SMT Material Transfer

This invention relates to a pallet for providing an SMT machine with SMT material, an SMT machine, a transfer system for transferring SMT material between an SMT machine and a pallet, a method for transferring SMT material to an SMT machine, a compliance plate, and a method of providing SMT material to an SMT production line.

Background and Prior Art

The present invention relates in general to the technical field of producing workpieces, such as printed circuit boards (PCBs), including providing them with electronic components in a so-called surface-mount technology (SMT) process (i.e. to produce printed circuit board assemblies or PCBAs).

FIG. 1 schematically shows, from the side, a simple production line for producing PCBAs in an SMT process. The workpieces travel in a transport direction T parallel to the X axis shown along the production line, generally carried by conveyors. At the start of the illustrated production line is a printing machine 1, in which a workpiece may receive a metallic patterning produced on at least one surface, by printing solder paste through a printing screen or stencil onto the workpiece surface. The quality of printing is checked by an inspection (or "SPI") machine 2. Assuming the print quality is sufficient, then the printed boards progress to at least one placement machine 3, with three such machines being shown in FIG. 1. These are operable to place components, in particular electrical / electronics components, onto the board, to coincide with the location of printed pads formed by the printing machine 1. Placement machines are described in more detail below. Following placement, the PCBAs progress to a reflow oven 4, to reflow the printed solder paste. Other machines may be provided also, for example additional inspection machines may be provided after the placement machines 3, but these are not relevant to the present invention.

The placement machines 3 remove electronic components from a component supply device in an automated manner, and then place these components onto a component carrier such as, for example, a printed circuit board. A transfer of components from the component

supply device to their respective placement position occurs by means of a component handling device, for example a so-called placement head.

The most common packaging for small electronic components uses carrier tapes, sometimes referred to as "belts", into which small pockets are formed. In each of the pockets there is provided one component. Only one type of component is located within each carrier tape. To save space and for easier transport, the carrier tapes are conventionally formed as reels by winding on a spool. Typically, the tape reel is placed in a feeder module which includes drive means for driving the tape forward, such as a motor-driven pin-wheel which engages with holes provided along the length of the carrier tape, and a pick-up area or window which provides access to the components. The feeder module can be removably inserted into a placement machine.

More recently, a cartridge system has been proposed, in which a reel is placed in a passive cartridge module or cassette, which may conveniently be a relatively inexpensive plastic container or envelope of defined shape which may be easily held by a robot, which may be loaded at a central filling station and subsequently inserted into a feeder. As an alternative, if the placement machine itself is provided with tape driving mechanisms, then the cartridge module could be directly inserted into the placement machine. An example of a cartridge and feeder arrangement is described for example in DE 10 2019 127 299.8. In such systems, the feeder unit may be used to drive the carrier tape located within a cartridge unit so that components located within pockets of the carrier tape are moved to a picking region where a placement head of a placement machine can access the components. The picking region could be located within the cartridge or within the feeder, depending on the particular design.

For the operation of the placement machine it is necessary to be able to supply feeders (and / or cartridges depending on the set-up), including respective carrier tapes, to the placement machine. While the feeding of components is largely continuous during operation at high throughput rates, as is the case in smartphone production for example, other electronics manufacturing processes may be characterized by frequent set-up changes, requiring feeders and / or cartridges to be swapped or replaced in bulk. For the purposes of

the present specification, the term "set-up change" is to be understood to mean a bulk change in the feeders or cartridges engaged with a placement machine. This is to be contrasted with "replenishment changes" in which feeders and / or cartridges are replaced at the placement machine as they run out, or approach running out, of components, to ensure as uninterrupted a supply of components as possible.

The refilling of material (i.e. carrier tapes) at the line, as well as the retooling (i.e. fitting of different feeders / cartridges) are currently manual processes that require a high level of personnel input. For some years now, considerable efforts have been made to automate material replenishment and changeover.

As specific background art may be mentioned EP3419402A1. As described in this document, an external exchanging device may be provided to transfer a feeder, which includes both feeding capability and material storage, between a storage location and an operational location, with the exchanging device operable to move along a production line with one or more placement machines parallel to the direction of workpiece throughput. The exchanging device is operative to translate along a rail mounted along the production line, and is supported by the rail (for this reason the device may be termed a "rail-guided vehicle"). Such an approach has various advantages, for example using a machine-mounted rail avoids any problems that may arise due to imperfections in the floor surface, since the exchanging device is held at a fixed vertical position relative to the placement machines, and furthermore a high level of positioning accuracy along the production line is possible. However, there are also various disadvantages associated with such a system. For example, it is necessary to use a dedicated exchanging device for each side of the production line, which may limit how close adjacent lines may be placed. The described system also lacks flexibility, and for example cannot manage cartridge-based feeding systems. It has been found that the system is relatively slow, and is also expensive due to the large requirement for dedicated equipment for each production line.

It has been recognised that a more flexible and potentially cheaper solution may be to equip an automatic-guided vehicle (AGV) with a feeder / cartridge replacement mechanism. As is well-known in the art per se, AGVs are small mobile robot devices, typically movable

across a floor by means of a wheeled chassis, with at least a degree of autonomy. AGVs are available from many manufacturers (and hence relatively inexpensive and with a likelihood that a production line operator may already possess suitable AGVs), and are typically provided with a vertically-drivable upper platform (or "lifting platform") which can carry a load (not shown) such as job-specific equipment. A conventional AGV 5 is schematically shown in FIG. 2, with the chassis 6, wheels 7 and lifting platform 8, including two engagement features 9 which permit a load to be correctly positioned onto the lifting platform 8, highlighted. These are generally quite simple, for example upwardly pointing conical projections which provide centring of the load onto the lifting platform 8. Naturally, this requires that the load is provided with corresponding features that mate with features 9, such as conical recesses on the underside of the load. Using such conical features does not hinder removal of the load from the lifting platform 8, as long as the load is removed by raising it vertically upwards away from the lifting problem 8.

Unfortunately, the use of AGVs, such as that shown in FIG. 2, for feeder / cartridge changeover is problematic, since the positioning accuracy of AGVs is generally below that required for feeder / cartridge changeover at a placement machine. If additional means for improving the accuracy are provided, these generally add to the time taken for proper positioning, resulting in unacceptable delays.

EP23194335.8 discloses a transfer system which makes use of such a conventional AGV to provide a placement machine with replacement feeders. This is achieved by using a mechanical positioning system associated with a storage, such as a feeder / cartridge storage, mountable on an AGV platform. While that transfer system is effective, it is relatively mechanically complex, and of significant mass, which must be carried by the AGV. In addition, it is necessary for the AGV to remain attached to the transfer mechanism at least semi-permanently and certainly during the entire transfer operation. This means that i) it is necessary to use dedicated AGVs to perform dedicated transfer operations (for example it would be necessary to use dedicated AGVs to transfer SMT material at a placement machine and at a printing machine), and ii) the AGV must remain proximate the placement machine during the transfer process.

For the purposes of the present invention, printing machines 1 and placement machines 3 will be classed as "SMT machines", and they share the feature that they comprise receptacles accessible from the side of the machine, i.e. at a 'loading side' parallel to the X axis shown, such that transfer of SMT material may be effected from a storage located at or next to the loading side. In addition to feeders, placement machines may require transfer of other SMT materials such as nozzles, grippers etc. Printing machines meanwhile are typically loaded with printing screens or stencils into the main printing receptacle of the printing machine, the screens or stencils typically retained within tensioning frames, and these may require exchange for cleaning, replacement in the case of damage, or replacement for a new printing job. Other SMT materials may equally be exchanged, such as solder paste containers or cartridges, cleaning rolls, cleaning fluid, squeegees etc.

The present invention seeks to provide a cost-effective, robust and fast transfer system suitable to enable automatic provision of SMT material such as, but not limited to, feeders / cartridges, which can for example be implemented using commercially available AGVs (although may also be usable with custom-made AGVs). Advantageously the transfer system is modular, so that AGVs can pick up and deploy a required transfer system as required. In addition, during the transfer of SMT material the AGV is decoupled from both the SMT machine and the SMT material storage. The AGV is thus able to travel away from the SMT machine during the transfer, so that it may perform other, perhaps more urgent, tasks while the transfer is ongoing.

In accordance with the present invention, this aim is achieved by using a pallet system, in which single pallets may be carried by an AGV, and mechanically located at a machine as required. In particular, no additional lifting mechanisms are required other than that provided as standard in conventional AGVs (i.e. the above-mentioned vertically-drivable lifting platform). The pallet may be left in situ at the machine, drawing any required power from it, and so effectively becomes part of that machine.

For convenience, the following terms will be used hereafter in this document with the following meanings:

"Feeder" will be taken to encompass both feeders which include tape reel storage and

a driving means for advancing the carrier tape, and modular cartridge - feeder systems in which tape reel storage and driving means are located in separate interengaging cartridge and feeder parts;

"SMT machine" means a printing machine or placement machine for use in an SMT production line; and

"SMT material" means items or material required by an SMT machine to properly perform its SMT function, including, but not limited to, feeders, printing screens or stencils, component nozzles or grippers, replacement cleaning materials, squeegees and tooling (including support pins, tooling blocks and the like).

X, Y and Z axes will be used as is conventional in the art, with:

the X axis being parallel to the direction of workpiece transport along a production line, increasing in the downstream direction and being substantially horizontal,

the Y axis being orthogonal to the X axis, increasing in the direction towards the placement machine and being substantially horizontal, and

the Z axis being orthogonal to the X and Y axes, being generally vertical and increasing in the upwards direction.

Summary of the Invention

In accordance with a first aspect of the present invention there is provided a pallet for providing an SMT machine with SMT material, comprising:

a base configured for releasably and repeatably engaging with a lifting platform of an automatic-guided vehicle (AGV),

a storage for temporarily retaining the SMT material, and

a mechanical interface configured for releasable and repeatable engagement with a dock provided at the SMT machine through vertical movement of the pallet, such that when the mechanical interface is engaged with the dock, the pallet is retained in a docked configuration in which the base is disengaged from the lift platform of the AGV and supported by the SMT machine, and in which the SMT material may be transferred from the storage to the SMT machine.

In accordance with a second aspect of the present invention there is provided an SMT machine comprising:

a receptacle for receiving SMT material,

a dock configured for releasable and repeatable engagement with a mechanical interface of a pallet through vertical movement of the pallet, such that when the mechanical interface is engaged with the dock, the pallet is retained in a docked configuration on the SMT machine in which SMT material may be transferred from the pallet to the receptacle.

In accordance with a third aspect of the present invention there is provided a transfer system for transferring SMT material between an SMT machine and a pallet, comprising the pallet of the first aspect and the SMT machine of the second aspect.

In accordance with a fourth aspect of the present invention there is provided a method for transferring SMT material to an SMT machine in accordance with any of claims 13 to 18, comprising the steps of:

i) providing a pallet in accordance with any of claims 1 to 12, the storage of the pallet retaining the SMT material,

ii) supporting the base of the pallet on a lifting platform of an automatic-guided vehicle (AGV),

iii) lifting the lifting platform of the AGV into a lifted configuration;

iv) moving the AGV to a location proximate the SMT machine such that the mechanical interface of the pallet is adjacent a loading side of the SMT machine,

v) lowering the lifting platform so that the mechanical interface engages with the dock of the SMT machine and the pallet enters a docked configuration in which the base is disengaged from the lift platform of the AGV and supported by the SMT machine, and

vi) while the pallet is in the docked configuration, transferring the SMT material from the storage to the receptacle of the SMT machine.

In accordance with a fifth aspect of the present invention there is provided a compliance plate for use with an automatic-guided vehicle (AGV), the compliance plate comprising first and second parallel and planar overlying sheets, the first sheet comprising a first interface to engage with a lifting platform of the AGV and the second sheet comprising a

second interface to engage with a load,

wherein the first and second sheets are relatively movable parallel to the planes of the first and second sheets, and

wherein the first and second sheets are mechanically connected via a resiliently deformable intermediate member such that the first and second sheets are biased to a home position.

In accordance with a sixth aspect of the present invention there is provided a method of providing SMT material to an SMT production line comprising at least two SMT machines, the method comprising the steps of:

i) providing an automatic-guided vehicle (AGV),

ii) using the AGV to pick up a pallet carrying SMT material,

iii) driving the AGV to an SMT machine of the SMT production line,

iv) docking the pallet to the SMT machine to enable transfer of the SMT material from the pallet to the SMT machine,

then, while the pallet remains docked to the SMT machine:

v) driving the AGV away from the SMT machine,

vi) using the AGV to pick up a second pallet,

vii) driving the AGV to deliver the second pallet to a delivery location, and

viii) delivering the second pallet to the delivery location.

Other specific aspects and features of the present invention are set out in the accompanying claims.

Brief Description of the Drawings

The invention will now be described with reference to the accompanying drawings (not to scale), in which:

FIG. 1 schematically shows, from the side, an SMT production line;

FIG. 2 schematically shows, in perspective view, an AGV;

FIG. 3 schematically shows, in sectional side view, a pallet docked to an SMT machine

in accordance with an embodiment of the present invention;

FIG. 4 schematically shows, in perspective view from above, a lateral actuation system suitable for the pallet of FIG. 3;

FIG. 5 schematically shows, in perspective view from above, a power and control transfer mechanism for a pallet in accordance with a second embodiment of the present invention;

FIGs. 6 and 7 schematically show, in perspective view, sections of the power and control transfer mechanism taken along the line A-A of FIG. 5, in disengaged and docked configurations respectively;

FIG. 8 schematically shows, in exploded perspective view, a pallet and compliance plate arranged with an AGV, in accordance with an embodiment of the present invention;

FIGs. 9 to 12 schematically show, in a sectional side view, stages in a transfer operation in accordance with an embodiment of the present invention;

FIG. 13 schematically shows a compliance plate in accordance with an embodiment of the present invention from above; and

FIG. 14 schematically shows the compliance plate of FIG. 13 in a sectional side view.

Detailed Description of the Preferred Embodiments of the Invention

FIG. 3 schematically shows, in sectional side view, a pallet 10 docked to an SMT machine 11, with the pallet 10 and the SMT machine 11 being in accordance with the present invention. Also shown is a standard AGV 5, with a chassis 6 supported on wheels 7, and a lifting platform 8 supported by the chassis 6. The upper surface of the lifting platform 8 is mostly flat and arranged in the horizontal X-Y plane, except for conical engagement features 9.

The pallet 10 takes the general form of a tray, lying substantially in the horizontal X-Y plane in use, with a base 28 having an underside comprising pallet engagement features 12 adapted to engage with the engagement features 9, such that when engaged, the pallet 10 is both centred into a set horizontal position with respect to the lifting platform 8, and prevented from significant movement in the horizontal plane. The upper surface of the base 28 of the pallet 10 carries a storage 13 for SMT material (not shown). The storage 13 may be formed

as an integral part of the pallet 10, or may alternatively be modular, i.e. repeatably and releasably attached to the pallet 10. SMT material retained within the storage 13 may be transferred from the storage 13 to a receptacle 26 of the SMT machine 11 via a loading end of the pallet 10, which is shown at the left side of the pallet 10 in FIG. 3.

The pallet 10 comprises, at its loading end, a mechanical interface 14, which in this embodiment comprises a downwardly extending spur and a centring surface 29. The SMT machine 11 meanwhile is provided with a dock 15, in this embodiment a bar which is supported by a strut 27 and which runs along and spaced from a loading side of the SMT machine 11, the loading side being that side of the SMT machine 11 through which SMT material may be loaded into the receptacle 26, i.e. the right hand side of the SMT machine 11 as shown. The dock 15 may be integrally formed with a new SMT machine 11, or alternatively may be retrofitted to an existing SMT machine 11.

The mechanical interface 14 and dock 15 are configured for mutual engagement. In more detail, the mechanical interface 14 is configured for releasable and repeatable engagement with the dock 15 through vertical, i.e. downward, movement of the pallet 10, so that the spur enters the space between the bar and the loading side of the SMT machine 11. The bar abuts against the centring surface 29 so that when the mechanical interface 14 is engaged with the dock 15, the pallet 10 is retained in a docked configuration, at a fixed and repeatable Z and Y position relative to the SMT machine 11, in which the base 28 is disengaged from the lift platform 8 of the AGV 5 and wholly supported by the SMT machine 11. In this docked configuration, the SMT material may be transferred from the storage 13 to the receptacle 16 of the SMT machine 11. In this docked configuration, the pallet 10 is in a stable cantilevered position, with its movement in the Z and Y axes, and clockwise rotation about an axis parallel to the X axis, all being prevented by mechanical interaction between the mechanical interface 14, dock 15 and the loading side of the SMT machine 11.

To enter the docked configuration, the pallet 10 is raised by the lifting platform 8 of the AGV 5 at a location spaced from the SMT machine 11, then the AGV 5 is driven towards the SMT machine 11 until the spur of the mechanical interface overlies the dock 15, then the lifting platform 8 is powered, bringing the pallet 10 down. It should be noted that this

positioning need not be particularly accurate, since the round shape of the bar provides a centring surface that guides the spur towards the SMT machine 11 during insertion of the spur into the dock 15, while the centring surface 29 provides final fine positioning of the pallet 10. The process is explained in more detail with reference to FIGs. 9 to 12 below. Importantly, because of the compliance provided by this design, no additional X-Y or Z positioning means is required by the AGV 5 or pallet 10, with the AGV's built-in lifting platform 8 providing all necessary movement of the pallet 10 to enter the docked configuration. It will however be appreciated that some horizontal force may be exerted on the lifting platform 8 as it descends, lowering the pallet 10 into the docked configuration. Many standard AGVs have sufficient compliance to withstand this horizontal force. However, if the AGV cannot withstand this force, then the process may be adapted by using a separate compliance plate intermediate the pallet 10 and lifting platform 8, and this is described in more detail below.

As noted above, in the docked configuration the pallet 10 is at a fixed Y and Z position relative to the SMT machine 11. It is possible to provide a mechanical interface / dock which also provides reasonably accurate relative positioning in the X direction also (see for example the embodiment shown in FIG. 8). However, for certain types of SMT material, such as feeders for transfer to a placement machine, a higher positional accuracy is required in the X direction than is readily possible using only mechanical centring and / or the AGV's movement accuracy. For such uses it is therefore required to provide means for moving the storage 13 relative to the receptacle 26 parallel to the X axis. An example of such a means is described below with reference to FIG 4.

In addition, although not shown in FIG. 3, the pallet 10 is provided with a pallet power interface for engaging with and drawing power from a machine power interface located at the SMT machine 11, while the pallet 10 is retained in the docked configuration. An exemplary power transfer mechanism is described in more detail below, with reference to FIGs. 5 to 7.

Those skilled in the art will also appreciate that to achieve SMT automation, it is also required to provide for transfer of the SMT material from the storage 13 to the receptacle 26, and indeed from the receptacle 26 to the storage 13, while the pallet 10 is in the docked configuration. Preferably, such a transfer mechanism is provided on the pallet 10, in which

case a transfer system similar to that described in, for example, DE 10 2022 122 895.9 may be used. Alternatively, a transfer mechanism may be provided at the SMT machine 11, and operable to receive and expel SMT material from and to the storage of a docked pallet 10.

As mentioned previously, means for moving the storage 13 relative to the receptacle 26 parallel to the X axis, while the pallet 10 is in its docked configuration, may be provided. FIG. 4 schematically shows, in perspective view from above, such a lateral actuation system suitable for the pallet 10 of FIG. 3. The storage 13 comprises a carriage 16 which is movable relative to the base 28 of the pallet 10 along a horizontal axis, i.e. the X-axis when the pallet 10 is in its docked configuration. The carriage 16 runs on rails 31 which are provided on the upper surface of the base 28, and which thus permit constrained movement of the carriage 16 in this direction relative to the base 28. An actuator 32, here a simple rotary motor, is mounted to the base 28 via an upstanding bracket 33. The actuator 32 drives a belt 34 which in turn rotates a threaded rod 40. The threaded rod 40 engages with a nut 41 attached to the carriage 16, such that rotation of the threaded rod is converted into linear motion of the nut 41, and hence carriage 16, along the rails 31.

As shown in FIG. 4, the storage 13 comprises a magazine for at least one component feeder (not shown). As is well-known in the art, component feeders may be positioned by being slotted into tracks of mating dimensions. For example, the base of a feeder and the associated slots may comprise complementary omega-profiles, such that a feeder slotted into that track is held in a vertical orientation and constrained from all movement relative to that track except along the major axis of the track. The storage 13 comprises a plurality of pallet feeder tracks 42, preferably of the same quantity and pitch as a number of machine feeder tracks 43 provided within receptacle 26 of SMT machine (here a placement machine) 11. To transfer a feeder between the storage 13 and receptacle 26, it is necessary to accurately align the pallet feeder tracks 42 and machine feeder tracks 43, so that a feeder may be slid from one to another. Of course, the feeder tracks 42, 43 must also be at the same height, but this is ensured by the pallet 10 entering the docked configuration. Alignment is achieved by providing a sensor 44 on the carriage 16 at a loading end which is proximal to the SMT machine 11 while the pallet 10 is retained in the docking configuration, which sensor 44 is adapted to detect an alignment feature 45 provided at the loading side of the SMT machine 11. The

sensor 44 may take various forms as will be apparent to those skilled in the art, such as an optical sensor, magnetic sensor or even a mechanical sensor activated or triggered by cooperation with the alignment feature 45 when correctly aligned. Other alignment means are equally possible, for example using optical, laser or magnetic position encoders or the like.

The lateral actuation system described above, including the alignment sensing arrangement, requires power to operate. Similarly, assuming the pallet itself is provided with a transfer system for the SMT material, this too will require power. These systems also require control, preferably by the main control process running the SMT production line including the SMT machine in question.

In a preferred embodiment, the pallet comprises a pallet power interface for engaging with and drawing power from a machine power interface located at the SMT machine, while the pallet is retained in the docked configuration. Advantageously, the pallet power interface is also configured to receive control signals from the SMT machine, while the pallet is retained in the docked configuration.

FIG. 5 schematically shows, in perspective view from above, such a power and control transfer mechanism for a pallet 10' in accordance with a second embodiment of the present invention.

The pallet 10' of this second embodiment has many similarities with that of the first embodiment, which need not be described further. Like reference numerals will therefore be retained wherever possible. Here though the mechanical interface comprises downwardly extending projections 47 of sidewalls 46 of the base 28. Extending between upper and lower ends of the projections 47 are an upper bar 17 and lower bar 18, here each of circular cross-section. The SMT machine 11 comprises a dock 15, which in this embodiment comprises first and second brackets 48 projecting out from the loading side, each bracket 48 having a substantially V-shaped recess 49 dimensioned to receive the upper bar 17 therein. When the pallet 10' is lowered into the docked configuration, the upper bar 17 being guided by the sloping surfaces of the recesses 49, the dock 15 constrains the upper bar 17, and hence the pallet 10', in the Z and Y directions. The lower bar 18 is arranged to abut

against the side of the SMT machine 11 while in the docked configuration, preventing rotation of the pallet 10' about an axis parallel to the X axis.

Projecting from the loading end-side of the base 28 is at least one pallet power interface 38, with two being shown in FIG. 5. Each pallet power interface 38 comprises a board including one or more pogo pins 39 (here three are shown) arranged so that their contact ends point downwardly. As is well-known in the art, pogo pins have resiliently deformable contact ends, usually spring-biased, that may be pressed into contact with conductive contact pads to form an electrical connection. The SMT machine 11 meanwhile is provided with corresponding machine power interfaces 35, supported by respective cantilever supports 37 from the loading side of the SMT machine 11. Each machine power interface 35 comprises a board provided with a number of machine power pads 36 in the form of conductive contact regions, each machine power pad 36 configured to align with and underlie a respective pogo pin 39 while the pallet 10' is in the docked configuration. It is to be understood that there is sufficient 'play' or compliance between the pogo pins 39 and machine power pads 36 that the accuracy of the AGV 5 itself is sufficient to guarantee their mutual alignment in the X direction. The numbers of pogo pins 39 and machine power pads 36 are chosen so that all required electrical power connections and control signals may be passed from the SMT machine 11 to the pallet 10', while in the docked configuration, via these contacts.

FIGs. 6 and 7 schematically show, in perspective view, sections of the power and control transfer mechanism taken along the line A-A of FIG. 5, in disengaged and docked configurations respectively. For clarity, electrical power / control lines extending from pogo pins 39 to the various components of the pallet 10' are not shown, nor are electrical power / control lines extending from machine power pads 36 to the SMT machine 11. The figures show that, as the pallet 10' is lowered into the docked configuration, the contact ends of pogo pins 39 abut with respective machine power pads 36, the contact ends deforming if necessary during this contact.

This type of power and control transfer mechanism may equally be used with the pallet 10 of FIG. 3, and indeed with other embodiments such that that described below with

reference to FIGs. 8 to 12.

FIG. 8 schematically shows, in exploded perspective view, a pallet 10'' and compliance plate 30 arranged with an AGV 5, in accordance with a further embodiment of the present invention. The pallet 10'' is very similar to the pallet 10' of FIG. 5, and reference numerals are retained for similar components wherever possible.

As shown, upper and lower bars 17 and 18 are provided, similar to pallet 10'. In this embodiment however, the upper bar 17 is provided with first and second interface discs 19 at spaced locations along the length of the upper bar 17. Perhaps more clearly shown in FIG. 9, each interface disc 19 is of frustoconical form, with the axis of the cone colinear with the upper bar 17, with the interface discs 19 pointing in opposite directions. When used with a dock similar to that shown in FIG. 5 for example, the sides of the dock recesses may slidingly engage with the curved surfaces of the interface discs 19 to provide additional centring of the pallet 10'' in a direction parallel to the X-axis.

As mentioned previously, because of the compliance provided by this design, typically no additional X-Y or Z positioning means is required by the AGV 5 or pallet 10'', with the AGV's built-in lifting platform 8 providing all necessary movement of the pallet 10'' to enter the docked configuration. It will however be appreciated that some horizontal force may be exerted on the lifting platform 8 as it descends, lowering the pallet 10'' into the docked configuration. If the particular AGV 5 used cannot withstand this force, then the process may be adapted by using a separate compliance plate 30, as shown in FIG. 8, intermediate the pallet 10'' and the lifting platform 8.

As can be seen in FIG. 8, the compliance plate 30 has engagement features 23 ('plate engagement features') similar to those (9) of the AGV 5, so that it may engage with the pallet 10'' in a similar manner. In addition, although not visible in FIG. 8, the underside of the compliance plate 30 has engagement features similar to those (12) of the pallet 10'', so that it may engage with the lifting platform 8 in a similar manner.

FIGs. 9 to 12 schematically show, in a sectional side view, stages in a transfer operation

in accordance with an embodiment of the present invention, using the pallet 10'' of FIG. 8 and an SMT machine 11 with a dock 16 similar, but slightly modified, to that shown in FIG. 5. As can be seen in FIG. 9, here the dock 16 comprises a substantially U-shaped channel 21, with a sloping edge 22 at at least one side thereof to provide centring of the interface disc 19 as it is lowered into the docked configuration. The dock 16 further comprises an abutment wall 25 at the loading side of the SMT machine 11, for abutting with the lower bar 18 and thus preventing rotation of the pallet 10'' about an axis parallel to the X axis when in the docked configuration.

FIG. 9 shows an early stage in an SMT transfer method, in which a pallet 10'' (with its storage retaining the SMT material, as well as the receptacle of the SMT machine 11, omitted for clarity) has been provided and placed onto the lifting platform 8 of an AGV 5, here with an intermediate compliance plate 30, so that its base is supported (here indirectly) on the lifting platform 8. The AGV 5 is moving towards an SMT machine, and the lifting platform is lifted into a lifted configuration (under control of the AGV 5) in readiness for docking. In this lifted configuration, the interface discs 19 are sufficiently high to avoid collision with the dock 16. It should be noted also that the height of the SMT machine 11 may be adjusted to ensure such clearance, for example by extending or retracting legs 20.

As shown in FIG. 10, with the lifting platform in the lifted configuration, the AGV 5 is moved to a location proximate the SMT machine 11 such that the mechanical interface (which in this embodiment includes the interface discs 19 for example) of the pallet 10'' is adjacent the loading side of the SMT machine 11. In this position, the interface discs 19 at least partially overlie the dock 16. The lifting platform 8 begins to lower (FIG. 10 shows a state in which some lowering has taken place). As will be described in more detail below, the compliance plate 30 comprises first and second parallel and planar relatively movable sheets. During lowering of the lifting platform 8, the resultant horizontal force imposed on the pallet 10'' may cause the first and second plates to move relative to each other. As shown, the upper plate is moved in the positive Y direction, while the lower plate remains fully engaged with the lifting platform 8. In this way, the horizontal force is not transmitted to the lifting platform 8.

Next, and as shown in FIG. 11, the lifting platform 8 is further lowered, under control of the AGV 5, so that the interface discs 19 engage with the dock of the SMT machine 11, in this case the interface discs 19 are moved both in the positive Y direction through their engagement with sloping edges 22, and in the X direction (not visible), due to interaction between the frustoconical surfaces of the interface discs 19 and the sloping edges 22. In addition, the lower bar 18 slidingly abuts against the abutment wall 25, both assisting guidance of the pallet 10'' into the docked configuration, and preventing relative rotation of the pallet 10'' and SMT machine 11. The pallet 10'' thereby enters a docked configuration in which the base is disengaged from the lift platform 8 of the AGV 5, and also from the compliance plate 30, which remains engaged to the lifting platform 8. In this docked configuration, the pallet 10'' is wholly supported by the SMT machine 11.

Once the pallet 10'' is in the docked configuration, the respective power and control interfaces of the pallet 10'' and SMT machine 11 engage, as described previously. Power and control signals may now be supplied from the SMT machine 11 to the pallet 10'', e.g. to a transfer mechanism (not shown) to move the SMT material from the storage to the receptacle. Before this however, the supplied power and control signals may be used to align the storage with the receptacle along the horizontal X axis parallel to the loading side, as described with reference to FIG. 4.

While the pallet 10'' is in this docked configuration, the SMT material may thus be transferred from the storage to the receptacle of the SMT machine 11, using the transfer mechanism.

While the AGV 5 may remain close to the SMT machine 11 during the transfer, this is not essential. As shown in FIG. 12, since the AGV 5 is completely separated from the pallet 10'', the AGV 5 may move to other locations during transfer, for example to perform more urgent operations in the SMT production line.

Once the transfer operation has been completed, the pallet 10'' may be removed from the SMT machine essentially by implementing these steps in reverse: the AGV 5 is moved to a location below the docked pallet 10'', the lifting platform 8 is lifted into the lifted

configuration, engaging with the engagement features on the underside of the pallet base during lifting, and then the AGV 5, with the pallet 10'', may be driven away from the SMT machine 11, and the lifting platform 8 lowered when convenient to do so.

The addition of a sprung-loaded compliance plate 30 allows for increased misalignment without inducing unnecessary forces into either the SMT machine 11 or the AGV 5.

FIG. 13 schematically shows a compliance plate 30 in accordance with an embodiment of the present invention from above, and FIG. 14 schematically shows this compliance plate 30 in a sectional side view, with the upper and lower plates 50, 51 relatively displaced.

The compliance plate 30 comprises lower 51 and upper 50 parallel and planar overlying sheets, the lower sheet 51 comprising a first interface, i.e. lower engagement features 24, to engage with a lifting platform 8 of the AGV 5 (see FIG. 2 for example) and the upper sheet 50 comprising a second interface, i.e. engagement features 23, to engage with a load such as a pallet 10''. The upper and lower sheets 50, 51 are relatively movable parallel to the planes of the sheets, i.e. within the horizontal X-Y plane as shown. The upper and lower sheets 50, 51 are mechanically connected via at least resiliently deformable intermediate member, in this case by four springs 53, located within openings 52 formed in the upper and lower sheets 50, 51, such that the sheets are biased to a home or neutral position in which the sheets directly overlie, such as is shown in FIG. 13. In a preferred embodiment, and as shown in FIG. 13, each spring 53 is aligned to extend from a respective corner of the compliance plate 30 towards the centre. With such an arrangement, the upper and lower sheets 50, 51 may be relatively displaced in any direction within the horizontal X-Y plane and be biased towards the neutral position. In order to facilitate displacement and avoid damage to the sheets 50, 51, bearings 54 may be provided intermediate the upper and lower sheets 50, 51. In FIG. 14, the upper sheet 50 is relatively displaced in the positive X direction (i.e. to the left as shown) compared to the lower sheet 51. It can be seen that the springs 53 on the left side of the compliance plate 30 are stretched, while those on the right side of the compliance plate 30 are compressed, with dimensions of the openings 52 being chosen to accommodate the springs 53 throughout their entire range of extension.

This type of compliance plate 30 may equally be used with the pallet 10 of FIG. 3, pallet 10' of FIG. 5 or indeed other types of pallet of load to be carried by an AGV 5.

The above-described embodiments are exemplary only, and other possibilities and alternatives within the scope of the invention will be apparent to those skilled in the art. For example, while the above-described embodiments have focused on arrangement where the SMT machine comprises a placement machine and the SMT material comprises a component feeder, the present invention is much more widely applicable than this. For example, the SMT material may comprise other material required by placement machines, such as replacement nozzles or grippers, tooling pins and the like. Alternatively the SMT machine may comprise a printing machine and the SMT material could comprise a printing screen or stencil. In particular, the SMT material could comprise a printing screen or stencil mounted within a tensioning frame, or alternatively a printing screen or stencil which is to be inserted laterally into a tensioning frame located within the printing machine, as is generally described in WO 2021/094962 for example. For such applications, the storage may comprise a magazine for at least one printing screen or stencil. The SMT material may equally comprise other material for a printing machine, such as tooling pins, replacement squeegees, cleaning material such as cleaning fluid or cleaning rolls, solder paste containers or the like.

As described above, preferably both power and control signals are received by the pallet through an interface with the SMT machine. However, for some applications it may be possible to provide a charge store, such as a battery, on the pallet to provide local power. Additionally or alternatively, control signals may be received wirelessly by the pallet, for example using internet, Bluetooth (RTM) or other wireless protocols.

As described above, preferably fine alignment parallel to the loading side of the SMT machine is achieved by moving the storage relative to the pallet base. However, it is equally possible to move the bulk of the pallet (i.e. the base and the storage) relative to the mechanical interface of the pallet. This may be achieved by, for example, connecting the mechanical interface to the base via a threaded shaft. An actuator (similar to that previously described) could then be provided which is operable to rotate the threaded shaft, and thus linearly shift the base.

The form of the mechanical interface and dock may also vary from the three specific embodiments shown in FIGs. 3, 5 and 8. For example, mechanical interface could comprise downwardly-extending prongs, with the dock comprising infundibuliform or funnel-shaped ports to receive the same.

Reference numerals used:

1 - Printing machine
2 - Inspection machine
3 - Placement machines
4 - Reflow oven
5 - AGV
6 - Chassis
7 - Wheels
8 - Lifting platform
9 - Engagement features
10, 10', 10'' - Pallet
11 - SMT machine
12 - Pallet engagement features
13 - Storage
14 - Mechanical interface
15 - Dock
16 - Carriage
17 - Upper bar
18 - Lower bar
19 - Interface discs
20 - Leg
21 - Channel
22 - Sloping edge
23 - Engagement features
24 - Lower engagement features
25 - Abutment wall

26 - Receptacle
27 - Strut
28 - Base
29 - Centring surface
30 - Compliance plate
31 - Rails
32 - Actuator
33 - Bracket
34 - Belt
35 - Machine power interface
36 - Machine power pads
37 - Cantilever support
38 - Pallet power interface
39 - Pogo pins
40 - Threaded rod
41 - Nut
42 - Pallet feeder tracks
43 - Machine feeder tracks
44 - Sensor
45 - Alignment feature
46 - Sidewalls
47 - Projection
48 - Brackets
49 - Recess
50 - Upper sheet
51 - Lower sheet
52 - Openings
53 - Springs
54 - Bearings
T - Transport direction

Claims

1. A pallet for providing an SMT machine with SMT material, comprising:

a base configured for releasably and repeatably engaging with a lifting platform of an automatic-guided vehicle (AGV),

a storage for temporarily retaining the SMT material, and

a mechanical interface configured for releasable and repeatable engagement with a dock provided at the SMT machine through vertical movement of the pallet, such that when the mechanical interface is engaged with the dock, the pallet is retained in a docked configuration in which the base is disengaged from the lift platform of the AGV and supported by the SMT machine, and in which the SMT material may be transferred from the storage to the SMT machine.

2. The pallet of claim 1, wherein the mechanical interface is configured to guide the pallet, within the horizontal plane, into a predetermined position relative to the SMT machine during the vertical movement.

3. The pallet of either of claims 1 and 2, comprising a pallet power interface for engaging with and drawing power from a machine power interface located at the SMT machine, while the pallet is retained in the docked configuration.

4. The pallet of claim 3, wherein the pallet power interface is configured to receive control signals from the SMT machine, while the pallet is retained in the docked configuration.

5. The pallet of any preceding claim, comprising a loading end which is proximal to the SMT machine while the pallet is retained in the docking configuration, and

wherein the pallet comprises an actuator configured to move the storage relative to the SMT machine, while the pallet is retained in the docked configuration, along a horizontal axis parallel to the loading end, to align the storage with the receptacle.

6. The pallet of claim 5, comprising a sensor or camera operable to determine the alignment of the storage relative to the SMT machine, while the pallet is retained in the

docked configuration.

7. The pallet of either of claims 5 and 6, wherein the storage comprises a carriage which is movable relative to the base along the horizontal axis, and the actuator is configured to move the carriage along the horizontal axis relative to the base.

8. The pallet of either of claims 5 and 6, wherein the actuator moves the base and storage along the horizontal axis, relative to the mechanical interface.

9. The pallet of claim 8, wherein the mechanical interface is connected to the base via a threaded shaft, and the actuator is operable to rotate the threaded shaft.

10. The pallet of any preceding claim, comprising a transfer mechanism for transferring SMT material from the storage to the receptacle, while the pallet is in the docked configuration.

11. The pallet of any preceding claim, wherein the storage comprises a magazine for at least one component feeder.

12. The pallet of any of claims 1 to 10, wherein the storage comprises a magazine for at least one printing screen or stencil.

13. An SMT machine comprising:

a receptacle for receiving SMT material,

a dock configured for releasable and repeatable engagement with a mechanical interface of a pallet through vertical movement of the pallet, such that when the mechanical interface is engaged with the dock, the pallet is retained in a docked configuration on the SMT machine in which SMT material may be transferred from the pallet to the receptacle.

14. The SMT machine of claim 13, wherein the dock is configured to guide the pallet, within the horizontal plane, into a predetermined position relative to the SMT machine during the vertical movement.

15. The SMT machine of either of claims 13 and 14, comprising a receiving side which is proximal to the pallet while the pallet is retained in the docking configuration, and wherein the SMT machine comprises an actuator for moving at least part of the pallet along a horizontal axis parallel to the receiving side, to align the at least part of the pallet with the receptacle.

16. The SMT machine of any of claims 13 to 15, comprising a machine power interface for engaging with and providing power to a pallet power interface, located at the pallet, while the pallet is retained in the docked configuration.

17. The SMT machine of any of claims 13 to 16, comprising a placement machine, and the SMT material comprises a component feeder.

18. The SMT machine of any of claims 13 to 16, comprising a printing machine, and the SMT material comprises a printing screen or stencil.

19. A transfer system for transferring SMT material between an SMT machine and a pallet, comprising the pallet of any of claims 1 to 12 and the SMT machine of any of claims 13 to 18.

20. The transfer system of claim 19, comprising a AGV having a lifting platform for supporting the base of the pallet, the lifting platform being drivable in the vertical direction.

21. The transfer system of claim 20, comprising a plate supported by the lifting platform and arranged to lie intermediate the lifting platform and base when the pallet is located on the AGV, the plate enabling relative movement of the pallet and lifting platform in the horizontal plane.

22. A method for transferring SMT material to an SMT machine in accordance with any of claims 13 to 18, comprising the steps of:

i) providing a pallet in accordance with any of claims 1 to 12, the storage of the pallet retaining the SMT material,

ii) supporting the base of the pallet on a lifting platform of an automatic-guided vehicle (AGV),

iii) lifting the lifting platform of the AGV into a lifted configuration;

iv) moving the AGV to a location proximate the SMT machine such that the mechanical interface of the pallet is adjacent a loading side of the SMT machine,

v) lowering the lifting platform so that the mechanical interface engages with the dock of the SMT machine and the pallet enters a docked configuration in which the base is disengaged from the lift platform of the AGV and supported by the SMT machine, and

vi) while the pallet is in the docked configuration, transferring the SMT material from the storage to the receptacle of the SMT machine.

23. The method of claim 22, wherein step vi) comprises aligning the storage with the receptacle along a horizontal axis parallel to the loading side.

24. The method of either of claims 22 and 23, wherein step vi) comprises supplying power from the SMT machine to a transfer mechanism to move the SMT material from the storage to the receptacle.

25. The method of any of claims 22 to 24, wherein the SMT machine comprises a placement machine and the SMT material comprises a component feeder.

26. The method of any of claims 22 to 24, wherein the SMT machine comprises a printing machine and the SMT material comprises a printing screen or stencil.

27. A compliance plate for use with an automatic-guided vehicle (AGV), the compliance plate comprising first and second parallel and planar overlying sheets, the first sheet comprising a first interface to engage with a lifting platform of the AGV and the second sheet comprising a second interface to engage with a load,

wherein the first and second sheets are relatively movable parallel to the planes of the first and second sheets, and

wherein the first and second sheets are mechanically connected via a resiliently deformable intermediate member such that the first and second sheets are biased to a home

position.

28. The compliance plate of claim 27, wherein the first and second sheets are mechanically connected via a plurality of springs.

29. A method of providing SMT material to an SMT production line comprising at least two SMT machines, the method comprising the steps of:

i) providing an automatic-guided vehicle (AGV),

ii) using the AGV to pick up a pallet carrying SMT material,

iii) driving the AGV to an SMT machine of the SMT production line,

iv) docking the pallet to the SMT machine to enable transfer of the SMT material from the pallet to the SMT machine,

then, while the pallet remains docked to the SMT machine:

v) driving the AGV away from the SMT machine,

vi) using the AGV to pick up a second pallet,

vii) driving the AGV to deliver the second pallet to a delivery location, and

viii) delivering the second pallet to the delivery location.

30. The method of claim 29, wherein the delivery location comprises a second SMT machine of the SMT production line.

31. The method of either of claims 29 and 30, wherein the pallet comprises a pallet in accordance with any of claims 1 to 12, and wherein each of the at least two SMT machines comprises an SMT machine in accordance with any of claims 13 to 18.