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(54) **ENGINE CONTROL SYSTEM**

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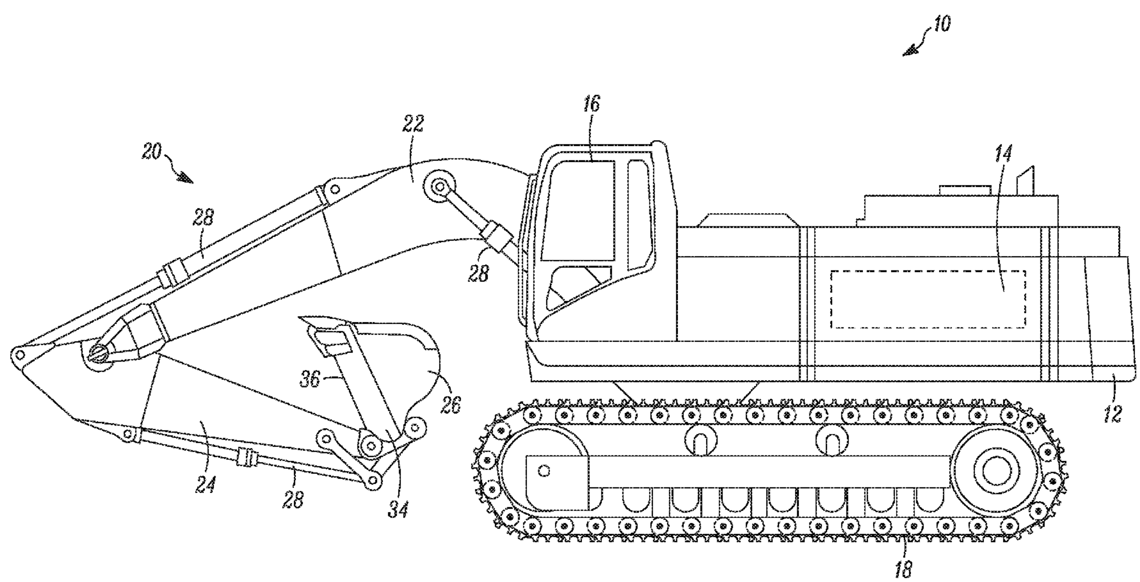
(57) **ABSTRACT**

An engine control system is provided. The engine control system includes a moisture content sensor associated with an implement of a machine. The moisture content sensor is configured to generate a signal indicative of a moisture content of soil. The engine control system also includes a control module coupled to the moisture content sensor. The control module is configured to receive the signal indicative of the moisture content of the soil. The control module is configured to receive a signal indicative of mass readings associated with the soil. The control module is configured to correlate the moisture content and the mass readings associated with soil based on a type of the soil. The control module is configured to control at least one of a power and a speed setting associated with an engine of the machine based, at least in part, on the correlation.



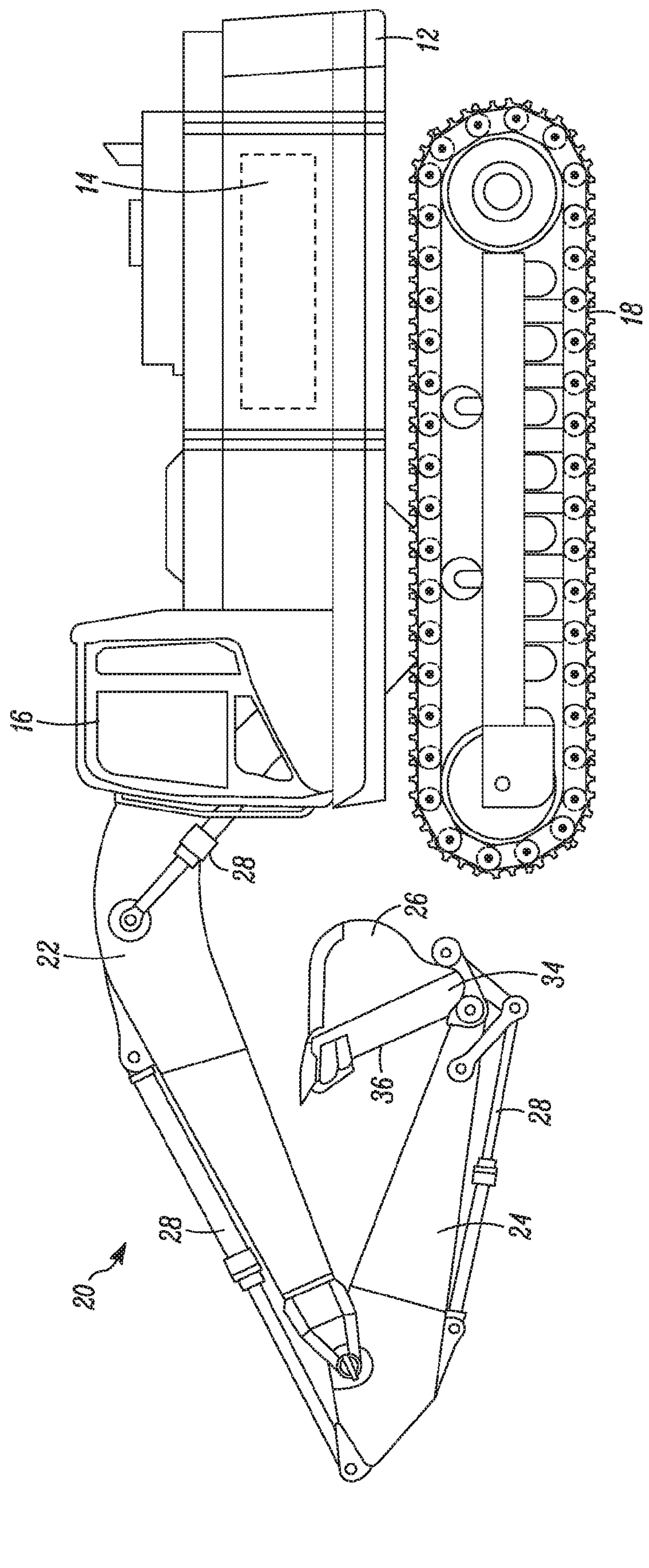


FIG. 1

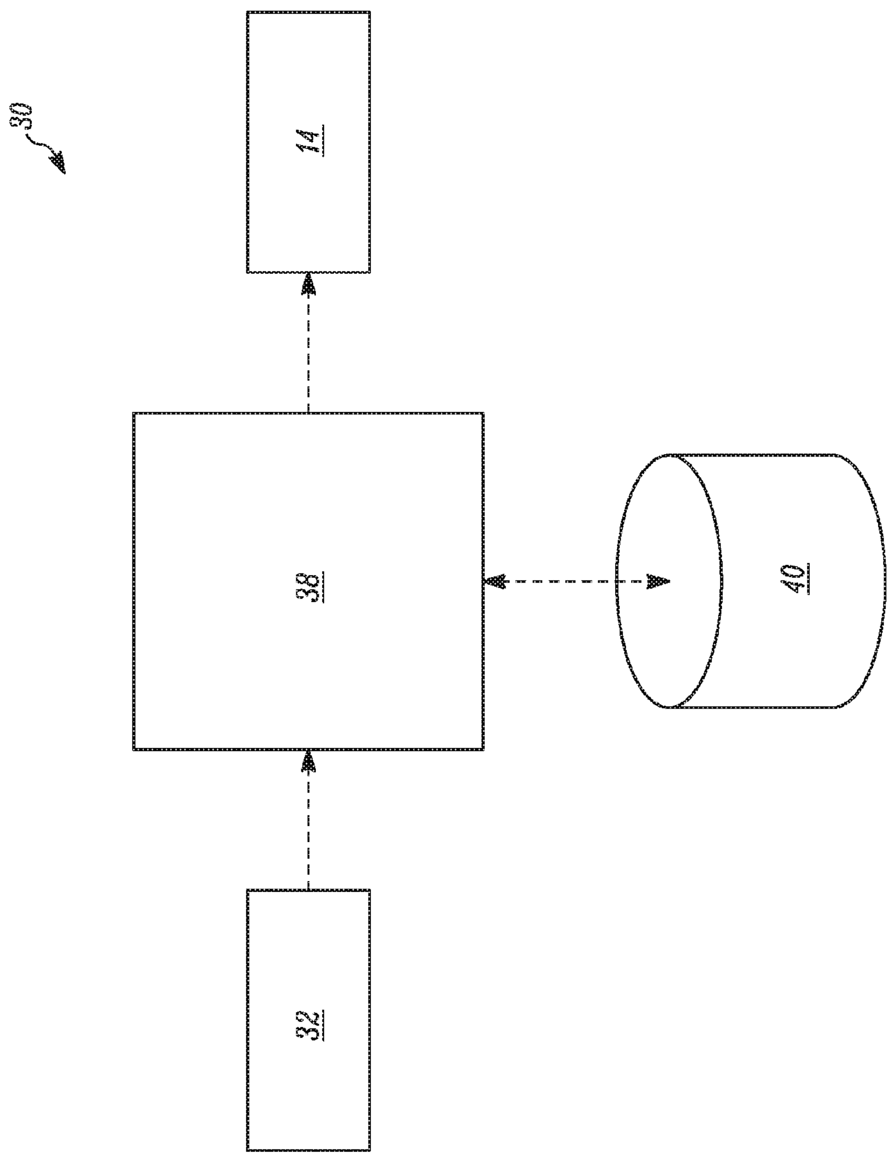


FIG. 2

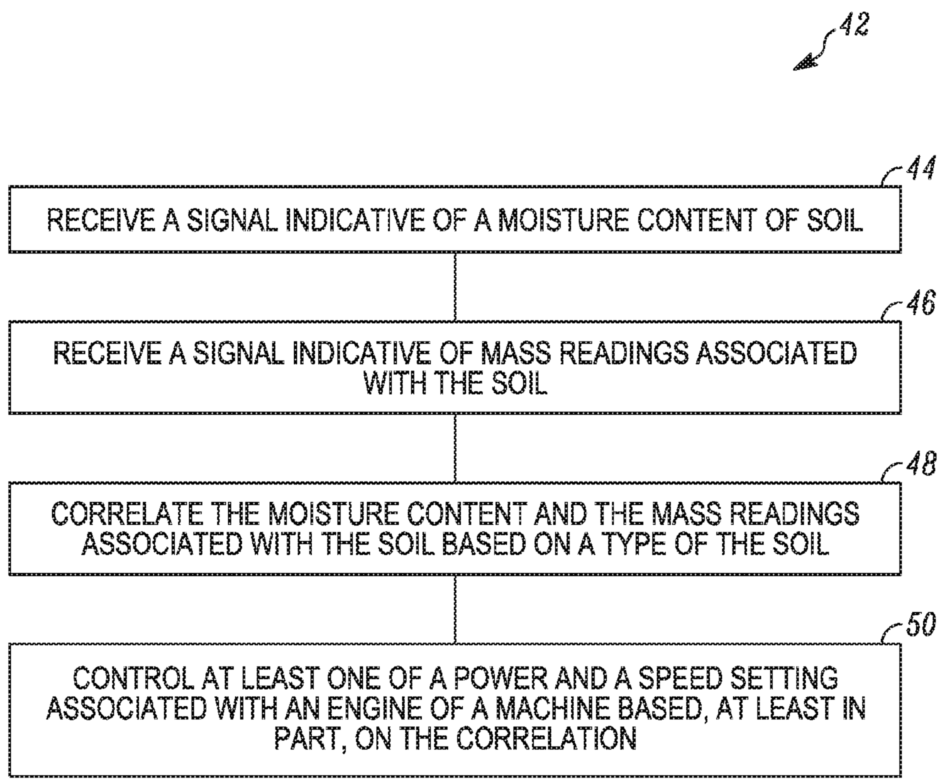

42
44
RECEIVE A SIGNAL INDICATIVE OF A MOISTURE CONTENT OF SOIL
46
RECEIVE A SIGNAL INDICATIVE OF MASS READINGS ASSOCIATED WITH THE SOIL
48
CORRELATE THE MOISTURE CONTENT AND THE MASS READINGS ASSOCIATED WITH THE SOIL BASED ON A TYPE OF THE SOIL
50
CONTROL AT LEAST ONE OF A POWER AND A SPEED SETTING ASSOCIATED WITH AN ENGINE OF A MACHINE BASED, AT LEAST IN PART, ON THE CORRELATION

FIG. 3

ENGINE CONTROL SYSTEM

TECHNICAL FIELD

[0001] The present disclosure relates to an engine control system of a machine. More particularly, the present disclosure relates to the engine control system based on soil parameters of a payload associated with the machine.

BACKGROUND

[0002] Machines such as, for example, wheel loaders, track type tractors, and other types of heavy machinery may be utilized for a variety of tasks. These machines include a power source, which may be, for example, an engine, such as a diesel engine, a gasoline engine, or a natural gas engine that provides power required to complete such tasks. Such power is directed to various tools, implements, and other components of the machine to assist in performing these tasks.

[0003] In some situations based on a moisture content of soil, engine power required to operate the machine and perform the desired tasks may vary. In one example, relatively more engine power may be required to operate the machine when the moisture content of the soil is optimized based on soil type and therefore maximum density. In another example, for soils having less optimized moisture content and therefore lower density, lesser engine power may be required to perform the tasks. Generally, an operator of the machine may manually control an operation of the engine based on engine lug and/or feel. However, this may not be a very efficient way of handling and operating the machine since reliance on manual operation may be high in this situation.

[0004] U.S. Patent Published Application Number 2014/0255095 describes a method for construction of earthen fills that comprises use of actual, cumulative field compaction energy generated by soil compactors as a function of rolling resistance with soil densification, to determine the asymptotic energy-density approach range.

[0005] In known systems that do not consider soil parameters while operating, the machine sometimes uses excessive power to move material. This use of excessive engine power can increase fuel consumption, increase fuel refill frequency and result in increased operating costs. Hence there is a need for an improved automated system and method for controlling engine operation.

SUMMARY OF THE DISCLOSURE

[0006] In an aspect of the present disclosure, an engine control system is provided. The engine control system includes a moisture content sensor associated with an implement of a machine. The moisture content sensor is configured to generate a signal indicative of a moisture content of soil. The engine control system also includes a control module coupled to the moisture content sensor. The control module is configured to receive the signal indicative of the moisture content of the soil. The control module is configured to receive a signal indicative of mass readings associated with the soil. The control module is configured to correlate the moisture content and the mass readings associated with the soil based on a type of the soil. The control module is configured to control at least one of a power and a speed setting associated with an engine of the machine based, at least in part, on the correlation.

[0007] Other features and aspects of this disclosure will be apparent from the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a side view of an exemplary machine, according to one embodiment of the present disclosure;

[0009] FIG. **2** is a block diagram of an engine control system associated with the machine of FIG. **1**, according to one embodiment of the present disclosure; and

[0010] FIG. **3** is a flowchart illustrating a method of operation of the engine control system, according to one embodiment of the present disclosure.

DETAILED DESCRIPTION

[0011] Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. Referring to FIG. **1**, an exemplary machine **10** is illustrated. More specifically, the machine **10** is an excavator. The machine **10** is configured to perform various tasks such as excavation, demolishment, material handling, and so on. In other embodiments, the machine **10** may be any other machine such as a wheel loader, a dozer, a track type tractor, a truck, and so on. The machine **10** may be any machine related to an industry such as construction, agriculture, transportation, forestry, material handling, waste management, and so on.

[0012] The machine **10** includes a frame **12**. The frame **12** is configured to support various components of the machine **10** thereon. The machine **10** includes an engine **14** mounted on the frame **12**. The engine **14** may be any internal combustion engine powered by a fuel such as diesel, gasoline, natural gas, and so on or a combination thereof. The engine **14** is configured to provide motive power to the machine **10**.

[0013] The machine **10** includes an operator cabin **16** mounted on the frame **12**. The operator cabin **16** is configured to house various controls of the machine **10** including, but not limited to, a steering, levers, pedals, joysticks, buttons, an operator interface, audio video devices, and an operator seat. The controls are configured to operate and control the machine **10** on the ground. The machine **10** also includes tracks **18** mounted to the frame **12**. The tracks **18** are configured to support and provide mobility to the machine **10** on the ground.

[0014] The machine **10** includes a linkage assembly **20**. The linkage assembly **20** includes a boom **22** movably coupled to the frame **12**. The linkage assembly **20** also includes a stick **24** movably coupled to the boom **22**. The linkage assembly **20** further includes an implement, such as a bucket **26**, movably coupled to the stick **24**. In other embodiments, the linkage assembly **20** may include any other implement such as, a blade, an auger, a hammer, and so on based on application requirements. The linkage assembly **20** also includes one or more hydraulic cylinders **28** configured to provide movement to the boom **22**, the stick **24**, and/or the bucket **26**.

[0015] The linkage assembly **20** is configured to perform activities such as excavation, demolishment, transportation, material handling, and so on based on application requirements. Additionally, the machine **10** may include other components and systems such as, an engine control system **30** (see FIG. **2**), a transmission system (not shown), a drive control system (not shown), a safety system (not shown), and so on without limiting the scope of the disclosure.

[0016] Referring to FIG. **2**, a schematic representation of the engine control system **30** is illustrated. The engine control system **30** includes a moisture content sensor **32** associated with the implement of the machine **10**. More specifically, the moisture content sensor **32** is coupled to the bucket **26** of the machine **10** in a manner such that the moisture content sensor **32** is in contact with material such as soil being moved by the bucket **26**.

[0017] In one embodiment, the moisture content sensor **32** may be coupled to an inner surface **34** of the bucket **26**. In another embodiment, the moisture content sensor **32** may be coupled to an outer surface **36** of the bucket **26**. In yet another embodiment, the moisture content sensor **32** may be coupled to any other component of the machine **10** such as the boom **22**, the stick **24**, the track **18**, the frame **12**, and so on based on application requirements. The moisture content sensor **32** is configured to generate a signal indicative of a moisture content of the soil.

[0018] The engine control system **30** also includes a control module **38** coupled to the moisture content sensor **32**. The control module **38** is configured to receive the signal indicative of the moisture content of the soil from the moisture content sensor **32**. The control module **38** is also configured to receive a signal indicative of mass readings associated with the soil present in the bucket **26**. In one embodiment, the mass readings of the soil may be received from one or more pressure sensors (not shown) associated with the bucket **26** and/or the hydraulic cylinders **28**. In another embodiment, the mass readings of the soil may be received based on a movement of the linkage assembly **20** or the frame **12**.

[0019] In another embodiment, the mass readings of the soil may be received based on hydraulic power generated by a hydraulic system (not shown) of the machine **10** and/or hydraulic power required by the hydraulic cylinders **28**, and so on. In yet another embodiment, the mass readings of the soil may be received from a payload control system (not shown), a production measurement system (not shown), and so on of the machine **10**. It should be noted that the mass readings of the soil present within the bucket **26** described herein is merely exemplary and may be determined by any method **42** known in the art without limiting the scope of the disclosure. The moisture content and the mass readings of the soil are received by the control module **38** on a per bucket basis.

[0020] Further, the control module **38** is also configured to receive a signal indicative of a type of the soil. For example, the type of soil may vary such as sandy, clay, rocky, and so on based on a geographic location of a worksite. More specifically, in one embodiment, the control module **38** may receive the signal indicative of the type of soil based on a location signal of the machine **10**. The location signal of the machine **10** may be received from a positioning system (not shown) of the machine **10** coupled to the control module **38** such as a Global Positioning System (GPS), an Inertial Navigation System (INS), and so on. In such an embodiment, the control module **38** may be coupled to a database **40**. The data related to the type of the soil may be retrieved from the database **40** based on a current location of the machine **10**.

[0021] In another embodiment, the control module **38** may receive the signal indicative of the type of the soil based on a location map stored in the database **40**. The location map may include the type of the soil for different locations. In another embodiment, the signal indicative of the type of the soil may be based on a site of the machine **10**. In such an embodiment, the database **40** may include a dataset having the type of the soil for different sites. In yet another embodiment, the type of the soil may be manually fed to the control module **38** via the operator interface.

[0022] Further, the control module **38** is configured to determine a volume of the soil present in the bucket **26** based on the type of the soil, the mass readings of the soil and the moisture content of the soil. Accordingly, the control module **38** is configured to provide a notification of a current volume of the soil dug by the machine **10**. This notification of the volume of the soil dug by the machine **10** may be provided to the operator via a suitable text or audio message, based on the requirement. In one example, a display notification may be provided to the operator seated within the operator cabin **16** of the machine **10** via a display panel.

[0023] In one embodiment, the volume of the soil present in the bucket **26** may be equivalent to a volume of the bucket **26** when the bucket **26** is fully filled with the soil. The control module **38** may determine the volume of the bucket **26** based on bucket specifications stored in the database **40** such as a type of the bucket **26**, a part number of the bucket **26**, dimensions of the bucket **26**, a machine status/configuration, and so on. In another embodiment, the volume of the bucket **26** may be manually fed to the control module **38** through the operator interface.

[0024] In another embodiment, the control module **38** may be configured to determine the volume of the soil in the bucket **26** based on a cohesion estimate of the soil. The cohesion estimate may be determined based on a correlation stored in the database **40**. The correlation may include a mathematical expression between the moisture content of the soil, the type of the soil, and the mass readings of the soil in the bucket **26**. In another embodiment, the control module **38** may receive the cohesion estimate from the database **40**. The database **40** may include a dataset having values of the cohesion estimate for varying values of the moisture content of the soil, the type of the soil, and the mass readings of the soil in the bucket **26**.

[0025] In some embodiments, the control module **38** may be configured to control the hydraulic cylinders **28** associated with the bucket **26** based on the cohesion estimate of the soil. More specifically, based on the moisture content of the soil, the type of the soil, the mass readings of the soil, and the cohesion estimate of the soil, the control module **38** is configured to determine a fill factor of the bucket **26**. The fill factor of the bucket **26** is indicative of a quantity of the soil present in the bucket **26** in order to determine loading levels such as overloading, under loading, optimum loading, and so on of the bucket **26**. Based on the fill factor, the control module **38** is configured to control the hydraulic cylinders **28** in order to optimize a dig effort of the bucket **26** and/or to optimize the loading level of the bucket **26**.

[0026] Based on the mass readings and the determined volume of the soil in the bucket **26** for a given cycle, the control module **38** is configured to determine a density or a dry density of the soil. Further, the control module **38** is configured to determine a soil zone on a proctor curve stored in the database **40** for the given type of the soil. The proctor curve is a graphical representation of soil conditions based on a dry density and a moisture content of the soil, for the given type of the soil. The soil zone is a relative segment of the proctor curve that determines soil conditions such as loosely packed, tightly packed, optimum moisture, maximum dry density and so on. According to the type of the soil, the control module **38** may select a relevant proctor curve. Further, based on the density and the moisture content of the soil, the control module **38** is configured to determine the soil zone on the relevant proctor curve. The control module **38** may determine the soil zone based on a dataset stored in the database **40**. The dataset may include various soil zones based on varying values of the density and the moisture content of the soil. In another embodiment, the database **40** may include a correlation such as a mathematical expression between the soil zone, the density, and the moisture content of the soil for the given type of the soil.

[0027] Based on the determined soil zone, the control module **38** is configured to control at least one engine parameter associated with the engine **14** of the machine **10** based, at least in part, on the correlation. The engine parameter may include a power of the engine **14**, a speed setting of the engine **14**, and so on. For example, when the control module **38** determines a dense, or optimized proctor curve load, the control module **38** may be configured to increase the power and/or the speed setting of the engine **14** so that the engine **14** operates at a higher power or speed setting. Similarly, when the control module **38** determines a less dense or less optimized proctor curve load, the control module **38** may be configured to reduce the power and/or the speed setting of the engine **14** so that the engine **14** operates at a lower power or speed setting.

[0028] In one embodiment, based on the type of the soil, the mass readings of the soil, and the moisture content of the soil, the control module **38** may utilize the determined cohesion estimate of the soil to control an operation of the hydraulic cylinders **28** associated with the linkage assembly **20**. For example, based on the cohesion estimate of the soil, the control module **38** determines if the linkage assembly **20** of the machine **10** needs to be operated more aggressively or less aggressively and accordingly sends control signals to actuate the hydraulic cylinders **28** associated with the bucket **26**.

[0029] Additionally, the control module **38** is configured to estimate a fuel refill schedule of the machine **10**. Based on the moisture content of the soil, the type of the soil, the mass readings of the soil, and bucket usage data, the control module **38** is configured to determine bucket load data per work cycle. The control module **38** is configured to receive fuel rate data indicative of rate of fuel consumption in the system from an engine control module (not shown) coupled to the control module **38**. Based on the type of the soil, the moisture content of the soil, and the mass readings of the soil, the control module **38** is configured to combine the fuel rate data with the data associated with the soil to predict a fuel usage of the engine **14** required for completing the designated task. Further, based on a known fuel tank capacity of the fuel tank of the machine **10** and the predicted fuel usage, the control module **38** may determine a fuel refill schedule of the machine **10**. The fuel refill schedule may include fuel consumption per work cycle, time for next refuel, and so on.

[0030] In situations when the moisture content of the soil, the type of the soil, and/or the mass readings of the soil may change, the dig effort of the bucket **26** may change accordingly resulting in change of fuel usage and engine working conditions. For example, if the moisture content of the soil over multiple bucket cycles remains approximately constant, the control module **38** may predict that the fuel usage may not differ significantly over time. In another example, if the moisture content of the soil either increases or decreases over multiple bucket cycles, the control module **38** may predict that the fuel usage may correspondingly vary. Accordingly, based on the predicted fuel usage and engine usage parameters, the control module **38** may predict the fuel refill schedule of the machine **10**. During high fuel usage, time required for the fuel tank to empty may be less, leading to increased fuel refill cycles. Similarly, during low fuel usage, the time required for the fuel tank to empty may be more, leading to reduced fuel refill cycles.

INDUSTRIAL APPLICABILITY

[0031] The present disclosure relates to a method **42** of controlling the engine **14** of the machine **10** by the control module **38**. Referring to FIG. **3**, a flowchart of the method **42** is illustrated. At step **44**, the control module **38** receives the signal indicative of the moisture content of the soil from the moisture content sensor **32**. At step **46**, the control module **38** receives the signal indicative of the mass readings associated with the soil. The mass readings of the soil may be received from the pressure sensors associated with the bucket **26** and/or the hydraulic cylinders **28**, based on the movement of the linkage assembly **20**, based on the hydraulic power generated by the hydraulic system of the machine **10** and/or the hydraulic power required by the hydraulic cylinders **28**, the payload control system, the production measurement system, and so on.

[0032] At step **48**, the control module **38** correlates the moisture content and the mass readings associated with the soil for the given type of the soil. The type of the soil may be received based on the location signal of the machine **10**, the location map stored in the database **40**, a site data, and so on. At step **50**, based on the correlation, the control module **38** is configured to control at least one of the power and the speed setting associated with the engine **14** of the machine **10**. The control module **38** is configured to control the engine parameter in order to optimize the engine working conditions for each work cycle.

[0033] The control module **38** provides an effective and a cost efficient method **42** to optimize the engine working conditions for different soil types and work cycles. For example, the control module **38** may reduce the engine parameters in situations when the type of soil may not require a more aggressive digging style. Also, the control module **38** may increase the engine parameters in situations when the type of soil may require a more aggressive digging style. It should be noted that the control module **38** may be overridden by operator commands and vice versa based on application requirements.

[0034] Also, the control module **38** may determine the volume of the soil present in the bucket **26** based on the bucket specifications without use of additional systems. Additionally, the control module **38** may estimate the fuel refill schedule for the machine **10** based on the moisture content of the soil, the type of the soil, the mass readings of the soil, and the bucket usage data without use of additional systems. As a result, the control module **38** in turn improves machine efficiency, improves fuel efficiency, improves component life, reduces machine abuse, reduces operator dependency, and so on.

[0035] While aspects of the present disclosure have been particularly shown and described with reference to the embodiments above, it will be understood by those skilled in the art that various additional embodiments may be contemplated by the modification of the disclosed machines, systems and methods without departing from the spirit and scope of the disclosure. Such embodiments should be understood to fall within the scope of the present disclosure as determined based upon the claims and any equivalents thereof.

What is claimed is:

1. An engine control system comprising:

a moisture content sensor associated with an implement of a machine, the moisture content sensor configured to generate a signal indicative of a moisture content of soil; and

a control module coupled to the moisture content sensor, the control module configured to:

receive the signal indicative of the moisture content of the soil;

receive a signal indicative of mass readings associated with the soil;

correlate the moisture content and the mass readings associated with the soil based on a type of the soil; and

control at least one of a power and a speed setting associated with an engine of the machine based, at least in part, on the correlation.

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