TITLE: <u>CLUTCH LESS TRANSMISSION INTEGRATED WITH CO-AXIAL INTEGRATED STARTER GENERATOR FOR HYBRID ELECTRIC VEHICLE</u>

ABSTRACT

An axial flux machine comprises of a permanent magnet rotor which is connected to the output shaft of a heat engine. The stators wound with electrically conducting material are placed coaxially on either side of the rotor. In contrast to a radial flux machine, this machine has the magnetic poles placed on the side faces of a disc shaped rotor. The rotor is virtually supported by bearings on the heat engine and the transmission unit that transmits power from the heat engine to the wheels of a vehicle. The splined shaft on the flywheel simply slides along a coupling element between the engine & the rotor. This reduces the complexity in assembling the flywheel & rotor. Shims on the heat engine side ensure that there is appropriate air gap maintained for the proper functioning of the Axial Flux Machine.

With the plurality of gears inside the gearbox, and the synchronized engagement of the engine shaft with the input shaft the need for a clutch system is removed.

TECHNICAL FIELD

The present disclosure relates to an axial flux machine. More particularly, relates to the axial flux machine mounted onto an output shaft of a heat engine for the purpose of starting the engine, generating electric power and also as a device for assisting the output shaft of the heat engine to boost the torque.

BACKGROUND OF DISCLOSURE

In a conventional heat engine of an automobile, a starter motor is mounted onto a pinion gear which rotates the flywheel bolted onto the heat engine to initiate the combustion process.

Apart from the gears provided, this mechanism also includes provisions for selectively engaging the pinion gear only at the time of starting. Due to the very high torque required to rotate the output shaft of large engines, such motors are also provided with multiple gears for multiplication of torque. As a result, part count increases and also the cost for manufacturing these parts increases, which has an adverse effect on the weight of the vehicle and fuel efficiency. The engagement of the pinion gear with the ring gear is noisy and sometimes unpleasant to the users.

Further, in order to charge the energy storage systems such as a battery in the vehicle, additional devices like an alternator or an electric generator has to be coupled by belt / gears / chains / similar means with the output shaft of the engine. This leads to additional consumption of energy from the combustion engine which reduces the fuel efficiency and power delivered from the engine.

Hence there is a need to develop an integrated system wherein, the rotor of the electrical machine in the hybrid system is directly coupled to the output shaft of the heat engine which performs dual work of starting the engine and charging the battery. Also, the time taken to achieve the minimum speed for starting the engine is also grossly reduced. This helps in the reduction in the content of harmful gases in the exhaust system.

In a conventional vehicle with heat engine or hybrid electric vehicle especially in parallel operation mode, where in a heat engine is used in conjunction with an electric motor to power the wheels, a clutch kind of mechanism is required for smooth transmission of power during the engagement of engine power to the wheels.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

The disclosure itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following description of an illustrative embodiment when read in conjunction with the accompanying figures. One or more embodiments are now described, by way of example only, with reference to the accompanying figures wherein like reference numerals represent like elements and in which:

Figure 1 illustrates hybrid powertrain having an engine mounted to the axial flux machine assembly placed in-between the engine and the transmission.

Figure 2 illustrates axial flux machine mounting scheme with flywheel mounted coaxial to the crankshaft axis.

Figure 3 illustrates cut sectional view of the hybrid electric power train.

Figure 4 illustrates shafts layout within the transmission.

Figure 5 illustrates the shaft layout in the transmission when only electric traction motor is running.

Figure 6 illustrates the cranking of the engine with the help of Integrated Stator Generator (ISG).

Figure 7 illustrates the shaft layout in the transmission when only the engine is running to drive the wheels.

Figure 8 illustrates the shaft layout in the transmission when both engine and electric motor is driving the wheels.

Figure 9 illustrates the shaft layout in the transmission during series mode.

Figure 10 illustrates power flow when only electric motor is driving the wheels.

Figure 11 illustrates power flow when only Engine is running.

Figure 12 illustrates power flow when both engine and electric motor are driving the wheels.

Figure 13 illustrates power flow during series mode.

Figure 14 illustrates regeneration mode of power flow during electric traction motor.

Figure 15 illustrates regeneration mode of power flow during engine drives the wheels and also drives the wheels.

DESCRIPTION

The foregoing has broadly outlined the features and technical advantages of the present disclosure in order that the description of the disclosure that follows may be better understood. It should be appreciated by those skilled in the art that the conception and specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present disclosure. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the disclosure. The novel features which are believed to be characteristic of the disclosure, both as to its organization and method of operation, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present disclosure. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and make part of this disclosure.

Figure 1 illustrates hybrid powertrain (100) having an engine (1) mounted to an axial flux machine (2) and geared to an input gear (3) assembly placed in-between the engine (1) and transmission (9). The engine bay housing consists of rotating and stationary components, the battery pack (4) is connected to the traction motor controller (7) which receives and distributes the current coming from the battery pack (4), and it also helps in charging of the battery pack (4). The traction motor (6) is connected to the electric motor shaft (29) which in turn is connected to the input gear (3) via the motor gear (33). The engine (1) is coupled to the axial flux machine (2), and in-turn coupled to the transmission (9) through gearing mechanisms. Similarly the traction motor (6) is also coupled to the transmission (9) of the vehicle via a motor gear (33). An electro mechanical actuator (8) is provided which gives the option of switching to a variety of modes namely electric mode, parallel mode, series mode etc. At times when only engine (1) is being operated to induce charging of the battery pack (4), or when the engine (1) is involved in driving the vehicle or both, an Energy Management System (EMS) (10) controls the speed & torque delivered by the engine. The actions of the engine management systems (10) are controlled by Vehicle ECU (5).

Figure 2 illustrates axial flux machine assembly (101) mounting scheme with flywheel (15) mounted coaxial to the crankshaft axis (18). In conventional flywheel mounting systems the flywheel (15) was bolted onto the engine (1). In the present disclosure the flywheel (15) is mounted coaxially to the crankshaft axis (18) coming out from the engine (1). The flywheel (15) is mounted by the aid of coupler (23) and coupler bush (24) this allows free rotary motion of the flywheel (15). A crankshaft flange (25) is also coupled with the flywheel (15) to transmit the torque from the crankshaft of the engine (1). A damper (20) is used on the other end of the flywheel (15) which is used to connect the input shaft (19). Coupler (23) acts as an extension to the crankshaft of the engine (1) along the axis of the crankshaft (18). A resolver rotor (16) is assembled to the coupler (23) using a key (Other possibilities to mount the resolver could also be included – bolting, gluing, etc.). An ISG rotor (22) is bolted to the crankshaft flange (25) sandwiching the coupler (23). Resolver rotor (16) is assembled to the Coupler (23) assembly while the Resolver stator (26) is assembled to the Stator holder plate (21). The resolver wires are routed through the Stator holder plate (21) to the Transmission Front half (27). Resolver assembly is used to detect and convey the position of the ISG rotor (22) during different operations. Flywheel (15) has a splined shaft, which is used to transmit the torque from the Engine (1) to the Input shaft (19). Damper (20) is used to damp the torsional vibrations during Engine Parallel/Series operations. The flywheel (15) slides over the internal splines provided on the Coupler (23) assembly. Flywheel (15) is supported by the coupler bush (24) at one end of the spline and by the Coupler inner race at the other end of the spline on the Flywheel (15). The Coupler bush (24) restricts the axial movement of Flywheel (15) in one direction, while the shim collar (17) restricts the other side along the crankshaft axis (18). The entire parts are housed within a transaxle bell housing (11) on the side of an electric traction motor (6) side and an engine adapter (12) on the engine (1) side.
The Axial flux machine (101) also referred as Integrated Starter Generator (ISG). In an embodiment of the present disclosure, the axial flux machine (101) can be replaced with other types of electric machines also, which means the scope of using an electric machine in this context is not limited to use of axial flux machine only.

Figure 3 illustrates cut sectional view of the hybrid electric power train (100) showing axial flux machine assembly (101) mounted to the engine (1) on the one side and electric motor shaft (29) on the other side via motor gear (33). The transmission front half (27) is comprising of the flywheel (15) mounted to the coupler (23) by way of coupler bush (24), an ISG rotor (22) mounted over the coupler (23) assembly. The transmission rear half (28) has all the necessary parts which aid in transmitting the power from the electric traction motor (6) to the transmission (9) for vehicle movement. An electric traction motor shaft (29) is coupled to the input gear (3) via motor gear (33). Integration of the engine (1), axial flux machine (101) and the electric traction motor (6) to transmission (9) helps in transmission of power from either of the drivers through a single gearing system. A shifting mechanism is also employed at the transmission rear half (28) which helps in shifting of the gears within the transmission (9) whenever the electromechanical actuator (8) is pushed for operations of only the electric traction motor (6) or engine (1) or both. A shifter actuator (32) is fixed to the shifter sleeve (30) and this shifter sleeve (30) is connected to the shifter rod (31) which shifts the gearing mechanism whenever the electromechanical actuator ~~(8)~~ (32) is actuated.

Figure 4 illustrates shafts layout within the transmission (9). The electric traction motor shaft (29) has a motor gear (33) geared to an input gear (3). The input gear (3) shifter sleeve (30) and shifter hub (37) mounted on the input shaft (19) are coaxially placed. A rolling element (34) is provided in-between the input shaft (19) and the input gear (3). A lay shaft (35) transmits torque from the input gear (3) to the differential unit (36).

Figure 5 illustrates the shaft layout in the transmission (9) when only electric traction motor (6) is running. In this mode the actuator is deactivated and electric motor (6) is kept on whereas, the engine (1) is in off condition. Electric traction Motor (6) is connected to the motor shaft (29) through the splines provided in the motor shaft (29). The motor shaft (29) and motor gear (33) are integrated together. Differential Unit (36) is connected to the wheels using an Axle. Electric traction motor (6) is rotated which transmits the torque to the motor shaft (29) and the motor gear (33). Motor gear (33) transmits the torque to the input gear (3), the input gear (3) rolls over the rolling element (34) without transmitting the torque to the Input shaft (19), thus transmitting the torque to the Differential unit (36) through Lay shaft (35). This shaft layout and gearing is active only when electric motor option is selected. The electromechanical actuator (32) is in the retracted position such that the shifter sleeve (30) and the synchro cone (40) are not engaged with the input gear (3).

Figure 6 illustrates the cranking of the engine (1) with the help of axial flux machine (2). The control algorithm embedded in an electronic control unit commands the axial flux machine (2) to start the engine (1). The Electrical energy is converted to Mechanical energy to crank the Engine (1). ISG stators (13 & 14) are excited to rotate the ISG Rotor (22). Torque generated by the axial flux machine (2) is transmitted to the Engine (1) crankshaft through the Coupler (23). This cranks the engine for combustion.

Figures 7 and 11 illustrates the shaft layout in the transmission (9) when only the engine (1) is running and power flow when only engine (1) is running. In this mode the actuator is kept activated and the electric traction motor (6) is kept off while the engine (1) is kept running. This mode of operation is applicable only when the vehicle has already gained some speed, and not applicable to start the vehicle from a halt. The speeds of the electric motor shaft (29) and input shaft (19) are measured by sensors. The control algorithm embedded in an electronic control unit synchronizes the speeds of the input shaft (19) such that its speed matches almost to that of the input gear (3). When the speed difference is small enough, the control algorithm commands the actuator to move the shifter sleeve (30) through the shifter shaft (38), shifter rod (31), syncro cone (40) and shifter yoke (39). This achieves a clutch-less engagement of gears within the transmission (9). The spring ball arrangement in the shifter hub (37) locks itself with the shifter sleeve (30) by means of a spring ball mechanism. This way a positive locking is achieved between the shafts.

Figures 8 and 12 illustrate the shaft layout in the transmission (9) when both engine (1) and electric traction motor (6) are running and power flow when both engine (1) and electric traction motor (6) are running. In this mode electric traction motor (6) and the engine (1) all are kept running. The speeds of the electric motor shaft (29) and input shaft (19) are measured by sensors. The control algorithm embedded in an electronic control unit synchronizes the speeds of the input shaft (19) such that its speed matches almost to that of the input gear (3). When the speed difference is small enough, the control algorithm commands the actuator to move the shifter sleeve (30) through the shifter shaft (38), shifter rod (31), syncro cone (40) and shifter yoke (39). This achieves a clutch-less engagement of gears within the transmission (9). The spring ball arrangement in the shifter hub (37) locks itself with the shifter sleeve (30) by means of a spring ball mechanism. This way a positive locking is achieved between the shafts. Torque from the electric traction motor (6) to the input gear (3) flows identical as in Pure Electric mode, while the Engine (1) is cranked by the axial flux machine (2). Torque is transmitted from the Engine (1) to the Input shaft (19) through Engine crankshaft (1), Coupler (23), Flywheel (15), Damper plate (20). Further, all the torques are supplied to the input gear (3) is amalgamated to a single torque for further transmission to the wheels through Lay shaft ~~(36)~~ (35) and Differential Unit (36).

Figures 9 and 13 illustrate the shaft layout in the transmission (9) during series mode and power flow in series mode. In this mode the actuator is deactivated and the engine (1) is kept in running condition and simultaneously the electric traction motor (6) is also activated. Torque from the engine (1) is transmitted to the ISG Rotor (22) through the engine crankshaft and Coupler (23). The control algorithm embedded in an electronic control unit commands the axial flux machine (2) to generate and hence mechanical energy is converted to electrical energy to charge the battery (4). Electrical energy from the battery & electrical energy generated by the axial flux machine (2) support the running of the electric traction motor (6).

Figure 10 illustrates power flow when only electric motor (6) is running. The current from the battery pack (4) is supplied to the electric traction motor (6) which rotates the electric motor shaft (29). The torque from the electric motor (6) shaft is transferred through the input gear (3), Lay shaft (35), differential (36) & the wheels. The engine (1) is totally cut off during operation of the electric traction motor (6).

Figure 14 illustrates regeneration mode of power flow. When the vehicle is required to slow down or come to a halt, the-Electrical motor (6) converts the energy received from running the gears in the transmission (9) to useful energy for charging the battery pack (4) through the traction motor controller (7).

Figure 15 illustrates power flow during engine (1) runs the generator and the traction motor drives the wheels. The actuator (32) is in the disengaged position there by there is no power flow from the engine to the wheels. The engine drives the axial flux machine only. The axial flux machine generates electrical energy which is stored in the battery.(4)

<u>**Advantages**</u>

Using only a single electric traction motor charging of the battery pack as well as running of the vehicle can be carried out.

Absence of starter motor and alternator leads to no noise and cuts down on cost.

The Integrated Starter Generator (ISG) is used to crank the engine as well as transmit the torque from the electric traction motor and the engine.

REFERRAL NUMERALS

100	Hybrid powertrain
101	Axial flux machine assembly
1	Engine
2	Axial flux machine/Integrated Starter Generator
3	Input Gear
4	Battery pack
5	Vehicle ECU
6	Traction motor
7	Traction motor controller
8	Axial machine actuator
9	Transmission
10	Energy management system (EMS)
11	Transaxle bell housing
12	Engine adaptor
13	Engine Side ISG stator
14	Transmission side ISG stator
15	Flywheel
16	Resolver rotor
17	Shim collar
18	Crankshaft axis
19	Input shaft
20	Damper/Damper plate
21	Stator holder plate
22	ISG rotor
23	Coupler
24	Coupler bush

25	Crankshaft flange	
26	Resolver stator	
27	Transmission front half	
28	Transmission rear half	
29	Electric motor shaft	
30	Shifter sleeve	
31	Shifter rod	
32	Shifter actuator	
33	Motor gear	
34	Rolling element	
35	Lay shaft	
36	Differential unit	
37	Shifter hub	
38	Shifter shaft	
39	Shifter yoke	
40	Syncro cone	
41	Axles	