S65/S85 Throttle Actuator Procedure (E9X M3, E60 M5)

The following information is provided for reference purposes only and should be used at your own risk.
In no event shall Beisan Systems, LLC or its members be liable for incidental, consequential, or special loss or damages of any kind however caused.

Introduction

An automotive throttle actuator is an electromechanical device that actuates (positions) the opening of an engine throttle. An engine throttle is a valve that controls the air intake into the engine. A throttle is normally a spring loaded, default position closed, butterfly valve. The S65/S85 engine has 8/10 cylinders and is a V engine. Thus there are two engine head banks with each having 4/5 cylinders. Each cylinder has a dedicated throttle. Thus each bank has 4/5 throttles. These 4/5 throttles are controlled simultaneously by a single mechanical rail that controls their position identically. Each throttle rail, with row of 4/5 throttles, is controlled by a single throttle actuator. Therefore there are 2 throttle actuators, one for each engine bank.

The S65/S85 throttle actuator is an intelligent device with a microcontroller, which includes microprocessor, RAM, and ROM. It is connected to a CAN (controller area network) bus and communicates with the DME (digital motor electronics, engine computer) for throttle opening position commands. It also connects to two throttle position sensors, one at each end of the throttle rail, which provide throttle opening position data for feedback control. The throttle actuator incorporates a DC (direct current) brush motor and two stepdown gears for throttle opening physical control. The DC motor is driven by 2 sets of transistor banks, each consisting of 2 power transistors connected in series, to drive the motor rotationally and counter rotationally. A PWM (pulse width modulation) signal is used to drive the motor. A PWM signal is a square wave. The high pulse turns the motor rotationally, and the low pulse turns the motor counter rotationally. The frequency (cycle time) of the PWM signal is undocumented. Modulation (changing) of the PWM (square wave) signal duty cycle (length of the pulses) controls the rotational / counter rotational position of the motor and in turn the throttle rail and throttles open position.

The S65/S85 throttle actuator experiences multiple failures and has an expected life of ~70k miles.

A primary failure of the throttle actuator is wearing step down plastic gear teeth. The gears are made from PPA (Polyphthalamide) plastic with fillers. The combination of load from the throttle springs and vibration from the engine causes the plastic gears teeth to press on each other with high force and rub. This high force contact and rubbing movement causes significant gear teeth wear and eventual gear function failure.

One of the two primary throttle actuator electronic failures is the PC (printed circuit) board voltage regulator IC (integrated circuit, chip), which provides board input voltage

level stabilization (normalization). This voltage regulator IC is a problematic part which degrades and eventually fails. It causes relative slow function of the throttle actuator as it degrades, and full throttle actuator failure once it fully fails. It can also cause the EEPROM and CAN bus driver power transistor to fail.

The second primary electronics failure is the PC board DC motor driving power transistors. The transistors failure is due to high voltage spikes from the DC motor that occur when the motor driving polarity is reversed by the PWM signal, ie rotation / counter rotation reversal. The throttle actuator has circuity to dampen the voltage spikes. This includes a large capacitor located under the plastic cover bulge on the outer side of the throttle actuator cover. Although the circuity and capacitor are sufficient to protect the power transistors during "normal" function, the voltage spikes from the motor increase beyond the capabilities of the circuitry and capacitor and this exposes the transistors to voltage spikes that eventually cause them to fail. The cause of the higher voltage spikes is buildup of carbon dust from wearing motor brushes that interferes with the contact of the motor brushes to the motor commutator and increases the contact resistance.

A more rare failure is DC motor internal brush housing plastic melting. This occurs from high heat generated from brush carbon dust buildup and electricity. When this occurs, the DC motor can malfunction. If a PC board lead DC motor power transistor is darkened (burnt out), then there is a chance that DC motor brush housing plastic melting has occurred.

Lastly, the DC motor brushes wear and are not replaceable. But indications are the brushes wear slowly and will last the lifespan of the car.

New throttle actuator gears with shaft can be acquired from Beisan System, www.beisansystems.com. The gears are made from powder metal steel that is sintered and hardened to 55 HRC (bearing steel hardness). They have a surface alloy finish from tempering that deters rusting. The half gear has a pressed in stainless steel shaft that is hardened to 50 HRC and has a ground surface finish. The gears' hardened steel is over engineered for the throttle actuator application, and thus the gear teeth should never wear. The stainless steel shaft is made from the same stainless steel, and is hardened to the same hardness, as the OE (original equipment) shaft, and should never wear.

A throttle actuator electronics rebuild service is provided by Bimmer Throttle Repair, www.bimmerthrottlerepair.com. The following tests and repairs are performed. The DC motor driving 4 power transistors are replaced with new OE (original equipment) transistors. The voltage regulator is replaced with a new redesigned version of the OE voltage regulator that addresses the degradation and failure. The rebuilt electronics are then tested and assessed on an S65 engine test bed. If the EEPROM is failed, it is replaced with a new OE EEPROM. If the CAN bus transistor is failed, it is replaced with a new OE CAN bus transistor. These repairs and tests and further repairs address 99.9% of electronics failures. If the electronics are still not functioning after the repairs, the customer is contacted and offered replacement rebuilt electronics for an additional $70.

This procedure shows how to clean the DC motor to remove the brush carbon dust and prevent the PC board power transistors from failing and brushes plastic housing from melting. It also shows how to test the motor continuity to check for internal melted brushes housing plastic. The DC motor brush length is also inspected to estimate the remaining life of the brushes and motor.

The throttle actuator DC motor will need to be cleaned every 60k miles (100k km) to remove the brushes carbon dust buildup and prevent potential damage to the PC board DC motor power transistors and DC motor brushes plastic housing.

Symptoms

Limp mode, loss of power, DSC and EML lights

Diagnosis

One or more of the following fault codes:
P0638 (2B15): Throttle Actuator Control Range/Performance Bank 1
P0639 (2B16): Throttle Actuator Control Range/Performance Bank 2
2B21: Throttle Valve Actuator Pre-drive Check Bank 1
2B22: Throttle Valve Actuator Pre-drive Check Bank 2
2B25: Throttle Valve Monitoring Bank 1
2B26: Throttle Valve Monitoring Bank 2

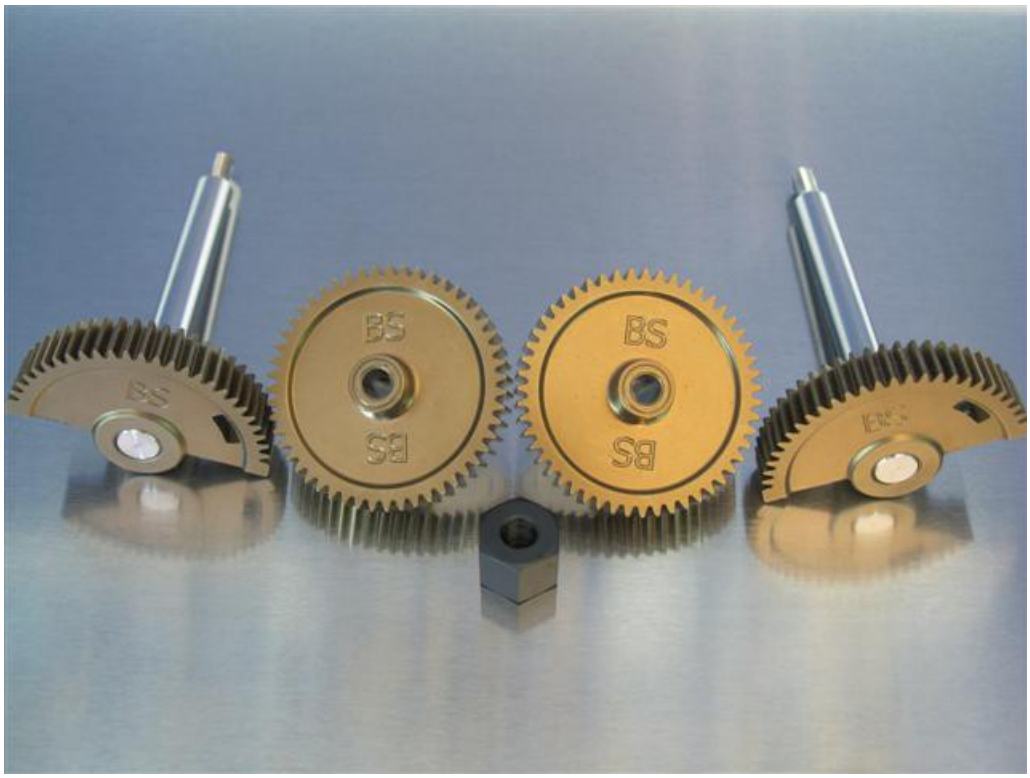
Repair Procedure

The following is an E9X/E60 M3/M5 throttle actuators rebuild R&R (remove and replace) procedure.

Repair time: 3 hours mechanic, 4+ hours DIY.

Parts, Tools, and Shop Supplies

Parts with part number pattern xx-xx-x-xxx-xxx are BMW parts and can be acquired from a BMW dealership.
Beisan Systems only provides the throttle actuator gears and throttle actuator press nut.



2 x S65/S85 throttle actuator gears (BS101)

Note: Gears are made from highly hardened steel. Gold color is an alloy surface finish.

16mm socket 3/8”, 13mm socket 3/8”, T30 torx bit socket 1/4", 3/8” to 1/4” socket adapter
3/8” short-arm ratchet
3/8” torque wrench (8 Nm [6 ft-lb]), 14 Nm [10 ft-lb]) (not shown)
Metric feeler gauges, including range .30-.40 mm (not shown)
2 lb handheld sledgehammer

Note: Torque wrench is not necessary as needed small torque values are not critical and can be assessed by feel.

Digital caliper, digital multimeter, alligator clip wires

Note: Tools are needed to assess DC motor

Paper towels, water based cleaner (simple green 10:1), brake cleaner

Flat wood (1”x4”x5.5”), synthetic grease non-separating non-gumming (Super Lube), oil lubricant w/ dropper (3-in-one), cotton swabs, parts plate

Repair

Removal and installation of throttle actuators on car will be documented in future revision.

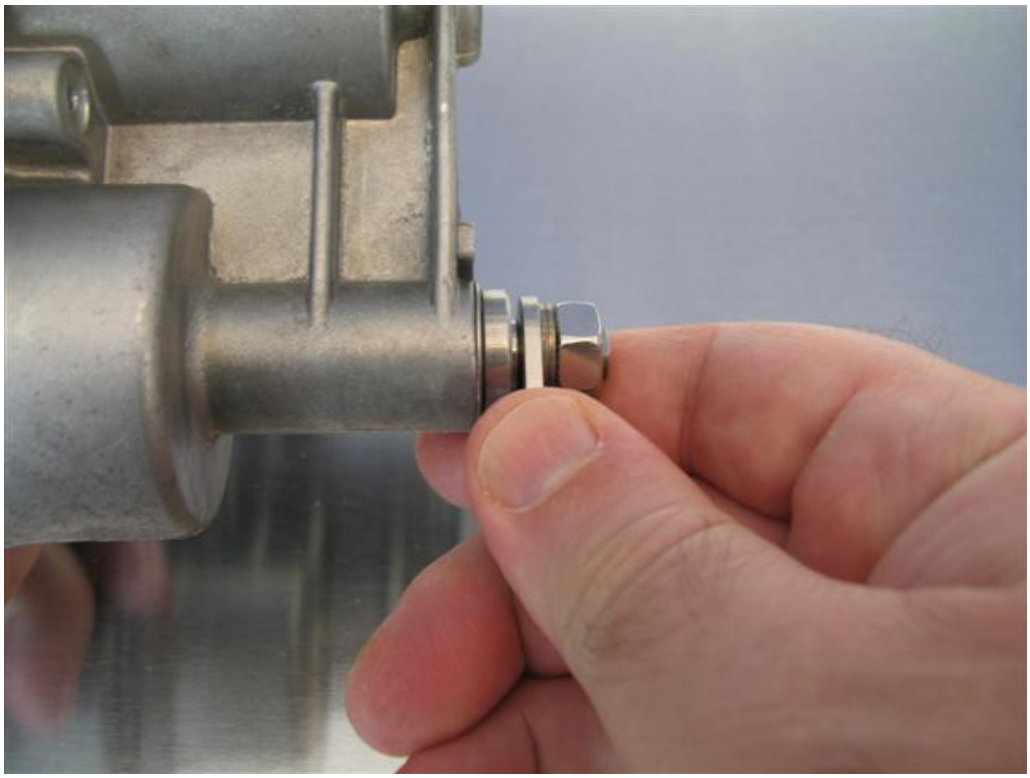
Rebuilding of throttle actuators

Perform following work on table to prevent parts from falling and being damaged.

Perform following throttle actuator rebuild for each throttle actuator.

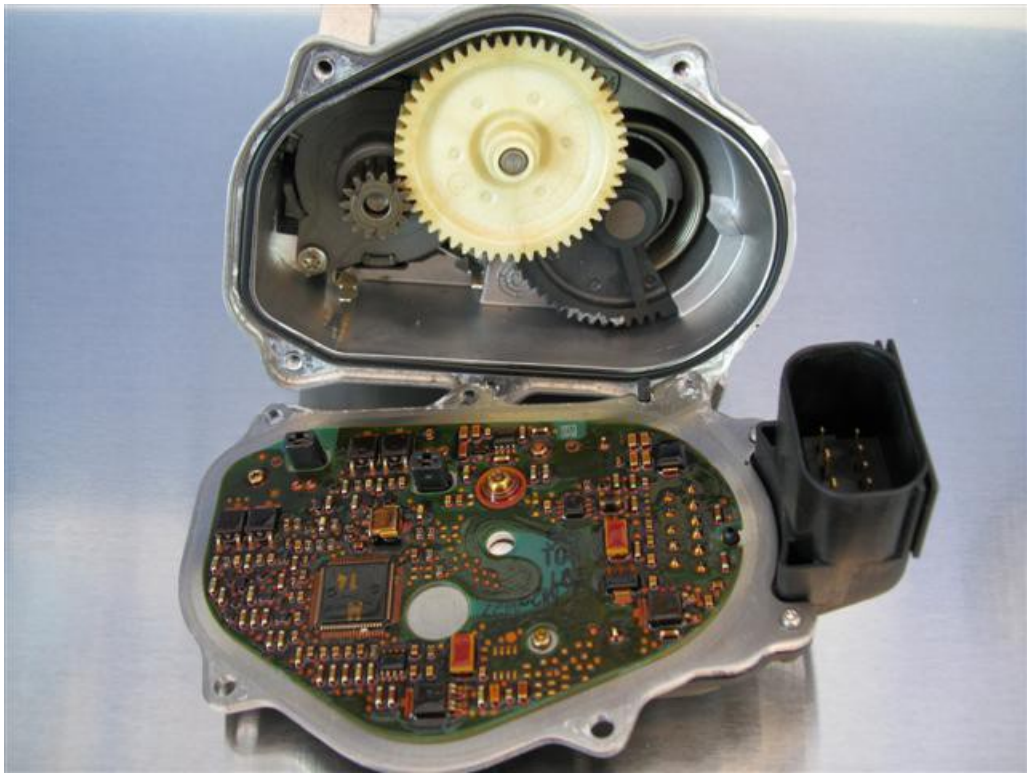
Disassembly of throttle actuator

Spray clean throttle actuator external body (brake cleaner / towels).

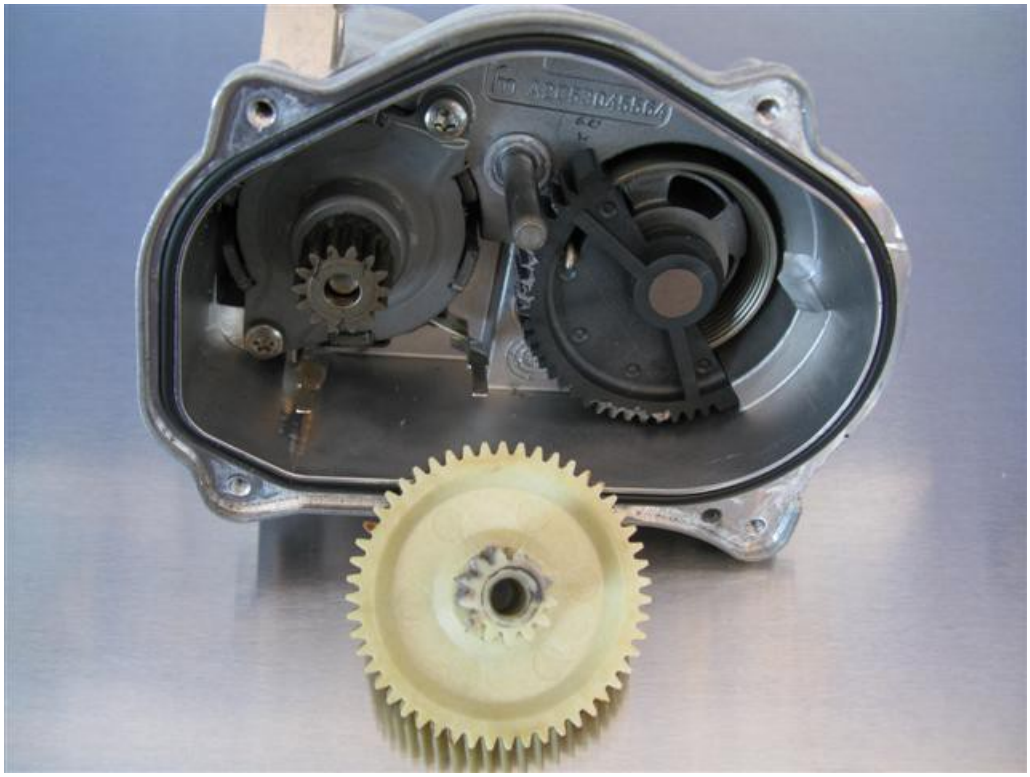


Rotate throttle actuator shaft arm through full rotation range to get sense of operation.
Partially rotate shaft arm and wiggle arm to get sense of gears teeth fit.
Push/pull shaft in/out of throttle actuator to get sense of play (space) of shaft fit in throttle actuator.

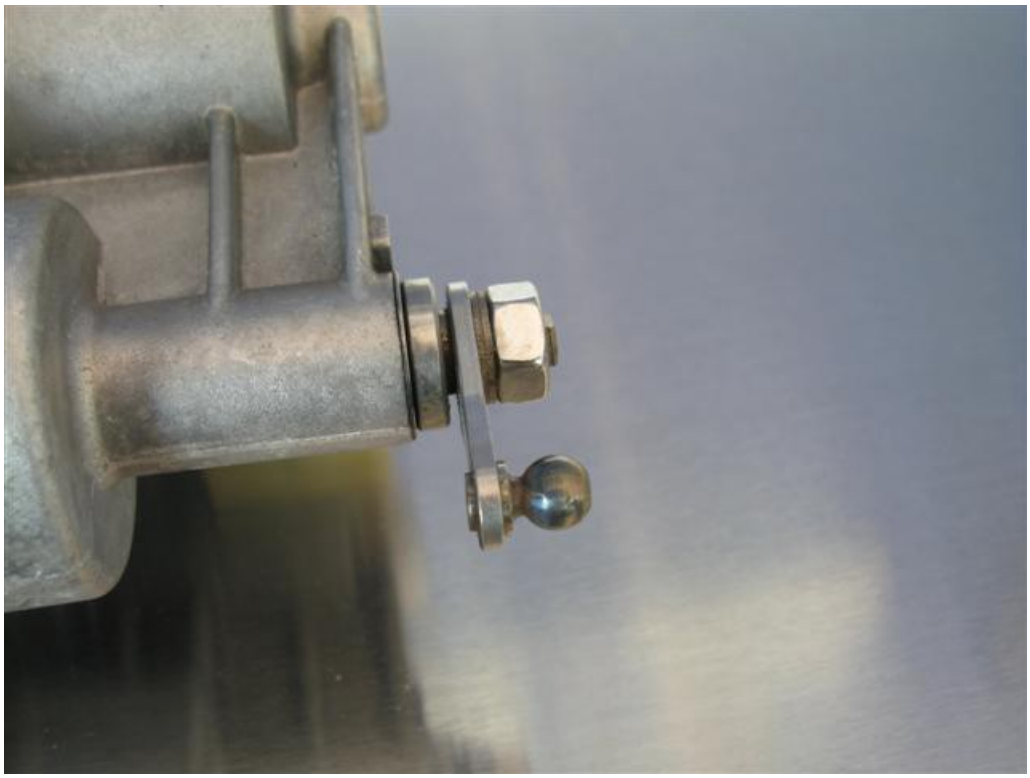
Remove throttle actuator cover mounting bolts.
Remove 5 bolts (T20 torx bit socket 1/4" w/ 3/8” to 1/4” socket adapter / 3/8” ratchet).


Remove throttle actuator cover.
Pull cover off from electrical connector and remove.

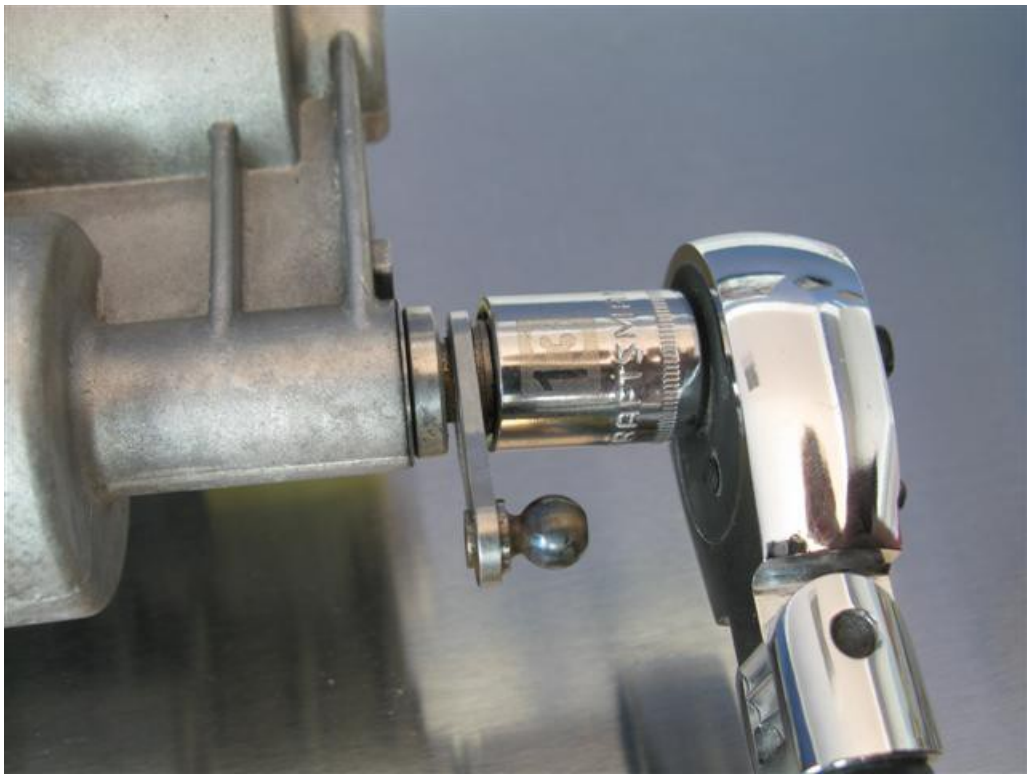
Note: Tiny black plastic grommet will be torn off and removed. This part is not needed and can be discarded.

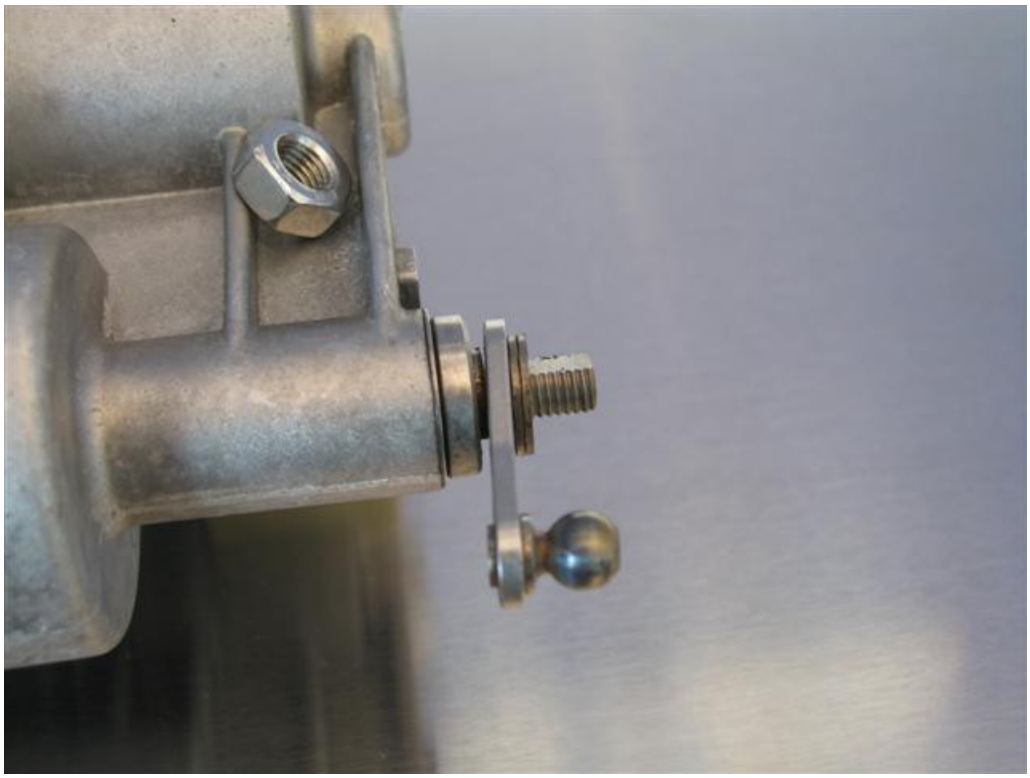


Remove combo gear from throttle actuator.
Pull combo gear straight off mounting shaft.

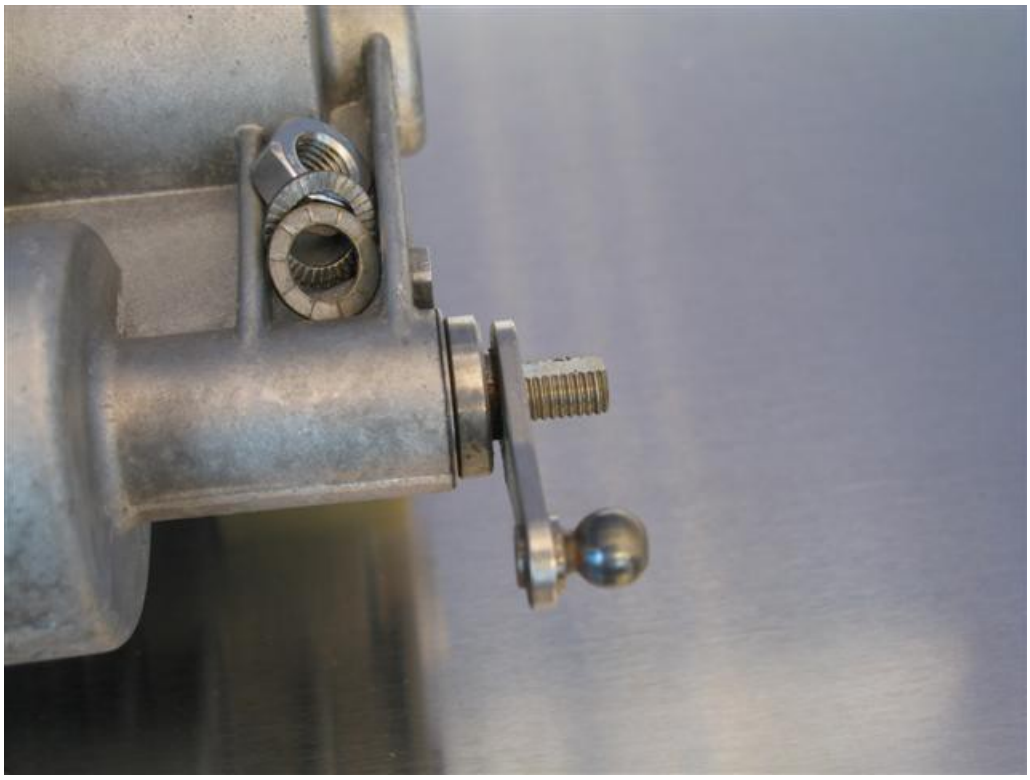


Visually inspect throttle actuator shaft arm, mounting nut, and associate washers.
Arm ball is oriented to side and rear of throttle actuator.
Two small washers are located between mounting nut and arm.
Thick press washer is located between arm and throttle actuator housing.
Small thin washer is located between thick press washer and throttle actuator housing.
These parts will be removed in following steps.



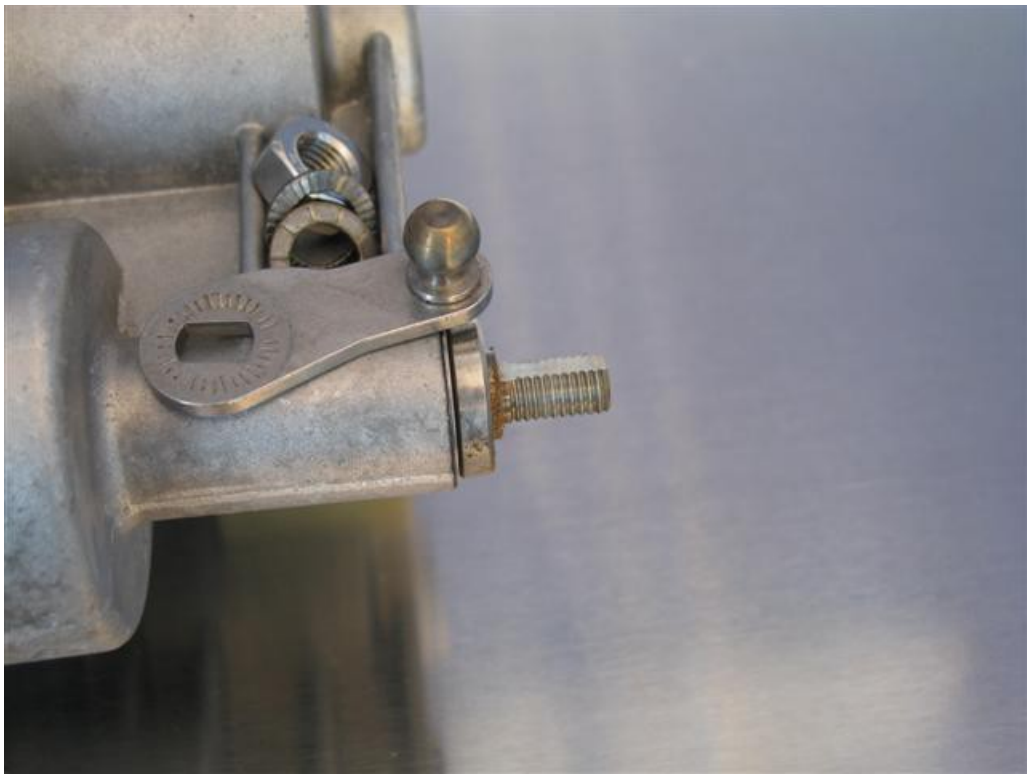


Remove shaft mounting nut.
Remove nut (13mm hex socket 3/8" / 3/8” ratchet).
Note: Rotate shaft arm to end of rotation range, then press down on arm ball on table and break nut seize. Place pad under arm ball (flat wood).

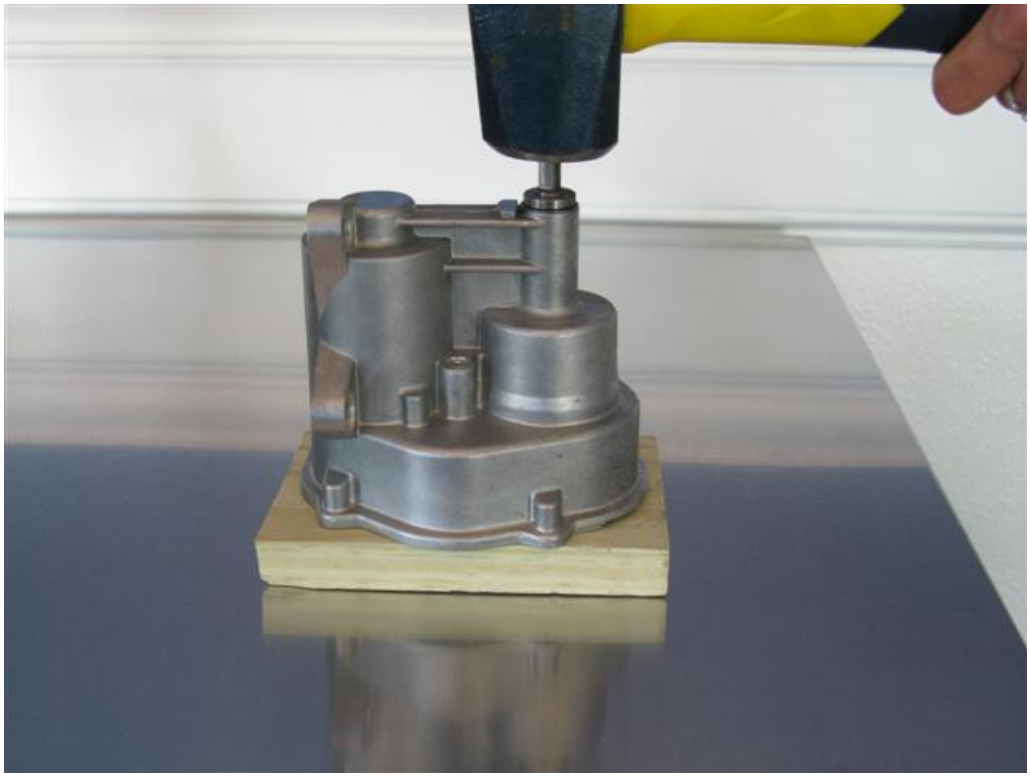


Remove shaft two small ribbed washers.
Pull washers off shaft.

Note: Washers tight ribbed side is oriented one to arm and one to mounting nut.



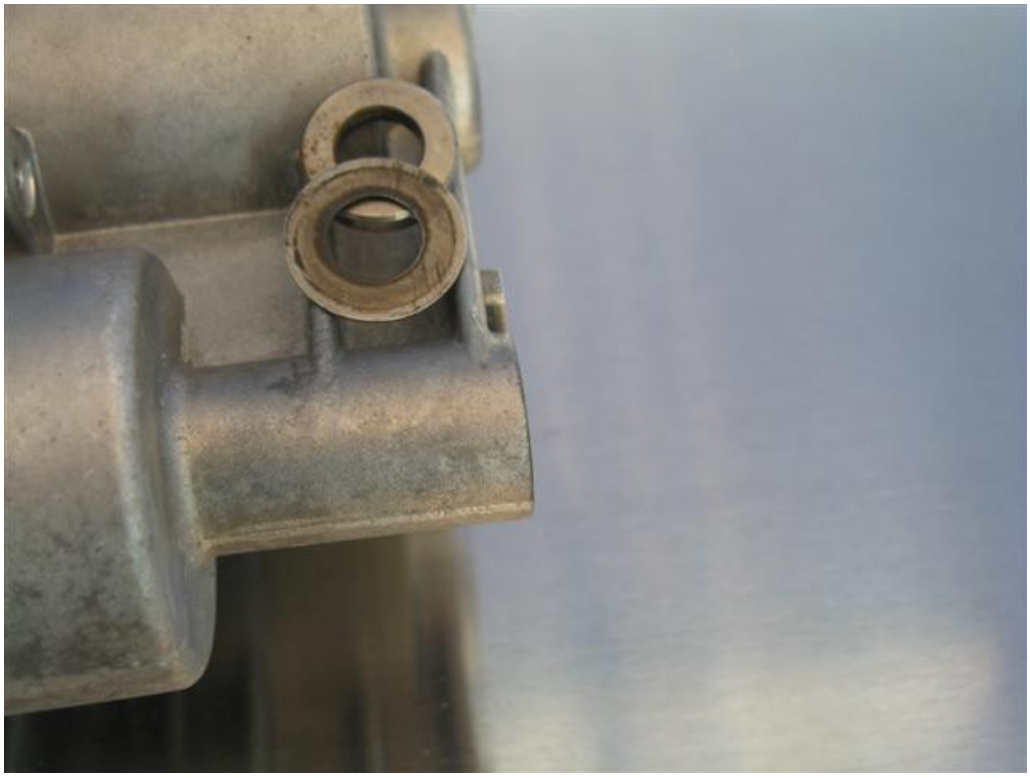
Remove shaft arm.
Pull arm off shaft.



Remove thick press washer from shaft.
Place throttle actuator on flat surface with shaft pointing up (flat wood / ground).

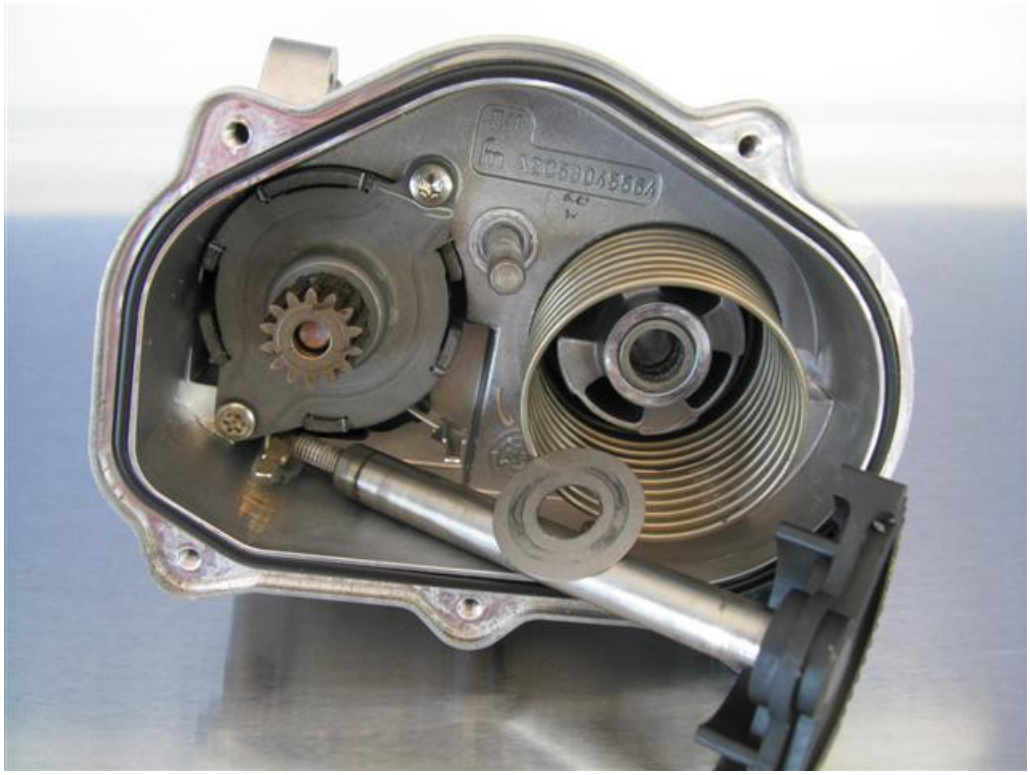
Moderately strike shaft end multiple times into throttle actuator until thick press washer is removed from shaft (2lb handheld sledgehammer).

Note: Perform work on very solid surface or ground.
Note: Shaft will be pushed into throttle actuator and thick press washer and small thin washer will fall off throttle actuator.



Collect fallen thick press washer and small thin washer.

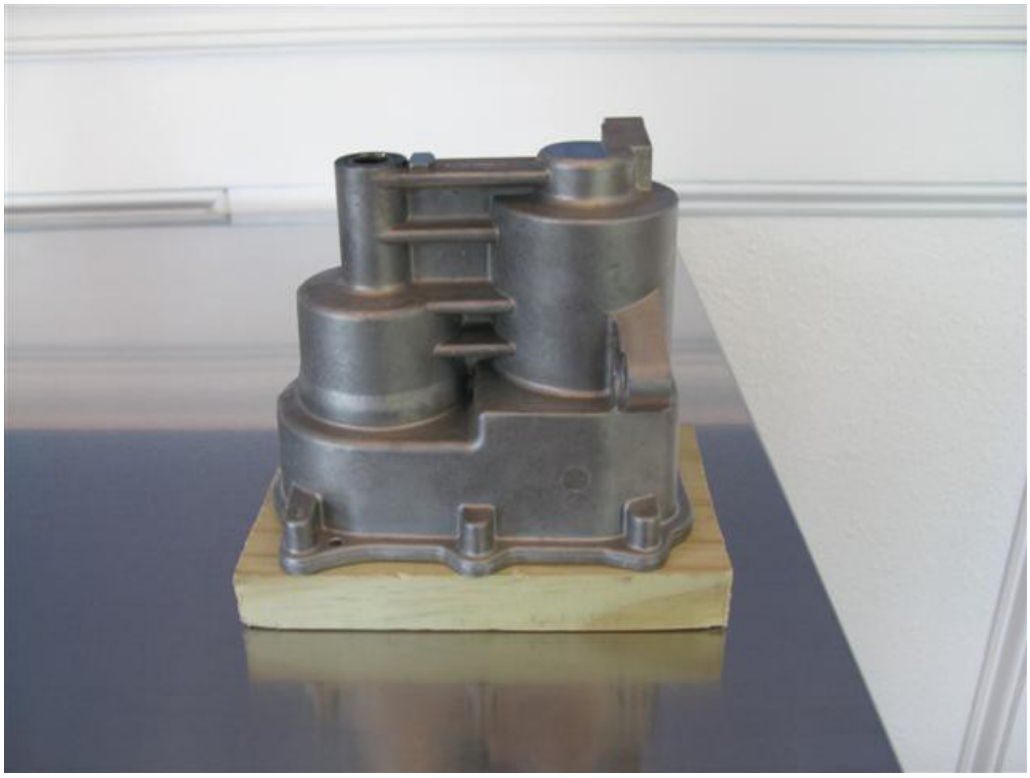
Remove half gear with shaft.
Rotate half gear counter-clockwise to release spring hook from half gear slot, then pull half gear and shaft straight out of throttle actuator.



Remove large thin washer from half gear shaft.
Pull washer straight off shaft.

Remove DC motor 2 mounting bolts.
Remove 2 bolts (T20 torx bit socket 1/4" w/ 3/8” to 1/4” socket adapter / 3/8” ratchet).

Note: Once bolts removed, notice DC motor bracket bolt holes are pressed onto throttle actuator mounting studs.



Dislodge DC motor from throttle actuator housing.
Hit throttle actuator with open face down on flat surface (flat wood).
Repeat hit until DC motor dislodges from throttle actuator housing.

Note: DC motor bracket is press fit onto throttle actuator housing and requires some force to dislodge.

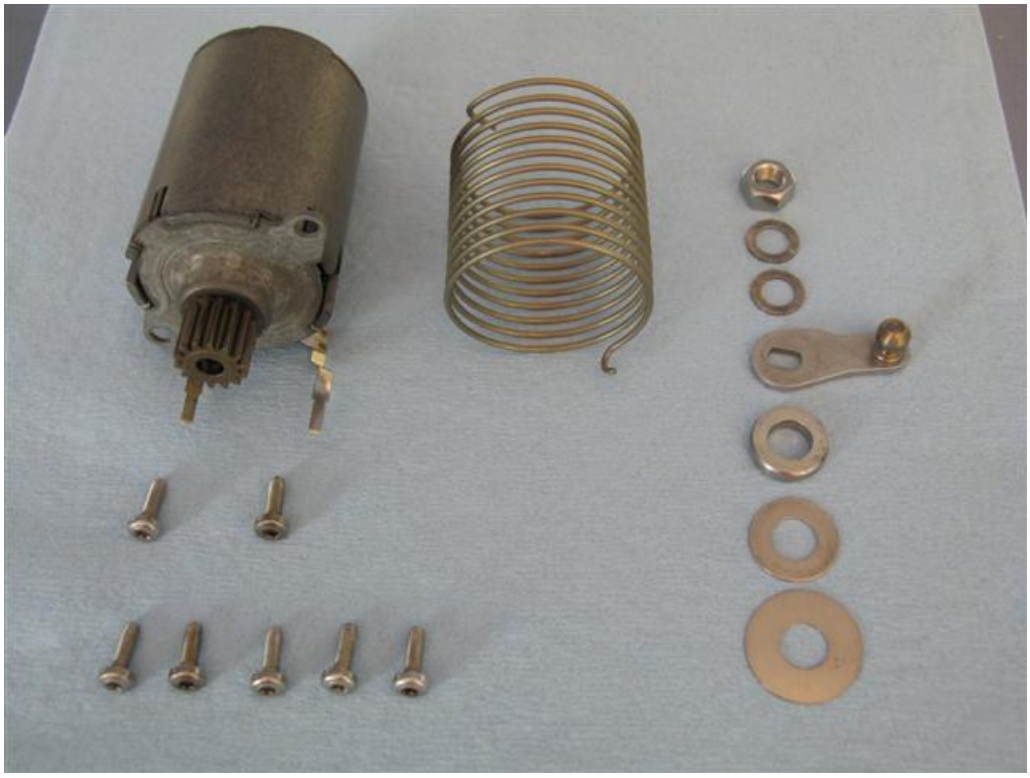
Remove DC motor and half gear spring.
Pull dislodged DC motor and spring straight out of throttle actuator.

Throttle actuator housing is now empty.

Note: Throttle actuator housing is normally dirty with black dust from the DC motor carbon brushes.

Cleaning and inspection of throttle actuator components

Discard throttle actuator gears, as they will be replaced.



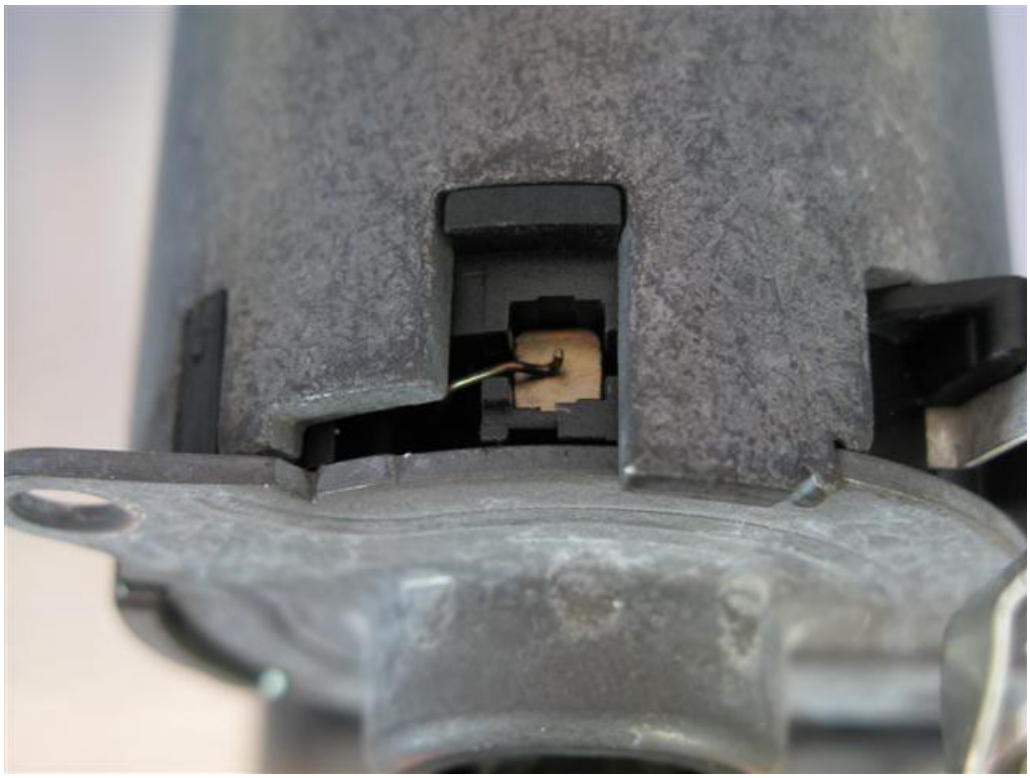
Spray clean all throttle actuator components, except electronics/cover (brake cleaner / towels).
Be sure to clean both radial roller bearings, which mount half gear shaft, in throttle actuator housing.
Note: Also spray clean new gears and shaft as they can have residue.

Spray cleaner into DC motor from both end available openings until cleaner runs clear from motor (brake cleaner). Black residue from motor is brush carbon dust.
Motor top end (gear end) opening is adjacent to one brush on outer side (picture below).
Motor bottom end opening is small hole at bottom face.

Caution: DC motor must be cleaned per above instructions before performing following test.

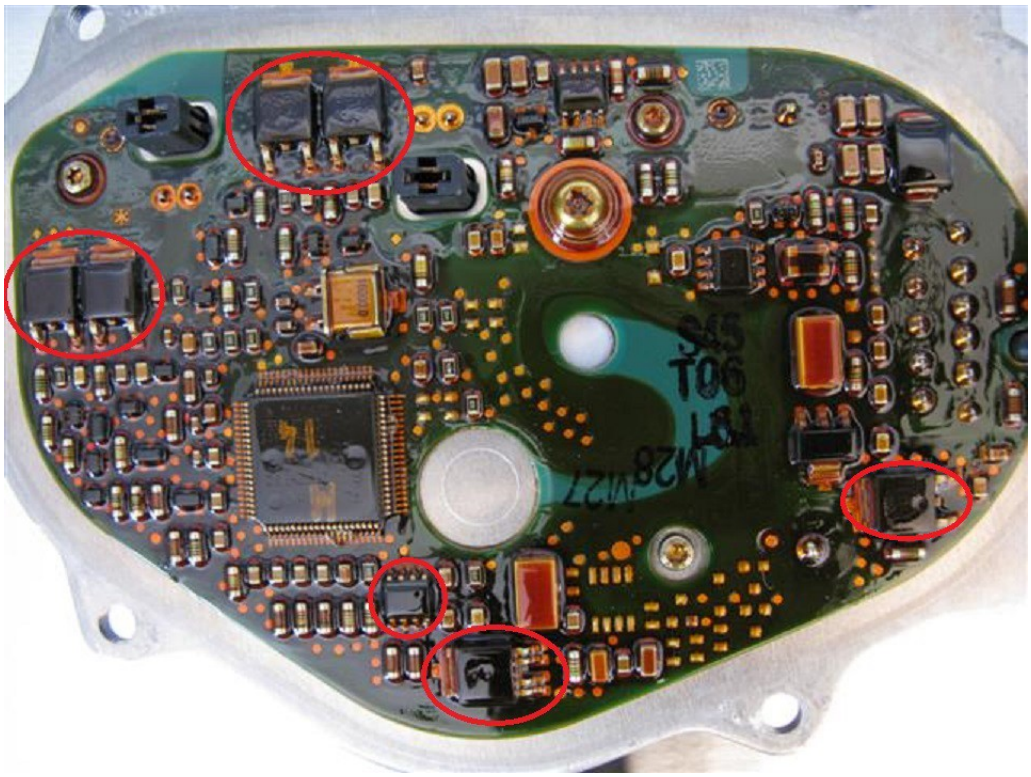
Test DC motor continuity.
Clamp digital multimeter probes w/ alligator clip wires onto DC motor prongs.
Turn on digital multimeter and set to low ohms (resistance).
Turn DC motor gear slowly and note digital multimeter ohm reading.
Reading will fluctuate as gear is turned.
Reading should be .5-3 ohm range.

If DC motor resistance reading is high, then DC motor likely has internal damage from melted brush housing plastic and must be replaced. Contact Beisan Systems for possible options.



Inspect DC motor brushes length.
Measure, in mm, depth of 2 brushes in motor housing (digital caliper).
Open caliper jaws, then place caliper end extending rod on brush end and push down on caliper until caliper end mates with motor housing. Caliper reading is brush end depth from motor housing.
Subtract 4.5mm from measured depth value to remove motor housing thickness (2.5mm) and original (new) brush depth in plastic housing (2mm).
Remaining depth value is brush length wear.

Carbon brush length when new is 10mm.
Remaining brush is 10mm – brush length wear.

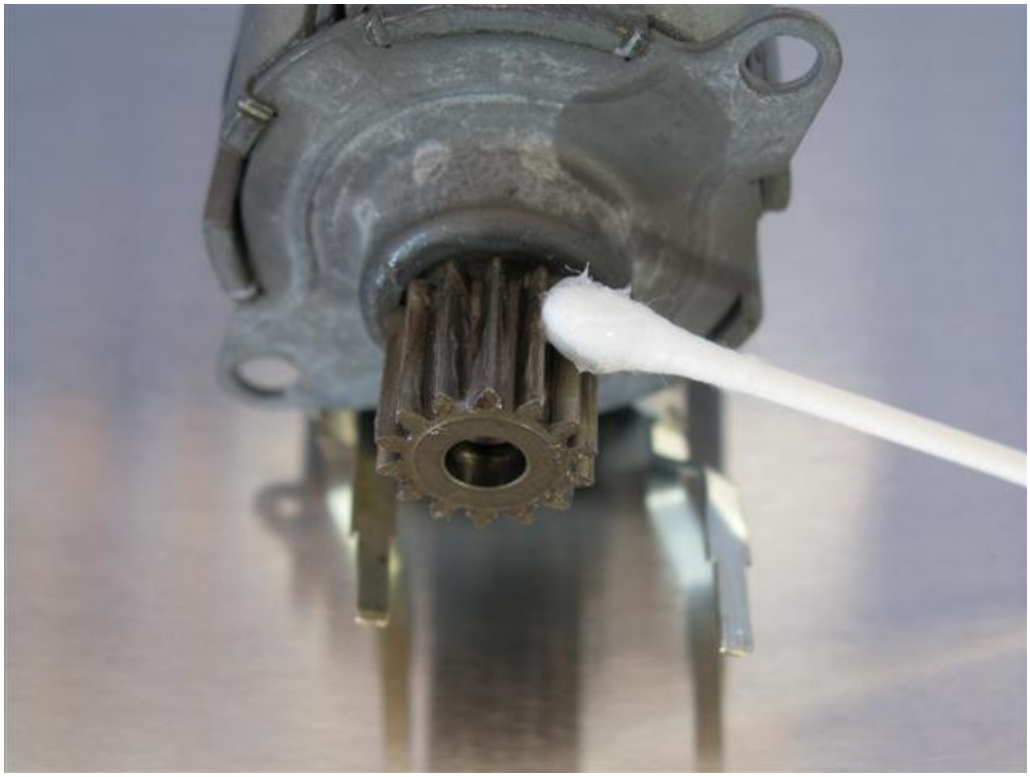


Inspect throttle actuator electronics.
4 IC chips with 2 pins each adjacent to DC motor prong sockets (picture top left) are DC motor power transistors.
IC with 2 double pins (picture bottom center edge) is problematic voltage regulator.
Small 8 pin IC adjacent to voltage regulator is EEPROM (picture just left and above of voltage regulator).
2 pin IC adjacent to connector (picture right bottom) is CAN bus driver power transistor.
Thick brown coating on electronics is conformal coating. It provides protection from corrosion, electrical shorting from debris, and solder cracking from vibration.

<u>Assembly of throttle actuator</u>

Oil DC motor shaft radial bearings.
Place 1 drop of oil at each end of DC motor shaft (oil lubricant).
Rotate DC motor gear to work lubricant into radial bearings.
Wipe off excess oil (towels).

Note: DC motor gear is mounted on DC motor shaft. Place oil under gear and trickle into radial bearing under gear.

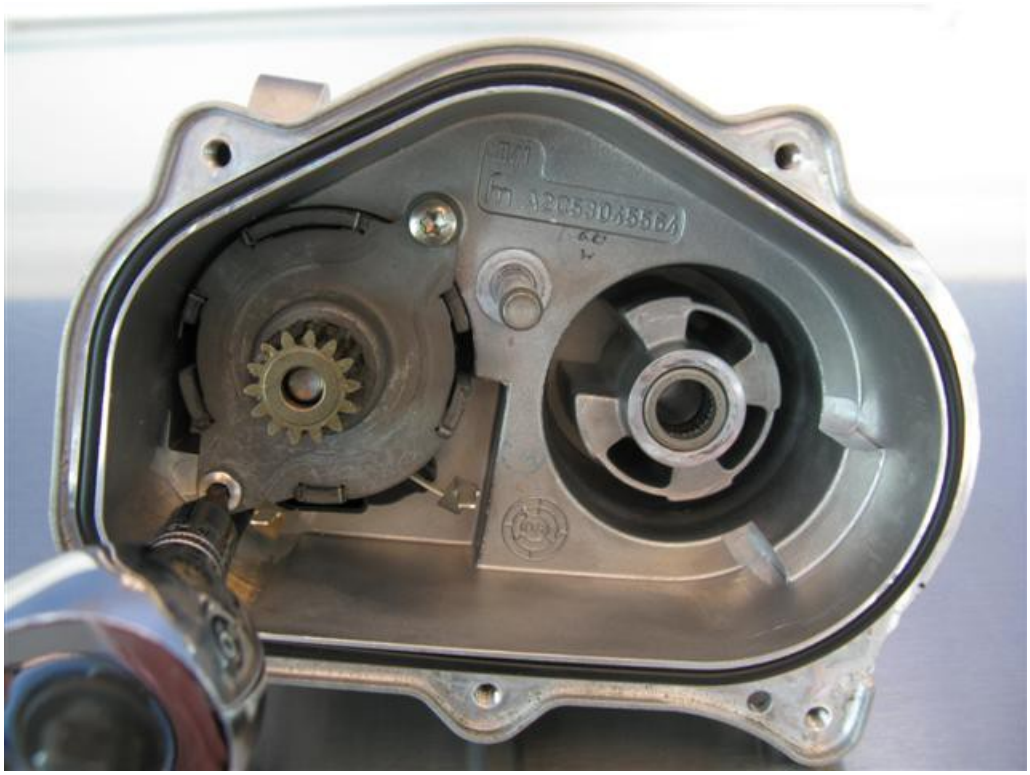


Apply grease to DC motor gear teeth.
Apply light layer of grease to gear teeth (bearing grease / cotton swab).

Note: Apply grease onto applicator, then swipe applicator along each tooth valley.

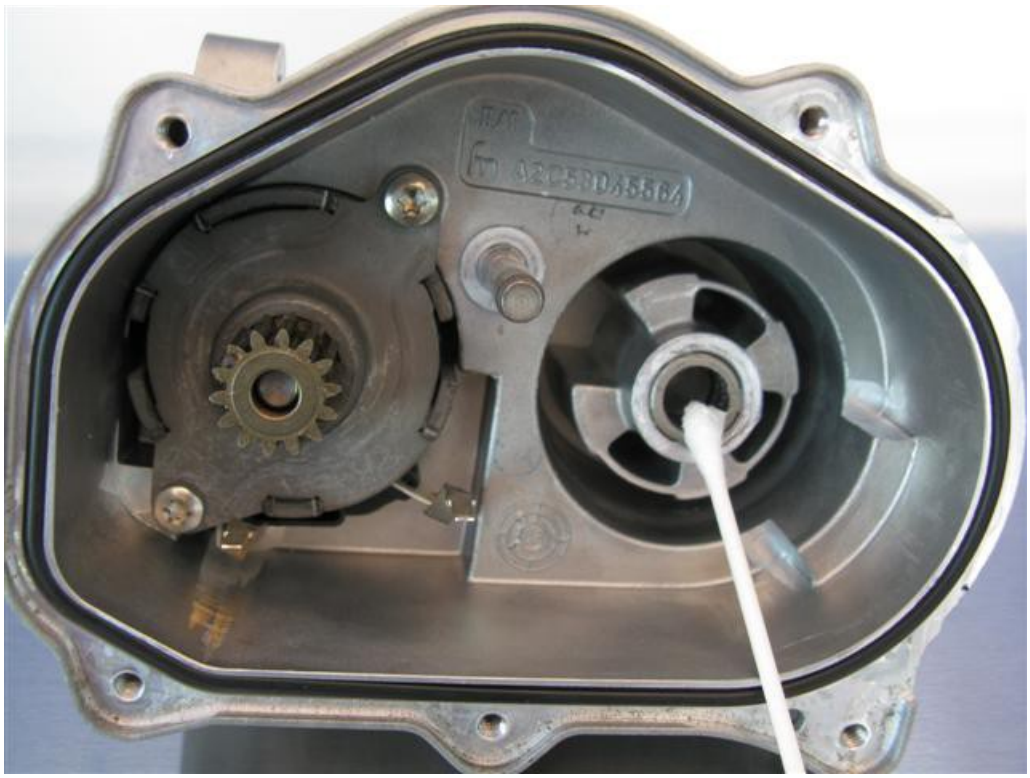
Insert DC motor into throttle actuator.
Orient DC motor with prongs at bottom and bolt mounting holes aligned to throttle actuator bolt mounting holes (picture).

Note: DC motor will be pressed into throttle actuator in following step.



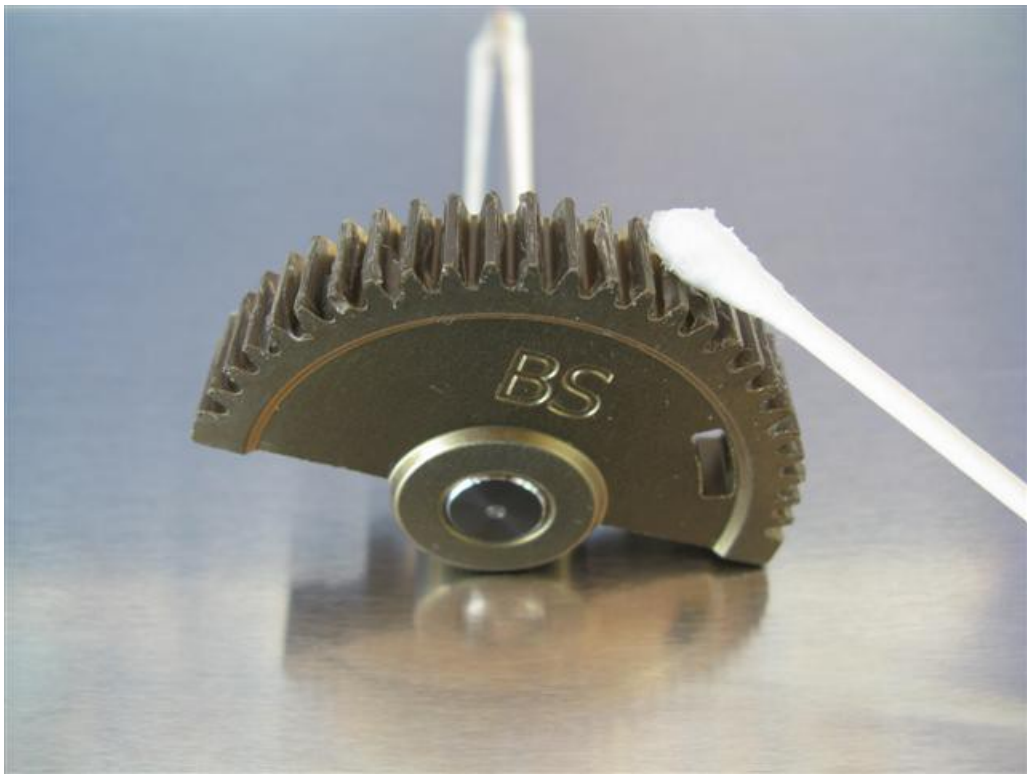
Install DC motor mounting bolts.
Install 2 bolts (T20 torx bit socket 1/4" w/ 3/8” to 1/4” socket adapter / 3/8” ratchet)
Once bolts mate with DC motor, tighten bolts evenly in multiple passes to evenly press DC motor bracket bolt holes onto throttle actuator housing mounting studs.

Fully tighten, 8 Nm (6 ft-lb) (T20 torx bit socket 1/4" w/ 3/8” to 1/4” socket adapter / 3/8” torque wrench).
Note: Hand snug w/ ratchet. Torque wrench not necessary.



Apply grease to throttle actuator radial bearings and adjacent face surfaces.
Apply light layer of grease to 2 radial bearings (holes inner surface) and adjacent face surfaces (grease / cotton swab).

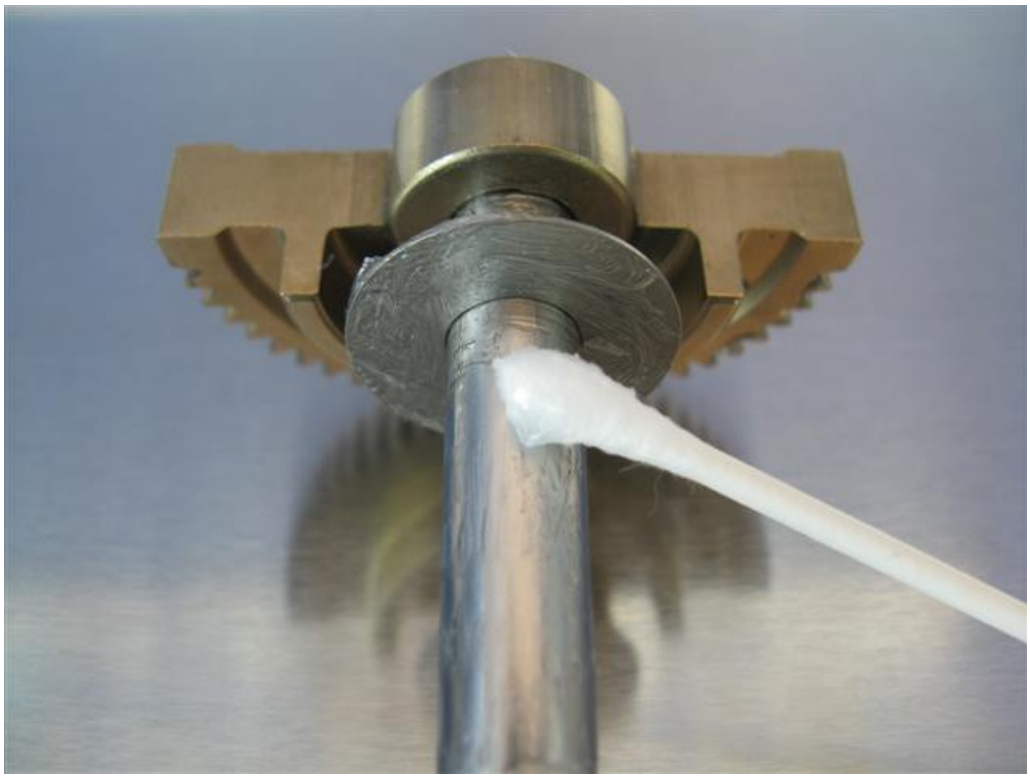
Note: Apply grease onto applicator, then roll applicator over radial bearing rollers.



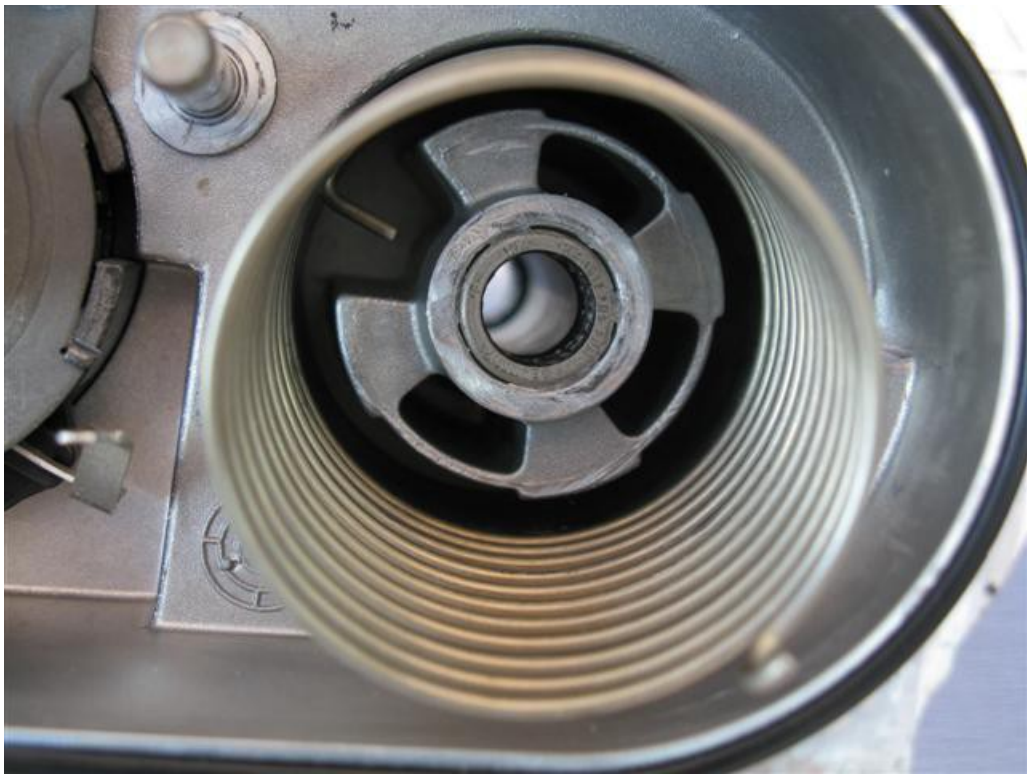
Apply grease to half gear teeth.
Apply light layer of grease to gear teeth (grease / cotton swab).

Note: Apply grease onto applicator, then swipe applicator along each tooth valley.

Apply grease to half gear shaft and gear base.
Apply light layer of grease to shaft and half gear base face adjacent to shaft (grease / cotton swab).
Do not grease shaft threads and flats section and ~10mm (~1/2”) of shaft past threads base (picture).



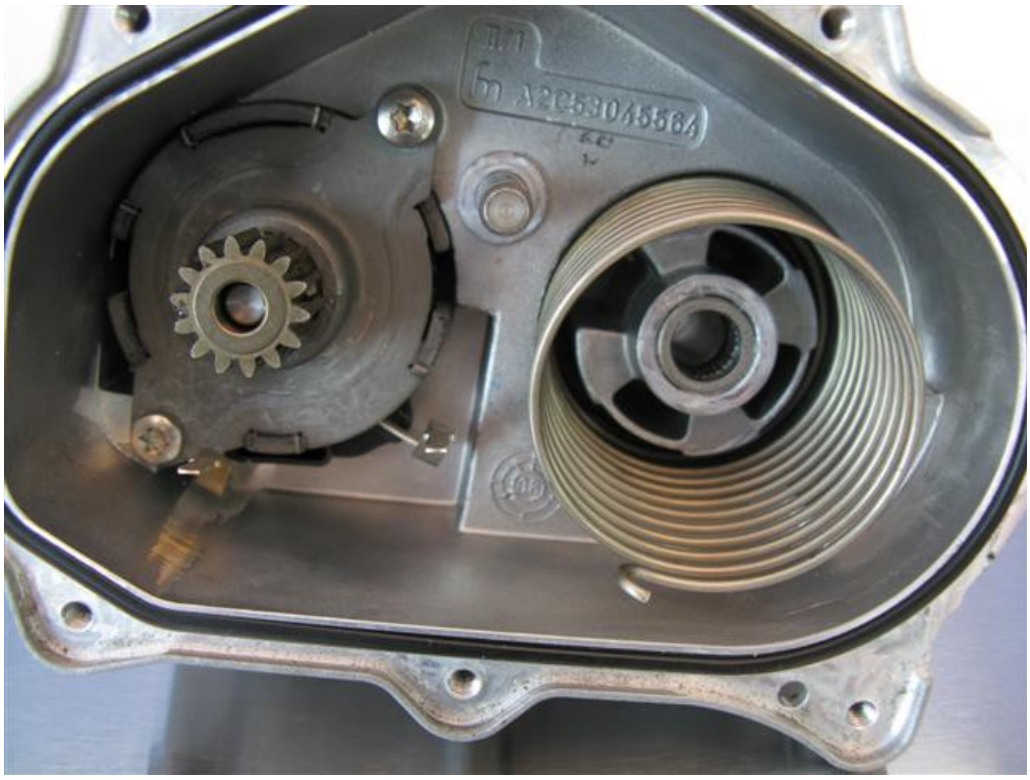
Apply grease to large thin washer and install onto half gear shaft.
Apply light layer of grease to washer faces (grease / cotton swab).
Install washer onto half gear shaft and slide washer up to half gear.



Install spring in throttle actuator.

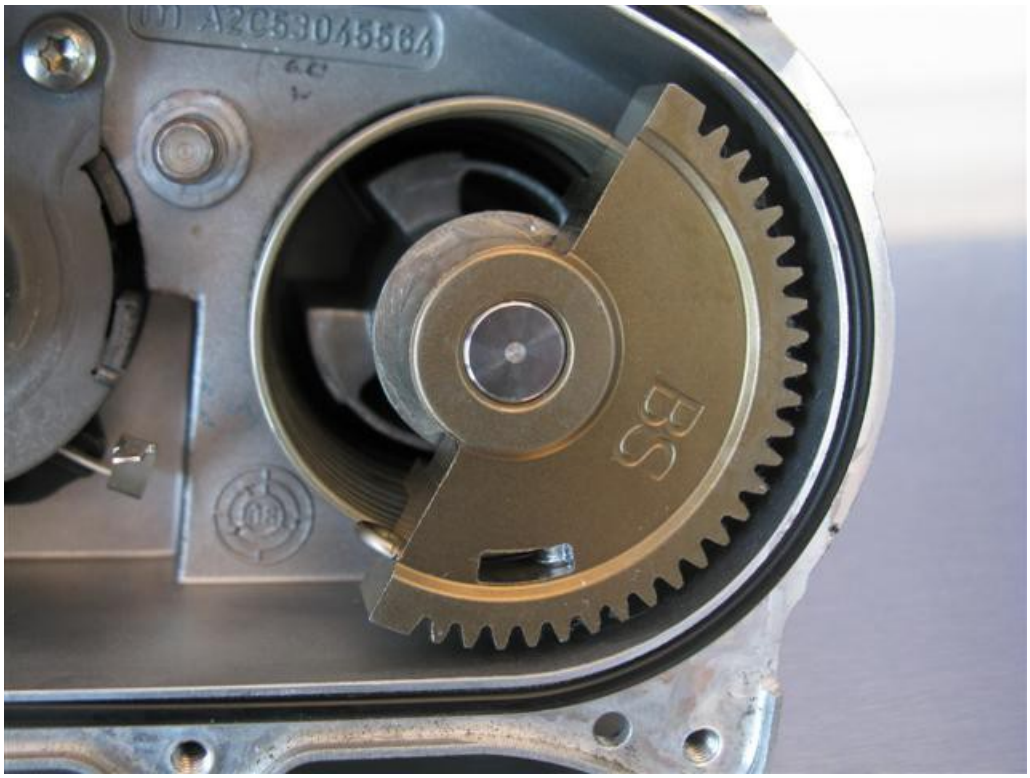
Orient spring with 90 degree bend end to throttle actuator and rotate spring to align bend end with slot in throttle actuator (picture).
Insert spring into throttle actuator.

Note: Spring will only insert slightly into throttle actuator.

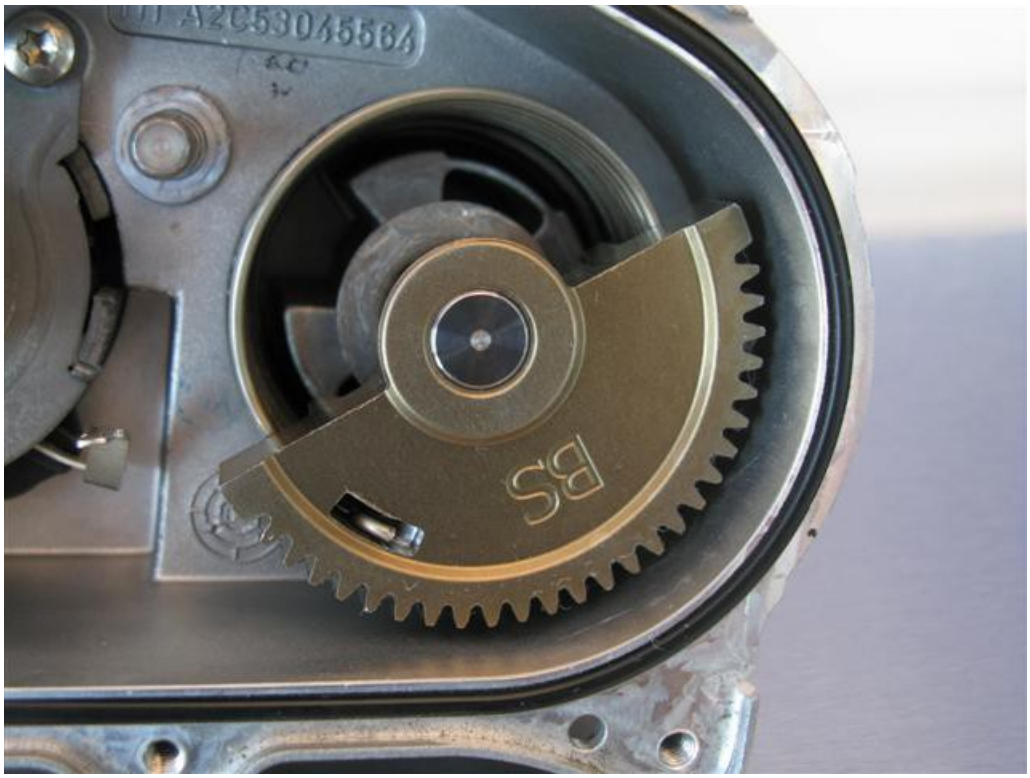


Install spring further into throttle actuator.
Coil (wind) spring, from hook end, ~1 rotation while pressing spring into throttle actuator.
Spring will insert slightly further into throttle actuator, and spring hook end will be positioned further clockwise (picture).

Note: This step is performed to further insert spring and prevent it from falling out of throttle actuator.
Note: Exact amount of spring insertion and rotational position of spring hook end does not need to be precise. Spring will be fully installed in upcoming step.



Install half gear and shaft with large thin washer into throttle actuator.
Note position of spring hook end in throttle actuator housing.
Align half gear shaft end with throttle actuator radial bearing (hole) and insert shaft into radial bearing.
Insert half gear and shaft into throttle actuator housing until half gear butts with spring.
As needed, rotate half gear counter-clockwise until spring hook appears at side of half gear (picture).

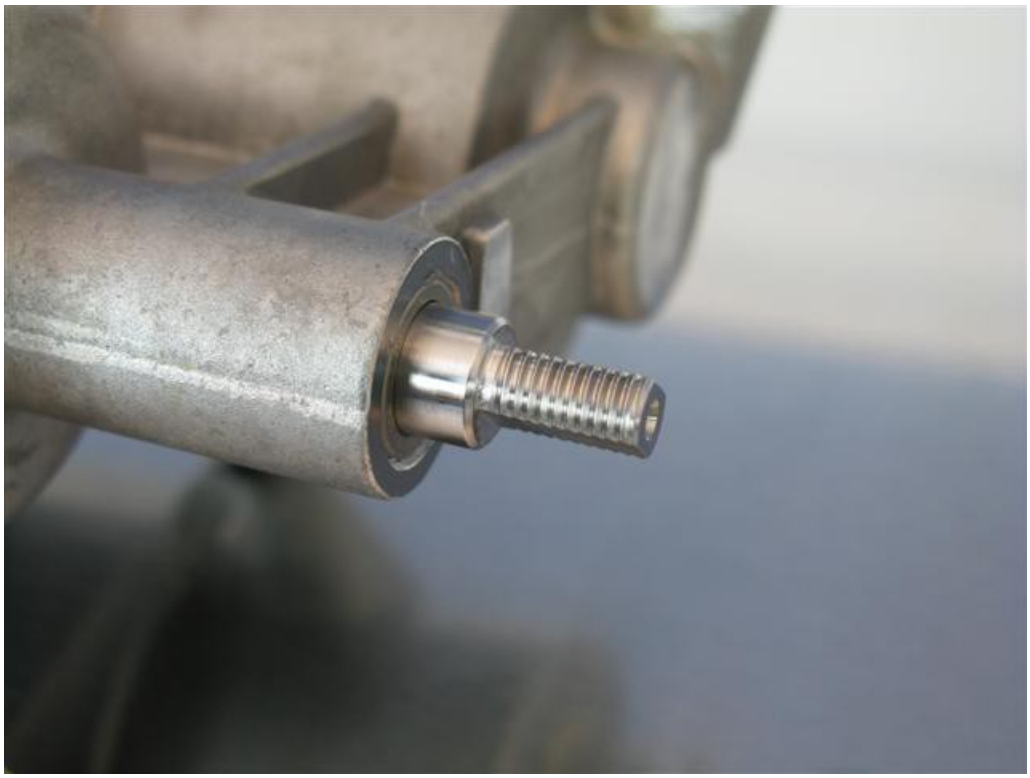


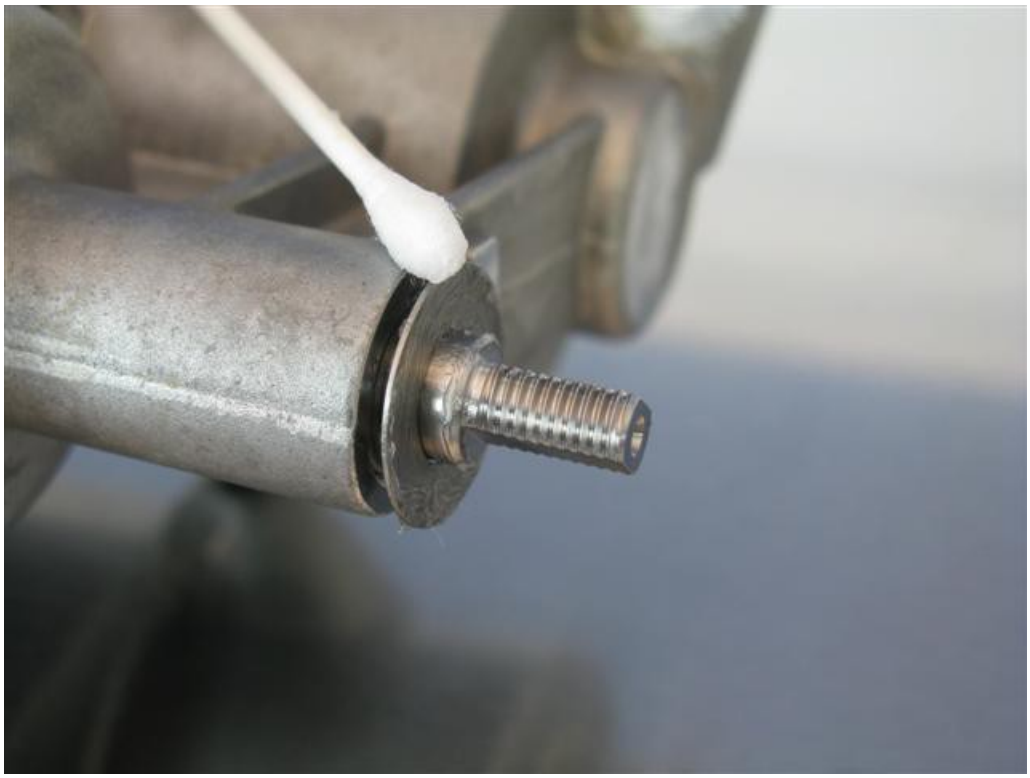
Insert spring hook end into half gear slot.
Press in on spring hook end and slide behind half gear.
Rotate half gear clockwise ~1/2”, while pressing spring hook to center slightly, until spring hook insets into half gear slot (picture).

Coil (wind) spring, and fully insert half gear into throttle actuator.
Rotate half gear clockwise ~1 1/4 rotation against spring tension until half gear side is past housing gear stop ledge.
Then push half gear further into housing and release to allow half gear side to rest on housing gear stop ledge.
Note: Pull half gear out some to allow full rotation of half gear without hitting housing gear stop ledge.

Note: Spring is now coiled to a smaller size and is fully inserted into housing.

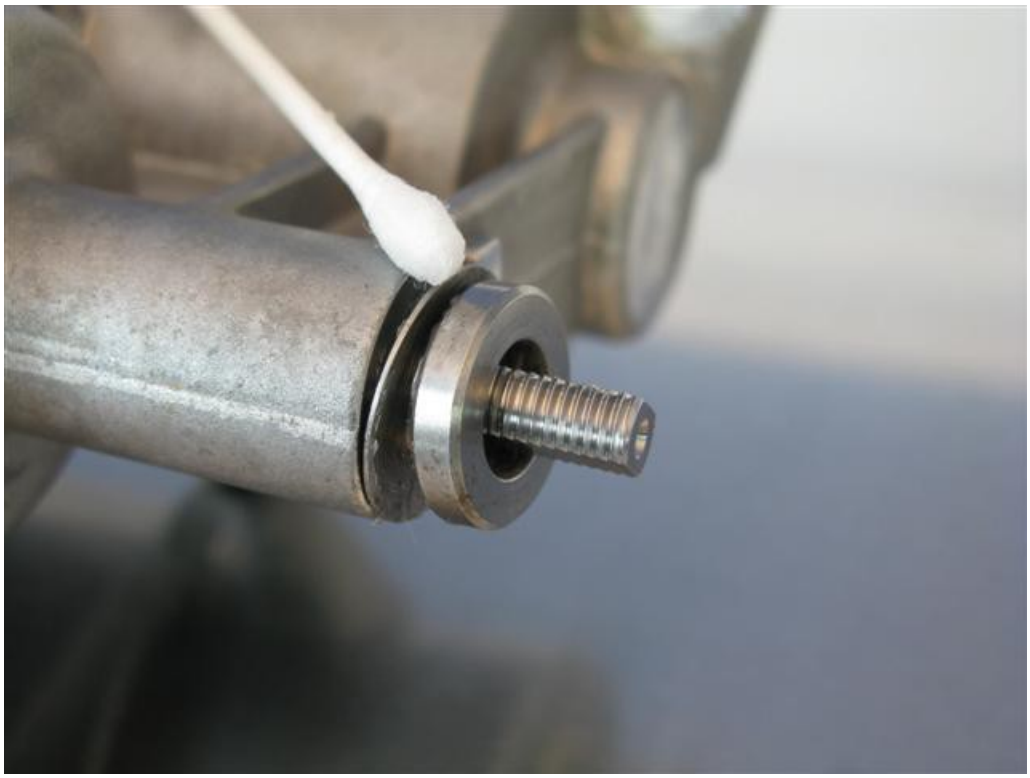
Note: Pay attention in following steps to maintain half gear in mounted position, as it can easily slip out.





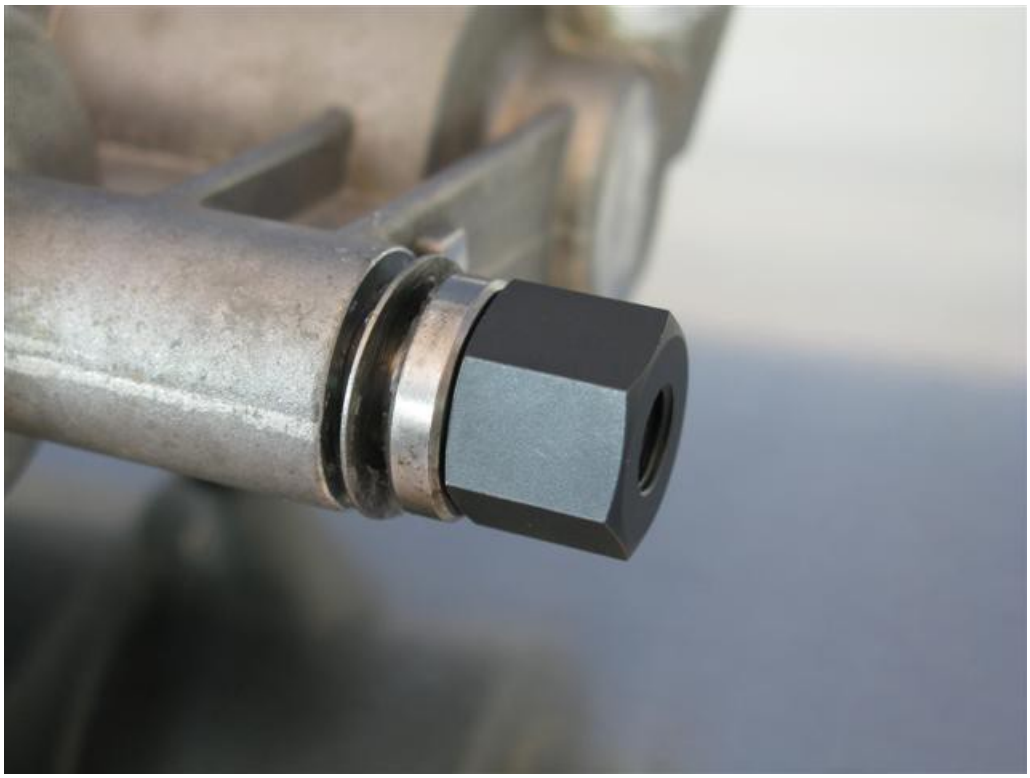
Apply grease to small thin washer and install onto shaft.
Apply light layer of grease to washer faces (grease / cotton swab).
Install washer onto shaft and slide washer up to throttle actuator housing.

Note: Press on half gear in throttle actuator to prevent it from dislodging (fingers).



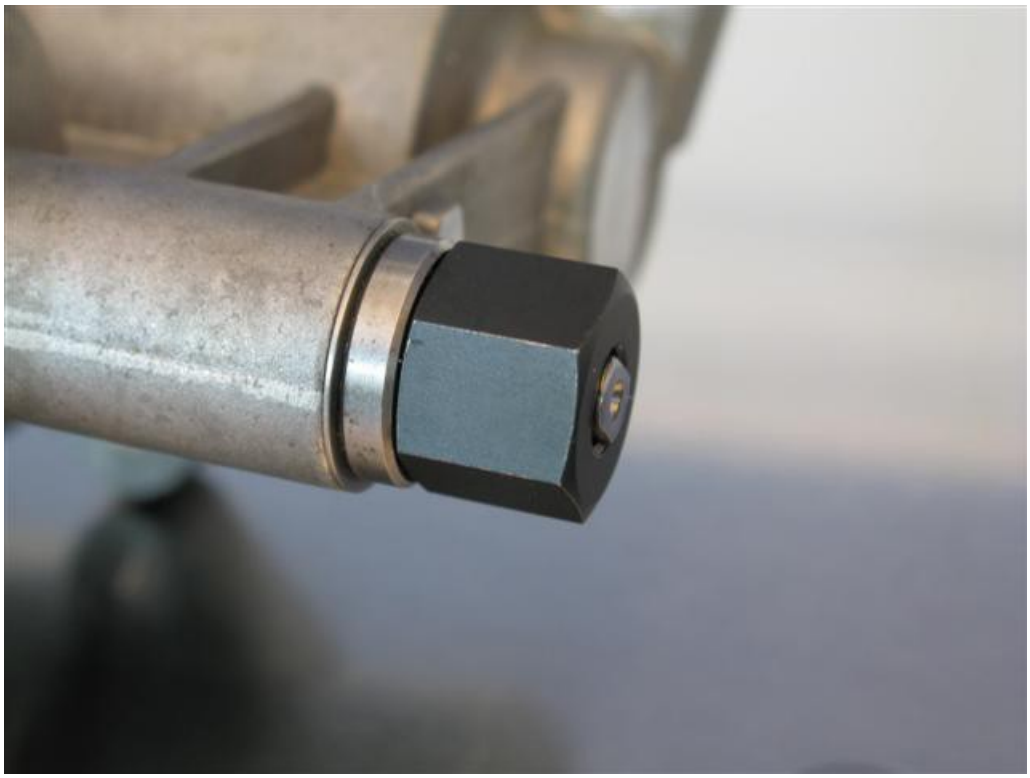
Mount thick press washer onto shaft.
Apply thin layer of grease to one face of thick washer.
Mount thick washer, greased face first, onto shaft wide diameter edge.

Note: Press on half gear in throttle actuator to prevent it from dislodging (fingers).



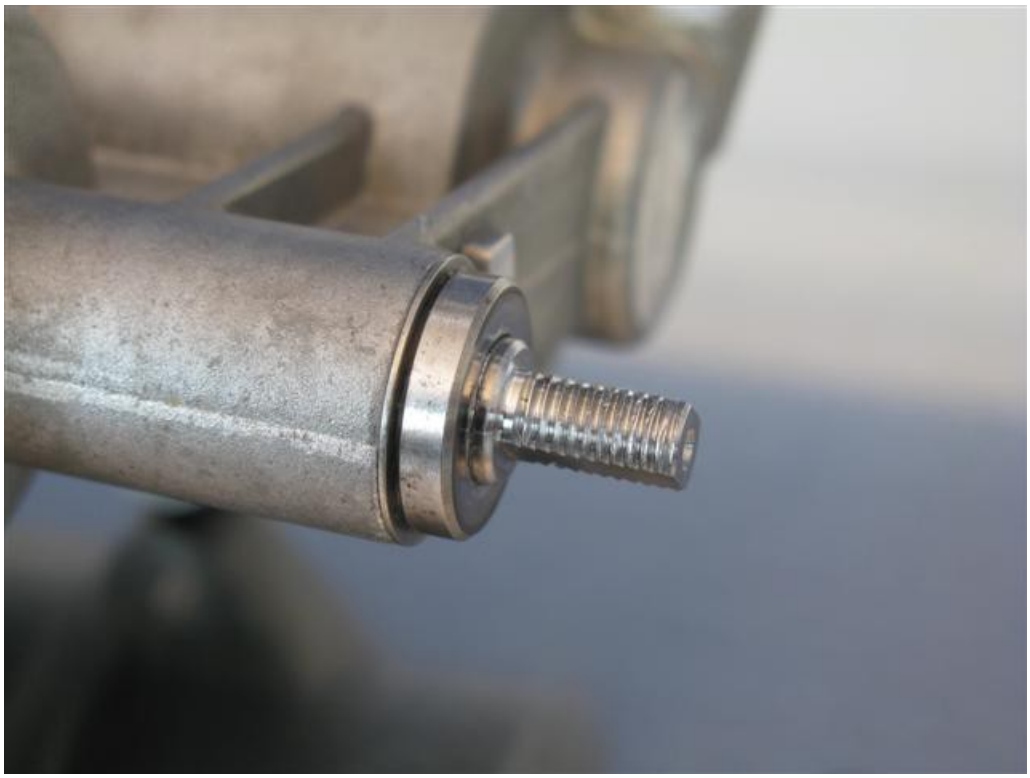
Install press nut.
Thread press nut, inner recess side first, onto shaft, and up to thick press washer (fingers).
Note: Press nut will be difficult to initially thread onto shaft due to minimal shaft threads.
Position press nut perfectly perpendicular to shaft to ease initial threading.

Note: Instead of press nut use the original nut and follow YouTube video from min 9:
Throttle actuator video
Note: Press on half gear in throttle actuator to prevent it from dislodging.

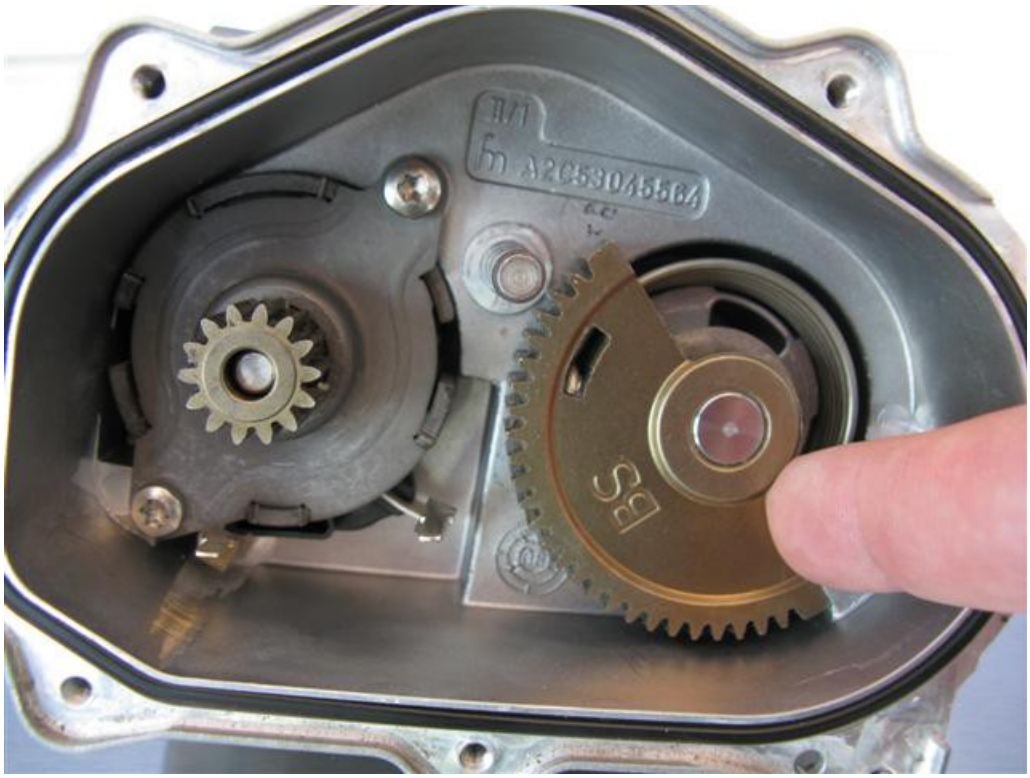


Press thick press washer onto shaft.
Tighten press nut to press washer onto shaft (16mm hex socket 3/8" / 3/8” ratchet).
Tighten press nut until stop. Do not further tighten.

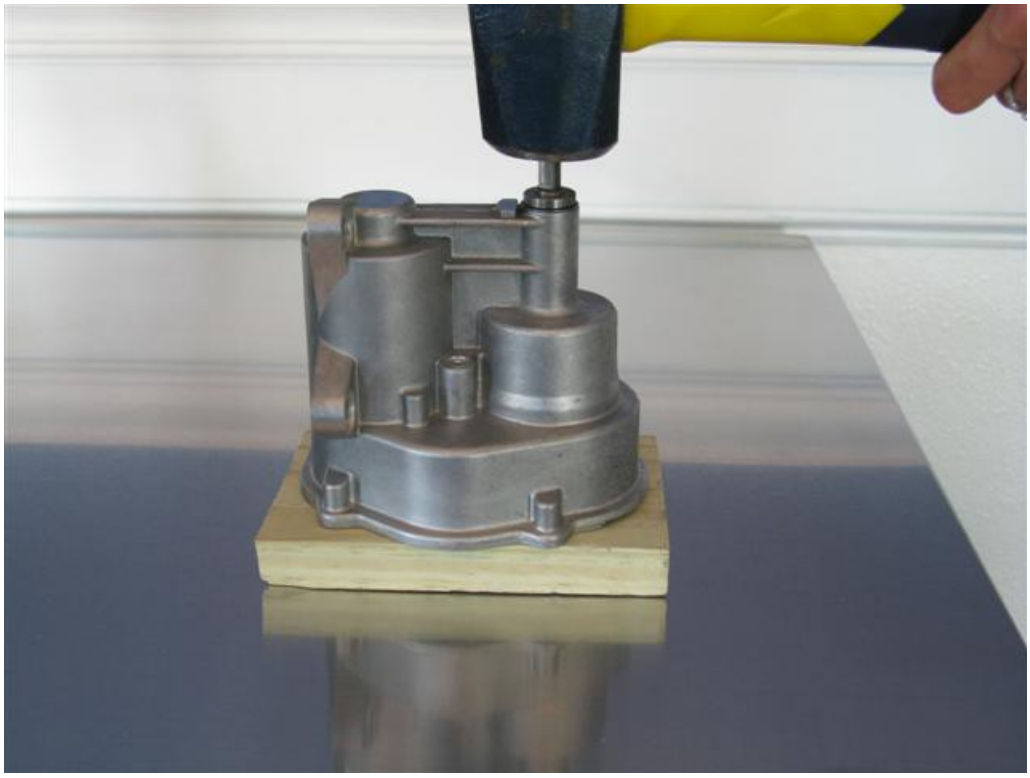
Note: Washer press takes minimal force.



Remove press nut form shaft (16mm hex socket 3/8" / 3/8” ratchet).

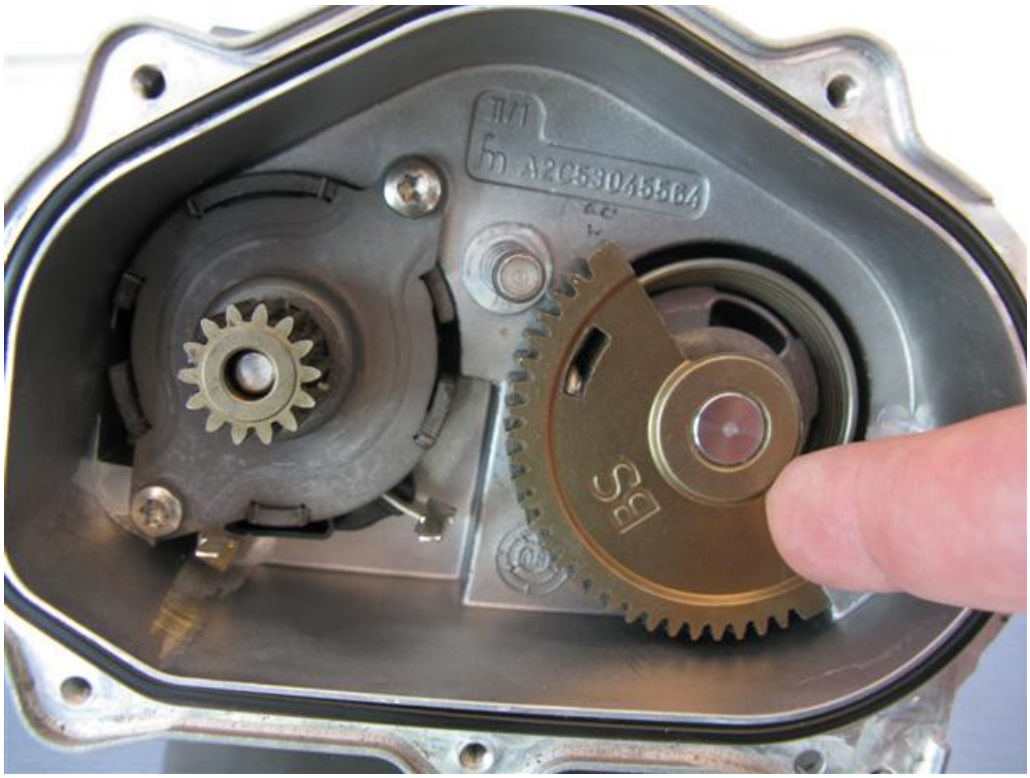


Attempt to rotate half gear (finger) and note binding and lack of free rotation.


Slightly retard (un-press) thick press washer on shaft to resolve binding and allow gear/shaft rotation.
Place throttle actuator on flat surface with shaft pointing up (flat wood).

Lightly tap shaft end into throttle actuator (2lb handheld sledgehammer).

Note: Only slight retard of thick press washer on shaft is needed to release binding.



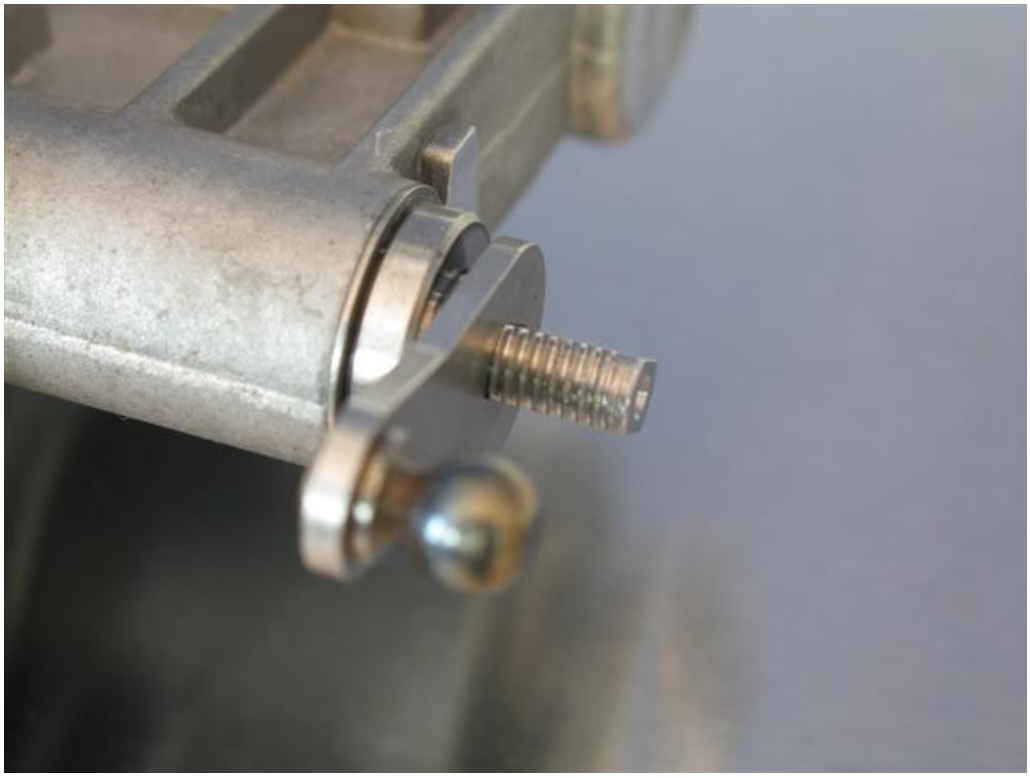
Verify half gear rotates freely through full range of rotation without binding (finger).

If half gear is binding, repeat above step of slightly retarding thick washer, and check binding again.

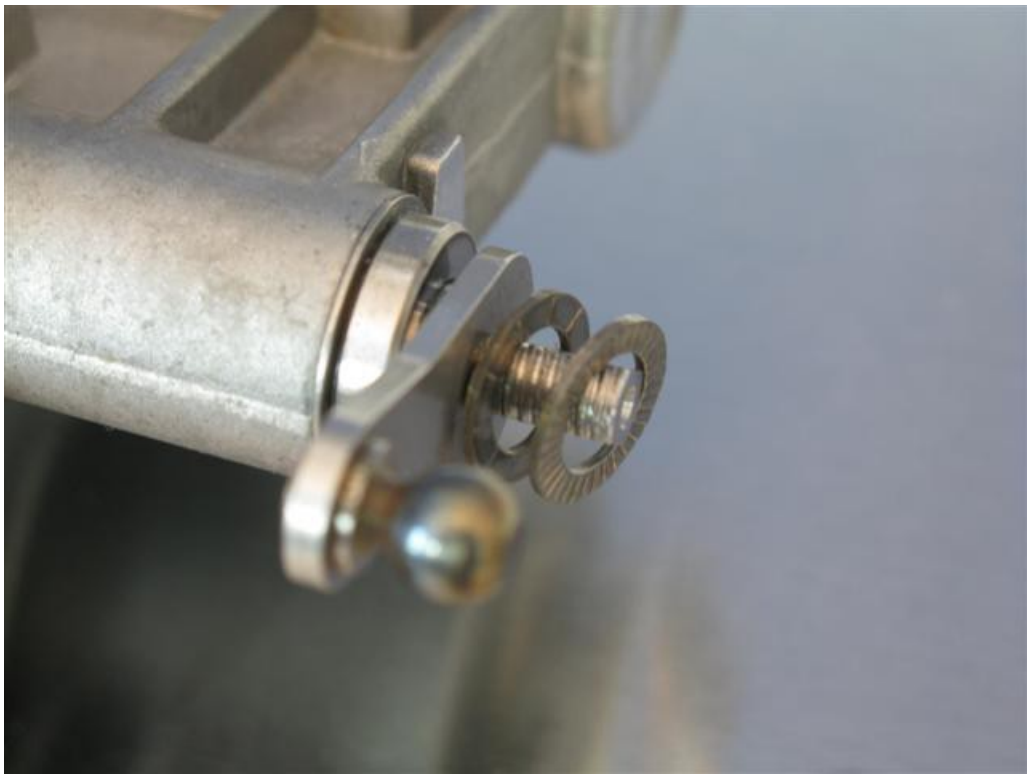
Check and adjust space between thick press washer and small thin washer.
Pull shaft from throttle actuator.
Measure space between thick press washer and small thin washer (feeler gauges).
Adjust thick press washer position, by pressing or un-pressing per above steps, to achieve

~.35mm space.
Available feeler gauge smaller than .35mm should fit in space, and available feeler gauge larger than .35mm should not fit in space (pictures).

Note: ~.35mm space is needed to prevent binding and allow gear/shaft rotation, but also prevent excessive gear/shaft axial (in/out) movement.

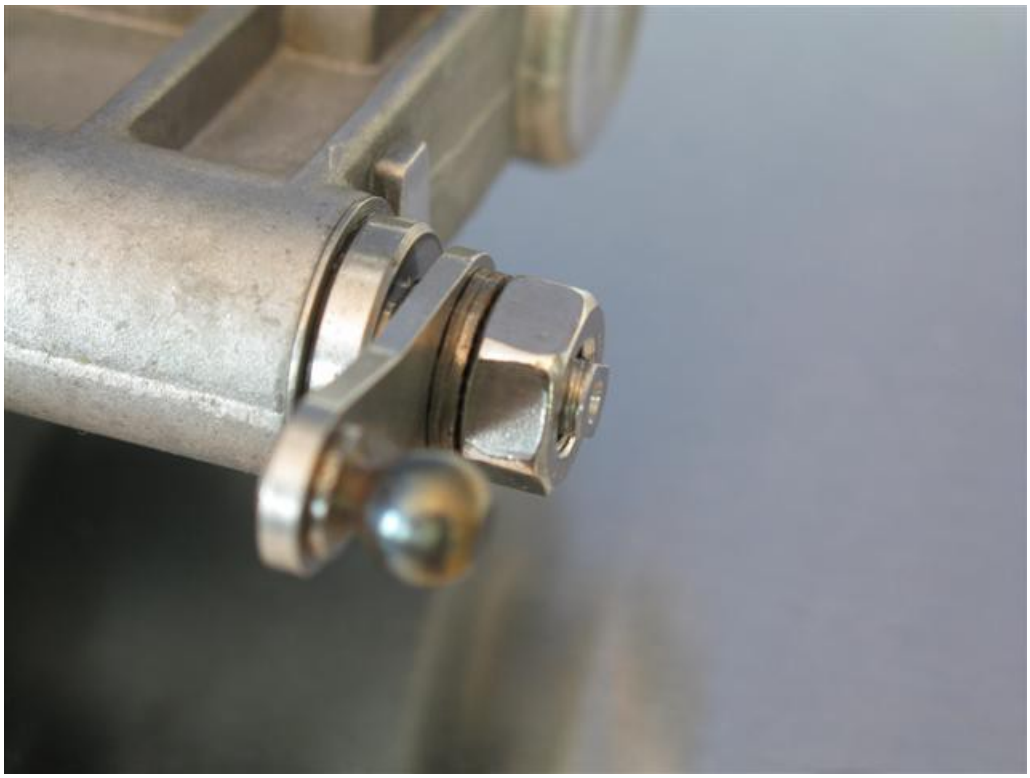


Install shaft arm onto shaft.
Orient shaft arm with ball to side and rear of throttle actuator (picture), and slide arm slot onto shaft end flats.



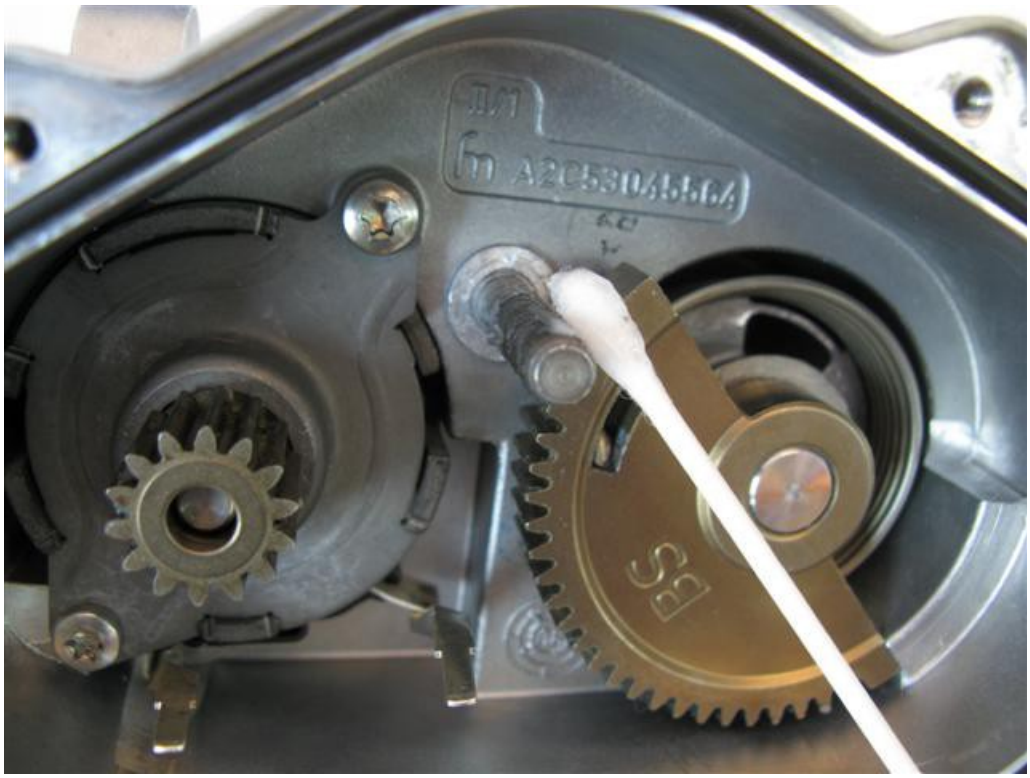
Install 2 small ribbed washers onto shaft.
Place first washer with tight ribbed side towards shaft arm (picture).
Place second washer with tight ribbed side away from shaft arm (picture).
Note: Washers are Nord-Lock washers and prevent nut, mounted in following step, from coming loose.

Caution: If washers are not oriented correctly, nut, mounted in following step, will come loose from engine vibration.

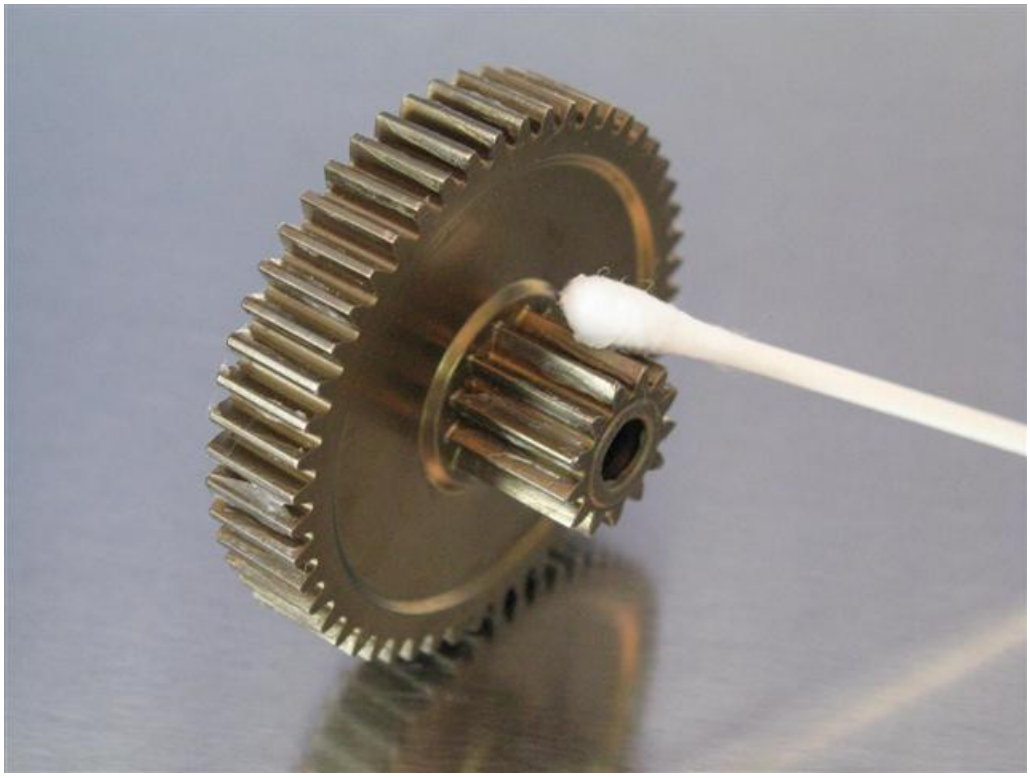


Install shaft mounting nut.
Thread nut onto shaft with face inscription side away from arm.
Note: Nut will be difficult to initially thread onto shaft due to minimal shaft threads.
Position nut perfectly perpendicular to shaft to ease initial threading.

Tighten shaft mounting nut.
Tighten nut (13mm hex socket 3/8" / 3/8” ratchet).
Fully tighten, 14 Nm (10 ft-lb) (13mm hex socket 3/8" / 3/8” torque wrench).
Note: Moderately tighten w/ ratchet. Torque wrench not necessary.



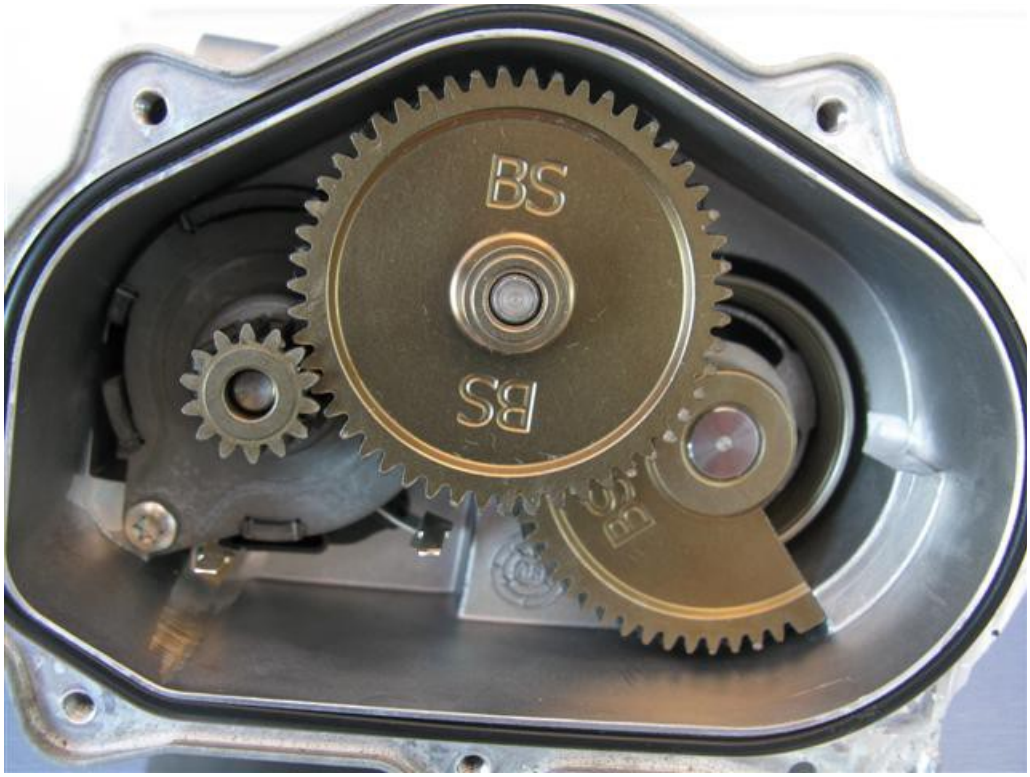
Apply grease to throttle actuator combo gear mounting shaft and base surface.
Apply light layer of grease to mounting shaft and base surface (grease / cotton swab).



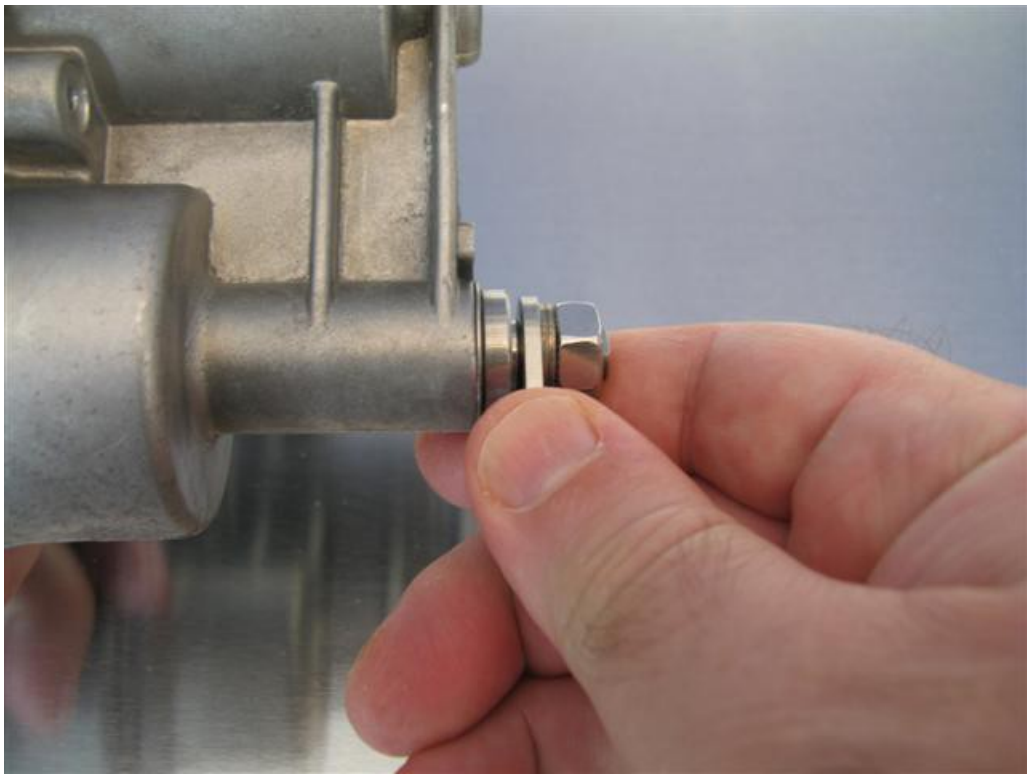
Apply grease to combo gear teeth.
Apply light layer of grease to gear small and large diameter teeth and small gear end

surface (grease / cotton swab).

Note: Apply grease onto applicator, then swipe applicator along each tooth valley.



Install combo gear.
Insert combo gear, small gear side first, onto throttle actuator mounting shaft.
Slightly rotate combo gear to fully insert and mate teeth with DC motor gear teeth and half gear teeth (picture).



Exercise throttle actuator mechanical operation.
Note: Do not tilt throttle actuator opening down as combo gear can fall out.
Rotate throttle actuator arm through full rotation range and monitor movement of gears in throttle actuator.
Repeat shaft arm rotation multiple times to disperse gear teeth grease and achieve smooth operation.
Wipe off visible excess grease from gear teeth ends (towels).
Partially rotate shaft arm and wiggle arm to get sense of gears teeth fit.

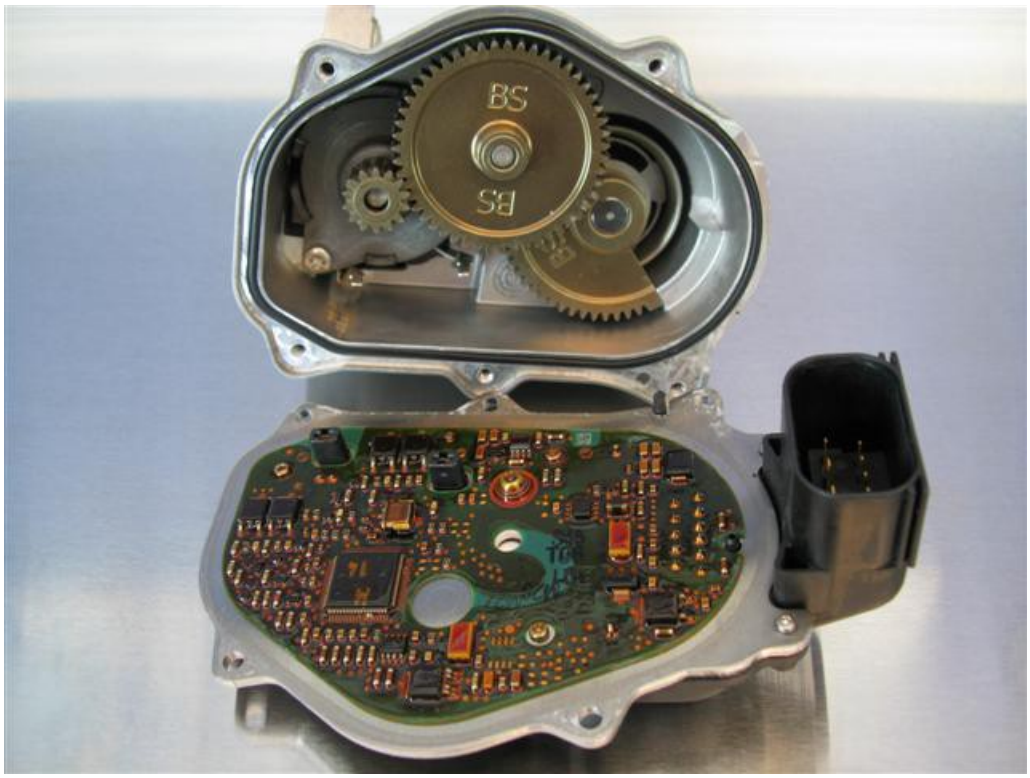
Slowly rotate throttle actuator arm through full rotation range and note any gears binding.
If binding is found, contact Beisan System.

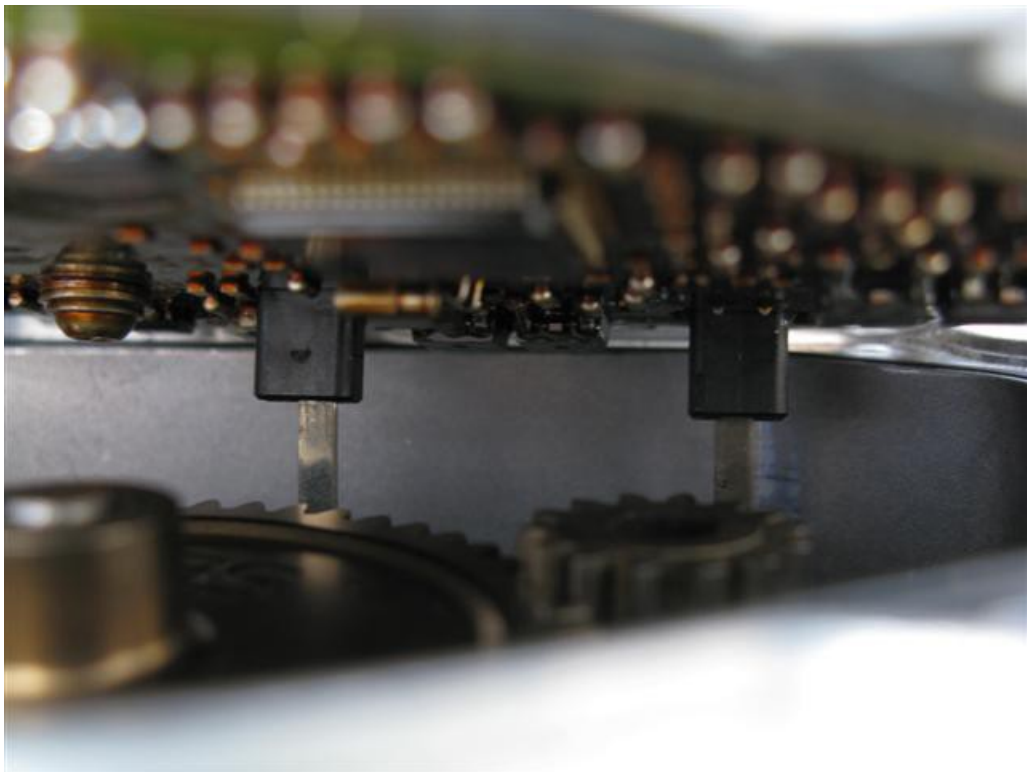
Throttle actuator electronics/cover will be installed once rebuilt electronics are received.

Repeat throttle actuator rebuild for second throttle actuator.

<u>Installation of electronics/cover</u>

Warning: DC motor must be cleaned per above cleaning instructions.

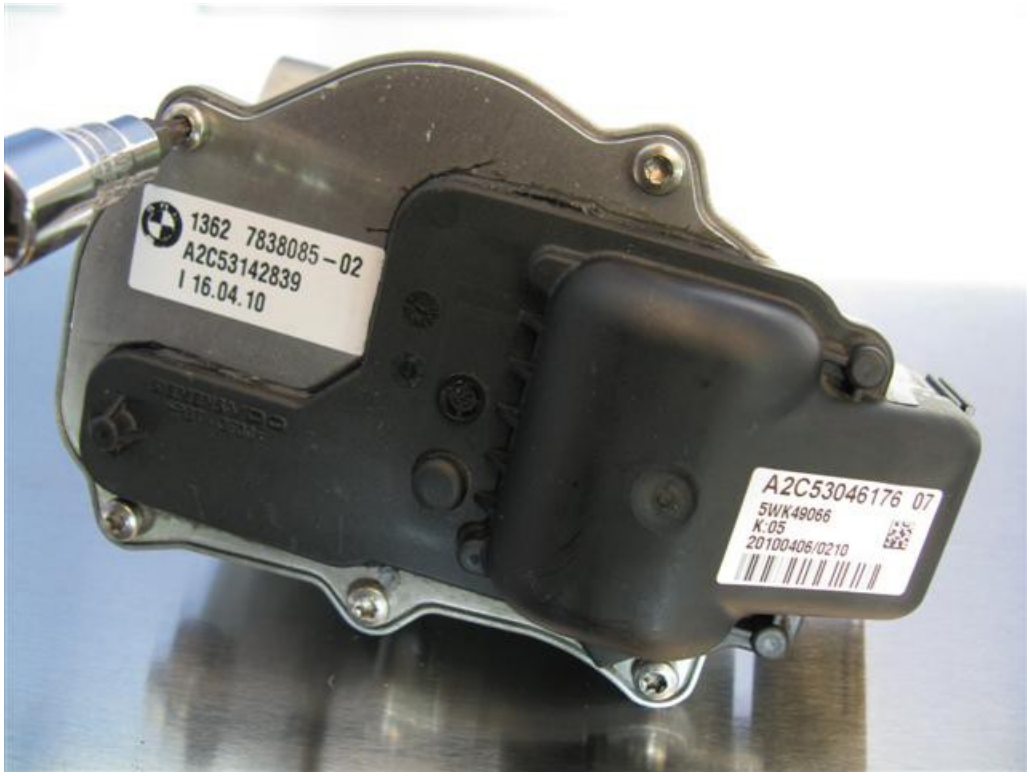




Install throttle actuator electronics/cover.
Orient cover to throttle actuator housing.
Orient throttle actuator with DC motor prongs and electronics prong sockets at bottom, and throttle housing to front and cover to rear (picture).

Insert electronics prong sockets onto DC motor prongs.
Fully mate cover onto throttle actuator housing.

Note: Bend DC motor prongs as needed to align with electronics prong sockets.



Install throttle actuator cover mounting bolts.
Mount 5 bolts onto cover (T20 torx bit socket 1/4" w/ 3/8” to 1/4” socket adapter / 3/8” ratchet).
Tighten bolts in multiple passes to evenly tighten.

Fully tighten, 8 Nm (6 ft-lb) (T20 torx bit socket 1/4" w/ 3/8” to 1/4” socket adapter / 3/8” torque wrench).
Note: Hand snug w/ ratchet. Torque wrench not necessary.

Check mechanical operation of throttle actuator by rotating shaft arm through its full range of rotation.

Repeat electronics/cover installation for second throttle actuator.

Post repair procedures

DC motor must be cleaned every 60k miles (100k km) to remove brushes carbon dust to prevent electronics from failing.