generated by an internal combustion engine 11 is supplied via a main transmission 13 (manual shift transmission or automatic transmission) to a two-axle differential gear 15. The two-axle differential gear 15 includes a coupling 16 in order selectively to lock the two-axle differential gear 15. A first output of the inter-axle differential gear 15 is coupled to a rear axle differential gear 19 via a Cardan shaft 17. The wheels 21 of the rear axle 23 are driven via it. A coupling 24 is associated with the rear axle differential gear 19 in order selectively to lock the rear axle differential gear 19. A second output of the inter-axle differential gear 15 is coupled to a rear axle differential gear 27 via a Cardan shaft 25. Some of the driving torque is transferred to the wheels 29 of the front axle 31 via it. A coupling 32 is associated with the front axle differential gear 27 in order selectively to lock the rear axle differential gear 27. The couplings 16, 24, 32 are clutches operative in form-fitting manner or friction-engaging manner.

Furthermore, a control unit 33 is shown in Fig. 1. It is connected to wheel speed sensors 35, 37 which are associated with the wheels 21 of the rear axle 23 or with the wheels 29 of the front axle 31. The control device 33 is furthermore connected to shaft speed sensors 38 for generating signals which represent the respective speed of the two outputs of the inter-axle differential gear 15, i.e. of the Cardan shaft 17 and of the Cardan shaft 25. The control device 33 is connected to further sensors 39, for example to a steering angle sensor, to a tilt sensor, to a yaw rate sensor and the like. The control device 33 generates control signals in dependence on the signals of the sensors 25, 37, 38, 39 to actuate the couplings 16, 24, 32 in order thereby to lock one or more of the differential gears 15, 19, 27. The shaft speed sensors 38 are not necessarily required to form shaft speed signals for the two outputs 17, 25 of the inter-axle differential gear 15. Instead, these shaft speed signals can also be derived from the signals of the wheel speed sensors 35, 37 of the respective axle 23, 31.

Claims

1. A method of controlling at least one coupling (16, 24, 32) in a powertrain of a motor vehicle, in particular of controlling at least one coupling operative in form-fitting manner of a differential lock of an off-road vehicle,
wherein at least the following steps are carried out in a respective calculation loop:
   - determining at least one slip value (SLP) which represents an instantaneous slip between different axles (23, 31) of the motor vehicle or between different wheels (21, 29) of an axle;
   - forming an absolute value of the slip value (SLP) which corresponds to the amount of the slip value;
   - summing the absolute value or a substitute value (RED) derived therefrom to a last-formed slip sum value to form an instantaneous slip sum value (SUM);
   - comparing the instantaneous slip sum value (SUM) with a slip sum threshold value (SUM-LIM); and
   - generating a control signal (CTL) for actuating the coupling (16, 24, 32) if the instantaneous slip sum value reaches or exceeds the slip sum threshold value.

2. A method in accordance with claim 1,
wherein on a first-time carrying out of the step of the summing, the absolute value or substitute value (RED) is preferably summed to a predefined starting value.

3. A method in accordance with claim 1,
wherein a check is made whether a slip oscillation is present, with the instantaneous slip sum value (SUM), the last-formed slip sum value or the slim sum threshold value (SUM-LIM) being modified if this is the case.

4. A method in accordance with claim 3,
wherein the slip sum value is multiplied by a weighting factor which has a value between zero and one for the modifying of the instantaneous or last-formed slip sum value (SUM);
or
wherein the slip sum threshold value is multiplied by a weighting factor larger than one for the modifying of the slip sum threshold value (SUM-LIM).

5. A method in accordance with claim 3,
wherein monitoring is carried out for the check of whether a slip oscillation is present whether the determined slip values (SLP) change sign at least once within a predefined time period or within a predefined number of calculation loops.

6. A method in accordance with claim 5,
wherein a positive and a negative response threshold value (SLP-LIM) are taken into account for the monitoring whether the determined slip values change sign at least once.

. A method in accordance with claim 5,
wherein a slip oscillation monitored value is increased by a predefined value if a sign change of the determined slip values is found, with the slip oscillation monitored value being reduced by a

predefined value when a predefined time interval or a predefined number of calculation loops has elapsed and with the presence of a slip oscillation being detected if the slip oscillation monitored value reaches or exceeds a slip oscillation threshold value.

8. A method in accordance with claim 1,
wherein the absolute value of the slip value (SLP) is compared with a slip response threshold value (SLP-LIM), with the absolute value being substituted by a substitute value (ABS) before or in the step of the summing which has the value zero or a negative value if the absolute value is smaller than the slip response threshold value (SLP-LIM).

9. A method in accordance with claim 8,
wherein the substitute value corresponds to a difference between the absolute value and the slip response threshold value if the absolute value is larger than the slip response threshold value.

10. A method in accordance with claim 1,
wherein the absolute value of the slip value or a substitute value (ABS) already derived herefrom is reduced by a slip reducing value before or in the step of summing to form a positive or negative substitute value (RED) on a case by case basis.

11. A method in accordance with claim 1,
wherein the absolute value of the slip value or a substitute value (ABS) already derived herefrom is compared with a slip reducing threshold value (ABS-LIM), with the absolute value or the substitute value (ABS) already derived herefrom being substituted by a substitute value (RED) having a negative sign before or in the step of

summing if the absolute value or the substitute value (ABS) already derived herefrom falls below the slip reducing threshold value (ABS-LIM).

12. A method in accordance with claim 1,
wherein the instantaneous slip sum value (SUM) is set to the value of the slip sum threshold value (SUM-LIM) if the instantaneous slim sum value exceeds the slip sum threshold value.

13. A method in accordance with claim 1,
wherein a check is made whether the instantaneous slip sum value (SUM) has a negative sign, with the instantaneous slip sum value being set to the value zero if this is the case.

14. A method in accordance with claim 1,
wherein a slip increase value is formed which represents a time gradient of a slip increase, with the absolute value or a substitute value already derived herefrom being substituted before or in the step of summing by a substitute value which corresponds to a product of the absolute value or the substitute value already derived herefrom, and of a slip increase weighting factor which depends on the slip increase value.

15. A method in accordance with claim 14,
wherein a difference between the absolute value formed in the instantaneous calculation loop and the absolute loop formed in a preceding calculation loop is formed for the forming of the slip increase value.

16. A method in accordance with claim 15,
wherein the named difference is divided by a value which represents the time duration between the preceding calculation loop and the instantaneous calculation loop.

17. A method in accordance with claim 14,
wherein the slip increase weighting factor is set to a positive value larger than one if the formed slip increase value represents a positive time gradient of a slip increase.

18. A method in accordance with claim 14,
wherein the slip increase weighting factor is selected to be the larger, the larger the slip increase value is.

19. A method in accordance with claim 1,
wherein the slip increase weighting factor is set to the value one if the slip increase value represents a slip decrease.

20. A method in accordance with claim 1,
wherein a check is made whether a slip oscillation is present, with the absolute value or a substitute value already derived herefrom being substituted if this is the case before or in the step of summing with a substitute value which corresponds to a product of the absolute value or the substitute value already derived herefrom, and of a slip oscillation weighting factor.

21. A method in accordance with claim 20,
wherein a monitoring is carried out for the check of whether a slip oscillation is present whether the determined slip values change

sign at least once within a predefined time period or within a predefined number of calculation loops.

22. A method in accordance with claim 21,
wherein a positive and a negative response threshold value are taken into account for the monitoring whether the determined slip values change sign at least once.

23. A method in accordance with claim 20,
wherein the slip oscillation weighting factor is set to a positive value unequal to one if it is detected that a slip oscillation is present, and wherein the slip oscillation weighting factor is set to the value one if it is found that no slip oscillation is present.

24. A method in accordance with claim 1,
wherein the coupling (16, 24, 32) is actuated for a predefined minimum holding duration in the closing direction in dependence on the generated control signal (CTL), with the coupling being biased in the opening direction and opening automatically as soon as the coupling is no longer actuated in the closing direction and no torque or only a small torque is transferred via the coupling.

25. A method in accordance with claim 1,
wherein a plurality of couplings (16, 24, 32) are provided in the powertrain of the motor vehicle, in particular a plurality of couplings operative in form-fitting manner of a respective differential lock; wherein, for some (24, 32) or all of the plurality of couplings, the steps are carried out in the respective calculation loop of determining at least one slip value (SLP1, SLP2) of the respective coupling; forming an absolute value of the slip value (SLP1, SLP2) of

the respective coupling; summing the absolute value or a substitute value (RED1, RED2) derived herefrom to a last-formed slip sum value for forming an instantaneous slip sum value (SUM1, SUM2) of the respective coupling; comparing the instantaneous slip sum value (SUM1, SUM2) with a slip sum threshold value (SUM1-LIM, SUM2-LIM) of the respective coupling; and generating a control signal (CTL1, CTL2) for actuating the respective coupling on reaching or exceeding the respective slip sum threshold value.

26. A method in accordance with claim 25, wherein some (24, 32) or all of the plurality of couplings are controlled independently of one another.

27. A method in accordance with claim 25, wherein different threshold values, different weighting factors and/or different minimum holding durations are used for controlling the plurality of couplings (16, 24, 32).

28. A method in accordance with claim 25, wherein the plurality of couplings include at least one coupling (16) of an inter-axle differential lock (15) and at least two couplings (24, 32) of a respective axle differential lock (19, 27), with at least the following steps being carried out for the coupling (16) of the inter-axle differential lock (15) in the respective calculation loop:

- determining at least one slip value (SLP3) which represents an instantaneous slip between different axles (23, 31) of the motor vehicle;
- forming an absolute value of the slip value (SLP3) which corresponds to the amount of the slip value;

- selecting a maximum value (RED3') from the absolute values formed for a group (16, 24, 32) of couplings in the respective calculation loop or from substitute values (RED1, RED2, RED3) derived herefrom;
- summing the maximum value (RED3') or a substitute value derived herefrom to a last-formed maximum slip sum value to form an instantaneous maximum slip value (SUM3') for the coupling (16) of the inter-axle differential lock (15);
- comparing the instantaneous maximum slip sum value (SUM3') with a maximum slip sum threshold value (SUM3'-LIM); and

generating a control signal (CTL3') for actuating the coupling (16) of the inter-axle differential lock (15) if the instantaneous maximum slip sum value reaches or exceeds the maximum slip sum threshold value.

29. A method in accordance with claim 28, wherein the selection of the maximum value (RED3') only takes place after a check has been made whether the absolute values formed in the respective calculation loop should be substituted by a respective substitute value and, if this is the case, after the respective absolute value has been substituted by the substitute value (RED1, RED2, RED3).

30. A powertrain of a motor vehicle having at least one coupling (16, 24, 32), in particular at least one coupling operative in form-fitting manner of a differential lock of an off-road vehicle, and having a control device which is designed to carry out at least the following steps in a respective calculation loop:

- determining at least one slip value (SLP) which represents an instantaneous slip between different axles (23, 31) of the motor vehicle or between different wheels (21, 29) of an axle;
- forming an absolute value of the slip value (SLP) which corresponds to the amount of the slip value;
- summing the absolute value or a substitute value (RED) derived herefrom to a last-formed slip sum value to form an instantaneous slip sum value (SUM);
- comparing the instantaneous slip sum value (SUM) with a slip sum threshold (SUM-LIM); and
- generating a control signal (CTL) for actuating the coupling (16, 24, 32) if the instantaneous slip sum value reaches or exceeds the slip sum threshold value.

generated by an internal combustion engine 11 is supplied via a main transmission 13 (manual shift transmission or automatic transmission) to a two-axle differential gear 15. The two-axle differential gear 15 includes a coupling 16 in order selectively to lock the two-axle differential gear 15. A first output of the inter-axle differential gear 15 is coupled to a rear axle differential gear 19 via a Cardan shaft 17. The wheels 21 of the rear axle 23 are driven via it. A coupling 24 is associated with the rear axle differential gear 19 in order selectively to lock the rear axle differential gear 19. A second output of the inter-axle differential gear 15 is coupled to a front axle differential gear 27 via a Cardan shaft 25. Some of the driving torque is transferred to the wheels 29 of the front axle 31 via it. A coupling 32 is associated with the front axle differential gear 27 in order selectively to lock the rear axle differential gear 27. The couplings 16, 24, 32 are clutches operative in form-fitting manner or friction-engaging manner.

Furthermore, a control unit 33 is shown in Fig. 1. It is connected to wheel speed sensors 35, 37 which are associated with the wheels 21 of the rear axle 23 or with the wheels 29 of the front axle 31. The control device 33 is furthermore connected to shaft speed sensors 38 for generating signals which represent the respective speed of the two outputs of the inter-axle differential gear 15, i.e. of the Cardan shaft 17 and of the Cardan shaft 25. The control device 33 is connected to further sensors 39, for example to a steering angle sensor, to a tilt sensor, to a yaw rate sensor and the like. The control device 33 generates control signals in dependence on the signals of the sensors 25, 37, 38, 39 to actuate the couplings 16, 24, 32 in order hereby to lock one or more of the differential gears 15, 19, 27. The shaft speed sensors 38 are not necessarily required to form shaft speed signals for the two outputs 17, 25 of the inter-axle differential gear 15. Instead, these shaft speed signals can also be derived from the signals of the wheel speed sensors 35, 37 of the respective axle 23, 31.

Claims

1. A method of controlling at least one coupling (16, 24, 32) in a powertrain of a motor vehicle, in particular of controlling at least one coupling operative in form-fitting manner of a differential lock of an off-road vehicle,

wherein at least the following steps are carried out in repeating calculation loops:

- determining at least one slip value (SLP) which represents an instantaneous slip between different axles (23, 31) of the motor vehicle or between different wheels (21, 29) of an axle;
- forming an absolute value of the slip value (SLP) which corresponds to the amount of the slip value;
- optionally deriving a substitute value (RED) from the absolute value;
- summing the absolute value or the substitute value (RED) derived herefrom to a last-formed slip sum value to form an instantaneous slip sum value (SUM);
- comparing the instantaneous slip sum value (SUM) with a slip sum threshold value (SUM-LIM); and
- generating a control signal (CTL) for actuating the coupling (16, 24, 32) if the instantaneous slip sum value reaches or exceeds the slip sum threshold value;

wherein in a respective calculation loop the slip sum value formed in a preceding calculation loop is taken as the last-formed slip sum value;

wherein on a first-time carrying out of the step of summing, a predefined starting value is taken as the last-formed slip sum value.

2. A method in accordance with claim 1,
wherein a check is made whether a slip oscillation is present, with the instantaneous slip sum value (SUM), the last-formed slip sum value or the slim sum threshold value (SUM-LIM) being modified if this is the case.

3. A method in accordance with claim 2,
wherein the slip sum value is multiplied by a weighting factor which has a value between zero and one for the modifying of the instantaneous or last-formed slip sum value (SUM);
or
wherein the slip sum threshold value is multiplied by a weighting factor larger than one for the modifying of the slip sum threshold value (SUM-LIM).

4. A method in accordance with claim 2,
wherein monitoring is carried out for the check of whether a slip oscillation is present whether the determined slip values (SLP) change sign at least once within a predefined time period or within a predefined number of calculation loops.

5. A method in accordance with claim 4,
wherein a positive and a negative response threshold value (SLP-LIM) are taken into account for the monitoring whether the determined slip values change sign at least once.

6. A method in accordance with claim 4,
wherein a slip oscillation monitored value is increased by a predefined value if a sign change of the determined slip values is

found, with the slip oscillation monitored value being reduced by a predefined value when a predefined time interval or a predefined number of calculation loops has elapsed and with the presence of a slip oscillation being detected if the slip oscillation monitored value reaches or exceeds a slip oscillation threshold value.

7. A method in accordance with claim 1, wherein the absolute value of the slip value (SLP) is compared with a slip response threshold value (SLP-LIM), with the absolute value being substituted by a substitute value (ABS) before or in the step of the summing which has the value zero or a negative value if the absolute value is smaller than the slip response threshold value (SLP-LIM).

8. A method in accordance with claim 7, wherein the substitute value corresponds to a difference between the absolute value and the slip response threshold value if the absolute value is larger than the slip response threshold value.

9. A method in accordance with claim 1, wherein the absolute value of the slip value or the substitute value (ABS) already derived herefrom is reduced by a slip reducing value before or in the step of summing.

10. A method in accordance with claim 1, wherein the absolute value of the slip value or the substitute value (ABS) already derived herefrom is compared with a slip reducing threshold value (ABS-LIM), with the absolute value or the substitute value (ABS) already derived herefrom being substituted by a substitute value (RED) having a negative sign before or in the step of

summing if the absolute value or the substitute value (ABS) already derived herefrom falls below the slip reducing threshold value (ABS-LIM).

11. A method in accordance with claim 1, wherein the instantaneous slip sum value (SUM) is set to the value of the slip sum threshold value (SUM-LIM) if the instantaneous slim sum value exceeds the slip sum threshold value.

12. A method in accordance with claim 1, wherein a check is made whether the instantaneous slip sum value (SUM) has a negative sign, with the instantaneous slip sum value being set to the value zero if this is the case.

13. A method in accordance with claim 1, wherein a slip increase value is formed which represents a time gradient of a slip increase; wherein the absolute value or the substitute value already derived herefrom is substituted, before or in the step of summing, by a substitute value which corresponds to a product of the absolute value or the substitute value already derived herefrom with a slip increase weighting factor which depends on the slip increase value.

14. A method in accordance with claim 13, wherein a difference between the absolute value formed in an instantaneous calculation loop and the absolute value formed in the preceding calculation loop is formed for the forming of the slip increase value.

15. A method in accordance with claim 14,
wherein the difference between the absolute value formed in the instantaneous calculation loop and the absolute value formed in the preceding calculation loop is divided by a value which represents the time duration between the preceding calculation loop and the instantaneous calculation loop.

16. A method in accordance with claim 13,
wherein the slip increase weighting factor is set to a positive value larger than one if the formed slip increase value represents a positive time gradient of a slip increase.

17. A method in accordance with claim 13,
wherein the slip increase weighting factor is selected to be larger for relatively larger slip increase values than for relatively smaller slip increase values.

18. A method in accordance with claim 13,
wherein the slip increase weighting factor is set to the value one if the slip increase value represents a slip decrease.

19. A method in accordance with claim 1,
wherein a check is made whether a slip oscillation is present;
wherein, if this is the case, the absolute value or the substitute value already derived herefrom is substituted, before or in the step of summing, by a substitute value which corresponds to a product of the absolute value or the substitute value already derived herefrom with a slip oscillation weighting factor.

20. A method in accordance with claim 19,
wherein a monitoring is carried out for the check of whether a slip oscillation is present whether the determined slip values change sign at least once within a predefined time period or within a predefined number of calculation loops.

21. A method in accordance with claim 20,
wherein a positive and a negative response threshold value are taken into account for the monitoring whether the determined slip values change sign at least once.

22. A method in accordance with claim 19,
wherein the slip oscillation weighting factor is set to a positive value unequal to one if a slip oscillation is present, and wherein the slip oscillation weighting factor is set to the value one if no slip oscillation is present.

23. A method in accordance with claim 1,
wherein the coupling (16, 24, 32) is actuated for a predefined minimum holding duration in the closing direction in dependence on the generated control signal (CTL), with the coupling being biased in the opening direction and opening automatically as soon as the coupling is no longer actuated in the closing direction and no torque or only a small torque is transferred via the coupling.

24. A method in accordance with claim 1,
wherein a plurality of couplings (16, 24, 32) are provided in the powertrain of the motor vehicle, in particular a plurality of couplings operative in form-fitting manner of a respective differential lock;
wherein, for some (24, 32) or all of the plurality of couplings, the

steps are carried out in the respective calculation loop of determining at least one slip value (SLP1, SLP2) of the respective coupling; forming an absolute value of the slip value (SLP1, SLP2) of the respective coupling; summing the absolute value or a substitute value (RED1, RED2) derived herefrom to a last-formed slip sum value for forming an instantaneous slip sum value (SUM1, SUM2) of the respective coupling; comparing the instantaneous slip sum value (SUM1, SUM2) with a slip sum threshold value (SUM1-LIM, SUM2-LIM) of the respective coupling; and generating a control signal (CTL1, CTL2) for actuating the respective coupling on reaching or exceeding the respective slip sum threshold value.

25. A method in accordance with claim 24, wherein some (24, 32) or all of the plurality of couplings are controlled independently of one another.

26. A method in accordance with claim 24, wherein different threshold values, different weighting factors and/or different minimum holding durations are used for controlling the plurality of couplings (16, 24, 32).

27. A method in accordance with claim 24, wherein the plurality of couplings include at least one coupling (16) of an inter-axle differential lock (15) and at least two couplings (24, 32) of a respective axle differential lock (19, 27), with at least the following steps being carried out for the coupling (16) of the inter-axle differential lock (15) in the respective calculation loop:

- determining at least one slip value (SLP3) which represents an instantaneous slip between different axles (23, 31) of the motor vehicle;

- forming an absolute value of the slip value (SLP3) which corresponds to the amount of the slip value;
- selecting a maximum value (RED3') from the absolute values formed for a group (16, 24, 32) of couplings in the respective calculation loop or from substitute values (RED1, RED2, RED3) derived herefrom;
- summing the maximum value (RED3') or a substitute value derived herefrom to a last-formed maximum slip sum value to form an instantaneous maximum slip value (SUM3') for the coupling (16) of the inter-axle differential lock (15);
- comparing the instantaneous maximum slip sum value (SUM3') with a maximum slip sum threshold value (SUM3'-LIM); and

generating a control signal (CTL3') for actuating the coupling (16) of the inter-axle differential lock (15) if the instantaneous maximum slip sum value reaches or exceeds the maximum slip sum threshold value.

28. A method in accordance with claim 27,
wherein the selection of the maximum value (RED3') only takes place after a check has been made whether the absolute values formed in the respective calculation loop should be substituted by a respective substitute value and, if this is the case, after the respective absolute value has been substituted by the substitute value (RED1, RED2, RED3).

29. A powertrain of a motor vehicle having at least one coupling (16, 24, 32), in particular at least one coupling operative in form-fitting manner of a differential lock of an off-road vehicle, and having a

control device which is designed to carry out at least the following steps in repeating calculation loops:

- determining at least one slip value (SLP) which represents an instantaneous slip between different axles (23, 31) of the motor vehicle or between different wheels (21, 29) of an axle;
- forming an absolute value of the slip value (SLP) which corresponds to the amount of the slip value;
- optionally deriving a substitute value (RED) from the absolute value;
- summing the absolute value or the substitute value (RED) derived herefrom to a last-formed slip sum value to form an instantaneous slip sum value (SUM);
- comparing the instantaneous slip sum value (SUM) with a slip sum threshold (SUM-LIM); and
- generating a control signal (CTL) for actuating the coupling (16, 24, 32) if the instantaneous slip sum value reaches or exceeds the slip sum threshold value;

wherein the control device which is designed to take, in a respective calculation loop, the slip sum value formed in a preceding calculation loop as the last-formed slip sum value;

wherein the control device which is designed to take, on a first-time carrying out of the step of summing, a predefined starting value as the last-formed slip sum value.