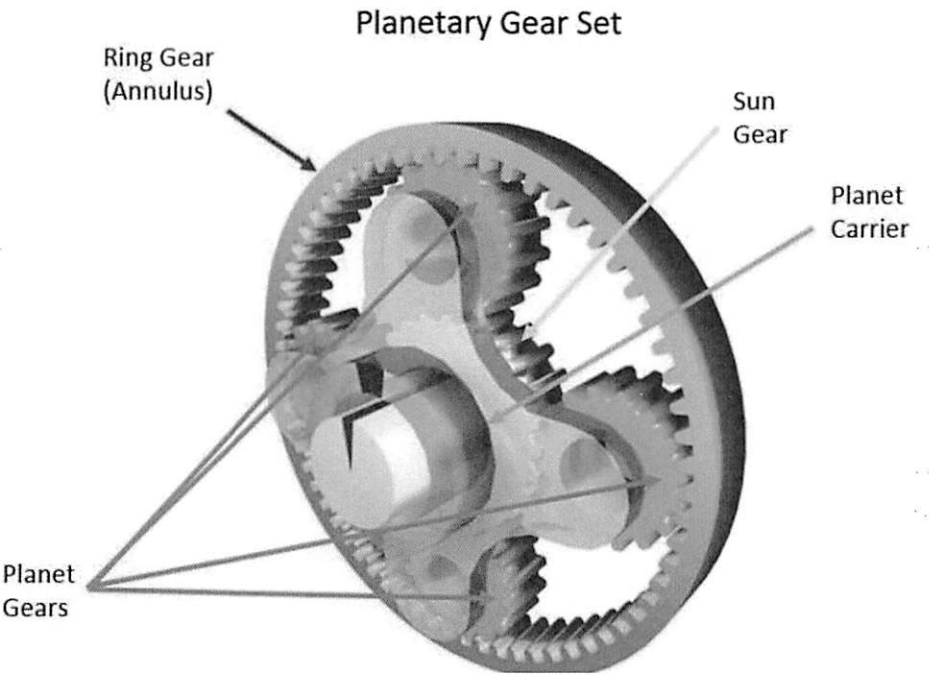


Figure 4: Planetary gear set, similar to that found in an automatic transmission.

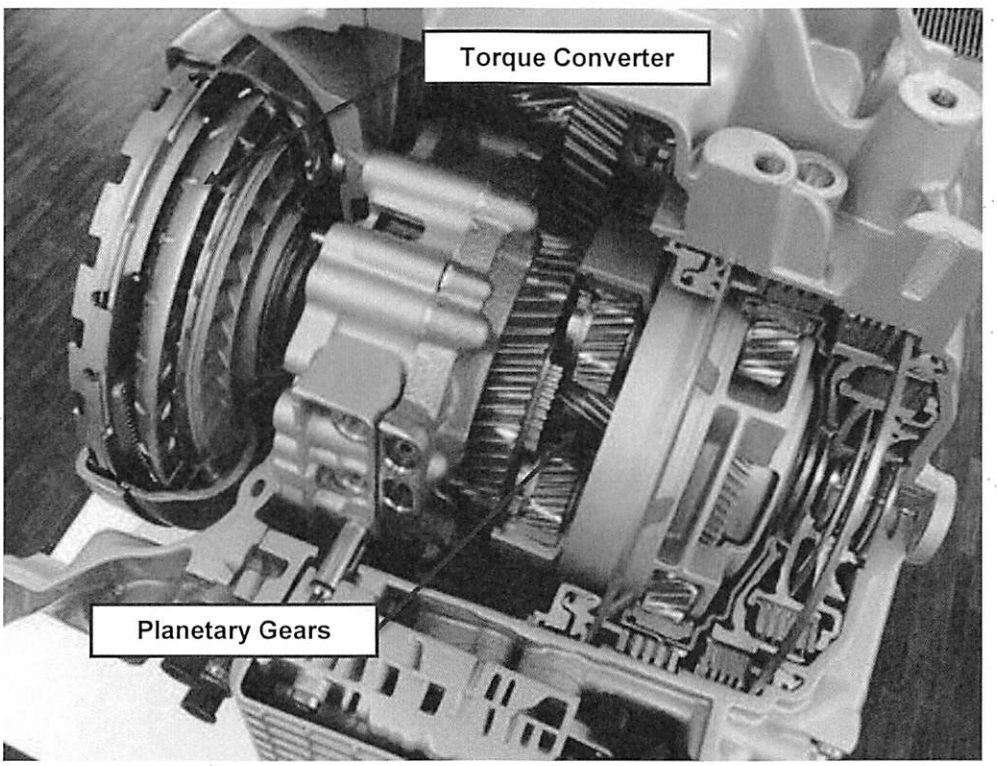


Figure 5: Cutaway view of an automatic transmission.

The Getrag 6DCT250 transmission is a dual-clutch transmission (herein referred to as the "Dual Clutch Transmission" or "DCT"), and functions more similar to a manual transmission than to a hydraulic automatic transmission. The DCT comprises of two input shafts which each contain half of the gears (odd gears on one shaft, even gears on the other) and a dry clutch attached to each input shaft. Rather than engaging and disengaging the clutches using a foot pedal, the DCT is equipped with electronically controlled clutch actuators. To engage a clutch, electrical current is applied to the actuator, which rotates a shaft that drives an actuator lever similar to a wedge. If the actuator is commanded to engage the clutch, the shaft will rotate in one direction until it reaches a specific location. If the actuator is commanded to disengage the clutch, it will rotate in the opposite direction. Figures 6 and 7 below and on the following page depict a cutaway view of a clutch actuator (there are two, one for each clutch) as well as a cutaway view of the dual-clutch assembly.

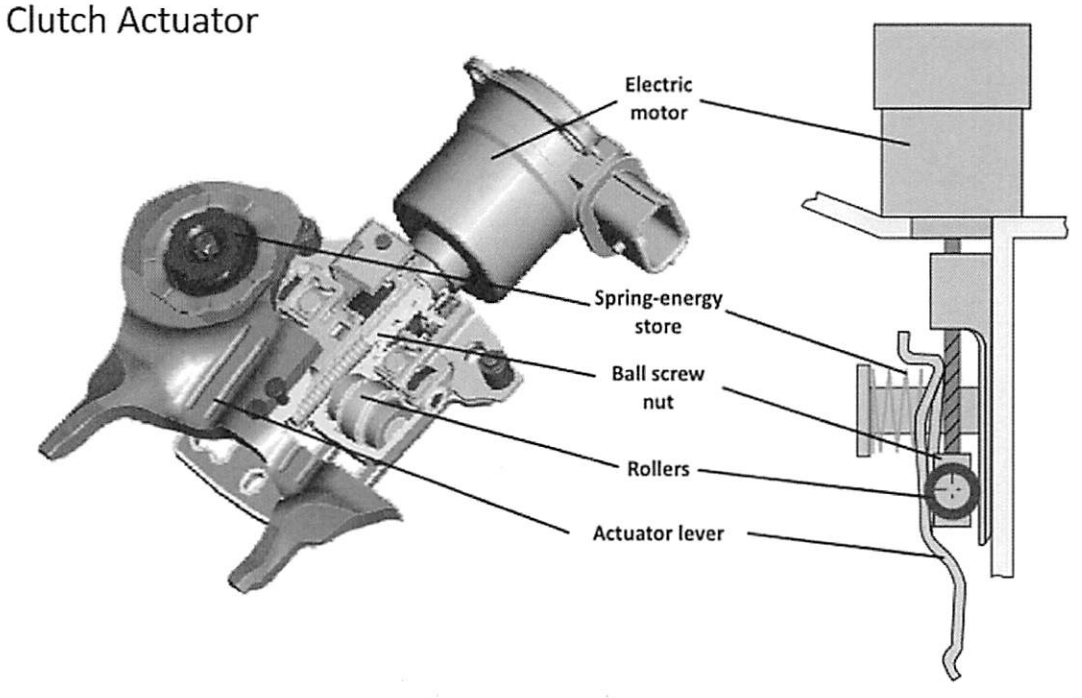


Figure 6: Clutch actuator cutaway view.

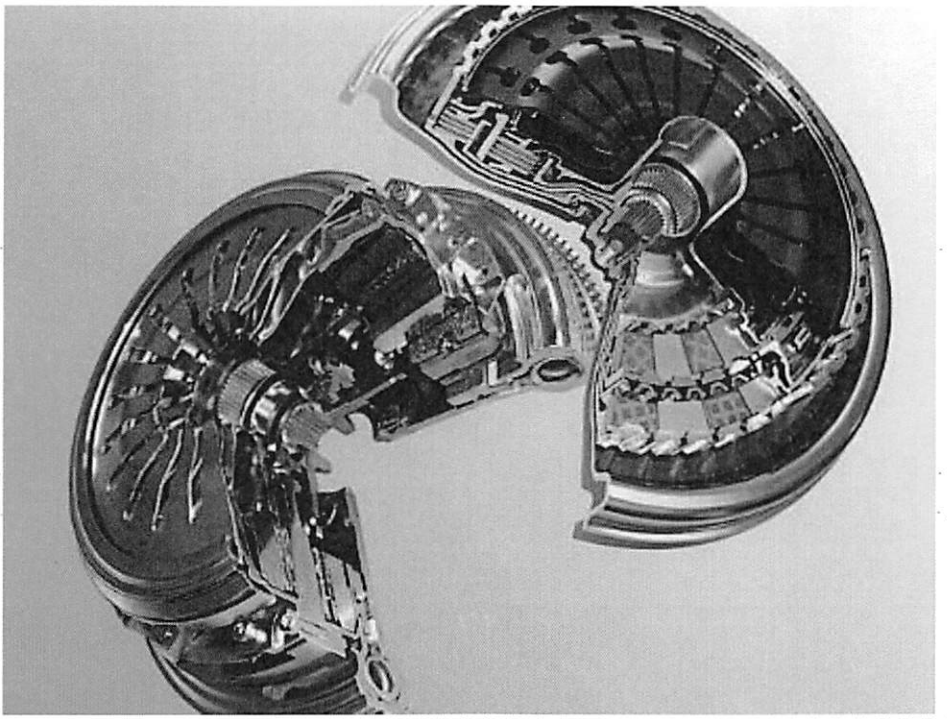


Figure 7: Dual-clutch assembly cutaway view.

The result of having two clutches and two input shafts is the ability for the system to shift between two adjacent gears (for example, first gear to second gear) without the need to change gears during the shift. In the case of a manual transmission, once the clutch is disengaged, the operator must select the gear he/she desires, then re-engage the clutch. This gear-change time is eliminated in the DCT, resulting in the possibility of having very fast shift times. Figure 8 depicts this time relationship.

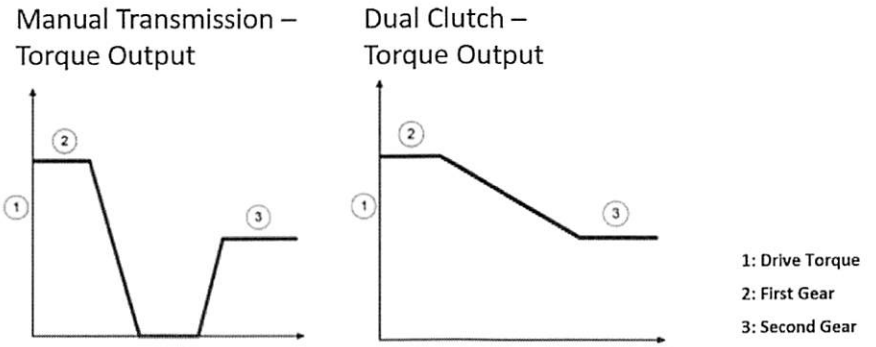


Figure 8: Torque output vs. time relationship (Manual vs. DCT).

The DCT is required to anticipate which gear will be desired next and shift the non-driven shaft into that gear before the actual shift can be executed. This is accomplished by two electronically controlled shift actuators. Similar to the clutch actuators, the shift actuators use electric current to rotate a shaft, which is mechanically converted to linear motion by way of a selector drum. As the actuator rotates, the selector drum rotates into one of several discreet positions, lining up with the correct positions for gear engagement. This shifting mechanism is similar to that of a motorcycle transmission. Figure 9 depicts a cutaway view of the shift actuators.

Both the actuation of the clutches and the changing of the gears (rotation of the selector drums) are controlled by the "Transmission Control Module", or "TCM". The TCM is attached to the transmission and is connected to the vehicle's electrical system. The TCM can be seen in Figure 9 below.

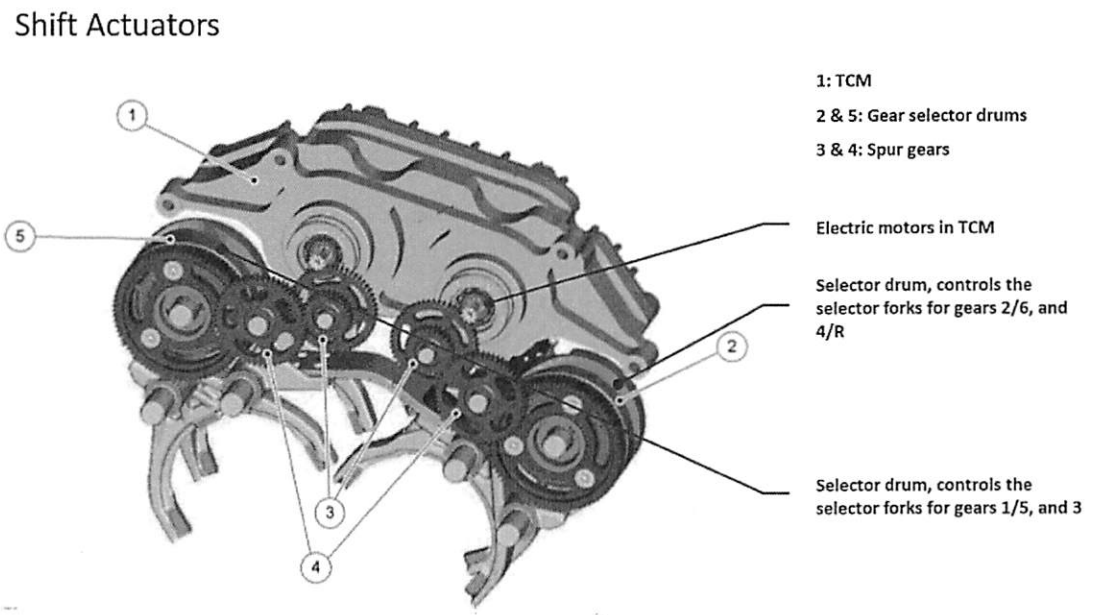


Figure 9: Shift Actuator Cutaway View.

Figure 10 depicts the transmission cutaway including the selector drums and selector forks.

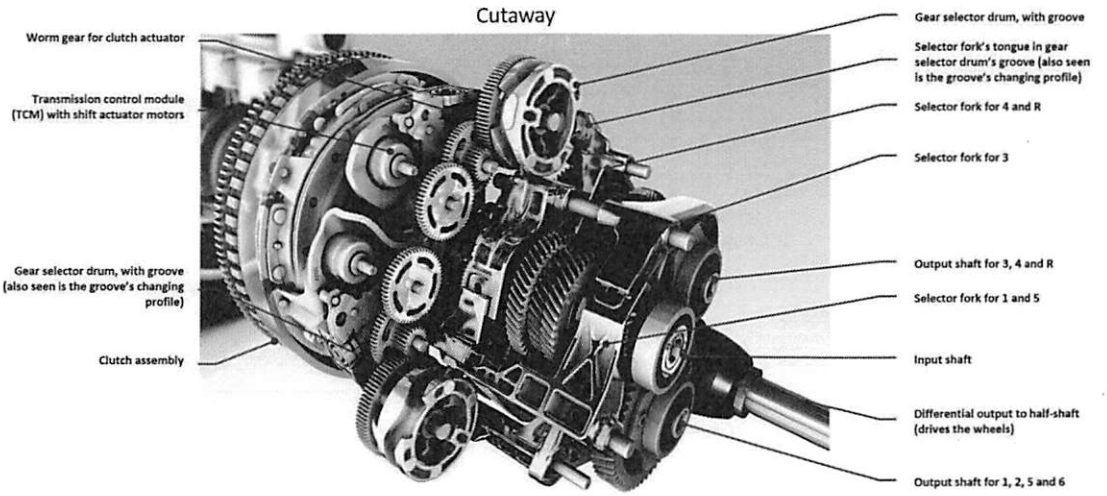


Figure 10: DCT cutaway, including selector drums and selector forks.

5.0 ANALYSIS AND DISCUSSION

Because both the Fiesta Vehicles and Focus Vehicles involved are equipped with the same transmission (the Getrag 6DCT250, the DCT), all safety and performance issues related to the DCT are common to both vehicles. The causes and remedies related to these DCT issues are also common.

After reviewing the Complaint Database, including the comments left with the mechanics and technicians included in the service records, the complaints fall into two distinct failure categories.

The first failure is that the clutch shudders while the vehicle is accelerating. Owners complained that the vehicle would shudder and a vibration would be felt and/or heard coming from the engine bay while accelerating. The shudder is not associated with a shift.

The second failure is that the clutch engagement or disengagement results in a harsh or jerky shift. Owners complained that their vehicle would roll back before launching, launch harshly, spin the front tires, or bog down and stall.

These two primary failures are discussed in Sections 5.1 and 5.2 respectively.

5.1 CLUTCH SHUDDERING WHILE ACCELERATING

Shuddering within the transmission is experienced as a result of a vibration within one of the clutches. With the clutch fully engaged (after the completion of the shift), the engine and transmission should be rotating at the same speed. Said another way, the relative speed between the engine and the transmission should be zero. With the clutch fully engaged, the available friction between the clutch disc and the pressure plate exceeds the force applied by the engine.

The shuddering phenomenon occurs when the relative speeds of the engine and transmission diverge and converge in rapid succession. If the friction between the clutch disc and the pressure plate is overcome, the engine speed begins to rise relative to the transmission's speed. If more force is applied to re-engage the clutch, the friction between the two surfaces rises and the relative speeds are reduced. However, when this happens, the engine is re-loaded, and required to provide more power to the wheels. As a result, the engine (and transmission) slow down. This cycle repeats, and an oscillation begins. The magnitude of the oscillation can be quantified by the difference in the speed of the engine relative to the transmission (measured in revolutions per minute, or rpm). The service records reviewed reported speed differences of between 200 and 600 rpm, resulting in this shudder. Figure 11 below is a reproduction of a system scan included in Ford's TSB 13-4-5, and highlights the shudder (labelled "C").

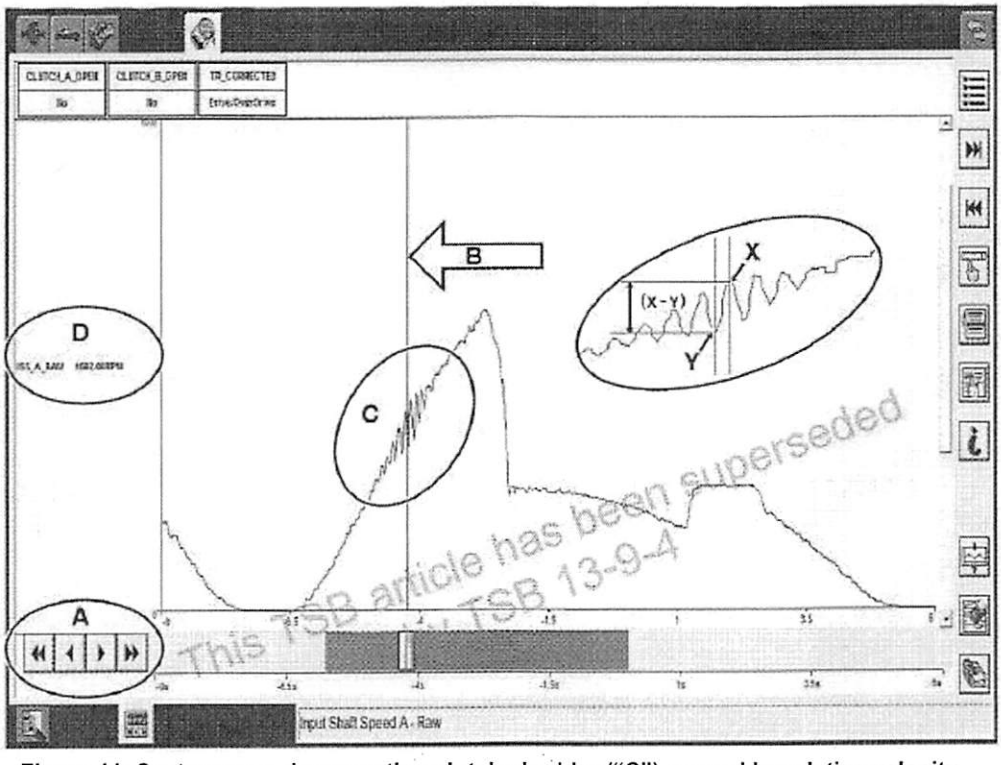


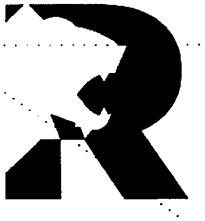
Figure 11: System scan documenting clutch shudder ("C") caused by relative velocity.

The reason for the clutches in the DCT to lose friction and become uncoupled from the engine has not been studied and analyzed completely. However, engineering principles and physical evidence can by analyzed in order to form a hypothesis.

It has been reported both through Ford's TSBs and from the service records reviewed that the clutches, which are intended to be dry, often become contaminated. There are two primary sources of contamination: transmission gear oil and bearing grease. The two input shafts, which exist to transmit power from the engine to the transmission, have seals between themselves and the transmission housing. The seals are responsible for keeping the gear oil inside of the transmission, preventing it from contaminating the clutches. When these seals fail, transmission gear oil travels into the bell housing (the area containing the dry clutch) and contaminates the clutch disc. In addition, the bearings, which allow the actuation of the clutches, contain a relatively heavy grease in order to keep them lubricated. This grease is reportedly blue in colour, and is thicker than transmission gear oil. As the bearings move, this grease can escape and contaminate the clutch disc surface.

The result of a contaminated clutch disc is an overall reduction in friction and an inconsistent friction profile across the surface of the disc. As such, the clutch disc no longer provides a consistent friction force within the clutch system, leading to issues such as shuddering.

As discussed previously, the Transmission Control Module (TCM) is responsible for controlling the shifting of the transmission, as well as the actuation of each of the clutches. In order for the TCM to know how far to rotate the actuators in order to properly engage or disengage the clutches, a system calibration procedure called "Adaptive Learning" is engaged. During this procedure, the TCM relies on feedback from sensors throughout the vehicle to determine when the clutches are engaged and disengaged. With this information, the TCM knows precisely how to command its actuators to perform smooth, precise shifts.



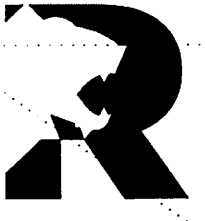
However, it appears that the "Adaptive Learning" system has its limitations. As components within the system change (temperatures change, clutch discs wear, springs lose tension, etc.), the critical positions relied upon by the TCM start to change. As such, the clutch engagement start and stop positions within the DCT begin to differ from the TCM's assumed positions. The result of these differences are clutches that, after shifts have been completed, are not fully engaged. A partially engaged clutch does not provide as much frictional force, and the loss of full engagement can cause the relative speed difference discussed above, felt as a shudder by the driver.

In the absence of an on-the-fly learning procedure, the TCM is forced to assume that its set points learned previously will continue to provide smooth, effective clutch engagement. The authors are not aware of any on-the-fly learning procedure which provides feedback to the TCM ensuring that these shudder events do not occur. Clearly, the presence of these clutch shudder events happening so regularly to so many owners indicates that either there is no on-the-fly learning procedure, or the on-the-fly learning procedure incorporated into the TCM is not adequate.

The impact of these shuddering events is the rapid degradation of the clutches, requiring the replacement of both clutches.

5.2 HARSH / INACCURATE CLUTCH ENGAGEMENT

Clutch engagement, for the purposes of this report, is defined as the process by which the clutch disc and flywheel make initial contact, up to the point where the transmission and engine are travelling at a common speed. When operating a manual transmission, the vehicle operator is responsible for engaging the clutch (releasing the clutch pedal) to the point where it begins to grip, adding throttle (speeding up the engine, adding power), and then allowing the clutch to engage smoothly up to the point where the clutch is fully engaged. In the case of the involved DCT, the TCM is responsible for the actuation of the clutch, and therefore, for the smoothness and precision of the shifts.



As discussed in Section 5.1, it has been reported that the transmission gear oil, as well as grease within the clutch bearings, contaminate the surface of the clutch. The result of this contamination is a change in friction within the clutch system. If the TCM is calibrated to operate within a certain friction range, and the available friction is reduced, the result is a harsh and/or inaccurate shift.

However, a system which includes friction elements such as a clutch, will inherently wear and the friction within the system will inevitably change. In the case of a manual transmission, this wear takes place slowly and the typical vehicle operator adapts to these changes without noticing. If the TCM does not calibrate itself with respect to the precise position at which the clutch engages and disengages (known as the "friction zone"), shifts will become harsh, the vehicle will stall, or the vehicle will be delayed in launching all together.

As discussed in Section 5.1, it is possible to run a calibration procedure known as "Adaptive Learning". During this procedure, the TCM performs a series of tests which allows the system to learn the specifics of the "friction zone": where it begins, where it ends, how much friction is available, etc. With this information, the TCM can perform smooth, accurate shifts. However, there does not appear to be an effective on-the-fly learning procedure. As such, the TCM does not compensate for the changes that the clutch system is experiencing. The result of the system's ignorance is no engagement when the system intends to engage (leading to roll back or slow launches), or engagement when the system does not intend to engage (leading to harsh launches, squealing tires, or stalling).

These repeated harsh clutch engagements result in damage to the clutch discs. As with the clutch shuddering, the damage caused by harsh engagements requires clutch replacement.

5.3 PERFORMANCE & SAFETY EFFECTS

Not only do the functional failures within the DCT described in the previous sections result in poor vehicle performance and a poor driving experience, but they also present safety concerns. These safety issues are present in every Fiesta and Focus vehicle equipped with the DCT, in all model years.

First, any mechanical failure or irregularity experienced by a driver while in the process of driving will require a response. This response presents a distraction from the driving task, and as such, presents a safety risk. In the best case scenario, the mechanical failure occurs in a wide open area free of hazards, allowing the driver to focus on the failure. In the worst case scenario, the mechanical failure occurs at a moment when other hazards are present, and the failure distracts the driver enough to cause an incident. Therefore, any mechanical failure should be considered a safety risk to a certain degree. In the case of a mechanical failure including the vehicle's transmission, a driver would most certainly be required to take attention away from the task of driving and place it on the failure.

The clutch shuddering, caused by clutch slippage, reduces the effectiveness of the vehicle's acceleration. This is clearly a performance issue, as one of the most common performance metrics of a vehicle is its ability to accelerate from a stop. The reduction in acceleration performance related to a shuddering clutch is significant.

For similar reasons, the harsh and/or inaccurate clutch engagement presents a performance reduction. In the most basic sense, the ability to launch a vehicle and shift gears smoothly provides a level of comfort to the driver as well as their passengers. The smoothness of a vehicle, therefore, can be considered an aspect of its performance. Timely clutch engagement during launches and shifts provides the driver with relatively rapid acceleration, and as such, high performance. The absence of this timely and precise clutch engagement detracts from the vehicle's performance.

A vehicle that cannot accelerate predictably and reliably can be dangerous. Typical drivers make decisions with respect to passing, turning left, and pulling out into traffic

(among others) with an assumption regarding their vehicle's acceleration performance in mind. If a driver's ability to accelerate is impeded, an otherwise good driving decision (such as turning left in front of someone on a green traffic signal) may turn into a dangerous one requiring an avoidance manoeuvre by the other driver. A vehicle must be capable of accelerating predictably and reliably in order to be considered safe.

The DCT equipped in the Fiesta Vehicles and Focus Vehicles cannot be relied upon to transfer power reliably while in gear, nor can it be relied upon to launch and shift smoothly and accurately. These failures represent both performance and safety concerns.

Of the 1,629 vehicles documented within the Complaint Database, 1,286 have been deemed unsafe by their owners. This is as a direct result of the above described transmission failures. Many owners have reported being involved in collisions as a result of these transmission failures, which is consistent with the authors' expectations.

5.4 REPAIRABILITY

The failures related to the DCT have been summarized as clutch disc contamination and TCM calibration failures. After reviewing the complaint database and the service records, contaminated clutches and out-of-calibration TCMs have been repaired, serviced, or replaced many times. However, the issues persist.

If the clutches were wet, meaning that they existed within the transmission oil bath and operated with a coating of oil (similar to a motorcycle clutch), there would be no requirement to have seals between the clutch and the input shafts. Changing the clutches from dry to wet would require a complete redesign of the DCT. Efforts have been made to re-design the input shaft seals. The original seals are black, while the replacement seals appear a brown colour. It is not clear whether the material has changed, or whether it is simply dyed a different colour to tell which version of the seal is installed. The design looks largely similar. Figure 12 on the following page depicts an old and a new seal.

Figure 12: Old input shaft seal (left) vs. new input shaft seal (right).

A flaw may exist within the design of the seal itself, or with the input shafts, which prevents this seal design from ever totally containing the transmission oil and protecting the integrity of the clutches. In this case, a seal/shaft/housing redesign would be required to fully remedy the failure.

A flaw may also exist within the clutch bearings, which have been recorded leaking blue grease. A repair or redesign to this component (including a retrofit) is necessary to prevent further contamination of the clutch discs.

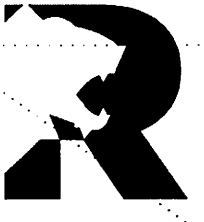
As discussed previously, the TCM is either not equipped with an on-the-fly calibration capability, or the on-the-fly calibration procedure is not adequate. If there is no capability for on-the-fly calibration, this capability must be added. If it is not added, as the clutch wears and the system changes, smooth and precise shifts will be impossible and clutch failures inevitable. This is exactly the situation that the owners of Fiesta and Focus vehicles have experienced. There exists the possibility that the required infrastructure for such a system is not available on the DCT as it is currently, at which point a transmission redesign would be required.

If the input shaft seal issues cannot be solved using the current shaft and housing dimensions, and an on-the-fly calibration process cannot be integrated into the TCM, these transmissions are not permanently repairable.

There is no permanent repair procedure available from Ford at this time. The current strategy employed by Ford to address the symptoms experienced by Fiesta and Focus vehicle owners is to provide replacement clutches and TCM updates under warranty. However, the warranty related to the clutches extends to 160,000 km, approximately half of the useful life of the vehicle. As such, the owners are projected to be out of pocket for clutch replacements for half of the vehicle's life. At a cost of approximately $1,100 per clutch replacement, and at a rate of approximately one clutch replacement per 20,000 km, these costs add up very quickly. At this projected rate, a Fiesta or Focus owner would be required to have 16 major clutch services performed on their vehicle in its lifetime. For reference, a typical vehicle which is equipped with either a hydraulic automatic transmission or a traditional manual transmission is expected to have zero, possibly one, major transmission repair/service in its lifetime.

An additional complication to these projected repairs is the low availability of clutches. Because of the prevalence of these clutch failures, the availability of replacement clutches is very low. As such, owners are waiting as long as three months for replacement parts. If an owner is required to rent a car during this time, the expense of a clutch failure increases vastly.

A permanent solution to these clutch failures is required.



6.0 CONCLUSIONS

1. Complaints regarding clutch shuddering and harsh/inaccurate clutch engagement impacts at least 1183 Ford Fiesta and Ford Focus vehicles equipped with a Getrag 6DCT250 dual-clutch transmission.

2. Because the transmissions equipped in both vehicle models are identical, all performance, safety, and repairability conclusions are applicable to both vehicles.

3. Clutch shuddering occurs as a result of a velocity difference between the engine and transmission, caused by clutch slippage.

4. Clutch shuddering is caused by contamination of the clutch discs and poor TCM calibration.

5. Harsh/inaccurate clutch engagement occurs as a result of the TCM not knowing when the clutches are engaging.

6. The TCM fails to know where the "friction zone" is located as a result of clutch disc contamination and poor TCM calibration.

7. Contamination of the clutch discs is caused by transmission oil bypassing the input shaft seals, and/or from blue grease originating in the clutch bearings.

8. The TCM system may or may not have an on-the-fly clutch calibration procedure. If it does not, it needs such a system to keep the clutch calibrated. If it does have one, it is inadequate.

9. The clutch shuddering and harsh/inaccurate clutch engagement failures present both performance and safety concerns. Smooth, precise, and consistent acceleration is required for safe driving.

10. It is possible that the input shaft seals cannot be redesigned and permanently fixed without a transmission redesign.

11. It is possible that the DCT cannot be equipped with an on-the-fly calibration system. If it cannot, the transmission will perpetually require clutch replacements and clutch calibrations as the complainants have already experienced.

12. The specific questions asked in the engagement letter are repeated and answered below:

- Is there a common design and/or manufacturing defect which impacts the safety of the 2012 – 2016 Ford Focus vehicles equipped with the Powershift dual-clutch transmission (the "Focus Vehicles")?
    - Yes, the contamination and calibration defects outlined previously represent design and/or manufacturing defects which impact the safety of the Focus Vehicles.
- Is there a common design and/or manufacturing defect which impacts the safety of the 2011 – 2016 Ford Fiesta vehicles equipped with the Powershift dual-clutch transmission (the "Fiesta Vehicles")?
    - Yes, the contamination and calibration defects outlined previously represent design and/or manufacturing defects which impact the safety of the Fiesta Vehicles.
- Is there a common design and/or manufacturing defect which impacts the performance of the Focus Vehicles?
    - Yes, the contamination and calibration defects outlined previously also impact the performance of the Focus Vehicles.
- Is there a common design and/or manufacturing defect which impacts the performance of the Fiesta Vehicles?
    - Yes, the contamination and calibration defects outlined previously also impact the performance of the Fiesta Vehicles.
- Is there a design and/or manufacturing defect(s) impacting safety and/or performance which is common to both the Focus and Fiesta Vehicles?
    - Yes, because all vehicles included in the definition are equipped with the Getrag PowerShift 6DCT250 dual-clutch transmission, all defects are common to the Focus and Fiesta Vehicles.
- If there is a common design and/or manufacturing defect(s) impacting the safety and/or performance of the Focus and/or Fiesta Vehicles, is Ford capable of permanently repairing those design and/or manufacturing defect(s)?
    - Currently, there are no permanent repair procedures that address the contamination and/or calibration issues present in these transmissions.

APPENDIX A

CURRICULUM VITAE:
DARRYL W. SCHNARR, P.ENG.

roarengineering.com

Darryl W. Schnarr, P.Eng.

Forensic Engineer, Accident Reconstruction Manager

Contact

cel 519.820.7772
tel +1 844.235.8565
darrylschnarr@roarengineering.com

Education

UNIVERSITY OF WATERLOO, WATERLOO, ON

Faculty of Engineering

Bachelor of Applied Science, Mechanical Engineering – Co-operative Program (With Distinction)

Specialized Professional Competencies

Inspected damaged vehicles, undamaged vehicles, and collision scenes related to a reported collision.

Reconstructed motor vehicle collisions involving automobiles, heavy trucks, trains, motorcycles, all-terrain vehicles, bicycles, skateboards, and pedestrians. Employed a combination of engineering software packages and hand calculations to solve complex collision dynamics.

Calculated collision forces and directions for use in biomechanical injury evaluations.

Assessed mechanical fitness of automobiles. Suspected issues included brake failures, accelerator pedal failures, tire tread inadequacy, fuel system failures, vacuum system failures, and suspension component failures.

Assessed mechanical fitness of motorcycles. Suspected issues included air box failures, fuel system failures, braking system failures, position of handlebar mounted controls, suspension failures, and tire failures.

Vehicle Event Data Recorder (Black Box) removal, downloading, and analysis.

Restraint and safety system usage and failure analysis, including seatbelts, air bag systems, and helmets.

Investigation of suspicious / fraudulent vehicle collisions, where the occurrence of a collision between two or more vehicles is in question.

Mechanical systems evaluation and failure analysis, including elevators and scaffolding failures.

Firearm failure, accidental discharge, and holster interaction analysis.

Forensic Engineering Experience

ROAR ENGINEERING — **Jun 2016 – PRESENT**
Forensic Engineer, Accident Reconstruction Manager

GIFFIN KOERTH INC. — **Nov 2009 – Dec 2013**
Forensic Engineer, Accident Reconstruction

FORENSIC DYNAMICS INC. — **May 2008 – May 2009**
Forensic Engineer, Accident Reconstruction

Industrial / Manufacturing Experience

HAMMOND MANUFACTURING — **Nov 2015 – Jun 2016**
Senior Methods Engineer

OWENS CORNING GUELPH GLASS PLANT — **Jan 2014 – Nov 2015**
Chopped Strand Mat Process Engineer

TRACTION TECHNOLOGIES — **May 2006 – May 2008**
Project Engineer

TOYOTA MOTOR MANUFACTURING CANADA — **Sep 2004 – Aug 2005**
Manufacturing Engineering Student

CAMI AUTOMOTIVE — **Sep 2002 – Dec 2002**
Maintenance Support Student

Additional Courses and Seminars

COURSES COMPLETED

Confined Space Entry Certified, Acute Environmental and Safety Services, 2014

Crash Data Retrieval (CDR) Analyst Course, Collision Safety Institute, 2013

Society of Automotive Engineers (SAE) International Congress, 2012

Society of Automotive Engineers (SAE) International Congress, 2011

Canadian Firearms Safety Course (CFSC), 2001

Experienced Rider Motorcycle Training Course, Conestoga College, 1999

Motorcycle Driver Training Course, Conestoga College, 1998

Professional Memberships

Professional Engineers of Ontario (PEO)

Society of Automotive Engineers (SAE)

Canadian Association of Technical Accident Investigators and Reconstructionists (CATAIR)

Institute of Transportation Engineers Inc. (ITE)

Court Experience

Qualified as an expert witness in the Ontario Court of Justice.

Qualified as an expert witness in the Ontario Superior Court of Justice.

APPENDIX B

CURRICULUM VITAE:
VINCENT R. ROCHON, P.ENG.

roarengineering.com

Vincent R. Rochon, P.Eng.

Consulting Engineer, Co-CEO

Contact

cel 416.720.2022
tel +1 844.235.8565
vincentrochon@roarengineering.com

Education

QUEEN'S UNIVERSITY, KINGSTON, ON

Faculty of Applied Science

Bachelor of Science, Electrical Engineering

Experience

ROAR ENGINEERING **2015 – PRESENT**

Co-CEO, Electrical and Fire Protection Engineer

Fire scene and failure (electrical, mechanical, and chemical) investigations (over 1900 completed).

Peer review of 90 percent of fire scene and failure investigations completed by Rochon Engineering.

Responsible for reviewing new building designs for compliance with all applicable Fire and Life Safety Codes and Standards.

Responsible for inspecting existing buildings and developing deficiency lists based on applicable Fire and Life Safety Codes and Standards.

Responsible for electrical systems, fire protection and life safety design of commercial, industrial, and institutional buildings (including fire alarm and security, fire protection, sprinkler, and fixed extinguishing systems).

Responsible for inspecting stairs, ramps, walking surfaces for compliance with applicable codes and standards including the Ontario Building Code.

Mentor and coach for engineers and managing engineers in the organization, focusing on technical training and business operations and administration.

Responsible for strategic planning initiatives including national expansion through organic and acquisition means, quality program, succession planning and human resources, IT initiatives and risk reduction, and sales and marketing.

Expert Witness testimony for formal judicial and quasi-judicial proceedings as well as informal pre-hearings.

FORE BEARS FORENSIC SCIENCE INC. **2012 – 2015**
Electrical and Fire Protection Engineer

Instructor, mentor and coach with a primary focus on technical training and business operations.

Forensic, Fire Protection and Electrical Engineering consulting, primarily focused on scientific investigations where a large loss, explosion or death has occurred.

Expert Witness testimony for formal judicial and quasi-judicial proceedings as well as informal pre-hearings.

ROCHON ENGINEERING INC. **1996 – 2012**
Co-CEO, Electrical and Fire Protection Engineer

Fire scene and failure (electrical, mechanical, and chemical) investigations (over 1900 completed). Peer review of 90 percent of fire scene and failure investigations completed by Rochon Engineering.

Responsible for reviewing new building designs for compliance with all applicable Fire and Life Safety Codes and Standards.

Responsible for inspecting existing buildings and developing deficiency lists based on applicable Fire and Life Safety Codes and Standards.

Responsible for electrical systems, fire protection and life safety design of commercial, industrial, and institutional buildings (including fire alarm & security, fire protection, sprinkler, and fixed extinguishing systems).

Responsible for inspecting stairs, ramps, walking surfaces for compliance with applicable codes and standards including the Ontario Building Code.

Mentor and coach for engineers and managing engineers in the organization, focusing on technical training and business operations and administration.

Responsible for strategic planning initiatives including national expansion through organic and acquisition means, quality program, succession planning and human resources, IT initiatives and risk reduction, and sales and marketing.

Expert Witness testimony for formal judicial and quasi-judicial proceedings as well as informal pre-hearings.

BATTAGLIA DEBERARDIS ROCHON AND ASSOCIATES INC. **1990 – 1996**

Fire Protection Engineer and Principal

Completed over 700 fire scene and failure (electrical, mechanical, and chemical) investigations. Peer review of 90 percent of fire scene and failure investigations completed by firm.

Responsible for reviewing new building designs for compliance with all applicable Fire and Life Safety Codes and Standards.

Responsible for inspecting existing buildings and developing deficiency lists based on applicable Fire and Life Safety Codes and Standards.

Responsible for electrical systems and fire protection design of commercial, industrial, and institutional buildings (including fire alarm, fire protection, and security systems).

Expert Witness testimony for formal judicial and quasi-judicial proceedings as well as informal pre-hearings.

FIRE INVESTIGATION RESEARCH AND ENGINEERING SERVICES **1989 – 1990**

Investigative Engineer/Adjuster

Completed over 60 failure and fire scene investigations.

Responsible for adjusting property and liability claims.

Expert Witness testimony for formal judicial and quasi-judicial proceedings as well as informal pre-hearings.

LABOUR CANADA DOMINION FIRE COMMISSIONERS OFFICE **1989**

Fire Protection Engineer

Responsible for approving architectural plans for new and renovated Government of Canada buildings regulated by National and Provincial Building Codes and Standards.

Inspected Government of Canada buildings for compliance with applicable Codes and Standards.

MINISTRY OF THE SOLICITOR GENERAL **1986 – 1989**
OFFICE OF THE ONTARIO FIRE MARSHAL
Fire Protection Engineer

Completed over 100 fire scene investigations and over 30 equipment examinations dealing with electrical failures.

Responsible for reviewing, interpreting and amending legislation (Building & Fire Codes).

Researched/reviewed Environmental Assessments and ULC/CSA/CAN Standards. Supervised the Lightning Rod Program (based on the Lightning Rod Act).

Inspected/reported on Fire Marshal's Order Appeals

Expert Witness testimony for formal judicial and quasi-judicial proceedings as well as informal pre-hearings.

KIDD CREEK MINES LTD. **1985**
Electrical Maintenance Engineer

Designed a system and programmed a Gould Modicon Micro 84 programmable logic controller to control the cycles of a bag-house.

Analyzed and modified several solid state DC drives, replacing thermal overload relays with solid state overload protection.

Replaced a casting machine's feed end limits with a shaft encoder and two electronic counters.

Reviewed and prepared equipment inspection procedures for electrical maintenance personnel.

Responsible for incorporating an electrical preventative maintenance checklist for motor control centers.

ONTARIO HYDRO **1983 - 1984**
Electrical Maintenance Engineer

Constructed three phase line diagrams of small generating stations.

Assisted in the dismantling and assembly of hydraulic turbine units.

Additional Courses and Seminars

INSTRUCTOR **1998 - PRESENT**

NFPA 921, **"Fire & Explosion Investigation"** course which prepares qualified participants to write the examination for Certified Fire and Explosion Investigator (CFEI) designation, and the Certified Canadian Fire Investigator (CCFI) designation.

Fire Loss Claims Handling - Fire Investigation by Certified Experts, 2012

'Insurance Subrogation' seminars and laboratory demonstrations, 2008 - 2012

Canadian Defence Lawyers - 'Boot Camp Toronto' presentation, **'Engineering Expert Evidence'**, 2008

"Electrical Power Distribution System Fires", CAFI course, 2007

"Slips & Falls - Code Requirements" seminar, The Hamilton Law Association, 2004

"Arson Investigations "The Importance of Fire Scene Documentation", CAFI course, 2003

Vehicle Fire Investigation seminar, CAFI, 2002

"Marine Fire Investigation" course, CAFI, 2001

"Marine Losses" seminar, Fernandes Hearn, 2001

"Live Burns" course, CAFI, 2000

"Electrical Equipment/Post Fire Analysis" course, CAFI/IAAI/Seneca College, 1999

"Fire Investigation Techniques" course, 1996

COURSES COMPLETED

National Association of Fire Investigators (NAFI), 2007
Certified Vehicle Fire Investigator course

National Association of Fire Investigators (NAFI), 2007
Vehicle Fire, Arson & Explosion Investigation Science & Technology Seminar

Building Code Identification Number (BCIN) 28758 - Exams, 2006-2007
Designer Legal, Fire Protection, Detection, Lighting and Power

University of Toronto, EPIC, 2005
Transformer Operational Principles, Selection and Troubleshooting

National Association of Fire Investigators (NAFI), 2004
Certified Fire Investigator Instructor Course

Society of Fire Protection Engineers, 1999
Advanced Computer Fire Modelling

Society of Fire Protection Engineers, 1997
Fastlite and FPE tool - Computer Fire Modelling

Society of Fire Protection Engineers, 1996
FPE tool - Computer Fire Modelling

University of Toronto, 1995
Programmable Logic Controllers

University of Toronto, 1994
Commissioning, Testing and Start-Up of Electrical Systems

University of Toronto, 1994
Power System Protection

University of Toronto, 1993
Electrical Safety Code

Canadian Association of Fire Investigators, 1992
Fire and Arson Investigation

Insurance Institute of Canada, 1989 - 1990
Principles and Practices of Insurance: Claims 1, Property 1, Automobile, Claims 2, Insurance Against Liability, Property 2

Institute for Research and Construction, 1987
Designing for Fire Safety, Investigators Conference Ontario Fire College, 1987
Investigators Conference

Canadian Association of Fire Investigators, 1987
Motor Vehicle Fire Investigation

Ontario Fire College, 1987
Fire Investigation Level 3, Fire Investigation Level 2, Fire Investigation Level 1

Insurance Advisory Organization (IAO), 1987
Sprinkler Systems and Water Supplies

University of Toronto, 1987
Fire Hazards and Their Control

Insurance Advisory Organization (IAO), 1986
Building Construction, Fire Protection and Basic Hazards

Professional Memberships

Professional Engineers of Ontario (PEO)

Society of Fire Protection Engineers (SFPE)

Building Code Identification Number (BCIN) - Designer (28758)
Fire Protection, Detection, Lighting and Power

Canadian Association of Fire Investigators (CAFI)

The Institute of Electrical & Electronics Engineers (IEEE)

Canadian Electrical Code (CEC), Section 32, "Fire Alarm Systems and Fire Pumps" and Section 46," Engineering Systems, Unit Equipment and Exit Signs" Subcommittee Member.

Canadian Standards Association Steering Committee on Fire Safety and Fuel Burning Equipment.

Canadian Standards Association Committee for Standard Number B365-M91, "Installation Code for Solid Fuel Burning Appliances".

National Fire Protection Association (NFPA)

Certified Fire and Explosion Investigator (CFEI)

Certified Fire Investigation Instructor (CFII)

Certified Vehicle Fire Investigator (CVFI)

Publications

Rochon, V.R. 1991, **"A Pocket Guide to Fire Investigations"**

Rochon, V.R. 1994, **"Woodburning Appliances and the Insurance Industry"**

Rochon, V.R. 1996, **"Motor Vehicle Accident Fraud"**

Rochon, V.R. 1996, **"The Incandescent Light Bulb and Its Fire Hazards"**

Rochon, V.R. 1997, **"Computer Fire Modelling"**

Rochon, V.R. 1998, **"Arc Patterns Tell the True Story"**

Rochon, V.R. 2001, **"Technical Investigations of Marine Fire and Explosions"**

Rochon, V.R. 2002, **"Criminal Investigations"**

Rochon, V.R. 2007, **"Post-Collision Vehicle Fire Incident"**

Rochon, V.R. 2008, **"Qualifications for Fire and Explosion Investigators"**

Rochon, V. R., Dr. Arthur Ameis and Samuel Howarth, PhD 2010, **"Accident Reconstruction, Documenting and Analyzing Injuries Sustained in a Collision"**

Volunteer Work

BRADFORD WEST GWILLIMBURY FIRE DEPARTMENT, FIRE PREVENTION **1993 – 1999**

Responsible for reviewing plans and specifications for new and renovated buildings in the municipality.

Responsible for training Fire Department personnel on techniques of fire investigation.

Responsible for conducting cause and origin investigations.

Court Experience

Qualified as an expert witness in provincial court up to the Supreme Court of Ontario.