Modernization of Tenryu Pick and Place Machine

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Abstract—This article discusses the possibility of extending the life of an older Tenryu automatic picking machine using modern technology with the possibility of connecting the machine to higher-level production planning and inventory control systems. The article describes the state of the machine before refurbishment and the design of a new system for its control, including the selection of control software.

Keywords - Automation, LinuxCNC, Mesa 5i24, OpenPnP, Pick and Place

I. INTRODUCTION

This article deals with the modernization of the Tenryu MT5530LQ setup machine, which is located at the headquarters of NNM Electric s.r.o. This machine is equipped with a now obsolete control system without the possibility of compatibility with superior systems and its maintenance is almost impossible due to the unavailability of spare parts. This setting machine is a full-size four-head placing machine with conveyor system in its original design. The conveyor allows very easy integration into the production line. The machine also includes an external computer with special software to create programs for the assembly process. Using this software, the machine can be controlled and the movement of all the assembly heads can be also controlled, including speeds, nozzle types and the order of the components to be assembled. However, the actual preparation of the setup program is very time consuming, and even the need to use an old MS-DOS computer is problematic nowadays. The original system has a big problem with fitting more complex or transparent components. The correct rotation of the component is sensed using special laser micrometers, which are now almost unobtainable and unreliable due to their age. These parts also need to be replaced by other technology and allow the recognition of all kinds of standard components.

The main task is to evaluate the current state of the machine, design and subsequently implement the modernization of the key parts of the machine. After such a modernization, the machine should be working again, and it should be possible to connect it with superior systems that will help to facilitate and streamline production in the company. These systems include, for example, database systems for parts inventory management, which allow the machine to be used efficiently and to have sufficient information on the status of the numbers of each type of parts. And to warn operators in time in case of stock shortages. The main advantage of upgrading should be compatibility with the spare parts available today and simpler operation including data preparation for the fitting cycle [3].

II. PRINCIPLE OF THE PLACING PROCESS

The principle of assembly is that components are removed from the packages and then placed in a precise position on a printed circuit board (PCB) using a three-axis manipulator. The assembly process itself can be divided into four phases.

The first phase is data preparation. By data preparation we mean the actual design of the PCB, from which data is then generated for the production of these boards. The next output from the design software is a file that carries information about the positions and number of components. This is basically a table where basic information about the location, rotation and type of component is given for each component. This data is then imported into the fitting software that is part of the machine.

The second phase is the preparation of the machine, importing data and setting up the whole machine for mounting. First, a file with data about components and positions is imported. After the import, the feeders with the individual parts must be inserted into the machine and these feeders must also be set up. There are many different types of feeders, with the most basic ones being plastic or paper tape feeders, matrix feeders or vibratory feeders for parts in plastic tubes. After the feeders are set up, there is still the preparation for clamping the conveyor...
and the PCB clamp, where the parameters of the so-called cross-sections are set. These crosspieces are the PCBs assembled into the matrix, where the program needs to specify where and how many PCBs to expect and which to place with components.

Once the machine is ready, the setup cycle can begin. At the beginning of this cycle, the machine will check the nozzle rack and calibrate the nozzles. Next, a camera is used to check the aiming points on the PCB, giving the possibility to adjust the machine coordinates and angle according to the physical state. After the check, the coordinates are recalculated and thanks to this we are able to fit the components very accurately regardless of the inaccuracies caused by clamping or milling the PCB during its manufacture. Once the coordinates have been successfully corrected, the machine starts to place the parts. During this process, the assembly head slides over the feeder and picks up the part using a vacuum nozzle. This component must first be oriented by the machine, where orientation is most often done using a camera. The part is moved over the camera and the dimension and rotation measurements are taken. The part is aligned and then the nozzle places it in the desired position in the pre-applied solder paste, where the part sticks.

The last stage is the soldering process. Soldering can be carried out in several ways, often using hot air furnaces or infrared furnaces. It is also possible to solder using wave or selective wave. After soldering, the assembly process is complete, and the PCB can start to come to life [3].

III. SETTING MACHINE MT-5530LQ

The Tenryu Automatic Placing Machine is a machine that is designed to be built into a production line. The main parts are a three-axis manipulator, a PCB conveyor, a quadruple setup head and 120 positions for feeders.

This machine has its own control computer that collects data from the process and controls all the actuators. The user interface includes a keyboard and two monitors. One monitor displays the direct output from one of the two cameras and the other monitor serves as the graphical interface to the automation system. Using this interface, the user can control the entire system. The system also includes a communication interface with an external computer running a program under MS DOS, which makes it easier to prepare the fitting data.

The machine has four set-up heads to handle up to 120 part feeders. Each head consists of two motors that take care of the lift and rotation of the parts. The machine can carry 4 nozzles directly in the heads and another 12 in the automatic nozzle changer. The nozzles have different shapes and diameters because the SMDs are different shapes and sizes, and a different nozzle is needed for each housing. There is also a laser micrometer on each head to measure the components. These micrometers are not used as much today and are being replaced by camera systems. There is a big problem with these micrometers on this machine. The micrometers are already very old and due to the aging of the materials their characteristics change and the control system of the machine does not allow to adjust or calibrate these sensors to their new values. Replacement micrometers are almost impossible to find and even then, they are very old pieces that may not work properly.

Another major disadvantage is the extreme time required to prepare the data and the entire machine. All the preparation has to be done manually, all the components and their positions with rotation angles have to be entered manually. For large batches this time is relatively small, but if the production needs to be changed frequently the impact is substantial and any small change leads to higher costs.

The machine is designed in such a way that if an error occurs during the setting cycle, the machine releases the PCB, and it is no longer possible to continue where the cycle left off. In the case of large batches this is negligible, but in small batches it is a significant loss also in terms of environmental friendliness. Massive throwing away of easily repairable parts is very common in large manufacturers, and yet often it would be enough to just fix a few things where the material and energy spent on production could be recovered instead of being thrown away.

The last disadvantage is the lack of network connectivity, including the possibility of integrating the machine into a business management system or inventory management system. The machine consumes on average thousands of parts per setup cycle and so it is necessary to know the stock status [3].

IV. MODERNIZATION PROPOSAL

The assembly of the entire machine requires a system that can handle the processing of camera signals, component measurements, reading and writing to digital and analog inputs. In addition, the system should be able to communicate with the parent database system and provide remote user access.

Due to the complexity of reassembling the entire system, it was decided to use ready-made software components to speed up the modernization. The machine needs to control the drives, actuators and perform the fitting algorithm. For the new system a new control computer has to be provided on which the control software will run. A standard DELL Workstation personal computer was selected for these needs, running the Linux operating system with Debian distribution. This configuration was chosen because of the intended use of the LinuxCNC software.

LinuxCNC is open-source software that allows you to control a large number of motor types from stepper motors to servomotors. This software is often deployed on computer-controlled machine tools. A special PCI slot card is required to control the drives and actuators. The Mesa 5i24 card was chosen for its parameters and compatibility with LinuxCNC. This card has an FPGA on it that can be configured for various applications from stepper generator for stepper motors or as an RS422 communication interface. This card will be used to control servo drives and collect data from the end position sensors of each axis of the machine [1][4].

However, to manage the assembly cycle, software is required to prepare the data for assembly and also to manage the component database and the ability to monitor and effectively manage the assembly cycle. After a survey of available solutions, the open-source software OpenPnP was selected. This software is designed to control automatic nozzle assembly machines for 1 to 4 heads with the possibility of future
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basic power circuits, which are the main supply, the switchboard

expansion. Furthermore, this system allows importing data from

PCB design programs without the need to rewrite coordinates, etc. Furthermore, this software is able to work better with the

setup cycle, where it can be freely paused and restarted from

where the user needs it, leading to faster and better production

with minimized losses. The software also supports many other

things such as interfacing with database systems using scripts

and other methods. The software is designed to run on both

Linux and Windows operating system and the interfacing with

LinuxCNC is done using network communication inside the

computer through Telnet interface [1][2].

This software will also help to get rid of the dependence on

the lack of spare parts for laser micrometers. These micrometers

are replaced here by a camera that scans the parts optically and

the image obtained is then evaluated and the part is placed in

position with the corrections recalculated. Most of today's

automatic machines already use this technology and laser

measurement is being abandoned. The field of image processing

is very attractive today and thanks to the use of OpenCV we are

able to recognize shapes, measure their dimensions, detect

anomalies and with these advances we are taking the accuracy

and reliability of machines to a whole new level [3].

V. MODERNISATION OF SELECTED PARTS OF THE MACHINE

After examining the available solutions and the needs of the

machine, the following design was decided. First of all, it is

necessary to remove the old and discarded parts of the machine.

Those parts that can be reused will be retained or modified to

ensure their compatibility with the new system. Those parts that

require communication to operate are taken out of service and

replaced with new parts due to the lack of documentation of

communication protocols.

It is possible to keep the whole machine chassis with the

basic power circuits, which are the main supply, the switchboard

with circuit breakers, the 230 V / 110 V transformer and the

power supplies for the 5 and 12 V control voltages. In addition,

the motors including their drivers will be retained. Two CRT

monitors will be removed from the original machine and

replaced by two new monitors. The video computer and the

micrometer signal processing unit will be removed along with

the main computer. Removing the old and unnecessary parts will

leave plenty of space that can be used to incorporate the new

systems. The original machine includes an extensive pneumatic

system that will be retained in its entirety and will be expanded
to include additional valves to control the pneumatic component

feeders.

A PCB for controlling the drivers for the motors, a new PCB

for controlling the mounting heads and their movement, and also

a PCB for communicating with the control computer need to be

made again. All these cards will be connected by an RS485

industrial communication interface, where the information

needed to control the entire machine system will be exchanged

using the Modbus protocol. Figure 2 shows the hierarchy and

symbolic connection of the control cards to each other, including

the different control levels. The interconnection and structure of

the new control system can be clearly seen. The main system is

the OpenPnP program, which controls all machine operations.

The movements are handled by LinuxCNC, which is controlled

by the OpenPnP program. Data acquisition from sensors and

closeup or confirm the execution of the command. The other cards will

periodically communicate with each other and pass status

information to each other, thus providing all the necessary

information from the process needed to control the further

operation of the machine.

So far, 3 different surface connections have been designed

for the new system. The first is the control electronics to control

the drivers for the actuators that move all 10 axes. These boards

are designed to be able to handle the signal from the Mesa 5i24

card, which is controlled by the LinuxCNC software. This

software sends motion commands in the form of step and DIR

signals. On this board, the conversion to CW and CCW occurs

in differential form. In addition, this board contains a processor

with RS485 communication interface, several current-amplified

transistor outputs, and the ability to connect the drive encoder

directly to the control software. This designed board is capable

of controlling 2 motors and therefore there will be a total of 5

motors in the machine. Each mounting head has two drives and

so will have one board, which means 4 boards for the heads and

the last board will be for the X and Y axis drives.

The next control board will be the electronics to control the

actuators and sensors for the mounting heads. Actuator means a

set of pneumatic valves to control the suction or blowing of air

through the nozzle. Sensorics means collecting data from the

end positions of the mounting heads as well as sensing vacuum

to check that the component is properly picked onto the nozzle.

This board also has an RS485 communication interface to

communicate with another boards. There is also a camera on the

mounting head which is used for aiming the aiming points and

for calibrating the positions of the components in the feeders.

Fig. 2. Diagram of the whole system
This camera needs good lighting to function properly. The original lighting of the machine will be retained, but its control will be replaced by switching drivers. This board will also include two channels for controlling the camera backlight.

The last board produced is the communication interface between the OpenPnP control program and the machine, and also between LinuxCNC and the end sensor states. This board will contain several communication interfaces and a direct connection to the Mesa card. The card will have two independent RS485 lines for communication with the motor control and for communication with the mounting head board. There will also be a conversion to a USB interface through which the OpenPnP program communicates with the machine hardware. The machine also includes a static bottom camera, which is used to aim the picked parts. There will be two channels on this board for this camera to control the camera lighting in the same way as there is for the head control board.

There are a large number of other actuators and sensors in the machine that need to be serviced. A programmable logic controller (PLC), developed by the company that owns the machine, will be used for these purposes. This PLC will take care of the operation of the conveyor system, the operation of the automatic nozzle changer, the operation of the new feeders for the parts and for the data acquisition from other sensors. Such as the pressure sensor in the pneumatic system or the detection of the presence of PCBs on the conveyor. This system will also include ensuring the functional safety of the machine, including safeguards to protect against accidents. The machine contains fast moving parts and therefore operator protection needs to be ensured. There are covers on all sides of the machine with end position sensors as well as emergency stop buttons. All these features will be restored and will be part of the new machine system.

The final part of the upgrade is to increase the number of positions for the parts feeder. The control of the feeders is purely mechanical. The mounting head has a small hammer on it that, when driven into position, strikes the mechanical feeder slider where it moves the part to the take-up position and the nozzle picks up the part. This hammer is located only on the front of the head and is not located on the rear. For this reason, it is not possible to put these mechanical feeders on the back side because they cannot be operated by the hammer. With the new system and the added pneumatic elements, it will now be possible to put the frequently used pneumatic feeders for larger parts also on the rear positions, which were previously only used for vibratory feeders, which are not used that much. The ability to use the rear positions of the machine will also make it possible to fit boards with more types of components. This will make the machine more efficient and there will be no need to switch feeders between the machine and the stand so often, which will lead to simpler machine operation and more efficient production.

VI. CONCLUSION

Thanks to the deployment of the previously mentioned system and functions, the machine can continue to operate. In its original configuration, the machine was able to assemble approximately 3,000 components in one hour of operation. The new system is a little weaker and the first tests have confirmed the possibility of seeding something between 2500-2800 components per hour of machine operation. However, the new system is far superior to the old one mainly because of its flexibility and compatibility of parts and software solutions with today's technologies and trends. Selected LinuxCNC and OpenPnP systems are still under development and thus some support for the future is guaranteed. Another huge advantage is the openness of the systems and the possibility of easy modifications in the software and hardware solutions.

Due to the large number of parts to be assembled, it is necessary to introduce an automatic reading of the removed parts from the warehouse. For this purpose, company uses the Inventree program, which offers the possibility of subtracting parts from the warehouse thanks to a common API. Thanks to the new system, the company will already be able to plan production better and the data in the system will automatically change according to the current status and there will no longer be time delays due to lack of information or low stock.

Another great advantage of the modernization is the versatility of the solution used, where the system can be deployed on other machines owned by the company. The company owns two more machines, the same Tenryu and then another Heeb. All these machines are already out of service due to obsolescence and unavailability of spare parts for the original systems. Thanks to this solution, a total of 3 machines can be made operational and can continue to perform their task.

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This is an internal project of NNM Electric s.r.o., where the machine is located. This project is conducted as a thesis. This solution uses a number of open-source solutions that are freely available on Github or their own websites. The project is further created with the help of the company's managing director Mr. Jan Navrátil and the thesis supervisor doc. Jan Mikulka. I would like to thank all of the above mentioned for their guidance and help in the project of upgrading the embedding machine.

REFERENCES