Title: COMBINED STARTER-GENERATOR-MOTOR-SUPERCHARGER

Abstract: By embodying a starter-motor-supercharger-generator (100) for an internal combustion engine with a mechanical supercharger (100) connected to a general shaft (21), with a motor generator (20) connected to the input shaft (21) and with a clutch unit (30) to connect the engine to the input shaft (21), it will be possible to reduce the internal friction and pump losses in a very compact unit (100).
COMBINED STARTER-GENERATOR-MOTOR-SUPERCHARGER

Prior art

The invention is related generally to a supercharger directly combined with a starter-generator in a very compact unit coupled to an engine, with a related control system providing boost-on-demand when necessary.

The increasing crude oil prices, the focus on limitations in the natural reserves and greenhouse gas emission concerns, puts focus on combustion engine consumption and emission.

The most efficient way to reduce fuel consumption known today is using boosted engines with reduced capacity and speed.

Therefore, downsizing and downspeeding has become accepted strategies to reduce fuel consumption and pollutants from internal combustion engines. Engine boosting is needed to increase specific power density in order to retain acceptable performance.

Single stage boosting has been sufficient for previous requirements, but as customers and governments mandate lower fuel consumption's and reduced emissions, multi stage boosting or advanced boosting will be required for downsized and down speeded engines in order to maintain the performance and the required emission levels.

Up to now, the turbocharger has been the motor manufacturer's preferred choice when boosting an engine, but the increased turbo lag when downsizing, has pushed the development of mechanical superchargers, as well as the combinations of multiple boosting devices.
The object of the present invention

The object of the present invention is to reduce the internal friction and pump losses in the engines so that the combustion takes place at a higher and more efficient mean pressure.

In general, superchargers offer performance and cost advantages over turbochargers. These advantages include no turbo lag and faster response, easy and inexpensive to install, and no introduction of a heat inertia effect in the exhaust system. This makes superchargers the most cost-effective way to increase engine power output.

The engine crankshaft drives the supercharger with a fixed ratio. Therefore, the boost increases with engine speed. At low engine speed, the boost ratio is low, and the air mass flow is insufficient to provide desired engine torque.

There is a strong desire to develop a boosting system capable of delivering optimal boost over most of the engine speed. Particularly torque at low engine speed is important.

The combination of the air supply from this system secures the ideal emission and consumption situation.

A pure battery driven supercharger can only work in a limited time with a limited boost and is not sufficient to establish a working area. Due to the high electrical power consumption, the battery capacity has to be unrealistic high.

Therefore, since a highly downsized engine needs a combination of a supercharger working efficiently with reduced emissions during both higher
and lower engines load, a pure electric supercharger is not sufficient. A more powerful device is needed.

The purpose of the invention is to further provide a powerful but very compact, cost effective device and control system capable of delivering boost on demand independently of engine speed and at the same time being able to start the engine, enhance engine performance and generate power to the battery system during normal driving as well as under braking by recuperation of some or most of the braking energy. The unit makes use of only one clutch and has no so-called one way bearings.

The controller of the system offers at least six operating modes by controlling the operational status of the electric machine.

The first controlled mode of operation is the high power low engine speed. The electrical machine being directly coupled to the supercharger input shaft drives the supercharger to desired boost. In this situation the drive pulley is decoupled from the main shaft of the electric machine.

In the second mode under high load when the engine has enough speed to drive the supercharger at high boost the pulley connects to the main shaft of the electric machine. The electric machine can now enhance the power from the engine crankshaft and improve the acceleration.

The third controlled mode of operation is a neutral mode with the pulley decoupled. This mode is used when no boost is needed and the battery is partly or fully charged, typically when cruising for limited periods.

During deceleration or braking, the fourth mode is used. The pulley now drives the electric machine that delivers power to the battery to a degree
related to the amount of braking capacity needed, at the same time helping the mechanical braking system of the car.

The fifth mode is the charging mode where the pulley drives the electric machine. Since the electric machine is directly connected to the supercharger, the supercharger is active. The small amount of power used to drive the supercharger is compensated by the reduced pumping losses of the engine. The build-in recirculating system in the compressor housing reduces the drive power further.

When the battery system is fully charged after a short while, the unit decouples, and more power can go to the wheels.

The sixth mode is the starter mode. A start-stop system further improves fuel economy.

The control system is based on closed-loop torque, speed and boost related information.

The functionality, features and benefits in the present disclosure will become more apparent after the following description as well as the drawings.

Description of the drawings

In the following the embodiments will be described according to the drawings, where

Fig. 1 is a longitudinal cross-sectional view of the first embodiment of the relevant components in the combined starter-generator-motor-supercharger,
Fig. 2 is a cross-section taken along line II-II in Fig. 1.

Fig. 3 is a longitudinal cross-sectional view of the relevant components of a further embodiment of the combined starter-motor-supercharger-generator and...

Fig. 4 is a cross-section taken along line IV-IV in Fig. 3.

Description of the embodiments

In the following paragraphs, the present invention will be described in details by way of example with reference to the attached drawings. Throughout this description, the preferred embodiment and examples shown should be considered as examples, rather than as limitations on the present invention. As used herein, the "present invention" refers to any one of the embodiments of the invention described herein and any equivalents. Furthermore, reference to various feature(s) of the "present invention" throughout this document does not mean that all claimed embodiments or methods must include the referenced feature(s).

Referring now to Fig. 1, a starter-generator-motor-supercharger is illustrated and generally designated by the reference number 100.

Starter-generator-motor-supercharger 100 include a compressor 10 having a built-in recirculation valve 14, an input shaft 11 connected to the electric machine 20 main shaft 21. The electric machine 20 has an integrated electrical clutch 30, which is able to connect the drive pulley assembly 40 to the main shaft 21. The clutch could be mechanic or of another type.
The electric machine subassembly contains a rotor 22 and a stator 23. The rotor 22 is fixed on the outer side of the hollow shaft 21, which in turn is supported through bearings 24 and 25. The hollow shaft 21 is connected to the rotor 31 of the electrical clutch.

When the electrical clutch 30 is engaged, the clutch plate 32 being fixed to the center shaft 26 through its flexible connection 33 locks the drive system 40 to the main shaft 21.

The center shaft 26 also positions the supercharger 10 input shaft 11 through bearing 12.

The supercharger 10 connects to the electrical machine 20 with screws 13. This type of connection secures a quick and easy assembly process. Drive plate 15 slides into locks 16 on rotor 31.

Fig. 2 shows how the drive plate 15 of the supercharger 10 connects to the rotor 31 of the electrical clutch 30. Clutch plate 32 is designed for maximum torque transfer.

The flexible connection 33 secures a good contact between clutch plate 32 and rotor 31 during engagement and an air gap when decoupled.

The specification and drawings are not intended to limit the exclusionary scope of this application.

Either a direct drive, sprockets or chain, can replace the drive pulley assembly 40.
Fig. 3 shows a further embodiment of the invention with the drive pulley positioned between the clutch 30 / supercharger 10 and the motor-generator 20.

On most belt driven starter-motor-generators the controlling electronics are positioned in the rear of the unit. It is therefore advantageous to connect the supercharger to the front end of the starter-motor-generator as shown in Fig. 3.

The input shaft 11 on the supercharger 10 has a key lock and precision fitting to the starter-motor-generator 20 shaft 21. Therefore a bearing on the input shaft 11 can be avoided making the combined unit 200 even more compact.

When the belt needs to be replaced during service unscrewing bolts 13 allows the supercharger 10 to be demounted in an easy and quick way.

The pulley 40 is integrated with the clutch plate 32 having a flexible connection 33 securing a good contact with the clutch rotor 31 connected to the input shaft 11.

Fig. 4 shows the opening in the bracket 36 that allows passage for the belt drive.

The functionality is identical to both embodiments shown in Fig. 1 and Fig. 3, but the supercharger can for various reasons be placed independently to the motor-generator.

The term "vehicle" includes motor vehicles in general such as passenger automobiles including sports utility vehicles, busses, trucks, various
commercial vehicles, watercraft including a variety of boats, ships and personal watercrafts.

The hybrid vehicles referred to herein is a vehicles that has two or more sources of power, for example both gasoline-diesel and electric-powered vehicles.

The system controlling the starter-generator-motor-supercharger can work together with a system that reads the road ahead and automatically adjusts brake energy regeneration levels accordingly in order to maximize the total efficiency.

When the battery is full, the electric motor can assist the engine so that the battery will have new capacity to receive energy under braking. Then a unique retarding effect is present at all times.

Since the boost, when the supercharger is driven electrically, can be varied according to demands, the adaption of a cooled exhaust gas recirculation system as well as the valve timing system can be designed simpler and cheaper.
C L A I M S

1. A starter-motor-supercharger-generator system for an internal combustion engine, comprising:
   a. a mechanical supercharger (100) arranged on a motor generator shaft (21),
   b. a motor-generator (20) connected to the supercharger input shaft (21),
   c. a clutch unit (30) connects the internal combustion engine to the input shaft (21) of the supercharger and where the supercharger (100) delivers compressed air to the internal combustion engine during start, acceleration, operation and generate and recuperate electrical energy under deceleration.

2. A system according to claim 1, wherein the supercharger (10)/clutch (30) is driven from the rear of the motor-generator (100).

3. A system according to claim 2, wherein the supercharger input shaft (11) is radically positioned by a bearing (12).

4. A system according to claim 1, wherein the supercharger (10)/clutch (30) is driven from the front of the motor-generator.

5. A system according to claim 4, wherein the supercharger input shaft (11) is fitted with a precision fitment reducing the need for an input bearing to the supercharger.
**INTERNATIONAL SEARCH REPORT**

**International application No**

PCT/DK2015/00Q015

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. F02B33/40 B60K6/46

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

F02B B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>WO 2008/020184 AI (NEXXXDRIVE LTD [GB] ; INTEGRAL POWERTRAIN LTD [GB] ; MCDONALD-WALKER RUAR) 21 February 2008 (2008-02-21) page 6, line 9 - page 7, line 9; figures 1, 2</td>
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Further documents are listed in the continuation of Box C.

X See patent family annex.

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Date of the actual completion of the international search

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