1 Typical conventional Bowden throttle cable 1999 RHD Toyota Corolla

Fig 1 below shows a typical mechanical accelerator pedal arrangement for a 1998 Toyota Corolla after approximately 100,000 miles running.



Fig 1. Accelerator pedal on a 1999 RHD (UK) Toyota Corolla

We are all generally familiar with the "look and feel" of such a conventional mechanical accelerator pedal and throttle linkage.

A certain amount of mechanical hysteresis is provided by the Bowden cable and the linkages. When you put your foot down on the accelerator pedal you not only have to counter the increasing spring pressure but a certain amount of friction that opposes the movement. Therefore you have to press a little harder than you would to get a given throttle angle than you would if your foot were acting against the spring(s) alone.

1 Electronic Throttles

Toyota introduced its first electronic throttle control system in 1998 on various Lexus models, the LS 400 for example.





A conventional accelerator pedal and Bowden cable were used. The dual accelerator position sensors (potentiometer type) were mounted on the throttle body and were operated on by the Bowden cable. It would appear that the accelerator sensor voltages were fed to the ECU and the ECU in turn determined the voltage fed to the throttle motor to control the throttle angle. In the event of a fault code, the ECU released the mechanical clutch, which allowed the Bowden cable to take over the control of the throttle. This design is covered by US patent 5,950,597 Sept 14 1999.

Abstract: In an electronic throttle control for an engine, two throttle sensors are used to detect a throttle opening. When a sensor failure is detected in either of those throttle sensors, a feedback control is executed according to the output of the other normal sensor if any. If both throttle sensors fail or it cannot be determined whether there is any normal sensor, the feedback is stopped and the feedback variables are initialized and a motor control duty is set to -30% or 0% according to the existing accelerator depression. Thereafter, if the throttle sensors are not restored even after a pre-set determination delay time is over, an electromagnetic clutch and a DC motor are turned off to stop the electronic throttle control. A throttle valve is controlled mechanically for a limp-home running.

With electronic throttles nearly all the mechanical friction in the pedal disappears and it is necessary to re-introduce friction or hysteresis in order to provide something approximating to the "look and feel" of the conventional mechanical pedal.

All of this is well put in the background to CTS's US Patent 7,404,342 of July 29th 2008:

Automobile accelerator pedals have conventionally been linked to engine fuel subsystems by a cable, generally referred to as a Bowden cable. While accelerator pedal designs vary, the typical return spring and cable friction together create a common and accepted tactile response for automobile drivers. For example, friction between the Bowden cable and its protective sheath otherwise reduce the foot pressure required from the driver to hold a given throttle position. Likewise, friction prevents road bumps felt by the driver from immediately affecting throttle position.

Efforts are underway to replace the mechanical cable-driven throttle systems with a more fully electronic, sensor-driven approach. With the fully electronic approach, the position of the accelerator pedal is read with a position sensor and a corresponding position signal is made available for throttle control. A sensor-based approach is especially compatible with electronic control systems in which accelerator pedal position is one of several variables used for engine control.

Although such drive-by-wire configurations are technically practical, drivers generally prefer the feel, i.e., the tactile response, of conventional cable-driven throttle systems. Designers have therefore attempted to address this preference with mechanisms for emulating the tactile response of cable-driven accelerator pedals. For example, U.S. Pat. No. 6,360,631 Wortmann et al. is directed to an accelerator pedal with a plunger subassembly for providing a hysteresis effect.

In this regard, prior art systems are either too costly or inadequately emulate the tactile response of conventional accelerator pedals. Thus, there continues to be a need for a cost-effective, electronic accelerator pedal assembly having the feel of cable-based systems.

The patent makes it clear that it is difficult making a satisfactory pedal for an electronic throttle because the frictional properties must be controlled over the entire life of the vehicle. An inelegant but very practical solution would have been to leave the Bowden cable in place and use that to provide the hysteresis effect.¹

3 The CTS Accelerator Pedal

CTS appear to be providing something equivalent to a miniature friction brake to give some hysteresis. Unlike the rear drum brakes on a car, which bear on the inside of the drum, in the CTS pedal the friction pad bears on the outside of a sector of a drum. The drum in this case is the outside of the bearing end of the foot pedal.

US Patent 7,404,342 of July 2008 shows a quite complicated mechanism that has to work equally well when the pedal is depressed as when the pedal is released. A key element is a brake shoe which bears against the circular bearing end of the foot pedal, The impression I get is that either PA46 or PPS plastic has been used for the lever.

It is being claimed that moisture will cause these materials to expand. I suppose that if the clearances are already very tight such postulated expansion may cause the surfaces to stick. However, without knowing the exact clearances and tolerances and the properties of the material with water present I cannot comment further.

Anyway, supposing that stiction does occur, this is going to make the use of the pedal difficult or perhaps impossible, but it is not going to cause sudden accelerations.

¹ I cannot help feeling that this may have been the reason why early Kia Amantis fitted with electronic throttles used a conventional pedal and Bowden cable through to a double sensor in the engine compartment. This may have provided a bit of hysteresis, but it also resulted in the sensor connector being subject to high vibration levels and the need to mitigate contact fretting by using Stabilant 22 contact enhancer. [TSB Number KT2007032202 2004-2006 Kia Amanti]



Fig 2 example of disassembled pedal from patent specification (CTS patent).

In the above disassembled view, when the pedal is depressed this compresses spring 46 which in turn applies a force to the circular spring holder which pivots and forces circular surface 70 against the drum. See the patent for details.

Now this may not be the exact arrangement and CTS have a patent for a completely different arrangement. Note that this shows two Hall effect sensors side by side at 92A and 92B. In the actual design the two sensors are in the same IC package

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Fig 3 – Alternative CTS pedal

The friction plates are not shown in the patent (USP 6,809,512 Oct 26 2004 and two others). Double tapered magnet assembly ringed in red. (North – South -North – South)

6



There is a picture circulating on the web which shows the fix:

Fig 4: Diagram of Toyota pedal construction emanating from Toyota

It looks as if something approximating to the 2008 patent has been used in practice rather than the 2004 patent. What Toyota propose inserting in their recall "fix" is what they call a "Precision cut steel reinforcement bar", as shown. Its function would appear to be to prevent the grey lever from rotating too far clockwise about its pivot and applying too much braking force and hence jamming. See Fig 4



Fig 5 Typical CTS Pedal 2010 Yaris (UK Spare 2010)



Fig 6 Underside of CTS Pedal (2010 Yaris). Magnetic stainless steel closing in plates clip into place and are not sealed against the plastic accelerator pedal body.



Fig 7a : Rear view of Pedal showing gap where rectangular spacer is supposedly fitted under the recall program



Fig 7b: metal shim in place Toyota Auris



Fig 8 : Close up of two halves of moving tapered magnet assembly with stationary housing for pedal angle sensor PCB between the two halves of the magnet.



Fig 9 : Double V notched friction lever arm and matching double V notched rotating drum. (Original design) The other end of the lever arm retains the pedal spring so that when pedal force is applied by the driver to the pedal the male projections on the friction arm are pressed into the matching female notches on the drum to provide mechanical hysteresis.



Fig 10 – Revised Single V friction pad arrangement

This design was sold to me under the same part number as the original and I was told that it had the spacer plate fitted. As can be seen it is a redesign with a different plastic used for the friction pad. There is now a single double width male V projection fitting into a single broad female V notch. In effect the contact area for the friction pad has been halved.

As far as I am aware, this re-design has never been declared.



Yaris – from County Durham scrapyard



Yaris – purchased from e-Bay



Yaris New

Fig 11: Damage to wall of protective pocket for Accelerator pedal sensors

Fig 11 shows a flaw that appears to be present in the wall of a number of CTS pedal assemblies in the protective pocket that surrounds the Hall Effect electronic sensors that measure pedal position.

I presume that this is a manufacturing flaw caused by imperfect casting.

This flaw is normally hidden by the magnets. The only way that I was able to get the pedal to stay depressed to allow photographs was place the tapered caliper head in the gap as shown in Fig 12..



12 Calliper head used to keep throttle open. A wooden trapezoidal wedge would do the same



Fig 13 : Sensor PCB partly removed from sheath within pedal assembly. Although there is a flexible seal to prevent water ingress, the sheath has a rectangular hole which would allow moisture in from the magnet space.

The flaw, as show in Fig 11 would also allow the ingress of moisture.

When an accelerator pedal is examined off the vehicle, there is usually clearance between the moving magnets and the protective pocket surrounding the electronics.

This is not necessarily the so when the pedal assembly is installed in the vehicle because there are only two holding down bolts on the diagonal as shown in Fig 13



Fig 13 Underside of the pedal assembly box, showing the diagonal fixing arrangement

The moment that the driver presses on the pedal, a turning moment is exerted about the holding down axis that distorts the pedal box structure with the effect of pushing one magnet towards the pocket containing the electronics. In some cases this will result in the magnet rubbing against the pocket.

This of itself might not matter were it not for the presence of the flaw shown in Fig 11. Eventually wear might allow one of the magnets to catch and occasionally prevent the return of the pedal to the idle position.

As far as is known, Toyota have not identified this as a potential problem and as a possible explanation of some examples of sticky pedals.

A video clip should go in here but the file is too big



fig 12 : Photos of typical Sensor PCB and 6 pin connectors



Fig 13 PCB showing pin connections

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Fig 14 : Non-component side of PCB. Solder globule and solder splat (circled in red) are trapped under varnish. Note the cracks in the protective coating near where connector pins are soldered to the PCB. Is this indicative of poor quality control? (2009 MY scrap Yaris exemplar)



Fig 15: Close up of cracks in coating on all six connector pins. Solder globule and solder splat can also be seen (2009 MY scrap Yaris exemplar)



Fig 16 Possible tin whisker on C9

Note: No certainty here!



Fig 17 Possible tin whisker on C9

Note: No certainty here!



Fig 18 Typical diagram for Toyota Accelerator Pedal Sensor arrangement (In this case a Prius)

4 Some thoughts on possible modes of accelerator pedal malfunction

Fig 18 above shows that two magnetic sensors give voltage against angular position of the same slope. As I understand it, the difference in voltage between the two signals is monitored and if that difference should change then the ECU will shut down the vehicle to limp home mode, or so the theory goes.

One failure mode that does not seem to have been considered is what happens if the magnetic field in the airgap either increases or decreases. A decrease in the airgap flux density will result in the pedal angle sensor voltages decreasing. This is equivalent to reqesting a decrease in throttle angle. An increase in the airgap flux density will result in an increase in the sensor voltages – equivalent to a request to increase the throttle angle.

The same sensor principle is used in the throttle sensor. In the throttle sensor a reduction in airgap flux density will result in a decrease in sensor voltages. i.e. for a given position of throttle plate the feedback voltage indicating angle will decrease. The control system will therefore open the throttle to compensate for the apparent drop in sensor output voltage. An increase in airgap flux density will cause the sensor voltages to increase and the control system will compensate by closing the throttle a little.

In the NHTSA Report on 2007 Toyota Lexus ES350 vehicles it says:

"Magnetic fields were introduced in proximity to the throttle body and accelerator pedal potentiometers and did result in an increase in engine revolutions per minute RPM) of up to approximately 1,000 RPM, similar to a cold idle engine RPM level".

This is a tacit admission that if the sensor airgap magnetic flux density is altered by an imposed magnetic field the sensor voltages will change in the manner suggested above and the result will be a change in engine speed. Surprisingly NHTSA have not picked up on the significance of their observations – namely that the resulting changes in pedal sensor voltage brought about by the magnet have not triggered the fault detection software and caused the throttle to go into the limp home mode.

In practical terms it is unlikely that sufficiently high magnetic fields could be generated to introduce significant throttle or accelerator pedal sensor voltages.

Antony Anderson

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Appendix 1

The following vehicles were recalled for the shim:

- 2009-2010 Corolla
- 2009-2010 Venza
- 2009-2010 Matrix/Pontiac Vibe
- Certain 2007-2010 Camry
- 2008-2010 Highlander
- 2007-2010 Tundra
- 2008-2010 Sequoia

Appendix 2 Suggested Visual Checklist

1	Original Design	Metal shim under spring heel
2	Original Double V profile of friction	Final single V profile of friction shoe in
	shoe	different plastic material
3	Protective pocket for APP sensors-	Protective pocket for APP sensors
	Is flavible gasket graduad?	
-	is meaning gasket clacked!	



8		
8	Check box torsional stiffness. Check for cracks	