Front End Auxiliary Drive (FEAD)

Technology
Damage Diagnostics
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## Contents

1. **Introduction**  
   - Page 6

2. **Front End Auxiliary Drive**  
   2.1 Multi-Ribbed Belt  
   2.2 Deflection Pulleys  
   2.3 Tensioning Elements  
   - Page 7

3. **Alternator Pulleys**  
   3.1 Alternator Pulleys on the Alternator  
   3.2 Function Testing, Removal and Installation  
   - Page 12

4. **Belt Pulley Decoupler**  
   - Page 17

5. **Water Pump**  
   5.1 Cooling Circuit  
   5.2 Water Pump  
   - Page 19

6. **Damage Diagnostics**  
   6.1 Multi-Ribbed Belt  
   6.2 Tensioning Pulleys and Deflection Pulleys  
   6.3 Water Pump  
   - Page 22

7. **Service**  
   - Page 31
1 Introduction

The importance of a vehicle’s front end auxiliary drive (FEAD) system is now more important than ever before. In an air-cooled engine, such as the one in a VW Beetle, the V-belt is responsible only for driving the alternator and therefore charging the vehicle battery. In this setup, the V-belt is tensioned by inserting different washers between the split belt pulley on the alternator.

In water-cooled engines, the water pump in the FEAD system is also driven. As a result, the V-belt must span a large area to connect the components. In this setup, the V-belt is tensioned by rotating the alternator housing.

In the face of increasing comfort requirements, steering pumps and then air conditioner compressors have been added to the FEAD system. The demand for charging capacity has also risen due to the growing amount of electronics in modern vehicles. The charging capacity of alternators has increased accordingly, leading to a dramatic rise in the amount of torque to be transferred. This level of torque transfer is no longer possible with a conventional V-belt. Therefore, the standard, flat multi-ribbed belts you see today have gradually replaced the conventional v-belt in the FEAD system. Due to its flat, ribbed structure, a multi-ribbed belt can transfer a substantially higher torque. It also reduces the contact ratios, therefore increasing the transmission ratios.

Deflection pulleys are used in the FEAD system to guide the multi-ribbed belt to the individual components. When required, the correct tension is maintained by using different types of tensioning elements.

Start/stop systems present another challenge for the FEAD system, as belt slippage during the start-up process is especially high, particularly in relation to the breakaway torque.

Due to these factors, it is more important than ever to routinely test the FEAD system during maintenance on modern engines.

All of the components required for the FEAD system to work at full capacity are subject to the same stresses and wear factors and therefore must be replaced at the same time whenever feasible. For this reason, Schaeffler Automotive Aftermarket has developed a comprehensive range of vehicle and engine specific kits designed to service the entire FEAD system.
Front end auxiliary drives can be separated into one or more belt drives but are mainly designed to use just one belt, known as a "serpentine drive". With this design, a multi-ribbed belt transfers the rotational movement of the crankshaft to the components being driven. The multi-ribbed belt must be tensioned to ensure that there is as little slippage as possible. The required tension is achieved using a mechanical or hydraulic tensioner.

A belt system can include some very tight angles, using deflection pulleys to guide the belt to each driven component.

This arrangement is advantageous, considering that engines are getting increasingly smaller (downsizing). The smaller the engine capacity, and the fewer cylinders there are in an engine, the greater the engine’s rotational irregularity. Rotational irregularity places a significant load on the entire FEAD system.

The operating principles of intake, compression, combustion and exhaust in four-stroke engines cause the crankshaft to accelerate and decelerate, causing rotational irregularities that are transferred via the belt drive to all other engine components.

In a diesel engine with 40% rotational irregularity and an idle speed of 800 rpm, the actual engine speed varies between 640 rpm and 960 rpm. This means that the rotating equipment (e.g. the alternator) in the FEAD system is also accelerating and decelerating.

These changes in speed can lead to FEAD system issues such as increased noise and vibration levels, high belt tension forces and premature wear.

To minimize the effects of rotational irregularities on the FEAD system, different types of damping components can be specified by the vehicle manufacturer, such as tensioners, overrunning alternator pulleys and crankshaft decouplers.
2.1 Multi-ribbed Belts

A conventional V-belt is driven by a wedge-shaped belt pulley that is mounted on the crankshaft. The rotational movement of the crankshaft is transferred via the flanks of the V-belt to the system components.

The elastomer element of the V-belt is comprised of an abrasion-resistant rubber compound that features embedded tensioning cords made of polyester fibers. The V-belt is stiffened and reinforced by a fabric section on the rear face. The wedged shape of the pulley means that it has minimal reverse flexibility and therefore there is limited scope for redirection. Furthermore, components can only be driven using the inner side of the V-belt.

The multi-ribbed belts used today have a flat design with several ribs placed in a row. In this design, the elastomer element, along with the rear structure, is comprised of a special synthetic rubber that is resistant to abrasion. The ribbed exterior absorbs sound and also ensures an acceptable noise level if misalignment occurs. The tensioning cords are generally manufactured from high-tensile polyester fibers and are especially resistant to stretching. These fibers, embedded in pairs and twisted clockwise and anticlockwise, enable neutral running behavior. The multi-ribbed belts enable much tighter wrap angles, allowing high transmission ratios to be achieved. Crucially, both sides of the belt can be used to drive components, and the route can also include reverse bends.

Thanks to these features, a multi-ribbed belt is able to drive a relatively high number of components within a limited mounting space. The number of ribs, and consequently the width of the belt, can vary depending on the amount of torque that needs to be transferred.

An elastic multi-ribbed belt looks very similar to a normal multi-ribbed belt, and is also generally constructed from similar materials. However, in an elastic multi-ribbed belt the tensioning cords are produced using elastic polyamide fibers. An elastic multi-ribbed belt requires no tensioning element to maintain a consistent tension for its entire service life. If an elastic multi-ribbed belt is installed by the vehicle manufacturer, it must be replaced with another elastic multi-ribbed belt. To avoid damaging the belt during installation, it is normally necessary to use a special tool.
2.2 Deflection Pulleys

Deflection pulleys are used to guide the course of the multi-ribbed belt to the auxiliary components. Deflection pulleys also serve as touch idlers that check for possible belt vibration when the run lengths are too great. These pulleys are specially calibrated for each application and enable an optimum, tailored belt drive design. Depending on the requirements, the running surface is either smooth or grooved and is made from a single row or double row deep groove bearing inside a steel or plastic outer pulley.

Plastic protective caps are usually fitted on the deflection pulleys once they have been mounted. However, a specially designed protective steel cap can also be fitted to the pulley to protect the bearing.

Deep-groove ball bearings in a single row...
... are modified ball bearings that make less noise
... have a wider design with a higher grease capacity
... have a higher load rating than comparable standard bearings
... are distinguished by a knurl on the outer ring of the bearing, which is used for torsion control when plastic rollers are used

Deep-groove ball bearings in a double row...
... are extremely durable
... have a wider design and with a higher grease capacity
... are distinguished by a knurl on the outer ring of the bearing, which is used for torsion control when plastic rollers are used
2.3 Tensioning Elements

There are essentially two different types of tensioning element: mechanical and hydraulic, with mechanical tensioners available in either manual or automatic versions.

The function of tensioning elements is to ensure that the multi-ribbed belt always remains at the optimum tension, thus preventing unnecessary slippage and belt vibration.

All tensioning elements consist of a base plate or a tensioning unit and a rolling element. These rolling elements are identical to the deflection pulleys previously described.

Mechanical tensioning elements

In a manual tensioner, the multi-ribbed belt is tensioned either by rotating the base plate or via an eccentric mechanism. In this scenario, it is the technician who determines, mostly by instinct, how tightly the belt must be tensioned. It is usually necessary to check during every service whether the belt tension is correct and whether any adjustments are necessary.

Depending on the requirements and the available mounting space, a tensioning element with a long-arm tensioner, short-arm tensioner or cone tensioner is used.

The multi-ribbed belt is adjusted to the correct tension using the force of a pretensioned spring (leg spring or torsion spring). Internal damping elements dampen the spring movement, reducing the vibrations in the belt drive.

In long-arm and short-arm tensioners, the damping element consists of a smooth friction disk; cone tensioners are equipped with a friction cone for this purpose.

Any sudden peaks in force are dampened in the belt drive by the mechanical friction between the friction elements. Slippage, noise and belt wear are also reduced. The service life of the entire front end auxiliary drive is longer as a result.

KEY

1 Tensioning pulley
2 Leg spring
3 Lever
4 Plain bearing
5 Friction disk and friction lining
6 Base plate
7 Friction cone with seals
8 Internal cone
Hydraulic tensioning elements

Hydraulic tensioning elements consist of a moveable double-sided lever arm and a roller. Instead of a torsion spring or leg spring, in this setup a hydraulic element with an integrated pressure spring is responsible for achieving the necessary belt tension.

The hydraulic element is attached to one end of the lever arm and the roller is attached to the other end. The pressure spring in the hydraulic element pushes the roller against the multi-ribbed belt via the lever arm, thereby tensioning the belt. The tensioning force is determined by the choice of pressure spring and the leverage ratio.

Compressing the hydraulic element causes oil from the high-pressure chamber to be forced into the reservoir through a precise gap. In this case, the smaller the gap, the greater the damping. When the hydraulic element is released, the oil is sucked out of the reservoir and back into the high-pressure chamber via a non-return valve. This process is also called directional damping.

With this setup, even the most dynamic and complex belt drives can be controlled in engines that do not run smoothly, whilst also providing the optimum belt tension. The choice of hydraulic tensioning element is determined by the available mounting space and operating conditions.
3 Alternator Pulleys

3.1 Alternator Pulleys on the Alternator

The alternator is the front end auxiliary drive component with the greatest mass moment of inertia, which means that it also has the biggest effect on the belt drive in conjunction with the rotational irregularity of the engine. The continuous improvement of comfort in modern vehicles has also led to a steady increase in the demand for electric power. The result is increasingly more powerful alternators with an even greater mass moment of inertia, meaning that the belt drive is subject to ever higher levels of vibration.

To dampen all vibration in the belt drive, modern engines use a pulley on the rotor shaft of the alternator, instead of a rigid belt pulley. The pulley disconnects the rotor from the rotational irregularities of the engine. This arrangement reduces the stress peaks in the belt drive and improves the noise behavior of the multi-ribbed belt.

Overrunning alternator pulleys are primarily used in diesel and petrol engines with a reduced idle speed and therefore a higher noise level.

There are two different types of alternator pulley: the Overrunning Alternator Pulley (OAP) and the Overrunning Alternator Decoupler (OAD).

Overrunning Alternator Pulley (OAP)

The OAP drives the alternator in the reverse direction. When this happens, the clamping rollers run into the conical clamping ring and are locked. The outer ring is held in place via a non-positive connection so that the multi-ribbed belt can transfer the rotational movement of the crankshaft to the alternator shaft.

In the overrunning direction, the clamping rollers rotate freely and the outer ring is not held in place via the non-positive connection. This means that the alternator shaft can "overtake" the crankshaft in its deceleration phase due to the alternator's inertia of masses. The entire front end auxiliary drive is dampened as a result. Needle roller bearings provide the lowest possible level of friction for rotation of the outer ring in the overrunning direction.
With an OAD, the alternator is driven using a torsion spring. This spring absorbs small irregularities in the rotation of the crankshaft to prevent speed differences within the front end auxiliary drive.

A slipping clutch balances out any serious differences in speed between the crankshaft and the alternator shaft in the overrunning direction. As with the OAP, the alternator shaft used with the OAD can also overtake the crankshaft in its deceleration phase. A ball bearing enables low-friction rotation of the outer ring in the overrunning direction.

The effect that the pulley has on the alternator speed is clearly illustrated by the graph above. The grey line shows the fluctuations in the rpm of the rotor shaft without an alternator pulley and the green line shows the fluctuations with an alternator pulley.
3.1 Alternator Pulleys on the Alternator

Measurements on a four-cylinder diesel engine

Numerous measurements of the dynamic forces in the FEAD system demonstrate the advantages of using an overrunning alternator pulley in contrast to solutions based on a rigid belt pulley.

The belt force at the deflection pulley and the travel of the tensioning pulley on a four-cylinder diesel engine have both been measured. Thanks to the alternator pulley, the maximum forces in this measurement are reduced from approx. 1,300 N to approx. 800 N.

The minimum forces also increase slightly. The risk of belt slippage is avoided as a result.

In this example, the vibration amplitudes of the belt tensioner decrease from 8 mm to 2 mm. The belt is therefore much less heavily loaded.
Effects on the front end auxiliary drive

The diagram above shows the FEAD system when operated without an overrunning alternator pulley. Since the multi-ribbed belt is vibrating, all components in the FEAD system are subject to stronger forces, resulting in greater wear. Amongst other things, the belt will have a shorter service life or the tensioner could fail.

The use of an OAP or OAD reduces belt vibrations, placing less load on FEAD system components and making the engine quieter.
3.2 Function Testing, Removal and Installation

Removal and installation and/or testing of an alternator pulley must be carried out using a specific special tool (INA tool kit part no. 400 0444 10). The alternator pulley can be tested when installed or when removed.

The tightening torque for fastening the alternator pulley to the rotor shaft is 80–85 Nm.

Operation without a protective cap or with a damaged cap will result in a premature malfunction due to insufficient sealing.

**Testing an OAP:**

- The tool cannot be rotated in an anticlockwise direction
- The tool can be rotated freely in a clockwise direction with a slight amount of resistance

**Testing an OAD:**

- There is a noticeable increase in spring force when the tool is rotated in an anticlockwise direction
- The tool can be rotated freely in a clockwise direction with a slight amount of resistance

**Caution:**

If it is not possible to perform one of these functions during testing, the OAP/OAD must be replaced!

**Note:**

Instead of a right-hand thread, a few alternator pulleys have a left-hand thread. With these pulleys, the methods described above are reversed.
4 Belt Pulley Decoupler

The belt pulley decoupler is a development of the torsional vibration damper and provides another way of damping the FEAD system. This component is particularly efficient when it comes to downsizing, where engines are made smaller yet must still deliver the highest possible performance level with maximum driving comfort. Mounted on the front side of the crankshaft, the belt pulley decoupler minimizes any vibrations of the multi-ribbed belt as they develop.

To do this, the belt pulley decoupler performs two important tasks:
- It dampens crankshaft oscillation and in doing so reduces engine running noise
- The transfer of rotational irregularities from the engine to the FEAD system is almost completely suppressed, thus preventing belt vibration. As a result, the load placed on FEAD components is reduced

The belt pulley decoupler has two decoupled flywheel masses: the primary flywheel and the secondary flywheel. Both flywheels are connected via a spring/damping system and are mounted so that they rotate in the opposite way to each other via a plain bearing. The primary flywheel is bolted to the crankshaft and comprises a hub, a flange, a sealing plate and a torsional vibration damper with an embedded damping element.

On the secondary flywheel, the belt pulley and the secondary cover form a cavity known as the spring channel. The arc springs within the spring channel are each supported by a stop. Guide shells enable smooth travel while grease filling in the spring channel reduces the friction between the arc springs and the guide shells.

The tabs on the flange of the primary flywheel reach between the arc springs.

The rotational movement of the crankshaft is transferred on the primary side from the hub to the arc springs via the tabs on the flange. The rotational movement passes into the front end auxiliary drive as a result of the arc springs being stopped in the spring channel of the secondary flywheel. The rotational irregularities of the engine are dampened by the precise travel of the arc springs in a similar way to the springs in the chassis.
Vibrations are dampened in exactly the same way as they are with a torsional vibration damper. The damping element absorbs oscillation of the crankshaft and in doing so minimizes noise, vibrations and the “rough” sensation associated with engine operation.
5 Water Pump

5.1 Cooling Circuit

During operation, combustion engines also generate a great deal of thermal energy alongside the required kinetic energy. The surplus heat produced has the potential to damage engine components, such as the pistons, valves and cylinder head.

To avoid this, the engine must be cooled. In modern combustion engines, cooling is achieved almost exclusively with the use of water, a process referred to as water (or liquid) cooling.

Since water freezes at low temperatures and could cause the engine block to burst, antifreeze (e.g. monoethylene glycol) is added. This combination is referred to as the coolant mixture.

The antifreeze also raises the boiling point of the coolant mixture to protect the engine from overheating. A protective coating builds up around the entire cooling system, which prevents the formation of limescale and corrosion caused by the water.

It is therefore especially important that an antifreeze product that has been approved by the vehicle manufacturer is used in the correct mixture ratio. The optimum mixture ratio of water to antifreeze is 1:1.

In addition to the coolant mixture, the other most important components of the cooling system include the water pump, which keeps the coolant moving, and the thermostat, which regulates the flow of coolant through the system.

Design and functionality of the cooling circuit
5.2 Water Pump

The water pump handles the circulation of the coolant mixture in the cooling circuit. Managing the circulation ensures that the heat removed from the engine is equal to the heat of the warmed coolant mixture supplied to the heating circuit.

The multi-ribbed belt is either smooth or profiled, depending on whether the front or the back of the belt is in contact with the belt pulley of the water pump.

The impeller and the bearing arrangement of the drive shaft are two important components of the water pump.

Impeller

The impeller is designed to ensure that a high level of performance and efficiency is achieved and the risk of air pockets forming in the coolant mixture is reduced.

This "cavitation" occurs at the edges of the impeller blades. Air pockets are carried along by the powerful current and are directed against the wall of the water pump housing. The pockets then implode and damage the material.

Water pump performance is affected by the choice of impeller blade material. Until a few years ago, cast iron and steel were primarily used for the impellers. However, modern water pumps are often fitted with plastic impellers.

Using plastic makes the impeller lighter, minimizing load on the bearing.
Bearing

Water pump bearings are arranged in a double row and, in contrast to standard double-row bearing arrangements, have running surfaces that are incorporated directly into the shaft instead of an inner ring. As a result, there is more mounting space for the rolling elements, which means that the specific load carrying capacity is higher than on solutions with standard single bearings.

This type of bearing also allows for rows of ball bearings and rollers to be combined, thereby providing a greater range for the load carrying capacity within a limited mounting space.

The type of bearing installed is dependent on the loads expected in the specified belt drive system. High-grade bearings are a deciding factor for the durability and long service life of a water pump.

Seal

The seal between the engine housing and the water pump is provided by a paper gasket, an O-ring or, in many cases, a sealant.

If a paper gasket or an O-ring is used, no additional sealant should be used! For engines in which a sealant is used as standard, the sealant must be used sparingly during water pump installation. The manufacturer's instructions must also be followed.

A thin film of sealant is perfectly sufficient. If too much is used, the surplus can loosen and contaminate the cooling system. The radiator and heat exchanger can subsequently become clogged or the seal at the drive end of the water pump can be damaged.
# 6 Damage Diagnostics

## 6.1 Multi-Ribbed Belt

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accumulation of Material</td>
<td>• Belt vibrations&lt;br&gt;• Damage caused by foreign object contamination&lt;br&gt;• Misalignment</td>
</tr>
<tr>
<td>Indentations</td>
<td>• Damage caused by foreign object contamination</td>
</tr>
<tr>
<td>Side Erosion</td>
<td>• Severe belt vibration&lt;br&gt;• Misalignment</td>
</tr>
</tbody>
</table>
### SEVERE RIB WEAR

**Cause**
- Severe belt vibration
- Belt tensioner malfunction
- Alternator pulley malfunction
- Misalignment
6.2 Tensioning Pulleys and Deflection Pulleys

**Cause**
- **Slipping belt**
  ➔ Caused by a malfunction in the belt drive, such as a defective water pump or insufficient belt tension

**Cause**
- **Misalignment**
  ➔ Belt running off-center, caused by e.g. a defective water pump bearing etc.
BROKEN TENSIONER

**Cause**
- Severe belt vibration due to a defective alternator pulley
6.2 Tensioning Pulleys and Deflection Pulleys

**BROKEN MOUNTING LUG ON THE HYDRAULIC BELT TENSIONER**

**Cause**
- Service life of the belt tensioning unit exceeded
- Loose mounting bolt / bolt not tightened to correct torque specification

**OIL LEAK FROM THE BELLOWS SEAL ON THE HYDRAULIC BELT TENSIONER**

**Cause**
- Torn bellows
  - Assembly error:
    - Bellows overtightened during installation

**SEVERELY WORN PROFILE TIPS**

**Cause**
- Insufficient belt tension, causing belt slippage
- Alternator pulley is not functioning correctly

**WORN GUIDE RIBS**

**Cause**
- Misaligned pulleys
- Belt fitted incorrectly
6.3 Water Pump

Leaks (fluid leakage via the drainage mechanism)

**LEAK CAUSED BY SEALANT MISUSE**

*Cause:*
- Surplus sealant between the slide ring and the counter ring, resulting in a leak in the slide ring seal

**LEAK CAUSED BY ABRASIVE MATERIAL**

*Cause:*
- Abrasive material, such as rust, aluminum oxide or dirt, between the slide ring and the counter ring, causing scratches on the surfaces of both rings, which results in the surfaces being destroyed and a leak developing
- Similar damage occurs when the engine runs without any coolant

**CRACK CAUSED BY SUDDEN CHANGES IN TEMPERATURE**

*Cause:*
- Cooling system incorrectly bled or coolant level too low (leading to alternate contact with air pockets and coolant)
- Overheating engine filled with cold coolant
- Engine started before being filled with coolant
- Damage in the form of a crack across the entire diameter of the slide ring or the counter ring
### 6.3 Water Pump

**Bearing damage**

**Cause:**
- Leak caused by a damaged slide ring seal. Grease flushed out by coolant leaking into the bearing through the damaged seal

**Cause:**
- Excessive load caused by incorrect belt tension
- Vibration in the belt drive system
- High load on the bearing when the pump was installed

**Cause:**
- Severe vibration and imbalance
- Bent, cracked or broken fan
- Cracked or bent belt pulley
- Incorrect torque applied to the mounting screws or incorrect tightening sequence
6.3 Water Pump

Coolant

**RUST AND CORROSION**

**Cause:**
- Incorrect coolant mix (antifreeze to water)
- Coolant level too low

**CAVITATION**

**Cause:**
- Incorrect coolant used
- Incorrect coolant mix (antifreeze to water)
- Coolant level too low

**COOLANT MIXTURE**

**Cause:**
- Incorrect specification coolant mix

**CALCIFICATION**

**Cause:**
- High lime content in the coolant (hard water)
6.3 Water Pump

**Miscellaneous**

**COOLANT LEAK FROM THE MOUNTING SURFACE**

*Cause:*
- Uneven or excessive sealant application
- Incorrect tightening torque
- Contamination
- Uneven mounting surface

**BROKEN HOUSING**

*Cause:*
- Severe vibration or imbalance that could have been caused by an extremely worn fan clutch or a bent fan
- High load when the pump was installed

**OVERHEATING**

*Cause:*
- Reduced radiator flow capacity
- Defective cylinder head/cylinder head seal
7 Service

Important:
Vehicle manufacturer testing and replacement intervals must be observed!

Inspection checklist

1. Check the condition of the multi-ribbed belt
2. Check the automatic belt tensioner setting
3. If required, manually adjust the tensioning elements and measure the belt tension
4. Check the condition of the profiled rollers
5. Check that any protective caps are in place
6. Check the condition of the mounting lugs on the hydraulic belt tensioner and check the bellows seal for traces of oil
7. Check the belt tensioner for ease of movement
8. Check the components for any corrosion
9. Check the antifreeze content of the coolant
10. Check the coolant for pollution/contamination
11. Check the pressure release valve on the cover of the compensation tank/radiator
12. Check the cooling system for leaks
13. Check torsional vibration damper and belt pulley decoupler for cracks or damage

Possible causes of failure

- Belt tension too high or too low
- Dirt contamination in the belt drive
- Worn multi-ribbed belt
- Incipient fracturing and pitting of the belt profile
- Squeaking sound caused by dry bearing seal lips
- Bearing roller grease flushed out
  ➔ Missing protective cap!
- Defective hydraulic belt tensioner
  ➔ Oil leak in the belt tensioning unit!
- Defective alternator pulley
  ➔ Bangs and squeaks from the belt!
- Check the alternator pulley (see page 16)

Note:
We recommend replacing all components (deflection pulleys, tensioners and alternator pulleys) in the FEAD drive when the multi-ribbed belt is replaced as all components are subjected to the same level of wear.