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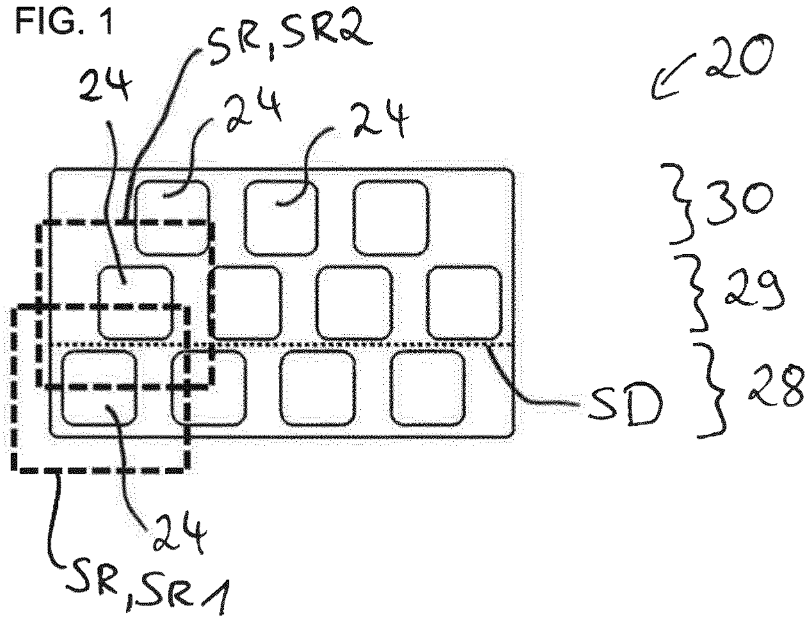
(54) ## SENSOR ARRANGEMENT FOR A RAILWAY SYSTEM

(57) A sensor arrangement (20) for a railway system (21) is provided, the sensor arrangement (20) comprising a plurality of sensors (24), each sensor (24) comprising a coil, wherein the sensors (24) are arranged in a two-dimensional arrangement, each sensor (24) has a sensing range (SR) within which the respective sensor (24) is configured to detect movement of electrically conductive material, and for each position along a sensing distance (SD) within the two-dimensional arrangement the sensor arrangement (20) comprises at least two sensors (24) of the plurality of sensors (24) whose sensing range (SR) extends over the respective position.

FIG. 1



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Description

[0001] A sensor arrangement for a railway system is provided.

[0002] For monitoring a railway track it is necessary to monitor the state of movable railway elements such as tongue rails and railway frogs. Tongue rails and railway frogs are components of railway switches. A prerequisite for a safe passage of a rail vehicle over a railway switch is that the movable railway elements of the railway switch are arranged at predefined positions. This can mean, that a tongue rail is either in a position where it is in direct contact or close to direct contact with a stock rail of the railway switch or in a position where the tongue rail is spaced apart from the stock rail far enough so that a wheel of a passing rail vehicle can safely pass the railway switch. The same is true for railway frogs. It is therefore necessary to monitor the state of these movable railway elements. Only if the movable railway elements are detected to be in a state in which a rail vehicle can safely, this means without the risk of a derailment, pass the railway switch, the rail vehicle is allowed to pass the railway switch. It is furthermore necessary to monitor if the movable railway elements stay at the measured positions.

[0003] It is an objective to provide a sensor arrangement for a railway system with an improved accuracy.

[0004] This objective is achieved with the independent claim. Further embodiments are the subject of dependent claims.

[0005] According to at least one embodiment of the sensor arrangement for a railway system, the sensor arrangement comprises a plurality of sensors, each sensor comprising a coil. Each of the coils can comprise an electrically conductive material. Each of the coils has at least one winding. Each of the sensors can be a contactless position sensor. Each of the sensors can be an inductive sensor. The sensor arrangement can comprise at least six or at least ten sensors. The railway system can be a railway switch. Other expressions for "railway switch" are "point switch", "railroad switch", "track switch", "turnout", "set of point", "points", "switch", "point". The sensor arrangement can be a sensor arrangement for a railway switch.

[0006] The sensors are arranged in a two-dimensional arrangement. The two-dimensional arrangement can be a two-dimensional array. The distribution of the sensors within the two-dimensional arrangement can be arbitrary. The sensors can each be arranged at a lattice point of a two-dimensional lattice.

[0007] Each sensor has a sensing range within which the respective sensor is configured to detect movement of electrically conductive material. Each sensing range can be a volume or an area. Each sensor can be configured to detect the movement of electrically conductive material within its sensing range. Thus, the sensing range is at least partially arranged outside of the respective sensor. For each sense of the respective sensing range can be larger than the sense of.

[0008] During operation of the sensor arrangement the sensors can be arranged within a magnetic field. If electrically conductive material moves within this magnetic field the sensor signals of the sensors change. For each sensor, a sensor signal can be detected. For each sensor, the sensor signal can be or comprise a current, a voltage, a frequency, an inductance, a capacity, a magnetic field, an electric field, a coil quality, a phase, an impedance or a combination of at least two of these. Each sensor can be connected with an evaluation unit which can comprise a voltmeter, an ampere meter or another sensor. For each sensor the movement of electrically conductive material within the respective sensing range causes a change of a respective sensor signal. This can mean that the respective sensor signal changes within the respective coil. The change of the sensor signal can be measured, as for example a change of a current within the respective coil that can be measured. In this way, each sensor is configured to detect movement of electrically conductive material within its sensing range.

[0009] For each position along a sensing distance within the two-dimensional arrangement the sensor arrangement comprises at least two sensors of the plurality of sensors whose sensing range extends over the respective position. The sensing distance can extend within the two-dimensional arrangement of the sensors. The sensing distance can extend along one direction. The sensing distance can extend over the whole extension of the two-dimensional arrangement of the sensors in one direction that extends within the two-dimensional arrangement. A position along the sensing distance can be arranged at any point on a line that extends perpendicular to the sensing distance within the two-dimensional arrangement of sensors. This can mean, a position along the sensing distance can be arranged at any point on a line that extends perpendicular to the sensing distance and parallel to a main plane of extension of the two-dimensional arrangement of sensors. It is possible that a position along the sensing distance is arranged at any point on a line that extends perpendicular to the sensing distance, parallel to a main plane of extension of the two-dimensional arrangement of sensors and within the two-dimensional arrangement.

[0010] At each position along the sensing distance at least two sensing ranges extend. For each position along the sensing distance the at least two sensing ranges can extend parallel to each other. For each position along the sensing distance the at least two sensing ranges can be shifted with respect to each other along the sensing distance. This means, the at least two sensing ranges overlap for each position along the sensing distance. Thus, the sensing ranges of the sensors overlap in such a way that for each position along the sensing distance at least two sensing ranges extend. For each position along the sensing distance movement of electrically conductive material at the respective position can be detected by at least two of the sensors. This means, for each position along the sensing distance at least two of the sensors are configured to detect movement of electrically conductive material at the respective position.

[0011] The sensing distance is thus the distance along which the sensor arrangement is configured to detect the movement of electrically conductive material. The sensor arrangement can be configured to detect movement of electrically conductive material within a volume or an area that comprises the sensing distance. This is achieved by measuring the sensor signals of the sensors of the sensor arrangement. From the position within the two-dimensional arrangement of a respective coil that detected movement of electrically conductive material, the position of the electrically conductive material can be derived. This is possible along the whole length of the sensing distance as for each position along the sensing distance at least two of the sensors are configured to detect the movement of electrically conductive material.

[0012] The sensor arrangement can be employed with a railway system. The railway system can comprise non-movable components and components that can be moved. Components that can be moved are referred to as movable railway elements in the following. A movable railway element comprises for example a tongue rail or a railway frog. Another expression for "tongue rail" is "switch rail". Another expression for "railway frog" is "movable frog". In order to avoid accidents of moving rail vehicles on the railway system it is necessary to monitor the movable railway elements. With the sensor arrangement it is advantageously possible to determine the spatial position of moving electrically conductive material. The movable railway elements usually comprise an electrically conductive material. Thus, the sensor arrangement can be employed to monitor the position of movable railway elements of the railway system. In a measurement carried out by the sensor arrangement it is possible to determine the spatial position of a movable railway element of the railway system. Thus, the actual position of the movable railway element is determined. This is advantageous in comparison to systems where only end positions of movable railway elements of a railway system are determined. This means, only two different positions of a movable railway element can be differentiated in these systems. The sensor arrangement described herein allows to analyze the position of a movable railway element of the railway system with an improved accuracy. It is not only determined if the movable railway element reached one of its end positions but the actual spatial position of the movable railway element can be determined. This allows to monitor defects and wear of the movable railway element.

[0013] Another advantage is that the spatial position of the movable railway element can be determined contactless. Thus, it is not necessary to mechanically connect the sensor arrangement to the movable railway element. In this way, installing and maintaining the sensor arrangement is simplified in comparison to a sensor arrangement which requires a mechanical contact to the movable railway element. The sensor arrangement described herein can be connected with a non-movable rail via a rail claw. The sensors are mechanically connected to the rail claw. A further mechanical connection of the sensors to other parts of the railway system is not required. Also, no drilling is required. This means that the time required for installing the sensor arrangement is reduced. With this, also the time for which it is required to stop railway traffic on the railway system can be reduced. This also increases the safety for personnel installing or maintaining the sensor arrangement as the time that they need to spend on or at the rails is reduced.

[0014] That the sensors are configured to measure contactless also has the advantage that the sensors are not exposed to friction or other mechanical impacts. Thus, a damage of the sensors due to mechanical contact to the movable railway element is avoided.

[0015] That the sensor arrangement comprises at least two sensors of the plurality of sensors whose sensing range extends over the respective position for each position along the sensing distance has the advantage that for each position along the sensing distance movement of electrically conductive material can be detected by at least two sensors. The sensors can all be operated independently from each other. Thus, the movement of electrically conductive material can be determined in a redundant measurement. Measuring the same parameter twice by independent sensors can increase the safety. For example, the signals detected by the at least two sensors for the same position along the sensing distance can be compared to each other. It is possible to only trust the measurement if the two sensors show the same result. It is also possible to generate an alarm signal in case that the results of the at least two sensors are different from each other. Consequently, movement of electrically conductive material can be detected by the sensor arrangement in a reliable and safe way.

[0016] If for at least one of the sensors the sensing range is larger than the sensor itself, the sensor arrangement or the two-dimensional arrangement of sensors can be smaller than an area or a volume within which moving electrically conductive material can be detected. Thus, the sensor arrangement can be employed for the detection of moving electrically conductive material within an area or a volume that is arranged outside of the sensor arrangement. The sensor arrangement can therefore have a compact size or shape.

[0017] According to at least one embodiment of the sensor arrangement, the sensor arrangement comprises at least one first evaluation channel and at least one second evaluation channel, where some of the sensors of the plurality of sensors are connected with the first evaluation channel and other sensors of the plurality of sensors are connected with the second evaluation channel. Each evaluation channel can comprise a connection between different sensors. It is possible that data can be transferred over each of the evaluation channels. Thus, each evaluation channel is configured to transmit data. The transmitted data can be provided by the sensors. At least two sensors of the plurality of sensors can be connected with the first evaluation channel and at least two other sensors of the plurality of sensors can be connected with the second evaluation channel. The first evaluation channel and the second evaluation channel can be independent from each other. Employing two independent evaluation channels increases the safety. If a defect occurs in one of the channels, the other channel can operate independently from the defect channel.

[0018] According to at least one embodiment of the sensor arrangement, sensors connected with the first evaluation channel and sensors connected with the second evaluation channel are arranged alternatingly along the sensing distance. Sensors connected with the first evaluation channel and sensors connected with the second evaluation channel can be arranged alternatingly along a direction that extends parallel to the sensing distance. This means, along the sensing distance or along a direction that extends parallel to the sensing distance a sensor connected with the second evaluation channel is arranged between two sensors connected with the first evaluation channel. Along the sensing distance or along a direction that extends parallel to the sensing distance a sensor connected with the first evaluation channel is arranged between two sensors connected with the second evaluation channel. This means, the sensors connected with the first evaluation channel are not arranged directly adjacent to each other along the sensing distance or along a direction that extends parallel to the sensing distance. Each sensor connected with the first evaluation channel is arranged directly adjacent to at least one sensor connected with the second evaluation channel. The sensors connected with the second evaluation channel are not arranged directly adjacent to each other along the sensing distance or along a direction that extends parallel to the sensing distance. Each sensor connected with the second evaluation channel is arranged directly adjacent to at least one sensor connected with the first evaluation channel. By arranging the sensors in an alternating way, the sensors are uniformly distributed within the sensor arrangement. This enables that the first evaluation channel and the second evaluation are operated independently from each other.

[0019] According to at least one embodiment of the sensor arrangement, for each position along the sensing distance within the two-dimensional arrangement the sensor arrangement comprises at least two sensors that are connected with the first evaluation channel and whose sensing range extends over the respective position. These at least two sensors can be arranged adjacent to each other along a direction that runs parallel to the sensing distance or along a direction that extends perpendicular to the sensing distance and parallel to a main plane of extension of the two-dimensional arrangement. The at least two sensors can be arranged shifted with respect to each other along the sensing distance. The sensing ranges of the at least two sensors can overlap along a direction that extends parallel to the sensing distance. With this arrangement of the sensors connected with the first evaluation channel it is guaranteed that for each position along the sensing distance at least one sensor connected with the first evaluation channel can detect the movement of electrically conductive material. The overlap of the sensing ranges enables that detected electrically conductive material can unambiguously be identified. For example, electrically conductive material detected by a first sensor of the sensors is also detected by a second sensor of the sensors before the electrically conductive material leaves the sensing range of the first sensor. In this way, with the sensors that are connected with the first evaluation channel the movement of an object comprising electrically conductive material over more than one sensing range can be related to the same object by the sensor arrangement. Thus, exclusively with the sensors that are connected with the first evaluation channel the position of moving electrically conductive material can be determined along the sensing distance.

[0020] According to at least one embodiment of the sensor arrangement, for each position along the sensing distance within the two-dimensional arrangement the sensor arrangement comprises at least two sensors that are connected with the second evaluation channel and whose sensing range extends over the respective position. These at least two sensors can be arranged adjacent to each other along a direction that runs parallel to the sensing distance or along a direction that extends perpendicular to the sensing distance and parallel to a main plane of extension of the two-dimensional arrangement. The at least two sensors can be arranged shifted with respect to each other along the sensing distance. The sensing ranges of the at least two sensors can overlap along a direction that extends parallel to the sensing distance. With this arrangement of the sensors connected with the second evaluation channel it is guaranteed that for each position along the sensing distance at least one sensor can detect the movement of electrically conductive material. The overlap of the sensing ranges enables that detected electrically conductive material can unambiguously be identified. For example, electrically conductive material detected by a first sensor of the sensors connected with the second evaluation channel is also detected by a second sensor of the sensors connected with the second evaluation channel before the electrically conductive material leaves the sensing range of the first sensor. In this way, with sensors that are connected with the second evaluation channel the movement of an object comprising electrically conductive material over more than one sensing range can be related to the same object by the sensor arrangement. Thus, exclusively with the sensors that are connected with the second evaluation channel the position of moving electrically conductive material can be determined along the sensing distance.

[0021] According to at least one embodiment of the sensor arrangement, the two-dimensional arrangement comprises at least one first row of sensors and at least one second row of sensors. The first row can have a main direction of extension. The main direction of extension of the first row can extend parallel to the sensing distance. The second row can have a main direction of extension. The main direction of extension of the second row can extend parallel to the sensing distance. The first row of sensors can comprise at least two sensors that are connected with the first evaluation channel and at least two sensors that are connected with the second evaluation channel. The second row of sensors can comprise at least two sensors that are connected with the first evaluation channel and at least two sensors that are connected with the second evaluation channel. The first row of sensors and the second row of sensors each extend within the two-dimensional arrangement.

[0022] The main direction of extension of the first row can extend parallel to the main direction of extension of the second row. The arrangement of the sensors in at least two rows enables that sensing ranges of different sensors overlap along the sensing distance.

[0023] According to at least one embodiment of the sensor arrangement, at least one sensor of the first row has a first sensing range along the sensing distance and at least one sensor of the second row has a second sensing range along the sensing distance, wherein the first sensing range and the second sensing range partially overlap. The first sensing range and the second sensing range can partially overlap along the sensing distance. This can mean, that along the sensing distance or along a direction that extends parallel to the sensing distance a part of the first sensing range extends parallel to a part of the second sensing range. However, other parts of the first sensing range may not extend parallel to the second sensing range. It is also possible that other parts of the second sensing range do not extend parallel to the first sensing range. The at least one sensor of the first row and the at least one sensor of the second row can both be connected with the first evaluation channel. It is also possible that the at least one sensor of the first row and the at least one sensor on the second row are connected with the second evaluation channel. This arrangement of the sensors enables that the sensors of the first evaluation channel can detect the movement of electrically conductive material at each position along the sensing distance and that the sensors of the second evaluation channel can detect the movement of electrically conductive material at each position along the sensing distance as well. Thus, the first evaluation channel and the second evaluation channel can be independent from each other.

[0024] According to at least one embodiment of the sensor arrangement, the sensor arrangement comprises an evaluation unit that is configured to receive signals detected by the sensors. The evaluation unit can be configured to evaluate the received signals. In this way, for example the position of detected electrically conductive material can be determined by the evaluation unit.

[0025] According to at least one embodiment of the sensor arrangement, the evaluation unit is configured to determine the spatial position of moving electrically conductive material along the sensing distance from signals received from the sensors. The received signals can each be a sensor signal. For example, a sensor signal can be a current or a voltage that is measured for a coil of the sensor arrangement, respectively. The received signals can be sensor signals that are measured for different sensors of the sensor arrangement. The evaluation unit can be configured to receive the information which sensor signal is measured for each sensor. From the measured sensor signal it can be determined where electrically conductive material moves within the sensing range of the respective sensor. The evaluation unit can receive or have the information at which position within the two-dimensional arrangement each sensor is arranged. The evaluation unit can be configured to determine the position of moving electrically conductive material along the sensing distance from a sensor signal measured for at least one sensor of the sensor arrangement and the position of the sensor within the two-dimensional arrangement. It is also possible that the evaluation unit is configured to determine the position of moving electrically conductive material along the sensing distance from sensor signals measured for several of the sensors of the sensor arrangement and the position of these sensors within the two-dimensional arrangement. Determining the spatial position of electrically conductive material can be employed for example in monitoring a movable railway element of a railway system.

[0026] According to at least one embodiment of the sensor arrangement, the evaluation unit is configured to differentiate between at least two different spatial positions of the electrically conductive material along the sensing distance. This can mean, that the evaluation unit is configured to determine the spatial position of the electrically conductive material from signals received from at least one of the sensors for at least two different spatial positions. It is also possible that the evaluation unit is configured to determine the spatial position of the electrically conductive material from signals received from several of the sensors or all sensors. The two different spatial positions are arranged spaced apart from each other. Determining the spatial position of the electrically conductive material has the advantage that the position of for example a movable railway element can be monitored with an improved accuracy.

[0027] According to at least one embodiment of the sensor arrangement, the evaluation unit is configured to differentiate between at least three different spatial positions of the electrically conductive material along the sensing distance. The three different spatial positions can be arranged spaced apart from each other. Determining the spatial position of the electrically conductive material has the advantage that the position of for example a movable railway element can be monitored with an improved accuracy. A higher number of spatial positions that can be differentiated also improves the accuracy.

[0028] According to at least one embodiment of the sensor arrangement, the evaluation unit is configured to differentiate between at least four different spatial positions of the electrically conductive material along the sensing distance. The four different spatial positions can be arranged spaced apart from each other. Determining the spatial position of the electrically conductive material has the advantage that the position of for example a movable railway element can be monitored with an improved accuracy. A higher number of spatial positions that can be differentiated also improves the accuracy.

[0029] According to at least one embodiment of the sensor arrangement, the evaluation unit is configured to differentiate between a plurality of different spatial positions of the electrically conductive material along the sensing distance. The plurality of different spatial positions can be arranged spaced apart from each other or adjacent to each other or a combination of both. Determining the spatial position of the electrically conductive material has the advantage that the position of for example a movable railway element can be monitored with an improved accuracy. A higher number of spatial positions that can be differentiated also improves the accuracy.

[0030] According to at least one embodiment of the sensor arrangement, the evaluation unit comprises an output and the evaluation unit is configured to provide the measured spatial position at the output. Via the output the spatial position can be provided to a superior unit which can for example be employed for monitoring an area or a volume within which the sensing distance is arranged. Thus, the sensor arrangement can be employed for monitoring an area or a volume for the movement of electrically conductive material. The measured spatial position can for example be provided to a monitoring unit that is configured to monitor railway traffic. In order to comply with safety requirements it is necessary to monitor where movable railway elements are arranged. Only if a movable railway element is arranged at a position where it is supposed to be a rail vehicle is allowed to pass the position of the movable railway element. Providing not only two possible end positions of the movable railway element but the measured spatial position has the advantage that the railway system can be monitored with an improved accuracy.

[0031] According to at least one embodiment of the sensor arrangement, the evaluation unit is configured to determine the spatial position of at least a segment of a movable railway element of the railway system along the sensing distance, and wherein the movable railway element comprises electrically conductive material. Also the segment of the movable railway element comprises electrically conductive material. A spatial position can be a position in space. This means, the evaluation unit can be configured to determine where the segment of the movable railway element is arranged. The evaluation unit is configured to determine the spatial position of the segment since the segment comprises electrically conductive material and the evaluation unit is configured to determine the spatial position of moving electrically conductive material along the sensing distance from signals received from the sensors.

[0032] The respective spatial position can relate to the distance between the segment of the movable railway element and a rail of the railway system. The rail can be a non-movable rail, for example a stock rail. Another expression for "stock rail" is "closure rail". The stock rail can be a non-movable rail of a railway switch. For the case that the movable railway element is in direct contact with the rail, the measured distance is 0. For the case that the movable railway element is not in direct contact with the rail, the distance between the segment and the rail is greater than 0. That the respective spatial position relates to the distance between the segment and the rail can mean, that the spatial position of the segment is measured in relation to the rail. In other words, the measured spatial position can give the distance between the segment and the rail.

[0033] As the sensor arrangement can only detect parts of the movable railway element that are arranged within the sensing range of at least one of the sensors, the sensor arrangement is configured to measure a spatial position of at least a segment of the movable railway element. This means, if the movable railway element is significantly larger than the sensor arrangement or the two-dimensional arrangement, the sensor arrangement can only measure the spatial position of a segment of the movable railway element. The sensor arrangement can be configured to measure the spatial position of that segment of the movable railway element that is arranged within the sensing range of at least one of the sensors. The segment of the movable railway element is a part of the movable railway element. The segment is not necessarily separated from other parts of the movable railway element. It is rather possible that it is not visible where the segment begins and where it ends. The position of the segment in the movable railway element is defined by the prerequisite that the segment is arranged within the sensing range of at least one of the sensors. This means, the segment of the movable railway element is that part of the movable railway element that the sensor arrangement is configured to detect. The sensor arrangement is not configured to detect the spatial position of parts of the movable railway element that are arranged outside of the sensing ranges of the sensors.

[0034] The segment of the movable railway element can be a front segment of the movable railway element. This means, that the segment can be arranged at the position of the movable railway element which is configured to be moved by the largest distance compared to other segments of the movable railway element. If the movable railway element is a tongue rail, the segment can be arranged at that position of the tongue rail which is supposed to be in direct contact with a non-movable rail of the railway system in one of the end positions of the tongue rail.

[0035] Measuring the spatial position of the segment of the movable railway element enables a monitoring of the railway system with an improved accuracy.

[0036] According to at least one embodiment of the sensor arrangement, the sensor arrangement comprises a rail claw that is connectable to a rail of the railway system. A rail claw is a mounting device that is connectable to a rail. The rail claw can be configured to be connected or fixed to a rail at the side of the rail which faces away from the side where wheels of rail vehicles can pass. This means, the rail claw is configured to be arranged below the rail. The rail claw can comprise at least one screw. The rail claw can be configured to be connected to a rail of the railway system by the at least one screw. The rail of the railway system can be a stock rail. Since the sensor arrangement comprises a rail claw the sensor arrangement can be mechanically fixed to the rail. Another mechanical connection to the railway system is not required. This has the advantage that the sensors are protected from damage caused by mechanical contact with the railway system.

[0037] According to at least one embodiment of the sensor arrangement, the sensors are mechanically connected with the rail claw. For employing the sensor arrangement a further mechanical connection of the sensor arrangement with the railway system is not required. The mechanical connection via the rail claw with a rail of the railway system can be the only mechanical connection of the sensor arrangement with the railway system. Thus, the sensors are not in mechanical contact with the movable railway element. This has the advantage that the sensors are protected from damage caused by mechanical contact with the railway system.

[0038] According to at least one embodiment of the sensor arrangement, the sensors are configured to be arranged spaced apart from a movable railway element of the railway system. This means, the sensors are configured to be not in direct mechanical contact with the movable railway element. This has the advantage that the sensors are protected from damage caused by mechanical contact with the movable railway element.

[0039] The following description of figures may further illustrate and explain exemplary embodiments. Components that are functionally identical or have an identical effect are denoted by identical references. Identical or effectively identical components might be described only with respect to the figures where they occur first. Their description is not necessarily repeated in successive figures.

Figure 1 shows a top view on an exemplary embodiment of the sensor arrangement.

Figure 2 shows a top view on another exemplary embodiment of the sensor arrangement.

Figure 3 shows a perspective view on another exemplary embodiment of the sensor arrangement.

Figure 4 shows a top view on a railway system.

Figure 5 shows a top view on an exemplary embodiment of the sensor arrangement.

[0040] With figures 6, 7 and 8 an exemplary embodiment of the sensor arrangement is described.

[0041] Figure 1 shows a top view on an exemplary embodiment of a sensor arrangement 20 for a railway system 21. The sensor arrangement 20 comprises a plurality of sensors and each sensor 24 comprises a coil. The sensors 24 are arranged in a two-dimensional arrangement. Each sensor 24 is schematically drawn with approximately the shape of a square in the top view. However, the sensors 24 can also have a different shape. Each sensor 24 has a sensing range SR within which the respective sensor 24 is configured to detect movement of electrically conductive material. For two of the sensors 24 the respective sensing range SR is drawn with dashed lines as an example. The respective sensor 24 is arranged in the center of the sensing range SR. The sensing range SR of these sensors 24 and of the other sensors 24 can also have a different shape and extension than shown in figure 1.

[0042] For each position along a sensing distance SD within the two-dimensional arrangement the sensor arrangement 20 comprises at least two sensors 24 of the plurality of sensors 24 whose sensing range SR extends over the respective position. The sensing distance SD is drawn as a dotted line in figure 1. This sensing distance SD is only an example and the sensing distance SD can also be arranged at another position and can have another shape. The sensing ranges SR of the two sensors 24 for which the sensing range SR is shown in figure 1 overlap along the sensing distance SD. This is also possible for the other sensors 24 so that for each position along the sensing distance SD the sensor arrangement 20 comprises at least two sensors 24 whose sensing range SR extends over the respective position.

[0043] The two-dimensional arrangement comprises a first row 28 of sensors 24, a second row 29 of sensors 24 and a third row 33 of sensors 24. Each row 28, 29, 33 extends parallel to the sensing distance SD. Within each row 28, 29, 33 the sensors 24 are equally spaced to each other. At least one sensor 24 of the first row 28 has a first sensing range SRI along the sensing distance SD and at least one sensor 24 of the second row 29 has a second sensing range SR2 along the sensing distance SD, wherein the first sensing range SRI and the second sensing range SR2 partially overlap. This is shown for the two sensors in figure 1 for which the sensing range SR is depicted. It is possible also for other sensors 24 that their sensing ranges SR partially overlap.

[0044] Figure 2 shows a top view on another exemplary embodiment of the sensor arrangement 20. The two-dimensional arrangement has the same setup as shown in figure 1. In comparison to the embodiment shown in figure 1, here the sensor arrangement 20 comprises a first evaluation channel and a second evaluation channel. Some of the sensors 24 of the plurality of sensors 24 are connected with the first evaluation channel and other sensors 24 of the plurality of sensors 24 are connected with the second evaluation channel. The sensors that are connected with the first evaluation channel are remarked with a "1" in figure 2 and the sensors 24 that are connected with the second evaluation channel are remarked with a "2" in figure 2. The sensors 24 connected with the first evaluation channel and the sensors 24 connected with the second evaluation channel are arranged alternatingly along the sensing distance SD. This means, for each row the sensors 24 connected with the first evaluation channel and the sensors 24 connected with the second evaluation channel are arranged alternatingly along the sensing distance SD.

[0045] For each position along the sensing distance SD within the two-dimensional arrangement the sensor arrangement 20 comprises at least two sensors 24 that are connected with the first evaluation channel and whose sensing range SR extends over the respective position. As an example, the sensing ranges SR of two sensors 24 connected with the first evaluation channel are marked in figure 2 with dashed lines in the same way as in figure 1. For each position along the sensing distance SD within the two-dimensional arrangement the sensor arrangement 20 comprises at least two sensors 24 that are connected with the second evaluation channel and whose sensing range SR extends over the respective position. As an example, the sensing ranges SR of two sensors 24 connected with the second evaluation channel are marked in figure 2 with dashed lines in the same way as in figure 1.

[0046] In figure 3 a perspective view on another exemplary embodiment of the sensor arrangement 20 is shown. In comparison to the embodiment shown in figure 1 the sensor arrangement 20 further comprises an evaluation unit 35 that is configured to receive signals detected by the sensors 24. The evaluation unit 35 is connected with the sensors 24. The evaluation unit 35 is configured to determine the spatial position of moving electrically conductive material along the sensing distance SD from signals received from the sensors 24. Furthermore, the evaluation unit 35 is configured to differentiate between at least two different spatial positions of the electrically conductive material along the sensing distance SD. The evaluation unit 35 comprises an output 30 and the evaluation unit 35 is configured to provide the measured spatial position at the output 30. Moreover, the evaluation unit 35 is configured to determine the spatial position of at least a segment 34 of a movable railway element 25 of the railway system 21 along the sensing distance SD, and wherein the movable railway element 25 comprises electrically conductive material. The determination of the spatial position of the segment 34 is described with figures 6 to 8.

[0047] Figure 4 shows a top view on the railway system 21 which is a railway switch. The railway switch comprises a movable railway element 25. In figure 4, a front part 38 of the movable railway element 25 is not in direct contact with a rail 23 of the railway switch. The rail 23 is a stock rail. The movable railway element 25 is arranged spaced apart from the rail 23. In this arrangement rail vehicles can move from the left to the top right position in figure 4 or the other way around. In another state the movable railway element 25 can be in direct contact with the rail 23 at a contact position 27. In this arrangement a rail vehicle can move from the left to the bottom right position in figure 4 or the other way around. For a safe railway traffic it is necessary to monitor the position of the movable railway element 25.

[0048] Figure 5 shows an exemplary embodiment of the sensor arrangement 20 mounted to a rail 23 of the railway system 21. The sensor arrangement 20 comprises a rail claw 22 that is connected to the rail 23 of the railway system 21. Figure 5 shows a top view on the rail 23. The rail claw 22 is arranged below the rail 23. Thus, only parts of the rail claw 22 are visible in figure 5. The sensors 24 are mechanically connected with the rail claw 22. Adjacent to the rail 23 a movable railway element 25 of the railway system 21 is arranged. The sensors 24 are arranged below the movable railway element 25. Therefore, the sensors 24 are not visible in figure 5.

[0049] Figure 6 shows a side view on an exemplary embodiment of the sensor arrangement 20. In addition, a cross section through a rail 23 of the railway system 21 and a movable railway element 25 are shown. The rail claw 22 of the sensor arrangement 20 is arranged below the rail 23 and fixed to the rail 23 with two clamp parts 31. The different parts of the rail claw 22 are connected with each other by screws 32. The sensors 24 are arranged adjacent to the rail claw 22 and mechanically connected with the rail claw 22. In figure 6 the two-dimensional arrangement of the sensors 24 is schematically drawn as a rectangle. Above the sensors 24 and adjacent to the rail 23, the movable railway element 25 is arranged. The sensors 24 are arranged spaced apart from the movable railway element 25. This means, the sensors 24 and the movable railway element 25 are not in mechanical contact. The movable railway element 25 is configured to be moved along a lateral direction x. The lateral direction x is indicated by an arrow. In figure 6 a situation is shown, where the movable railway element 25 is not in direct contact with the rail 23. The movable railway element 25 is positioned spaced apart from the rail 23.

[0050] Figure 7 shows the exemplary embodiment of figure 6 and the movable railway element 25 in another state. The movable railway element 25 is in direct contact with the rail 23. In a calibration step the spatial position measured by the sensor arrangement 20 for this situation can be saved. This measured spatial position can be employed as a reference value for the furthest position in one direction that the movable railway element 25 can reach. This measured spatial position is also the reference value for the closed position of the movable railway element 25. This means, if this spatial position is measured for the movable railway element 25, the movable railway element 25 is in direct contact with the rail 23. Therefore, a rail vehicle can safely pass the railway switch. The other spatial positions that are measured by the sensor arrangement 20 can be given with respect to this reference value. Thus, it can be measured how far the movable railway element 25 is arranged from the closed position. This information can be employed for deciding if it is safe for a rail vehicle to pass the railway switch.

[0051] In figure 7 a first edge 36 of the movable railway element 25 is arranged above the sensors 24 and a second edge 37 of the movable railway element 25 is not arranged above the sensors 24. The second edge 37 is the edge which is arranged close to the rail 23. The first edge 36 is arranged opposite to the second edge 37. In this configuration the second edge 37 is outside of the sensing ranges SR of all the sensors 24. As an example, the sensing ranges SR of two sensors 24 of the sensor arrangement 20 are drawn in figure 7. These two sensors 24 are arranged at opposite edges of the two-dimensional arrangement. As the second edge 37 is arranged outside of the sensing ranges SR, in this arrangement the sensor arrangement 20 cannot detect the second edge 37. However, the first edge 36 is still arranged above the sensors 24 and within the sensing ranges SR of at least some of the sensors 24. Thus, in this arrangement the sensor arrangement 20 can detect the movement of the first edge 36 of the movable railway element 25. As the movable railway element 25 always has the same size the position of the second edge 37 can be derived from the position of the first edge 36.

[0052] If the movable railway element 25 or one edge 36, 37 of the movable railway element 25 enters the sensing range SR of a sensor 24, the coil of that sensor 24 is partially damped and a sensor signal, as for example a current, is induced in the coil. Thus, this movement of the movable railway element 25 can be detected. Once the movable railway element 25 extends over the whole sensing range SR of a sensor 24, the coil of that sensor 24 is fully damped and a further movement of the movable railway element 25 does not change the sensor signal, as for example the current, in the coil. This means, in this situation a further movement of the movable railway element 25 cannot be detected by that sensor 24. A further movement of the movable railway element 25 can only be detected once the movable railway element 25 does not extend over the whole sensing range SR of the sensor 24 anymore. It is also possible that a movement of the movable railway element 25 is in this situation detected by another sensor 24 for which the movable railway element 25 does not extend over the whole sensing range SR.

[0053] It is possible to employ the coils that are fully damped for a calibration or a compensation. The coils can have a drift that can depend on time and/or temperature. For a fully damped coil the measured sensor signal should not change for that time that the coil is fully damped. Therefore, the change in the sensor signal during the fully damped state is caused by drift. By measuring the change in the sensor signal during the fully damped state the amount of drift can be determined. The determined amount of drift can be employed for the other coils in order to correct the sensor signals measured for these coils.

[0054] Figure 8 shows the exemplary embodiment of figure 6 and the movable railway element 25 in another state. The movable railway element 25 is in its position where it is arranged at the maximum possible distance from the rail 23. Also the measured spatial position of this arrangement can be saved in a calibration step as a further reference value. The further reference value can be employed in the same way as the reference value for providing the spatial position of the movable railway element 25.

[0055] In the configuration of figure 8 the first edge 36 of the movable railway element 25 is outside of the sensing ranges SR of all the sensors 24. In figure 8 two sensing ranges SR of the sensors 24 of the sensor arrangement 20 are drawn as examples. However, the second edge 37 of the movable railway element 25 is arranged within the sensing range SR of at least one of the sensors 24. Thus, the movement of the movable railway element 25 can be detected by the sensor arrangement 20.

Reference numerals

[0056]

20	sensor arrangement
21	railway system
22	rail claw
23	rail
24	sensor
25	movable railway element
26	tongue rail
27	contact position
28	first row
29	second row
30	output
31	clamp part
32	screw
33	third row
34	segment
35	evaluation unit
36	first edge
37	second edge
38	front part
SD	sensing distance
SR	sensing range
SRI	first sensing range
SR2	second sensing range
x	lateral direction

Claims

1. Sensor arrangement (20) for a railway system (21), the sensor arrangement (20) comprising:

   - a plurality of sensors (24), each sensor (24) comprising a coil, wherein
   - the sensors (24) are arranged in a two-dimensional arrangement,
   - each sensor (24) has a sensing range (SR) within which the respective sensor (24) is configured to detect movement of electrically conductive material, and
   - for each position along a sensing distance (SD) within the two-dimensional arrangement the sensor arrangement (20) comprises at least two sensors (24) of the plurality of sensors (24) whose sensing range (SR) extends over the respective position.

2. Sensor arrangement (20) according to claim 1, wherein the sensor arrangement (20) comprises at least one first evaluation channel and at least one second evaluation channel, where some of the sensors (24) of the plurality of sensors (24) are connected with the first evaluation channel and other sensors (24) of the plurality of sensors (24) are connected with the second evaluation channel.

3. Sensor arrangement (20) according to claim 2, wherein sensors (24) connected with the first evaluation channel and sensors (24) connected with the second evaluation channel are arranged alternatingly along the sensing distance (SD).

4. Sensor arrangement (20) according to one of claims 2 or 3, wherein for each position along the sensing distance (SD) within the two-dimensional arrangement the sensor arrangement (20) comprises at least two sensors (24) that are connected with the first evaluation channel and whose sensing range (SR) extends over the respective position.

5. Sensor arrangement (20) according to one of claims 2 to 4, wherein for each position along the sensing distance (SD) within the two-dimensional arrangement the sensor arrangement (20) comprises at least two sensors (24) that are connected with the second evaluation channel and whose sensing range (SR) extends over the respective position.

6. Sensor arrangement (20) according to one of the preceding claims, wherein the two-dimensional arrangement comprises at least one first row (28) of sensors (24) and at least one second row (29) of sensors (24).

7. Sensor arrangement (20) according to claim 6, wherein at least one sensor (24) of the first row (28) has a first sensing range (SRI) along the sensing distance (SD) and at least one sensor (24) of the second row (29) has a second sensing range (SR2) along the sensing distance (SD), wherein the first sensing range (SRI) and the second sensing range (SR2) partially overlap.

8. Sensor arrangement (20) according to one of the preceding claims, wherein the sensor arrangement (20) comprises an evaluation unit (35) that is configured to receive signals detected by the sensors (24).

9. Sensor arrangement (20) according to claim 8, wherein the evaluation unit (35) is configured to determine the spatial position of moving electrically conductive material along the sensing distance (SD) from signals received from the sensors (24) .

10. Sensor arrangement (20) according to claim 9, wherein the evaluation unit (35) is configured to differentiate between at least two different spatial positions of the electrically conductive material along the sensing distance (SD).

11. Sensor arrangement (20) according to one of claims 9 or 10, wherein the evaluation unit (35) comprises an output (30) and the evaluation unit (35) is configured to provide the measured spatial position at the output (30).

12. Sensor arrangement (20) according to one of claims 8 to 11, wherein the evaluation unit (35) is configured to determine the spatial position of at least a segment (34) of a movable railway element (25) of the railway system (21) along the sensing distance (SD), and wherein the movable railway element (25) comprises electrically conductive material.

13. Sensor arrangement (20) according to one of the preceding claims, wherein the sensor arrangement (20) comprises a rail claw (22) that is connectable to a rail (23) of the railway system (21).

14. Sensor arrangement (20) according to claim 13, wherein the sensors (24) are mechanically connected with the rail claw (22).

15. Sensor arrangement (20) according to one of the preceding claims, wherein the sensors (24) are configured to be arranged spaced apart from a movable railway element (25) of the railway system (21).

FIG. 1

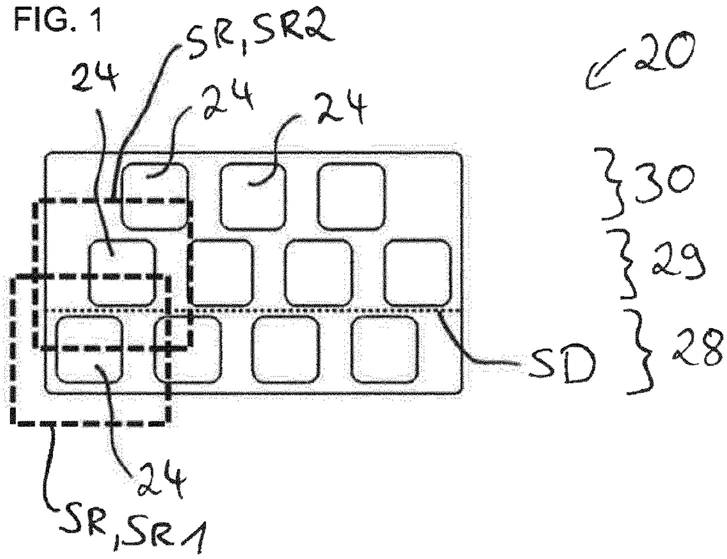


FIG. 2

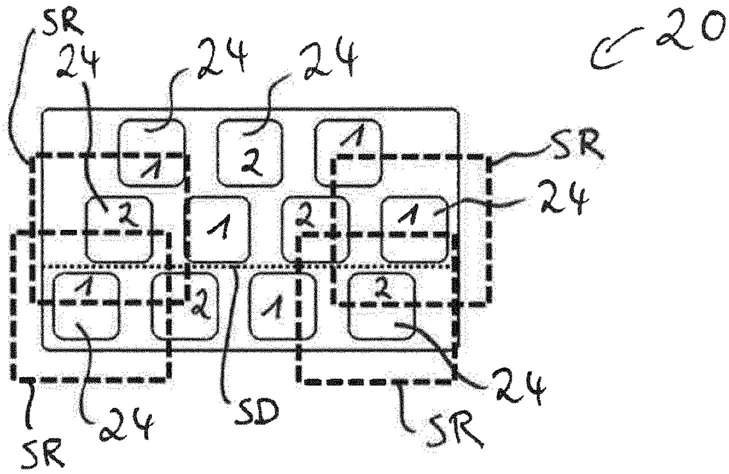


FIG. 3

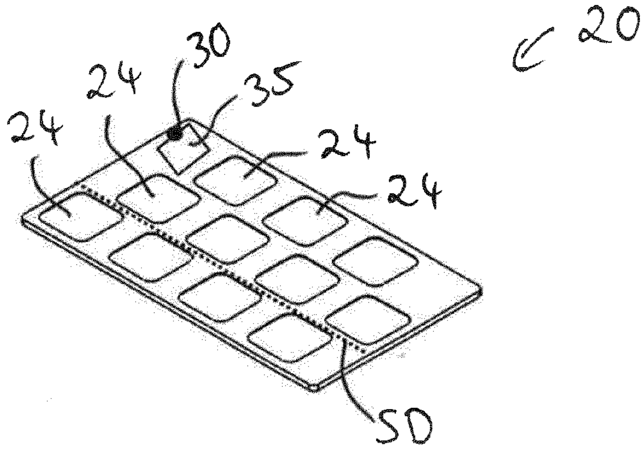


FIG. 4

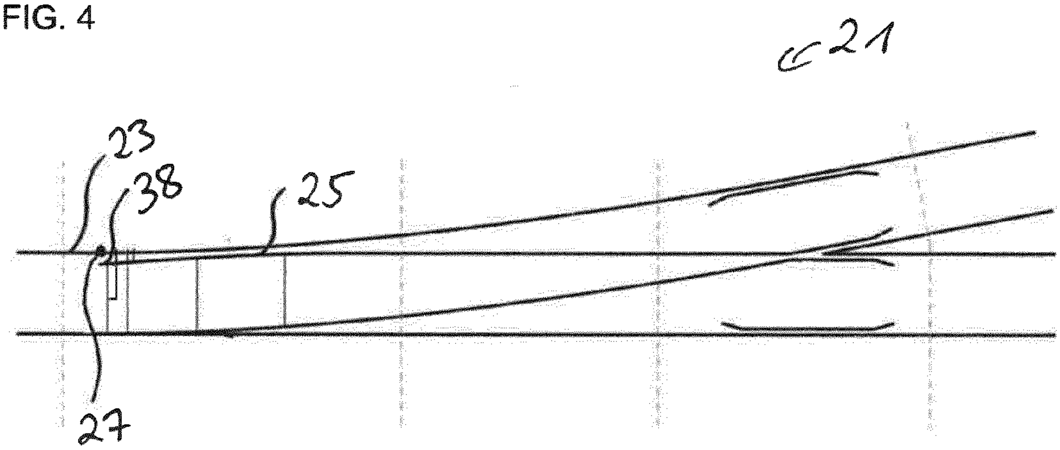


FIG. 5

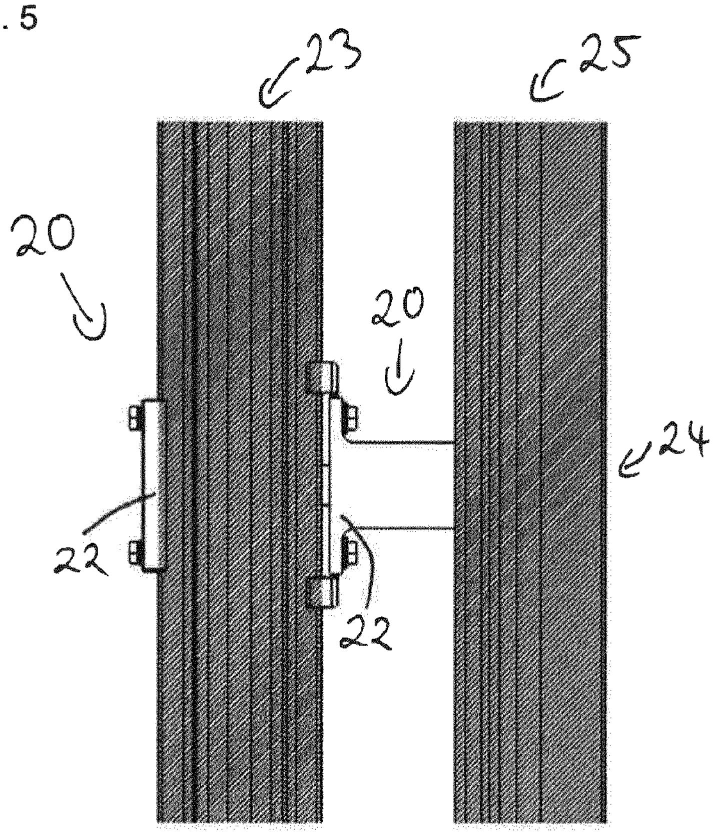


FIG. 6

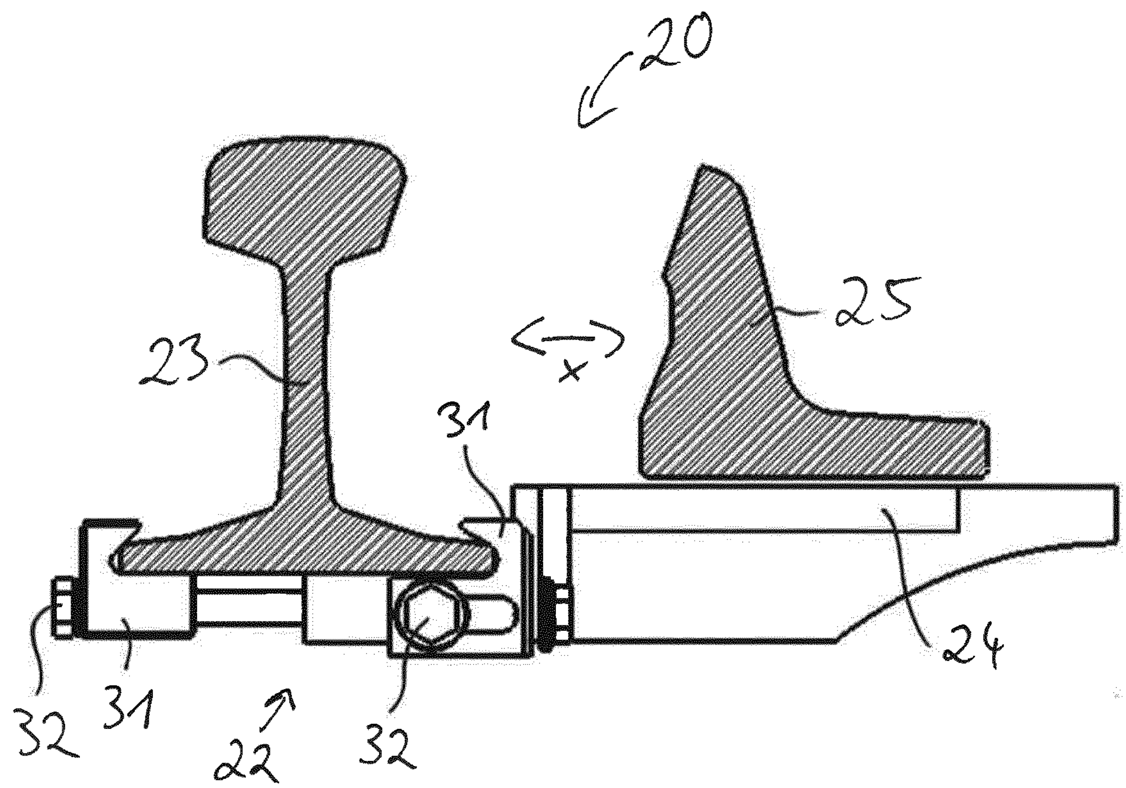


FIG. 7

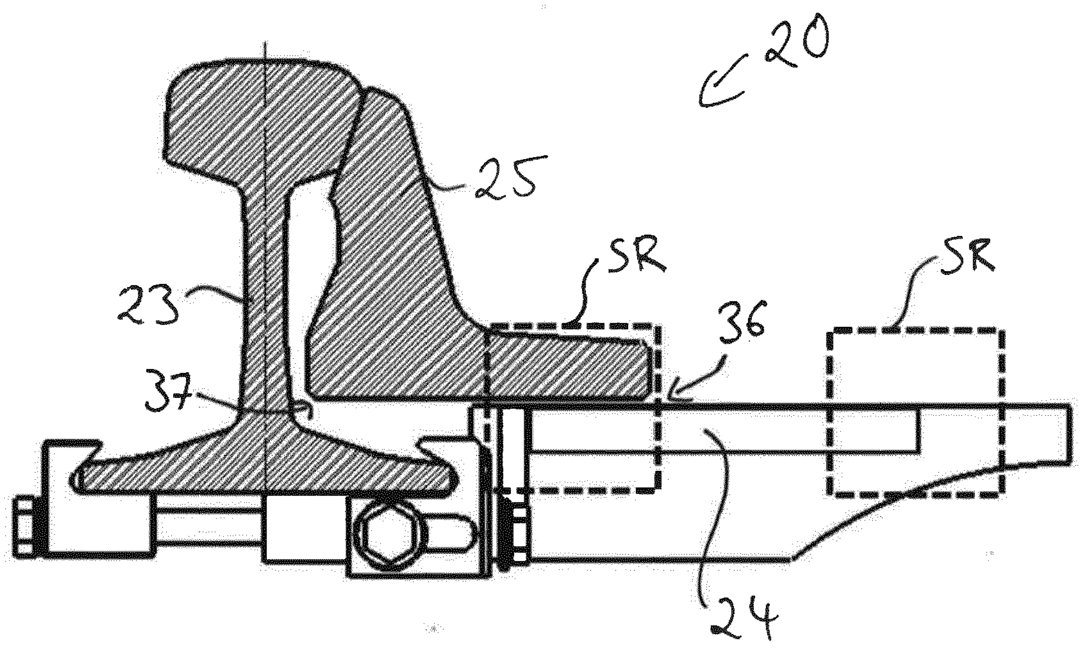
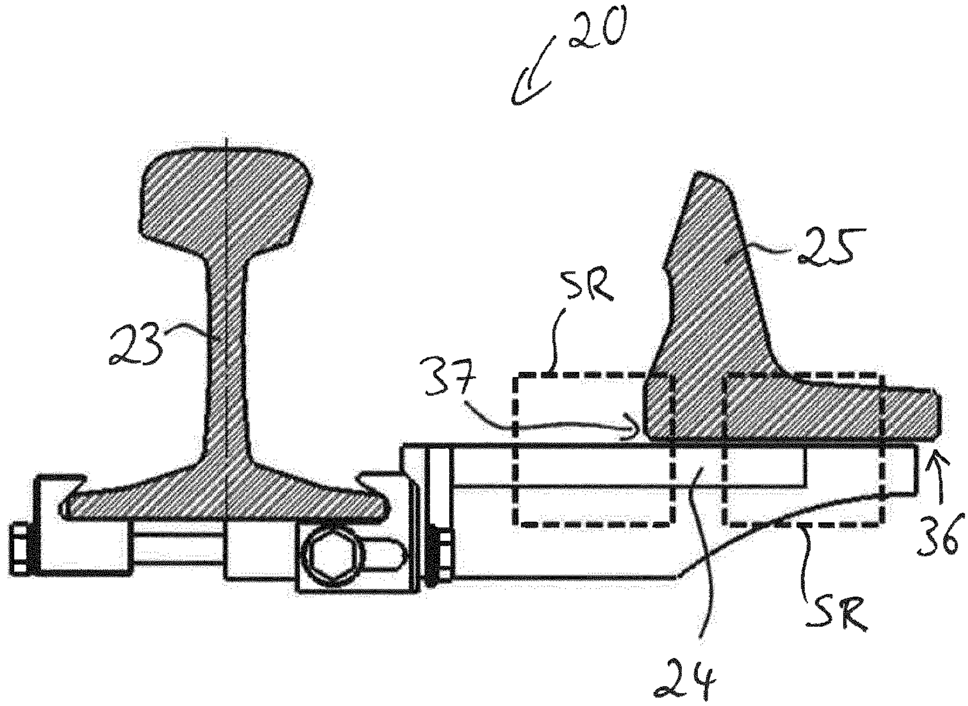


FIG. 8



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EUROPEAN SEARCH REPORT

Application Number
EP 21 20 3955

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 270 363 A1 (SIEMENS AG [DE]) 2 January 2003 (2003-01-02) * figures 1, 2 and 6 - 8; paragraphs [0012] - [0014], [0018], [0020], [0021], [0024] and [0026] *	1-15	INV. B61L5/10
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A	EP 0 374 697 A1 (FRAUSCHER J HYDRAULIK SENSORTE [AT]) 27 June 1990 (1990-06-27) * figure 1 and 2; column 1, lines 1 - 11 *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

B61L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	4 April 2022	Plützer, Stefan

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