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(54) Abstract Title
Controlling vibration in an internal combustion engine when the engine passes through a low speed resonance speed range

(57) A drive system for a vehicle comprises an internal combustion engine, a power train, a vibration damper and a controller. During a starting phase the controller prevents combustion until the rotational speed of the engine exceeds a resonance speed range in which excitation of sympathetic vibrations of the vibration damper is expected. During normal operation the controller reduces power output if the rotational speed of the engine falls below a threshold value; the threshold valve being higher than the resonance speed range. During a stopping phase the controller prevents generation of torque from the engine and an excitation preventer provides at least partial prevention of vibration excitation of the vibration damper. The controller acts on engine system, for example fuel supply, engine throttle, inlet/outlet valves including a decompression valve and ignition. The controller may cut power to some or all cylinders of the engine.

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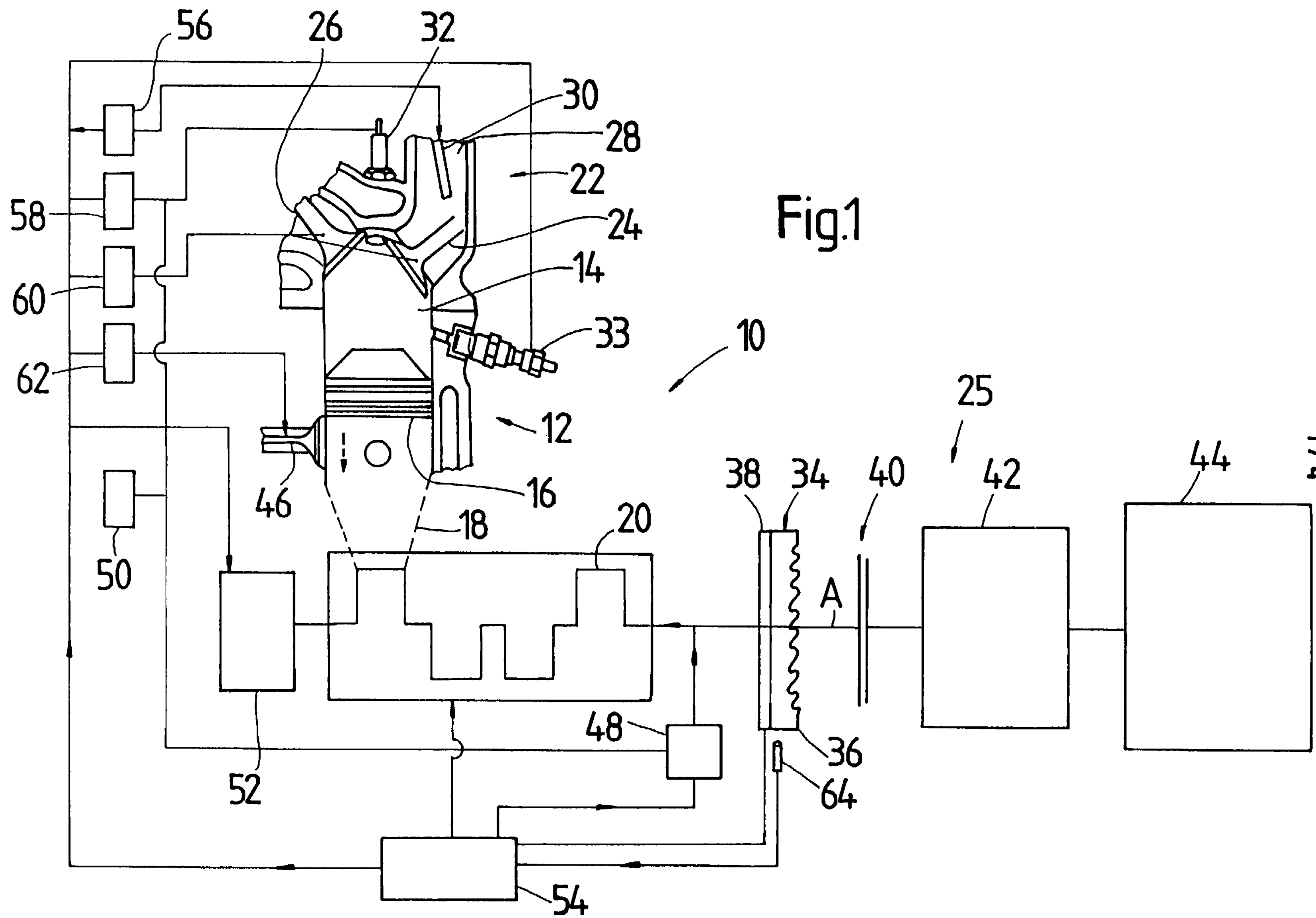
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Fig.1

Fig.2

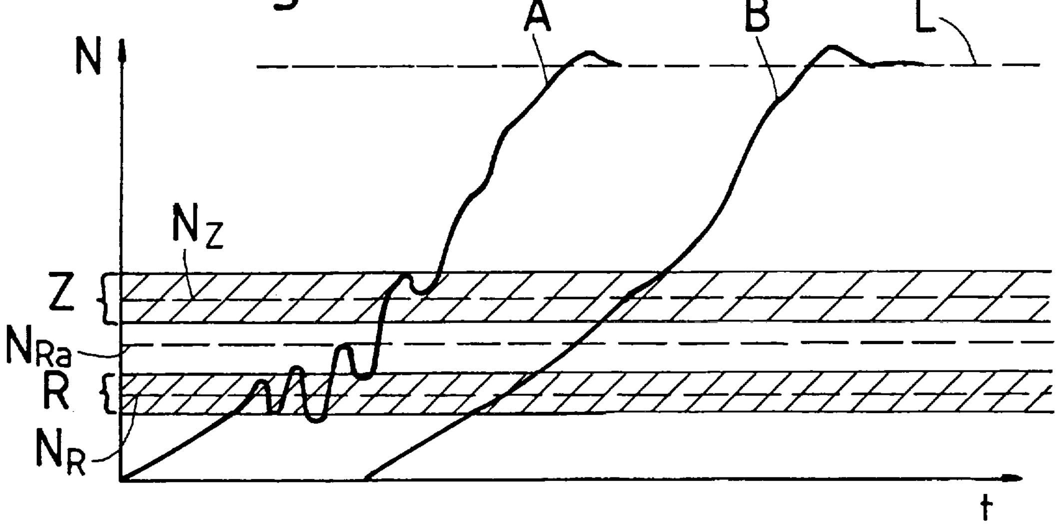


Fig.3

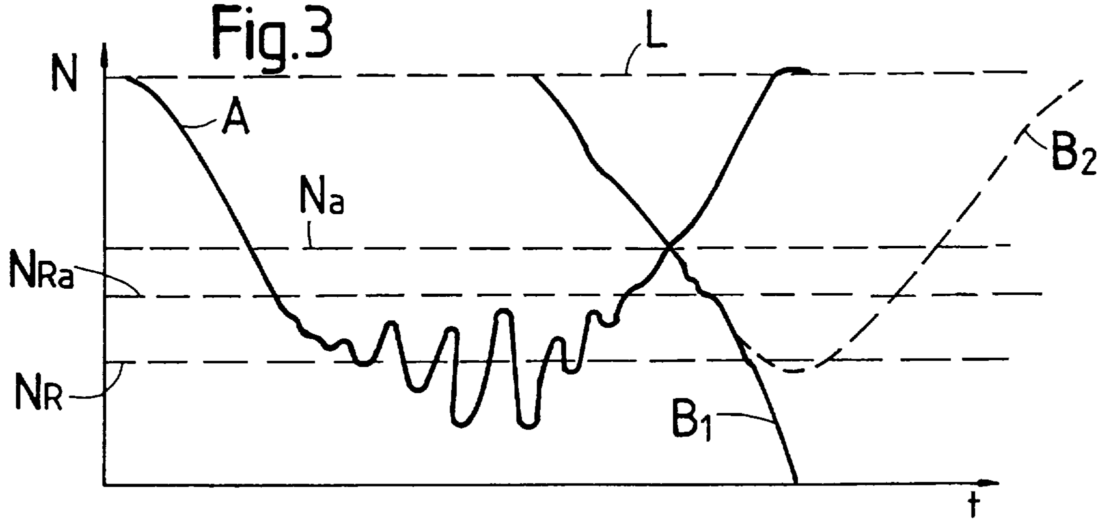


Fig.4

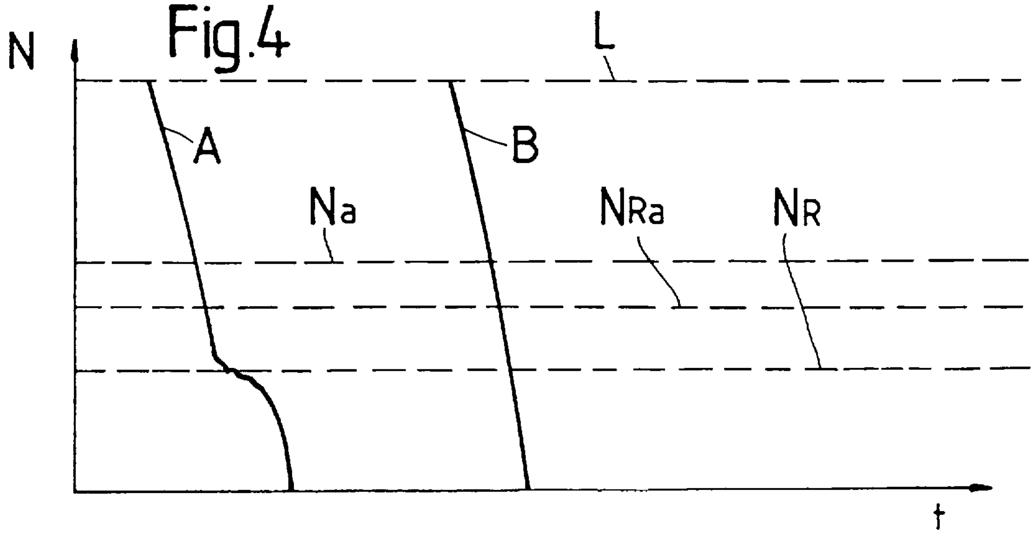


Fig.5

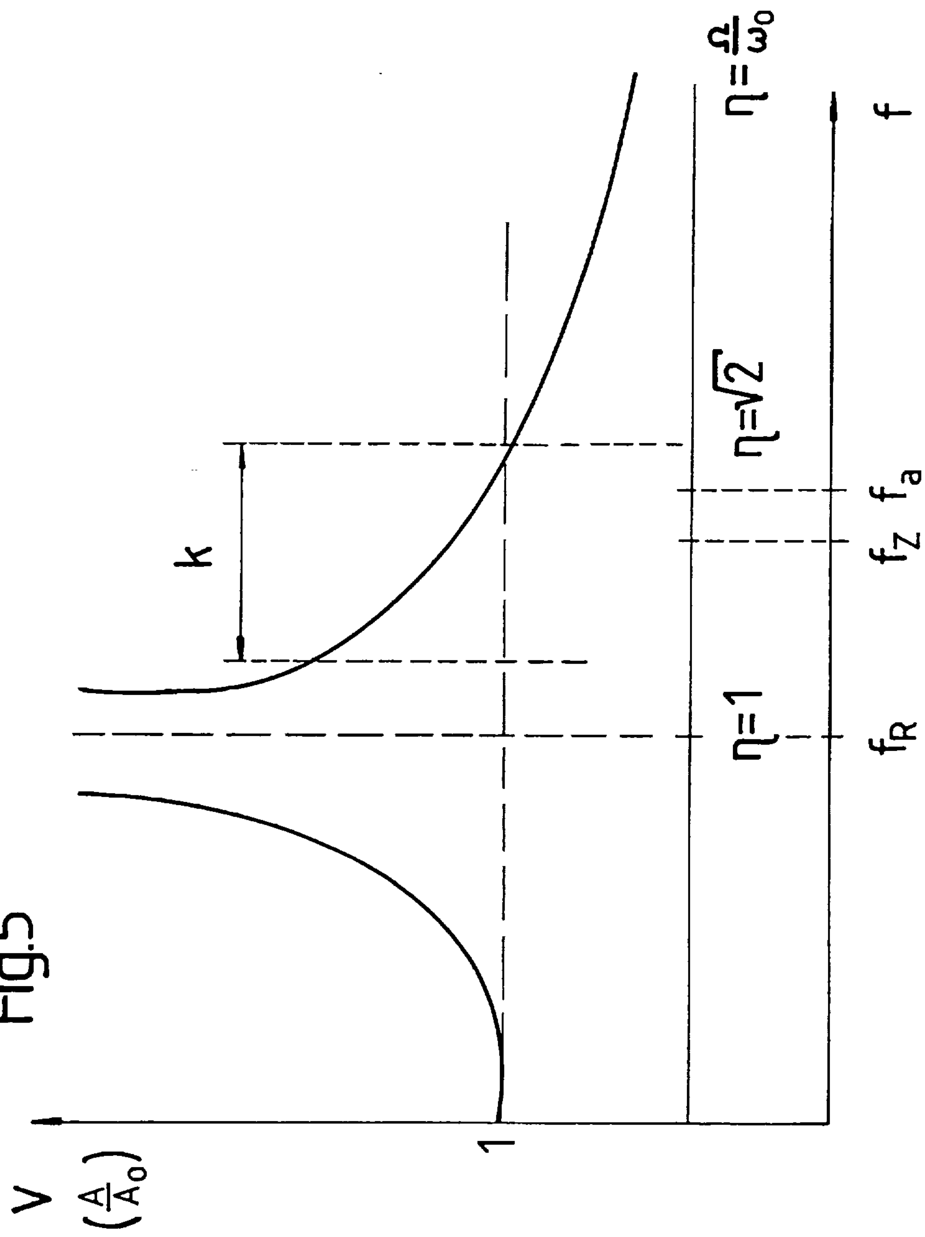


Fig.6

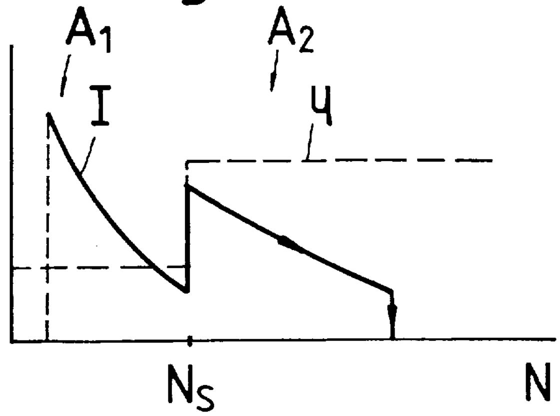
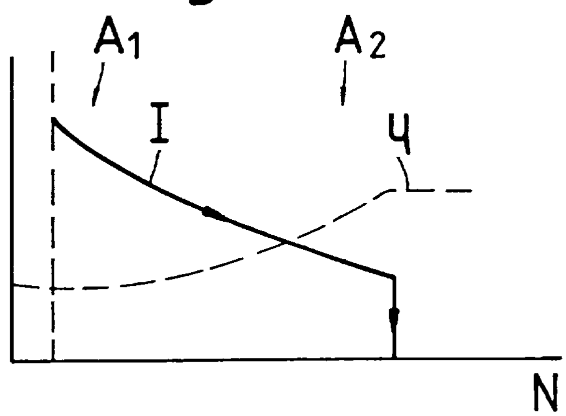


Fig.7



Drive system for a motor vehicle and a method of controlling the operation of such a system

The present invention relates to a drive system for a motor vehicle comprising an internal-combustion engine and a drive or power train which is coupled or can be coupled to the internal-combustion engine and includes at least one vibration damper. The present invention also relates to a method of controlling such a system.

Drive systems used in modern car design often employ a torsional vibration damper in the form of a dual mass flywheel connected to a crankshaft of the internal-combustion engine. As these dual mass flywheels comprise two masses capable of vibrating relative to one another, the vibration system formed from such a dual mass flywheel and the internal-combustion engine has a resonant frequency. Relatively pronounced sympathetic vibrations can occur at specific speeds of the internal-combustion engine. To avoid this, the vibration system is so designed that its resonance frequency is relatively low, i.e. vibrations can only be excited at very low speed in the range, for example, of 250 to 300 revolutions per minute in the internal-combustion engine. Relatively vigorously acting friction dampers are also provided in dual mass flywheels and provide pronounced damping, should sympathetic vibrations be created.

The design of the torsional vibration dampers such that they have relatively low resonant frequencies means that their vibration damping behaviour, owing to the special design for the lower resonant speeds, is inadequate in other speed ranges in which the excitation of vibrations is expected, for example owing to operation of the internal-combustion engine. Such a design of torsional vibration dampers and the provision of relatively vigourously acting friction devices demand a very robust and expensive construction of the torsional vibration dampers. Owing to these requirements, it has not been possible to use these dual mass flywheels, for example in three-cylinder internal-combustion engines with a correspondingly elevated resonant speed.

It is accordingly an object of the present invention to provide a drive system for a motor vehicle and a method of control in which the excitation of sympathetic vibrations in a vibration damper can be reliably avoided.

According to the first aspect of the present invention, there is provided a drive system for a motor vehicle which comprises an internal-combustion engine, a power train which is or can be coupled to the internal-combustion engine, at least one vibration damper arranged in the power train, a controller for controlling operation of components of the drive system as a function of a plurality of control parameters and a speed sensor for generating a signal depending on the speed of the internal-combustion engine which signal is supplied to the controller as one of the control parameters, wherein the controller serves to prevent ignition of the internal-combustion engine in a starting phase thereof until the speed of the internal-combustion engine detected by the speed sensor is higher than a resonance speed or a resonance speed range, in which the excitation of sympathetic vibrations of the at least one vibration damper is expected.

With such a design of the drive system, therefore, it is ensured that, during the starting of the internal-combustion engine when it passes through a speed range from zero to the idling speed and therefore also passes the relatively low resonance speed range, the internal-combustion engine is only ignited and delivers power when sympathetic vibrations can no longer be excited by this delivery of power because the resonance speed range or the resonance speed has already been exceeded. In other words, with this drive system according to the invention, the ignition speed or the ignition speed range is shifted upward in comparison with known drive systems in which ignition is also carried out in the speed range of 250 to 300 revolutions per minute of the internal-combustion engine. This leads to two advantageous consequences. First of all, as already mentioned, the excitation of sympathetic vibrations in the vibration damper can be avoided. On the other hand, as the ignition speed is shifted to higher speeds, the vibration damper can be so designed that the resonance frequency provided by the associated vibration system is also shifted upwardly but not so far that it lies in the range of the ignition speed again. As a result, the vibration damper can be optimized for vibration damping in other excitation frequency ranges as a special design for providing very low resonance frequencies is no longer required. Furthermore, with the drive system according to the invention, the at least one vibration damper can be designed and constructed with lighter components or even completely without additional friction dampers which otherwise ensure, in the known and above-described drive systems, that an adequately strong damping force can be provided if resonance frequencies are excited.

The drive system according to the invention also allows the use of vibration dampers, for example in the form of dual mass flywheels in internal-combustion engines with a small number of cylinders, for example three-cylinder internal-combustion engines, which have a correspondingly higher critical speed or frequency of the vibration system formed by internal-combustion engine and vibration damper.

In the drive system according to the invention, the controller can be designed to prevent ignition of the internal-combustion engine until the detected speed of the internal-combustion engine corresponds to a predetermined ignition speed or lies in a predetermined ignition speed range and such that a predetermined interval is provided between the resonance speed or the resonance speed range and the ignition speed or the ignition speed range.

The ignition speed can lie, for example, in the range of 300 to 500, preferably in the range of 400 to 450, revolutions per minute of the internal-combustion engine. This ensures, on the one hand, an adequate interval to the resonance speeds but, on the other hand, still permits relatively low idling speeds.

To prevent the excitation of sympathetic vibrations in the optimum manner, it is proposed that the predetermined interval has a range of 70 to 250, preferably 120 to 200 revolutions per minute of the internal-combustion engine.

A further operating state in which sympathetic vibrations can be excited in a drive system is so-called "engine depression". This engine depression is generated in an operating phase of the internal-combustion engine, i.e. a phase in which the internal-combustion engine delivers power when, for example, the driver accidentally shifts to a high gear when travelling slowly so the speed of the internal-combustion engine is depressed into a range well below the idling speed owing to the excessive translation of the gear. In particular, it is possible that the speed will be depressed to such an extent that it lies in the range of the resonance speed or of the resonance speed range of the vibration damper or of the vibration system formed from the vibration damper and internal-combustion engine. To avoid the excitation of sympathetic vibrations of the vibration damper during such "engine depression", a further aspect of the invention provides a drive system for a motor vehicle which comprises an internal-combustion engine, a power train which is or can be coupled to the internal-combustion engine, at least one vibration damper arranged in the power train, a controller for controlling operation of components of the drive system as a function of a plurality of control parameters and a speed sensor for generating a signal dependent on the speed of the internal-combustion engine which is supplied to the controller as one of the control parameters, wherein the controller is designed to reduce the power output of the internal-combustion engine at least in part during an operating phase of the internal-combustion engine if the speed detected by the speed sensor of the internal-combustion engine is lower than a predetermined threshold speed, the threshold speed being higher than a resonance speed or a resonance speed range in which the excitation of sympathetic vibrations of the at least one vibration damper is expected.

Therefore, if the speed of the internal-combustion engine is forcibly reduced to such an extent that the excitation of sympathetic vibrations is expected, the at least partial reduction of the power output of the internal-combustion engine ensures, in advance, when the engine speed falls below the threshold speed the energy which excites sympathetic vibration is at least significantly reduced. In other words, if the speed of the internal-combustion engine actually falls into the range of resonance speed, it is almost impossible to excite sympathetic vibrations owing to the at least reduced excitation energy.

With a drive system of this type, it is also advantageous if the threshold speed has a predetermined interval from the resonance speed or from the resonance speed range. The predetermined interval can have a range of 100 to 300, preferably 150 to 250 revolutions per minute of the internal-combustion engine. It can be seen that the predetermined interval preferably has a range which may be greater than the range of the corresponding interval in the starting phase. This is due to the fact that relatively continuous acceleration of the internal-combustion engine with a movement away from the resonance range exists in the starting phase whereas the speed of the internal-combustion engine approaches the resonance speed range during engine depression and it may therefore be advantageous if a greater safety interval is provided, i.e. the threshold speed is higher than an ignition speed or an ignition speed range of the internal-combustion engine.

Maximum protection against the excitation of sympathetic vibrations can be provided if the controller is designed to prevent complete ignition of the internal-combustion engine when the threshold speed is reached.

Alternatively, it is also possible to design the controller such that ignition of the internal-combustion engine is partially prevented when the detected speed falls below threshold speed.

This can be achieved, for example, if the internal-combustion engine has a plurality of cylinders in that the controller is designed to prevent ignition in a proportion of the cylinders when the threshold speed is reached.

In order to reduce the power output of the internal-combustion engine, at least in part, in the above-described critical operating states of an internal-combustion engine, i.e. starting phase and normal operating phase with engine depression, it is proposed that the controller prevents ignition by preventing the presence of ignition conditions.

For example, the drive system can comprise a fuel injection system and/or throttle system which can be controlled by the controller, and the controller can be so designed that it prevents ignition by at least partially preventing fuel injection through the fuel injection system and/or variation of a throttle or butterfly valve position.

In the drive system according to the invention, furthermore, the controller can act on an ignition system in such a way that ignition is prevented by preventing the generation of sparks.

An inlet valve mechanism which can be controlled by the controller can also be provided in the internal-combustion engine, the controller preventing ignition by keeping at least a proportion of the inlet valves of the inlet valve mechanism closed.

A further measure for preventing ignition, i.e. for preventing the presence of ignition conditions, which is advantageous, in particular, in conjunction with self-igniting internal-combustion engines, i.e. diesel engines, is to provide a decompression valve mechanism, controllable by the controller, in at least one cylinder of the internal-combustion engine, the controller preventing ignition by opening at least one valve of the decompression valve mechanism.

The decompression valve mechanism can comprise, for example, an inlet/outlet valve mechanism of the internal-combustion engine. In this case, a necessary rise in pressure in the cylinder which occurs with a necessary rise in temperature in the cylinder is avoided by keeping open the inlet/outlet valve or a proportion of the inlet/outlet valves to prevent ignition.

The drive system according to the invention advantageously also comprises a starter which can be controlled by the controller in order to accelerate the internal-combustion engine during the starting phase at least to the ignition speed or to the ignition speed range. The controller is advantageously designed in cooperation with the engine to keep the starting torque which is to be generated by the starter low in the starting phase. This measure allows conventional starter motors to be used in the drive system according to the invention merely for accelerating the internal-combustion engine to the formerly employed lower ignition speeds. However, as the starter torque to be generated by the starter device is kept low or reduced by suitable control of the controller, a starter motor which is smaller in size with respect to the power output can be used in conjunction with the drive system according to the invention for accelerating the internal-combustion engine to the higher ignition speeds. To achieve this, the drive system can comprise, for example:

a) a crankshaft decoupling device controlled by the controller for the decoupling/coupling of a part of the crankshaft of the internal-combustion engine and the cylinders cooperating with this part from/to the power train, and/or

b) an inlet/outlet valve mechanism controlled by the controller for operating at least a proportion of the inlet and/or outlet valves thereof, and/or

c) a changeover induction manifold mechanism controlled by the controller for selective opening to the environment, at least at one intake manifold resonance portion, and/or

d) a venting valve mechanism, controllable by the controller, in at least one cylinder of the internal-combustion engine, and/or

e) an inertial mass device which can be coupled to and decoupled from the power train by the controller,

The controller, in the starting phase, decouples a part of the crankshaft and/or decouples a proportion of the inlet and/or outlet valves and preferably keeps them in an open state and/or brings the changeover induction manifold mechanism into an intake dethrottling resonance state and/or brings the venting valve mechanism into a open state and/or decouples the inertial mass device from the power train.

Owing to one or more of these measures, the frictional or inertial forces generated in the internal-combustion engine in the starting phase are kept as low as possible so the necessary higher ignition speeds can be achieved even with a smaller starter device. It is pointed out here that this aspect of the reduction or minimization of the starting torques to be generated by the starter device is advantageous per se as smaller starter motors can also be used in conventional internal-combustion engines and thus contribute to a corresponding reduction in costs.

A further measure for achieving the necessary higher ignition speeds with a conventional starter is to provide a starting torque assisting device which generates an auxiliary force when the internal-combustion engine is started.

For example, the starting torque assisting device can comprise:

a) a dynamo which can be operated for driving the internal-combustion engine, and/or

b) an accumulator device for storing a medium under pressure and for delivering the medium under pressure in the starting phase for providing an auxiliary driving force, and/or

c) a starter regulating device for providing a first starter operating voltage during a first starting phase portion and for providing a second starter operating voltage which is higher than the first starter operating voltage during a second portion of the starting phase.

The provision of a starting torque assisting device of this type, dissociated from the basic principle of the present invention, contains its own inventive concept as better value power design of the starter devices can also be achieved with conventional drive systems.

A further operating state of a drive system, in which sympathetic vibrations can be excited in a vibration damper, is a stopping phase of the internal-combustion engine. A stopping phase in the context of the present application is a phase which begins when the internal-combustion engine is switched off, for example by the vehicle driver, for example by turning the ignition lock, and which lasts until the internal-combustion engine is completely stationary. The speed also passes through the resonance speed range in this phase of diminishing engine speed. Relatively high vibration excitation energy no longer exists owing to the power output of the internal-combustion engine, which has already generally been prevented, due to ignition. However, owing to the kinetic energy still present in the inertial system of the internal-combustion engine or of the power train, vibrations which can lead to a noise and also to an unpleasant ride and can damage the vibration damper which is excited when passing through the resonance speed.

According to a further aspect of the present invention, therefore, a drive system for a motor vehicle is also provided which comprises an internal-combustion engine, a power train which is or can be coupled to the internal-combustion engine, at least one vibration damper arranged in the power train, a controller for controlling operation of components of the drive system as a function of a plurality of control parameters, an internal-combustion engine stoppage detecting device for detecting termination of operation of the internal-combustion engine and for generating a stoppage signal and for supplying the stoppage signal to the controller as one of the control parameters, further generation of a driving torque by the internal-combustion engine being prevented after detection of the stoppage signal during a stoppage phase, an excitation preventer for at least partial prevention of vibration excitation of the at least one vibration damper, wherein the excitation preventer can be set into operation by the controller when the controller receives the stoppage signal.

For example, the excitation preventer can comprise a braking force generator, controllable by the controller, for generating a braking force which acts on the internal-combustion engine. Therefore, if the braking force generator is put into operation by the controller during the stopping phase, so a braking moment is exerted on the internal-combustion engine, this causes relatively rapid deceleration of the internal-combustion engine, i.e. a relatively rapid drop in its speed. Owing to the rapid drop in speed, the resonance speed range is accordingly passed through very rapidly so the excitation and stimulation of sympathetic vibrations is virtually impossible owing to the relatively short time of the engine speed in the resonance range.

For this purpose, for example, the braking force generator can comprise a pressure accumulator which can be operated by the controller after receiving the stoppage signal for storing a medium under pressure. Compression energy required for storing the medium under pressure can be provided by the internal-combustion engine. As already mentioned, this pressure accumulator can then advantageously also be used to generate an auxiliary force for the starter device in a starting phase.

In a further variation, the excitation preventer can be designed to reduce a rotational resistance of the internal-combustion engine and/or to reduce a rotational mass inertia of the internal-combustion engine coupled to the power train. As a result of these measures, the kinetic energy still present in the internal-combustion engine during the drop in speed or the inertial mass helping to excite the vibrations can be reduced.

For this purpose, the excitation preventer can comprise, for example:

a) a decompression valve mechanism controllable by the controller, and/or

b) a crankshaft decoupling device controlled by the controller for the decoupling of a part of a crankshaft of the internal-combustion engine and the cylinders allocated to this part from the power train, and/or

c) an inlet/outlet valve mechanism which can be coupled/decoupled by the controller, and/or

d) an inertial mass device which can be coupled to and decoupled from the power train by the controller,

wherein, in the stoppage phase, the controller opens at least one valve of the decompression valve mechanism and/or decouples the part of the crankshaft from the power train and/or decouples at least a proportion of the inlet valves/outlet valves from the inlet/outlet valve mechanism and preferably keeps them in an open state and/or decouples the inertial mass device from the power train.

The stoppage signal can be generated, for example, after detection of an actuation of an ignition lock mechanism in the sense of a termination of operation of the internal-combustion engine.

The at least one vibration damper can comprise a torsional vibration damper, preferably a dual mass flywheel coupled to the crankshaft of the internal-combustion engine.

The present invention also relates to a method of operating an internal-combustion engine which is or can be coupled to a power train, wherein at least one vibration damper is provided in the power train. In one aspect the method comprises in a starting phase of the internal-combustion engine, the prevention of ignition thereof until a speed of the internal-combustion engine is higher than a resonance speed or a resonance speed range in which the excitation of sympathetic vibrations in the at least one vibration damper is expected.

In another aspect the method comprises in an operating phase of the internal-combustion engine, the at least partial reduction of the power output of the internal-combustion engine when the speed of the internal-combustion engine drops below a predetermined threshold value.

In a further aspect the method comprises detecting an operational termination phase of the internal-combustion engine, and effecting rapid deceleration of the internal-combustion engine and/or reduction of the mass inertia coupled to the power train of the internal-combustion engine and/or reduction of the rotational resistance of the internal-combustion engine.

The present invention avoids the occurrence of sympathetic vibrations using components which are already present in various drive systems. In particular, by suitable design of the controller which is already provided in modern drive systems to control a plurality of components of the drive system, the internal-combustion engine or other components of the drive system can be influenced in such a way that the generation of vibrations is avoided. As already described hereinbefore, various other systems or components of the drive system which can be controlled by the controller, if they are already provided, can be incorporated in such control to enable effects which help to avoid the excitation of sympathetic vibrations.

It is pointed out that the term "control" used in the present description and claims should be interpreted not only as a control intervention without corresponding feedback but also any type of regulating interaction between a controlling and a controlled system in the sense of open- or closed-loop control.

The invention may be understood more readily, and various other aspects and features of the invention may become apparent, from consideration of the following description.

Embodiments of the present invention will now be described hereinafter, by way of examples only, with reference to the accompanying drawings, wherein:

Figure 1 is a block diagram of a drive system constructed in accordance with the invention;

Figures 2 to 4 are graphical representations of rotation speed with time in various operating phases, on the secondary side of a torsional vibration damper of the drive system;

Figure 5 shows the trend of a magnification function used in the system; and

Figures 6 and 7 are graphical representations which show the current and voltage trend with time in a starter motor power regulating device used in the system.

The present invention deals with the problem of vibration excitation in a torsional vibration damper. As already mentioned at the outset, torsional vibration dampers are designed with respect to their resonant frequencies such that these frequencies are located as far as possible from a normal operating state, i.e. a normal operating speed. With known torsional vibration dampers, the resonant speeds generally lie in the range of 250 to 330 revolutions per minute so a safety interval to an idling speed is provided which lies in the range between 700 and 900 revolutions per minute. However, as the ignition speed also lies in the range of the resonance, very robust frictional devices have to be provided in such torsional vibration dampers to prevent the torsional vibration dampers entering end stop positions, in which they can be damaged, in the starting phase during which resonances can still be excited. Embodiments of the present invention in which these problems are eliminated are described hereinafter.

A drive system 10 for a motor vehicle is initially described quite generally with respect to Figure 1. The drive system 10 comprises an internal-combustion engine 12 which can be, for example, a multi-cylinder internal-combustion engine with two, three, four or more cylinders. For convenience only one cylinder 14 is shown in Figure 1. A piston 16 is displaceably mounted in the cylinder 14. The piston 16 is connected to a crankshaft 20 by a connecting rod 18 only indicated schematically in the drawing, in order to set the crankshaft 20 into rotation. An inlet/outlet valve mechanism 22 which has at least one inlet valve 24 and at least one outlet valve 26 for the cylinder 14 is provided in an upper region of the cylinder 14. A butterfly valve 30 is provided in an air inlet duct 28 leading to the valve 24. At least one spark plug 32 is also arranged in the upper region of the cylinder 14. A fuel injection valve 33 which injects fuel into the cylinder, i.e.

the combustion chamber in the cylinder, is provided for supplying fuel. The internal-combustion engine 12 also comprises a decompression valve which is generally designated by 46 in the cylinder 14, the operation of which will be described hereinafter. The injection valve 33 can also be arranged in the region of the inlet duct 28 or a region of the cylinder 14 separated in the manner of a preliminary chamber and can be designed as a carburettor.

A dual mass flywheel 34 is rotationally engaged with the crankshaft 20 of the internal-combustion engine 12 and comprises a first output mass component 36 and a second input mass component 38. The two mass components 36, 38 are mounted on one another, for example by helical springs, and can therefore oscillate relative to one another round an axis of rotation A. A motor vehicle friction clutch 40 of known design can be rotationally engaged with the first mass component 36. On the output side, the clutch 40 is connected to gearing 42 which drives the driving unit, for example the driving wheels 44 of the vehicle.

A starter motor 48 for accelerating the internal-combustion engine 12 to an ignition speed is also coupled to the crankshaft 20, the starter motor 48 drawing its energy from a battery 50. At the other end of the crankshaft 20, the crankshaft is coupled to a dynamo 52, which is used, for example, for providing the energy for driving various accessory units.

This above-described drive system 10 is subjected to the open- or closed-loop control by means of a controller 54. The controller 54 controls the operation of the injection valve 33 and subjects the valve 30 to open- or closed-loop control. A throttle opening sensor 56 is provided by means of which the controller 54 receives information about the instantaneous degree of opening of the butterfly valve 30. The controller 54 also transmits an ignition command to an ignition system 58 which then generates the ignition voltage for the spark plug or each spark plug 32. The injection process is then initiated in a similar manner in diesel engines. The inlet/outlet valve mechanism 22 is connected via a valve actuator 60 to the controller 54. It is therefore possible, for example, after appropriate delivery of commands by the controller 54, for the valve actuator 60 to actuate only one of a plurality of inlet or outlet valves in each cylinder or/and only the valves of specific cylinders and to keep the valves of other cylinders in an open or closed state.

The controller 54 accordingly controls the decompression valve 56 via an actuator 62 for opening or closing, as described hereinafter. As also described hereinafter, the dynamo 52 and the starter motor 48 are also controlled by the controller 54. The crankshaft 20 itself can be controlled by the controller 54 if it is a crankshaft which can be split into several parts, in which a part of the crankshaft and therefore the cylinders coupled to this part can be decoupled from the power train 25 by opening a clutch. The dual mass flywheel 34 is also connected to the controller 54. On the one hand, the speed of the dual mass flywheel 34 which corresponds to the speed of the internal-combustion engine, is input into the controller 54 as a control parameter by a speed sensor 64. On the other hand, the dual mass flywheel 34 is controlled by the controller 54 in such a way that, as a function of specific operating states, for example a part of the second mass component 38 can be decoupled from the power train 25 in order to reduce the entire mass inertia of the power train 25.

Although not shown in the drawings, the internal-combustion engine 12 can also comprise a so-called changeover induction manifold in the air inlet system, which has a plurality of pipe resonance portions which can be connected or disconnected by appropriate flaps which are in turn controlled by the controller 54. A resonance in the inlet air column, which assists the introduction of air through the throttle device can be generated in the air inlet system by appropriate connection or disconnection of the resonance portions. Furthermore, the flow resistance can be greatly reduced by opening the air inlet system to the environment immediately before the cylinder.

The operation of the drive system 10 is as follows: A starting phase will initially be described, i.e. a phase which begins, for example, after a driver has introduced an ignition key into an ignition lock and has turned it to start the internal-combustion engine 12 and which ends when an idling speed L has been attained after acceleration of the internal-combustion engine 12. A phase of this type is shown in Figure 2 which illustrates the time-dependent trend of the speed of the gear-side output component of the dual mass flywheel 34, i.e. of the first mass component 36 of the dual mass flywheel 34. The curve A is a curve which reproduces the trend of the speed in systems known from the state of the art, and the curve B is a curve which reproduces the speed trend with the drive system 10 and control method according to the invention.

After starting, the starter motor 48 is initially set into operation by the controller 54 so it drives the crankshaft 20 and the piston 16 in the cylinder 14. As the internal-combustion engine 12 is accelerated, a speed band R is initially attained which lies around a resonance speed N_R of the dual mass flywheel 34. This frequency range R extends, for example, from 250 to 330 revolutions per minute of the internal-combustion engine 12. If the internal-combustion engine 12 runs in such a speed range, the excitation of sympathetic vibrations in the dual mass flywheel 34 is expected owing to the power output, as shown by the curve A. In the state of the art, in which the ignition speed also lies in this speed range, robust friction devices therefore have to be provided in the dual mass flywheels and the dual mass flywheels themselves have to be very robust in design. The present invention accordingly proposes that the ignition speed N_Z be shifted from the band R and up toward higher speeds. For example, the ignition speed N_Z can lie in an ignition speed range Z of 300 to 500, preferably 400 to 450 revolutions per minute of the internal-combustion engine 12. There is then an adequate safety interval between the resonance speed range R and the ignition speed range Z so, as shown by the curve B in Figure 2, the excitation of resonances can be almost completely prevented during the starting process.

With the drive system 10 according to the invention, therefore, the ignition conditions for the internal-combustion engine 12 are only provided on the controller 54 on attainment the ignition speed range Z or the ignition speed N_Z. The ignition conditions initially involve the presence of an ignitable mixture, i.e. the composition of the mixture must lie within the ignition limits. Externally ignited fuels of the type used, for example, in Otto engines, ignite only in very close limits of the air and fuel mixture so suitably metered control of the air supply through the respective butterfly valve 30 and the fuel supply through the injection valve 33 under the control of the controller 54 ensure that an ignitable mixture is present at the entrance into the ignition speed range Z. With self-igniting fuels, of the type used in diesel engines, ignition takes place in a substantially wider range so control is carried out here essentially via the metering of the injected fuel quantity and it is no longer necessary to throttle the air supply. The ignition conditions also demand that the necessary ignition temperature is attained at least at one point in the ignitable mixture. This is achieved in Otto engines by generating an ignition spark via the spark plugs 32, again under the control of the controller 54. With diesel engines, the ignition temperature is attained without additional energy, i.e. without introduction of an igniting spark owing to the compression of the mixture.

If the speed signal supplied to the controller 54 by the speed sensor 64 indicates that the ignition speed range Z is attained, the ignition conditions are adjusted by the controller 54, i.e. a suitable ignitable mixture is introduced into the respective cylinders or generated therein and a suitable ignition temperature is generated by spark generation in Otto engines. With diesel engines, the decompression valve 46 can additionally be kept open in each of the cylinders 14 under the control of the controller 54 in a speed state in which the ignition speed range Z is not attained, so, owing to the lack of compression, the mixture or the air introduced into the cylinders 14 cannot yet ignite. The decompression valve 46 is only closed by the controller 54 on attainment of the ignition speed N_Z or of the ignition speed range Z so ignition can take place.

The displacement of the ignition speed N_Z or of the ignition speed range Z to higher speeds has further advantages, in addition to the advantage of avoiding vibration excitation of resonances in conventional dual mass flywheels. For example, it is possible to use dual mass flywheels of which the resonance speed is higher, for example at N_{Ra} in Figure 2. As the resonance frequency does not have to be kept so low with these dual mass flywheels as in the state of the art, the dual mass flywheels can be optimized with respect to their vibration damping function for higher speed ranges in which vibration excitation is expected in the power train. It is also possible with such an upwardly shifted ignition speed to use dual mass flywheels in internal-combustion engines with few cylinders, for example, three cylinders, for which dual mass flywheels could not be developed in the past. As the excitation of sympathetic vibrations is not expected in practice in the starting phase, the very robust friction devices formerly required can be dispensed with so, on the one hand, better vibration damping behaviour of the dual mass flywheels in other speed ranges can be achieved and, on the other hand, considerable cost savings can be made.

It is pointed out here that the upward displacement of the ignition speed, i.e. the arrangement of the ignition speed or the ignition speed range above the resonance speed range in a multi-cylinder internal-combustion engine does not necessarily have to be carried out for all cylinders. For example, it is also possible to carry out ignition at a conventional ignition speed for a few cylinders and to set the ignition speed at higher values for other cylinders. The basic principle is therefore achieved that the power output of the internal-combustion engine is at least reduced in the range of the resonance speed in the starting phase. This has the advantage, on the one hand, that the excitation of sympathetic vibrations can be avoided owing to the reduced power output and, on the other hand, additional measures do not have to be taken to enable the internal-combustion engine to be accelerated to relatively high ignition speeds by means of a starter motor owing to the power output of the internal-combustion engine available in this speed range.

Operation of the drive system according to the invention during normal operation, of the internal-combustion engine 12, i.e. operation in which the engine 12 normally rotates above the idling speed L is described hereinafter. During operation of this type, it may happen, for example, that the speed of the internal-combustion engine 12 will be massively depressed owing to a gear-change error by the driver and falls well below the idling speed L. This may be the case, for example, when parking if the driver changes from the second to the third gear rather than from the second to the first gear. In normal operation of the internal-combustion engine 12 of this type, the speed of the internal-combustion engine 12 can drop so much that it in turn drops into the range of the resonance speed N_R in which the excitation of sympathetic vibrations is expected in the vibrating system consisting of internal-combustion engine 12 and dual mass flywheel 34. This is in turn shown in Figure 3 by the curve A reproducing a speed trend in the state of the art. When the engine speed is depressed and the resonance speed N_R is approached, there again occur massive sympathetic vibrations which formerly necessitated damping measures. According to the present invention, it is now ensured in such a case that measures are taken by the controller 54 to prevent the occurrence of sympathetic vibrations.

A first possible measure is that, when the speed falls below a shut-off speed N_a the controller 54 ensures the power output of the internal-combustion engine 12 is completely prevented, i.e. the controller 54 again ensures that the ignition conditions are not satisfied. For example, fuel injection and/or the supply of air and/or the generation of sparks are prevented. As a result, the resonance speed range or the resonance speed is passed through in such a state without power output by the internal-combustion engine 12 and therefore without significant excitation of sympathetic vibrations, and the internal-combustion engine 12 finally comes to a standstill (trend B1). Although this measure demands that the internal-combustion engine has to be restarted after such a gear-change error by the driver, great protection against the excitation of vibrations is provided so safety measures, for example friction devices or the like, do not have to be provided for such a state of speed depression of the internal-combustion engine.

According to a second possible measure, the power output of the internal-combustion engine 12 is only partially reduced by the controller 54. This can be achieved, for example, in that the ignition conditions are satisfied only in a proportion of the cylinders and a further proportion of the cylinders does not contribute to the power output, or a part of the crankshaft with the associated cylinders is decoupled from the power train so only a proportion of the cylinders again contributes to the power output in the power train. As the power output of the internal-combustion engine can be reduced so far in such a state that it merely suffices to increase the engine speed to the idling speed again and beyond the shut-off speed N_a, the excitation of vibrations is also almost completely avoided. This state is illustrated in Figure 3 by the broken line B2. It is mentioned here that a variety of other measures can be taken to reduce the output of the internal-combustion engine 12. For example, it is possible for the mixture to be rendered very lean or super-fat so only one of, for example, two injection valves of each cylinder is opened, or the like. It is also possible to decouple a part of the inertial mass of the dual mass flywheel 34 by means of the controller 54 so the vibration excitation energy existing on account of the kinetic inertial energy in the internal-combustion engine or in the power train can be reduced as far as possible. The power output can also be reduced by changing the ignition cycle in the cylinders, i.e. every other ignition is omitted, this measure being carried out in a proportion of or in all cylinders.

The shut-off speed N_a proposed for normal operation is preferably higher than the ignition speed N_z, for example higher than the ignition speed N_z by a factor of 1.4. This is for the following reason. As shown in Figure 5, which illustrates a magnification function for the sympathetic vibrations, the excitation falls markedly above the resonance frequency f_R at which the condition η = exciting frequency Ω/inherent frequency $\omega_o = 1$ is fulfilled. The ignition frequency f_z and the shut-off frequency f_a now lie in this decay phase designated by k. In the starting phase, the system moves along the magnification curve from left to right, as viewed in Figure 5, i.e. moves in a very markedly falling direction of the magnification curve. In other words, the ignition frequency f_z can be placed closer to the peak amplitude at the inherent frequency of the vibrating system as a further movement away from the peak amplitude takes place until the moment when the internal-combustion engine 12 actually ignites. During engine depression, however, a movement takes place along the amplitude curve to the peak amplitude. In other words, it must be ensured at an early stage that the ignition conditions are no longer fulfilled to avoid entering a relatively high range of excitation owing to the inertia of the system despite an initiated, at least partial reduction of the power output. For this reason, the shut-off frequency f_a and therefore also the shut-off speed N_a is higher than the ignition frequency f_z and therefore the ignition speed N_Z.

A further state in which it is possible to excite vibrations in the torsional vibration damper is the stopping phase of the internal-combustion engine. The stopping phase is initiated when, for example, the driver actuates the ignition key so as to switch off the internal-combustion engine 12 and ends when the speed of the internal-combustion engine 12 has dropped to zero. This state is illustrated in Figure 4 in which the curve A again shows the trend in the state of the art and the curve B the trend with the drive system 10 according to the invention. After actuation of the ignition key to switch off the internal-combustion engine 12, the ignition conditions are spontaneously prevented, i.e. the controller 54 ensures that the internal-combustion engine 12 does not ignite again from this moment. During a drop in speed, the resonance speed range or the resonance speed is again passed through. As there is still kinetic energy in the internal-combustion engine 12 owing to the mass inertia of the rotating crankshaft or the rotating power train, a sympathetic vibration can still be generated in the dual mass flywheel 34 by the oscillating forces of inertia and gas of the engine but this does however have much lower amplitudes than when the internal-combustion engine ignites. To prevent such excitation in the stopping phase, various measures are proposed according to the present invention which minimize the vibration excitation in the dual mass flywheel 34. These measures can be split into two categories, a first category of measures which ensure that the resonance frequency range is passed through as rapidly as possible in the stopping phase and a second category of measures which ensure that the kinetic energy still present in the internal-combustion engine or in the drive system can make the minimum contribution to vibration excitation. These measures will be described hereinafter in conjunction with a further aspect of the present invention which concerns acceleration of the internal-combustion engine 12 to the ignition speed or to the ignition speed range by the starter motor in the starting phase.

Conventional starter motors provided in internal-combustion engines are generally designed so they can rotate the internal-combustion engine roughly to the ignition speed or slightly higher. As the ignition speed lies in the range of the resonance speed, that is in the range of 250 to 330 revolutions per minute of the internal-combustion engine, in known systems, the starter motors provided for these internal-combustion engines are also designed with respect to their power output in such a way that they can accelerate the internal-combustion engine to this speed range. In order to obtain a higher speed range in accordance with the present invention, namely in the range of 400 to 550 revolutions per minute, one possible measure involves using a more powerful starter motor. For example, starter motors which are normally used in six cylinder engines can be employed for four cylinder internal-combustion engines. However, this is not always desirable for reasons of cost as these high power starter motors lead to correspondingly higher costs. A few measures are mentioned hereinafter which, in conjunction with conventional starter motors, i.e. starter motors designed to accelerate merely to the formerly required ignition speeds, allow the attainment of the higher ignition speeds in accordance with the present invention.

A first measure is the reduction of friction or inertia in the driving system during the starting phase. In other words, parts of the internal-combustion engine 12 not absolutely essential for ignition are brought to a standstill in the starting phase. Thus, a part of the crankshaft 20 and the associated cylinders 14 can be decoupled, for example, by the controller 54; parts of the inlet/outlet valve mechanism 22 can be brought to a standstill and only a few valves which permit ignition of the engine can be set into operation. Therefore, it is not necessary to drive the stationary components of the internal-combustion engine 12 so, on the one hand, the supply of kinetic energy can be reduced and, on the other hand, the friction occurring in these ranges in the starting phase do not contribute to a braking power. It is also possible to displace the changeover induction manifold discussed hereinbefore into a state in which an increased supply of air can be provided by the generation of resonances in the inlet region. At the same time, all these measures also help to reduce consumption and can be used without additional constructional measures merely on the basis of the appropriate design of the controller 54 in internal-combustion engines 12 equipped with crankshaft portions and the like which can be coupled and decoupled in this way. These are also measures which can help, during the above-mentioned stopping phase, to minimize vibration excitation in the dual mass flywheel 34. For example, if all valves are in fact kept in an open state or/and if a part of the crankshaft 20 is decoupled from the power train, on the one hand the inertial mass coupled to the dual mass flywheel 34 is reduced and, on the other hand, a contribution by the interaction of force between these disconnected components and other components of the internal-combustion engine 12 is avoided.

A further measure for reducing the torque to be generated by the starter motor 48 when starting the internal-combustion engine 12 is to keep the decompression valve 46 open by means of the controller 54 below the ignition speed. While ignition is to be avoided, this also helps to prevent compression of air contained in the cylinders 14 which otherwise contributes to a pronounced increase in the torque to be provided by the starter motor 48. Keeping the decompression valve 46 open during the stopping phase can accordingly also help to reduce the excitation of vibration in the dual mass flywheel 34.

A further measure for reducing the necessary torque of the starter motor 48 is appropriate control of the valve actuator 60 for the inlet/outlet valves 24, 26 such that, for example below the ignition speed, all valves are kept in an open state and/or the camshaft is simultaneously decoupled from the power train. This also helps to reduce the friction and the kinetic energy to be supplied. It is pointed out here that only a few of the valves need be decoupled and kept in an open state. This measure can also be used in the stopping phase to reduce vibration excitation in the dual mass flywheel 34.

A further measure is the controlled decoupling of a proportion of the inertial mass, for example of the dual mass flywheel 34. The second mass component 38 can, for example, comprise several individual mass parts of which at least one can be decoupled from the power train under the control of the controller 54. If a mass part which can be decoupled in this way is decoupled from the power train before the ignition speed is attained, the kinetic energy to be supplied can in turn be reduced and the mass moment of inertia to be overcome by the starter motor 48 can be clearly reduced. After attainment of the ignition speed and ignition, this mass can again be coupled to the power train so the desired vibration damping characteristics of the dual mass flywheel 34 can be provided.

Suitable control of a conventional starter motor 48 by means of the controller 54 can also be used to generate the necessary high speed of the starter motor 48. This is described hereinafter with reference to Figures 6 and 7. The maximum torque which can be generated by the starter motor 48 depends on the power provided by the battery 50. In an initial portion A1 of the starting phase in which relatively high torques are initially required because all the components of the internal-combustion engine initially have to be set into motion and a high breakaway torque has to be overcome and in which the starter motor 48 has a relatively low speed, a relatively high current I flows at relatively low voltage U, as shown in Figures 6 and 7, and the torque delivered by the starter motor 48 increases with the current I. However, as the speed N of the internal-combustion engine 12 increases, the frictional moments to be overcome and the torque required also fall accordingly and, as shown in Figures 6 and 7, this leads to a reduction in the current I. As the starter motor 48 no longer completely utilizes the power provided by the battery 50 in an average speed range of this type, the battery voltage is transformed up in a second portion A2 of the starting phase. As shown in Figure 6, this can be carried out abruptly at a changeover speed N_S. For this purpose, a chopper circuit is provided which initially generates an a.c. voltage from the d.c. battery voltage. This a.c. voltage can be transformed up by a transformer and converted into a higher d.c. voltage by a subsequent rectifier so, as shown on the right of the changeover speed N_S in Figure 6, there is a higher voltage value. The speed of the starter motor 48 increases with the voltage U so higher speeds than hitherto, which attain the ignition speed N_Z and even the idling speed can now be achieved owing to the higher voltage and owing to the torque which is to be output and is reduced at higher speeds with a conventional starter motor.

Instead of providing a defined changeover speed, a sliding transition of the voltage U by appropriate open- or closed-loop control can be carried out accordingly by means of the controller 54 which leads to a gradual increase in the voltage U, as shown in Figure 7, and, as in the above-described embodiment, enables higher speeds to be achieved with a conventional starter motor. With the embodiment shown in Figure 7, a controllable or switchable transformer with a variable transmission ratio is adopted.

A further method of assisting the starter motor 48 in the starting phase is to provide auxiliary drive units. This may be, on the one hand, an appropriately designed dynamo 52 which is switched by the controller 54 to assist the starter motor 48 in the starting phase in such a way that it is operated in the manner of an electric motor and therefore generates an additional assisting torque.

It is also possible to use a separate drive machine as an auxiliary drive unit. This may be, for example, a compressor of known design which is driven by an electric motor, for example the dynamo. It is also possible to provide a pressure accumulator which, in the starting phase, delivers medium which is stored under pressure and can generate an auxiliary torque in conjunction with a turbine. The medium stored under pressure can also be introduced directly into the cylinders 14 and can therefore have a driving effect on the piston. Furthermore, the electric starter motor 48 can also be equipped directly with a pneumatic part for introducing the flow energy of the medium under pressure, for example a turbine wheel on its drive shaft, so the auxiliary torque generated by the medium under pressure is introduced directly into the driving path of the starter motor 48. It is also possible to provide a turbine or a piston engine which receives the pressure medium and acts directly on the power train of the drive system 10 in parallel with the starter motor 48.

The exhaust gas which is produced by the internal-combustion engine 12, can be removed from the exhaust system and stored in a pressure accumulator. This process can advantageously also be used to minimize the vibration excitation of the dual mass flywheel 34 in the stopping phase. If the pressure accumulator is in fact operated by the controller 54 in such a way that it is open for storage purposes when the internal-combustion engine 12 is switched off and therefore stores gas ejected from the internal-combustion engine during the last strokes as pressure medium, the energy needed for compression for storage purposes is removed directly from the drive system, i.e. the internal-combustion engine 12 itself delivers the energy required for storing the pressure medium as a gas-ejecting unit. This in turn leads to a rapid reduction in the speed of the internal-combustion engine so the resonance range is passed through very rapidly and the excitation of vibrations is almost impossible owing to the inertia of the dual mass flywheel 34.

To ensure that adequate medium under pressure is available in the starting phase so an adequately long starting process can be carried out even if the internal-combustion engine 12 starts poorly, the pressure accumulator can be constructed, for example, in such a way that it comprises several chambers of which at least a few are charged during normal operation of the internal-combustion engine 12 whereas a few are only charged in the stopping phase and therefore help to decelerate the internal-combustion engine 12. The charging of the pressure accumulator can also be carried out just after starting the engine or, for example, during braking processes so the exhaust gas stream is conveyed at least partially into the pressure accumulator during these braking processes and an increased engine braking effect can therefore be achieved.

A pressure relief valve can be provided on the pressure accumulator to ensure that the pressure medium is not excessively compressed.

It is pointed out that different devices can be provided for decelerating the internal-combustion engine 12 which are set into operation on initiation of the stopping phase. For example, friction devices resembling friction brakes or the like can be provided so as to act in the power train or on the crankshaft 20, and generate a frictional moment when the internal-combustion engine 12 is switched off and therefore lead to more rapid deceleration.

The present invention provides a plurality of measures which can help, individually or in conjunction with one another, to reduce or prevent the excitation of sympathetic vibrations in a vibration damper in the power train. Many of the measures according to the invention can be provided or integrated in existing internal-combustion engines 12 as they comprise a suitable open- or closed-loop control effect owing to the already provided controllers on components which are also already provided. This allows very inexpensive conversion of existing or developed systems. The provision of various measures for increasing the speed of the starter motor also contributes, independently of the aspect of the invention concerned with the reduction of resonance excitation, to a reduction in the cost of drive systems, as light-weight starter motors with a lower power output can be used. It is therefore pointed out that the above-described measures which help to reduce the torque to be generated by the starter motor or which enable a smaller starter motor to attain a higher speed form an independent aspect of the present invention.

Claims

1. Drive system for a motor vehicle, comprising an internal-combustion engine (12), a power train (25) which is coupled to or can be coupled to the internal-combustion engine (12) and contains at least one vibration damper (34), a controller (54) for controlling operation of components of the drive system (10) as a function of a plurality of control parameters and a speed sensor (64) for generating a signal dependent on the speed of the internal-combustion engine (12) which is supplied to the controller (54) as one of the control parameters; wherein the controller (54) serves to prevent ignition of the internal-combustion engine (12) in a starting phase thereof until the speed of the internal-combustion engine (12) detected by the speed sensor (64) is higher than a resonance speed (N_R) or a resonance speed range (R), in which the excitation of sympathetic vibrations of said at least one vibration damper (34) is expected.

2. Drive system according to claim 1, wherein the controller (54) is designed to prevent ignition of the internal-combustion engine (12) until the detected speed of the internal-combustion engine (12) corresponds to a predetermined ignition speed (N_Z) or lies in a predetermined ignition speed range (Z) and a predetermined interval is provided between the resonance speed (N_R) or the resonance speed range (R) and the ignition speed (N_Z) or the ignition speed range (Z).

3. Drive system according to claim 2, wherein the ignition speed (N_Z) lies in the range of 300 to 500, preferably in the range of 400 to 450, revolutions per minute of the internal-combustion engine (12).

4. Drive system according to claim 2 or 3, wherein the predetermined interval has a range of 70 to 250, preferably 120 to 200 revolutions per minute of the internal-combustion engine (12).

5. Drive system for a motor vehicle, comprising an internal-combustion engine (12), a power train (25) which is coupled to or can be coupled to the internal-combustion engine (12), at least one vibration damper (34) arranged in the power train (25), a controller (54) for controlling operation of components of the drive system (10) as a function of a plurality of control parameters, and a speed sensor (64) for generating a signal dependent on the speed of the internal-combustion engine (12) which is supplied to the controller (54) as one of the control parameters, wherein the controller (54) serves to reduce the power output of the internal-combustion engine (12) at least in part during an operating phase of the internal-combustion engine (12) when the speed detected by the speed sensor (64) of the internal-combustion engine (12) is lower than a predetermined threshold speed (N_a), the threshold speed (N_a) being higher than a resonance speed (N_R) or a resonance speed range (R) in which the excitation of sympathetic vibrations of the at least one vibration damper (34) is expected.

6. Drive system according to claim 5, wherein the threshold speed (N_a) has a predetermined interval from the resonance speed (N_R) or from the resonance speed range (R).

7. Drive system according to claim 6, wherein the predetermined interval has a range of 100 to 300, preferably 150 to 250 revolutions per minute of the internal-combustion engine (12).

8. Drive system according to any one of claims 5 to 7, wherein the threshold speed (N_a) is higher than an ignition speed (N_Z) or

an ignition speed range (Z) of the internal-combustion engine (12).

9. Drive system according to any one of claims 5 to 8, wherein the controller (54) serves to prevent ignition of the internal-combustion engine (12) completely when the speed of the internal-combustion engine (12) falls below the threshold speed (N_a).

10. Drive system according to any one of claims 5 to 8, wherein the controller (54) serves partly to prevent ignition of the internal-combustion engine (12) when the speed of the internal-combustion engine falls below the threshold speed (N_a).

11. Drive system according to claim 10, wherein the internal-combustion engine (12) has a plurality of cylinders (14) and the controller (54) serves to prevent ignition in a proportion of the cylinders (14) when the speed of the internal-combustion engine falls below the threshold speed (N_a).

12. Drive system according to one of claims 1 to 11, wherein the controller (54) serves to prevent ignition by preventing the presence of ignition conditions.

13. Drive system according to one of claims 1 to 12, and further comprising a fuel injector (33) and/or a throttle (30) which can be controlled by the controller (54), the controller (54) preventing ignition by at least partially preventing fuel injection through the fuel injector (33) and/or variation of the throttle.

14. Drive system according to one of claims 1 to 13, and further comprising a spark ignition system (32, 58) which is controlled by the controller (54), the controller (54) preventing ignition by preventing the generation of sparks.

15. Drive system according to one of claims 1 to 14, and further comprising an inlet valve control mechanism (22, 60) which is controlled by the controller (54), the controller (54) preventing ignition by keeping at least a proportion of the inlet valves (24) of the internal-combustion engine (12) closed.

16. Drive system according to one of claims 1 to 15, and further comprising a decompression valve control mechanism (46, 62) which is controlled by the controller (12) for at least one cylinder (14) of the internal-combustion engine (12), the controller (54) preventing ignition by opening at least one valve (46) of the decompression valve mechanism (46, 62).

17. Drive system according to claim 16, wherein the decompression valve mechanism is an inlet/outlet valve mechanism of the internal-combustion engine.

18. Drive system according to one of claims 1 to 17, and further comprising a starter motor (48) which can be controlled by the controller (54) in order to accelerate the internal-combustion engine (12) during the starting phase at least to the ignition speed (N_Z) or to the ignition speed range (Z).

19. Drive system according to claim 18, wherein the controller (54) serves to keep the starting torque which is to be generated by the starter motor (48) low in the starting phase.

20. Drive system according to claim 18 or 19, and further comprising:

a device for the decoupling/coupling of the crankshaft of the internal-combustion engine (12), the device being controlled by the controller (54), for decoupling a part of a crankshaft (20) of the internal-combustion engine (12) and the cylinders (14) cooperating with this part from or to the power train (25), and/or

an inlet/outlet valve mechanism (22, 60), at least a proportion of the inlet and/or outlet valves (24, 26) being controlled by the controller (54), and/or

a changeover induction manifold mechanism for selective opening to the environment and controlled by the controller (54), to establish at least one intake manifold resonance portion, and/or

a venting valve mechanism (46), controllable by the controller (54), in at least one cylinder (14) of the internal-combustion engine (12), and/or

an inertial mass device (38) which can be coupled to and decoupled from the power train (25) by the controller (54),

wherein the controller (54), in the starting phase, decouples a part of the crankshaft (20) and/or decouples a proportion of the inlet and/or outlet valves (24, 26) and preferably keeps them in an open state and/or brings the changeover induction manifold mechanism into an intake dethrottling resonance state and/or brings the venting valve mechanism (46, 62) into an open state and/or decouples the inertial mass device (38) from the power train.

21. Drive system according to one of claims 18 to 20, and further comprising a starting torque assisting device (52).

22. Drive system according to claim 21, wherein the starting torque assisting device comprises:

a) a dynamo (52) which can be operated for driving the internal-combustion engine, and/or

b) an accumulator device for storing a medium under pressure and for delivering the medium under pressure in the starting phase for providing an auxiliary driving force, and/or

c) a starter regulating device for providing a first starter operating voltage during a first starting phase portion (A1) and for providing a second starter operating voltage which is higher than the first starter operating voltage during a second portion (A2) of the starting phase.

23. Drive system for a motor vehicle, comprising an internal-combustion engine (12), a power train (25) which is coupled to or can be coupled to the internal-combustion engine (12), at least one vibration damper (34) arranged in the power train (25), a controller (54) for controlling operation of components of the drive system (10) as a function of a plurality of control parameters, an internal-combustion engine stoppage detecting device for detecting termination of operation of the internal-combustion engine (12) and for generating a stoppage signal and for supplying the stoppage signal to the controller (54) as one of the control parameters, further generation of a driving torque by the internal-combustion engine (12) being prevented after detection of the stoppage signal during a stoppage phase, an excitation preventer for at least partial prevention of vibration excitation of the at least one vibration damper (34), wherein the excitation preventer can be set into operation by the controller (54) when the controller (54) receives the stoppage signal.

24. Drive system according to claim 23, wherein the excitation preventer comprises a braking force generator, controllable by the controller (12), for generating a braking force which acts on the internal-combustion engine (12).

25. Drive system according to claim 24, wherein the braking force generator comprises an accumulator device which can be operated by the controller (54) after receiving the stoppage signal for storing a medium under pressure, the compression energy required for storing the medium under pressure being provided by the internal-combustion engine (12).

26. Drive system according to one of claims 23 to 25, wherein the excitation preventer is designed to reduce a rotational resistance of the internal-combustion engine (12) and/or to reduce a rotational mass inertia of the internal-combustion engine (12) coupled to the power train.

27. Drive system according to claim 26, wherein the excitation preventer comprises:

a) a decompression valve mechanism (46, 62) controllable by the controller, and/or

b) a crankshaft decoupling device for decoupling of a part of a crankshaft (20) of the internal-combustion engine (12) and the cylinders (14) allocated to this part from the power train (25) under the control of the controller (54), and/or

c) an inlet/outlet valve mechanism (22, 60) which can be coupled/decoupled by the controller (54), and/or

d) an inertial mass device (38) which can be coupled to and decoupled from the power train (25) by the controller (54),

wherein, in the stoppage phase, the controller (54) opens at least one valve of the decompression valve mechanism (46, 62) and/or decouples the part of the crankshaft (20) from the power train (25) and/or decouples at least a proportion of the inlet valves/outlet valves (24, 26) from the inlet/outlet valve mechanism and preferably keeps them in an open state and/or decouples the inertial mass device from the power train (25).

28. Drive system according to one of claims 23 to 27, wherein the stoppage signal is generated after detection of an actuation of an ignition lock mechanism in the sense of a termination of operation of the internal-combustion engine (12).

29. Drive system according to one of claims 1 to 28, wherein the at least one vibration damper (34) comprises a torsional vibration damper (34), preferably a dual mass flywheel (34) coupled to the crankshaft (20) of the internal-combustion engine (12).

30. A vehicle drive system substantially as described with reference to and as illustrated in Figure 1 of the accompanying drawings.

31. A method of operating an internal-combustion engine which is coupled to or can be coupled to a power train (25), containing at least one vibration damper (34) said method comprising: preventing complete ignition in the engine during a starting phase of the internal-combustion engine (12), until a speed of the internal-combustion engine (12) is higher than a resonance speed (N_R) or a resonance speed range (R) in which the excitation of sympathetic vibrations in the at least one vibration damper (34) is expected.

32. A method of operating an internal-combustion engine which is coupled to or can be coupled to a power train (25), containing at least one vibration damper (34) said method comprising: at least partially reducing the power output of the engine during an operating phase of the internal-combustion

engine (12), when the speed of the internal-combustion engine (12) drops below a predetermined threshold value (N_a).

33. A method of operating an internal-combustion engine which is coupled to or can be coupled to a power train (25), containing at least one vibration damper (34) said method comprising: causing rapid deceleration of the engine in an operation termination phase of the engine (12), and/or reduction of the mass inertia coupled to the power train (25) of the engine (12) and/or reduction of the rotational resistance of the engine (12).

34. A method of operating an internal-combustion engine substantially as described herein with reference to and as illustrated in Figure 1 of the accompanying drawings in configuration with any one of Figures 2 to 7 of the accompanying drawings.

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Other: Online: EPODOC, PAJ, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0819561 A2	(Toyota) see particularly page 1 line 47 - page 2 line 18	1, 12, 13, 15-18, 31
A	US 5632238	(Furukawa *et al*)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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