Claims

1. A touch detection device used in water handling equipment, comprising:

a sensing portion for sensing contact with a target object;

a vibration excitation element attached to the sensing portion;

a drive circuit for exciting a vibration in the sensing portion by intermittently applying an AC voltage at a predetermined frequency to the vibration excitation element; and

a contact determination circuit configured to determine whether the target object has contacted the sensing portion based on vibration of the sensing portion after application of the AC voltage to the vibration excitation element by the drive circuit;

wherein the vibration excitation element comprises a piezo-electric element, and the contact determination circuit determines whether the target object has contacted the sensing portion based on an output signal from the vibration excitation element detected after stopping of the application of the AC voltage to the vibration excitation element;

wherein the vibration excitation element comprises an input terminal to which the AC voltage is applied by the drive circuit, the output signal from the vibration excitation element is obtained from the input terminal of the vibration excitation element, and the output of the drive circuit becomes high impedance after application of the AC voltage stops; and

wherein the contact determination circuit is configured to determine whether or not the target object has contacted the sensing portion based on a total of a plurality of voltage value acquired from the output signal of the vibration excitation element detected after the stopping of the application of the AC voltage by the drive circuit, and the contact determination circuit determines that the target object has made contact when the total is at or below a predetermined threshold value.

2. The touch detection device of Claim 1, further comprising a contact determination confirming circuit, wherein after the determination has first been made by the contact determination circuit that the target object has made

contact, the contact determination confirming circuit performs a contact determination confirming operation to further reduce the possibility of false sensing.

3. The touch detection device of Claim 2, wherein once the contact by the target object has first been determined by the contact determination circuit, the contact determination confirming circuit performs the contact determination confirming operation in which the AC voltage at a confirming frequency different from the normal frequency of the AC voltage is applied, and the contact determination confirming circuit fixes the judgment of contact with the sensing portion when the contact of the target object is also determined by the contact determination circuit by applying the AC voltage at the confirming frequency.

4. A faucet apparatus for switching between water spouting and shut off by a touch operation, comprising:

the touch detection device of Claim 1;

an operating portion including the sensing portion; and

an on-off valve for opening and closing based on a determination of contact by the target object with the sensing portion performed by the touch detection device.

5. A touch detection device used in water handling equipment, comprising:

a sensing portion for sensing contact with a target object;

a vibration excitation element attached to the sensing portion;

a drive circuit for exciting a vibration in the sensing portion by intermittently applying an AC voltage at a predetermined frequency to the vibration excitation element; and

a contact determination circuit configured to determine whether the target object has contacted the sensing portion based on vibration of the sensing portion after application of the AC voltage to the vibration excitation element by the drive circuit;

wherein the vibration excitation element comprises a piezo-electric element, and the contact determination circuit determines whether the target

object has contacted the sensing portion based on an output signal from the vibration excitation element detected after stopping of the application of the AC voltage to the vibration excitation element;

wherein the vibration excitation element comprises an input terminal to which the AC voltage is applied by the drive circuit, the output signal from the vibration excitation element is obtained from the input terminal of the vibration excitation element, and the output of the drive circuit becomes high impedance after application of the AC voltage stops; and

wherein the contact determination circuit comprises an anomaly sensing circuit configured to prevent false sensing, and the anomaly sensing circuit senses an anomaly based on the output signal from the vibration excitation element detected during application of the AC voltage to the vibration excitation element.

6. The touch detection device of Claim 5, wherein the anomaly sensing circuit senses the anomaly when the amplitude of the output signal detected during application of the AC voltage is larger than the amplitude in normal operations, and the contact determination circuit does not determine the contact of the target object when the anomaly has been sensed.

7. The touch detection device of Claim 5, wherein during application of the AC voltage to the vibration excitation element, the anomaly sensing circuit is configured to sense an anomaly when fluctuations in the amplitude of the output signal exceed a predetermined level, and the contact determination circuit does not determine the contact of the target object when the anomaly has been sensed.

8. A touch detection device used in water handling equipment, comprising:

a sensing portion for sensing contact with a target object;

a vibration excitation element attached to the sensing portion;

a drive circuit for exciting a vibration in the sensing portion by intermittently applying an AC voltage at a predetermined frequency to the vibration excitation element; and

a contact determination circuit configured to determine whether the target object has contacted the sensing portion based on vibration of the sensing portion after application of the AC voltage to the vibration excitation element by the drive circuit; and

a frequency adjustment circuit configured to adjust the frequency of the AC voltage applied to the vibration excitation element wherein the frequency adjustment circuit adjusts the frequency of the AC voltage to a resonant frequency of the sensing portion, to which the vibration excitation element is attached;

wherein the vibration excitation element comprises a piezo-electric element, and the contact determination circuit determines whether the target object has contacted the sensing portion based on an output signal from the vibration excitation element detected after stopping of the application of the AC voltage to the vibration excitation element;

wherein the vibration excitation element comprises an input terminal to which the AC voltage is applied by the drive circuit, the output signal from the vibration excitation element is obtained from the input terminal of the vibration excitation element, and the output of the drive circuit becomes high impedance after application of the AC voltage stops; and

wherein the frequency adjustment circuit applies the AC voltage for a predetermined period multiple times at different frequencies, and the frequency at which the amplitude of the output signal from the vibration excitation element is maximal following the stopping of the AC voltage application, is determined by the frequency adjustment circuit to be the mechanical resonant frequency of the sensing portion, to which the vibration excitation element is attached.

9. The touch detection device of Claim 8, wherein when there are multiple frequencies at which the amplitude of the output signal detected after application of the AC voltage, is maximized, then among the frequencies at which amplitude is maximized, the frequency at which amplitude fluctuations of the output signal are smallest during application of the AC voltage to the vibration excitation element, is determined by the frequency adjustment circuit to be the resonant frequency of the sensing portion, to which the vibration

excitation element is attached.

10. The touch detection device of Claim 8, further comprising a frequency offset sensing circuit configured to sense the occurrence of a frequency offset between the resonant frequency of the sensing portion and the frequency of the AC voltage applied to the vibration excitation element; wherein when the frequency offset is sensed by the frequency offset sensing circuit, the frequency adjustment circuit performs an adjustment so that the frequency of the AC voltage matches the resonant frequency of the sensing portion.

11. The touch detection device of Claim 10, wherein the frequency adjustment circuit adjusts the frequency when the frequency offset sensed by the frequency offset sensing circuit is continuously present for a predetermined frequency offset determination time or greater.

12. The touch detection device of Claim 11, wherein when the resonant frequency of the sensing portion is below the frequency of the AC voltage applied to the vibration excitation element, the frequency offset determination time is set to be longer than when the resonant frequency of the sensing portion is above the frequency of the AC voltage applied to the vibration excitation element.

13. The touch detection device of Claim 10, wherein the frequency adjustment circuit is constituted to search for the resonant frequency of the sensing portion within a predetermined frequency range, and to be capable of executing a first adjustment mode and a second adjustment mode between which different search frequency ranges are used, wherein in the first adjustment mode the resonant frequency is searched within a first frequency range which includes a standard frequency of the sensing portion, and in the second adjustment mode the resonant frequency is searched within a second frequency range narrower than the first frequency range, which includes the current frequency of the AC voltage.

14. The touch detection device of Claim 13, further comprising a determination circuit configured to determine whether a frequency adjustment by the frequency adjustment circuit has succeeded; wherein in the first adjustment mode, when the determination circuit determines that the frequency adjustment has failed, the resonant frequency is repeatedly searched until the frequency adjustment succeeds, while in the second adjustment mode, when the determination circuit determines that the frequency adjustment has failed, the frequency of the current AC voltage is maintained without repeatedly searching for the resonant frequency.

15. The touch detection device of Claim 14, wherein the frequency adjustment circuit is constituted for applying AC voltages to the vibration excitation element at multiple frequencies within the predetermined frequency range, respectively obtaining output signals from the vibration excitation element for each application of an AC voltage, and performing the frequency adjustment by analyzing envelope detection waveforms of these output signals, while the determination circuit determines that the frequency adjustment by the frequency adjustment circuit has failed when the envelope detection waveforms include a waveform which does not decrease monotonically after application of the AC voltage.

16. The touch detection device of Claim 14, wherein the frequency adjustment circuit is constituted to apply the AC voltage to the vibration excitation element at multiple frequencies within the predetermined frequency range, to acquire output signals from the vibration excitation element when each AC voltage is applied, to search for the resonant frequency based on these output signals, and then to make a determination, while the determination circuit determines that the frequency adjustment by the frequency adjustment circuit has failed when a vibration energy of the sensing portion detected after the AC voltage at the determined resonant frequency is applied, does not reach a predetermined threshold value.