Production, and Analysis of a Two-Axis Food Liquid Pouring Machine

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Abstract- People always want to feel special and different. This demand has not left us alone in the food sector and has improved itself as culinary arts and presentations. So much so that there are masters who can transform food liquids, such as pancake liquids, into art by making special shapes on them based on demand. As in every sector, the effects of technology are also seen here. Considering these needs and developments, this study focused on the production and tests of machines that would convert the drawings designed by people with the help of computers into food liquid. The machine, produced in the context of the study, has a two-axis mechanical structure and gives shape to the food liquid with the commands coming from a computer and the liquid pouring chamber. While this machine aims to provide convenience to people in terms of time and ability, it also contributes to the developing technology in the kitchen sector. As the machine's working principle, a drawing is created first with shapes that people can draw on a tablet or a computer in front of them if they want, or they can choose ready-made. Then, this drawing is converted to g code via the program and the movement coordinates of the pouring mouth of the machine are created. The system, controlled by a microprocessor, drives the motors and performs the operation. While the pouring process is supported with the help of a chamber air control system in which the food liquid is located, the cooking of the food liquid is ensured by the heat-adjustable tray under it.

Keywords Two-axis machine, Kitchen, Pancake

1. Introduction

It is an undeniable fact that the invention of machines and the mechanization process have made human life easier. For example, mobile phones and transportation vehicles that we use every day are machines that provide convenience for us in all areas of life. The mechanization process continues to affect the flow of life by growing and renewing.

Machines allow us to do many small or big jobs easier now and they provide many conveniences in all aspects of our lives. Jobs that were done by many people in the past can now be done with less cost and in a shorter time thanks to one machine. Today, autonomous devices and machines have moved toward systems that are called artificial intelligence.

Three- and two-axis autonomous machines, which are among the commonly used devices today, are the focus of this study. These machines are used in many fields such as industry, military, health, and agriculture. While these machines that shape materials such as plastic, metal, and wood continue to be effective in the market, the machine that we have chosen in this study is used to serve people in the kitchen and food field by shaping food liquids.

The capacity of the systems of these machines, which differ structurally in terms of the way they work, depends on the direction and number of their movements on the axes of motion. The differentiation of usage areas makes devices into systems that require research and development works at many points in terms of both software and hardware.

In this study, the designed and manufactured machine was created by inspiring the infrastructure of two-axis computer-controlled systems. In terms of its design, thanks to its portable feature, this machine is a device that facilitates life and will be able to be used in everyday life and even at home. A literature review and similar projects related to the topic of the study are presented below.

2. Literature Review

The machines manufactured today consist of many infrastructures and systems. These infrastructures and systems include mechanical, electronic, and software stages.

For example, biaxial food liquid pouring machines consist of mechanical parts, electronic control units, air flow systems, liquid flow, and heating plate units [1]. With Computer Numerical Controls (CNCs) and cartesian robots, processing, design, and manufacturing operations on raw materials can be performed [2-6]. Electronic control on CNCs can be provided on computers via embedded electronic systems [7-10]. During this control phase, communication can be carried out using wired, Wi-Fi, or IOT (Internet of Things) systems [11-12].

Elements produced by using the 3D printing method are actively used in robotic systems, mobile robots, and CNC production area [13-14]. The software control of robotic systems can be planned to include artificial intelligence algorithms depending on their usage areas [15-17]. In machine design, analysis and evaluation of software systems in terms of the control of devices, and the design of machines' axis movements are very important [18-24]. In a study conducted by Kurt et al. [23], which production methods or manufacturing techniques were used for the production of machine elements were examined based on the production drawings and taking into account the science of technology. In the literature review, it was seen that older food-liquid cooking machines (pancake machines) used a hopper filled with pancake batter that was manually dropped on a rotating grill, and the pancakes were manually turned and coated when cooking was complete [25].

Based on the usage areas, the steel to be used in the structure of the machines should be stainless. Studies have shown that the chromium and passivation rate in stainless steel determines the stainless quality of the steel, and the oxide layer formed on the material surface is too thin to be seen with the naked eye and is waterproof [26].

3. Design of Mathematical Modeling

3.1. Equipment and Elements Used in the System

The system developed in this study is basically composed of two sections: a control unit section and a mechanical section. In the mechanical section, commands from the control section gain function. In this section, motors, belts, plates, pulleys, linear bearings, and rails constitute the system. In the control part, the commands given from the computer are transferred to the mechanical part with the microprocessor, engine drivers, air pump, and power supplies. Our system saves time and labor by processing a shape drawn from a computer with a control unit and then transferring it to a mechanical part. The food liquid reservoir located in the mechanical system is drawn on the cooking plate by a two-axis movement mechanism and drained. While two stepper motors provide movements, the air pump ensures the pushing of the flow of food liquid into the pouring mouth.

3.2. Mechanical Elements in the System

The elements used in the system were selected in accordance with the food. For example, while stainless steel was used in the Plate parts, hoses and hoppers were supplied from the food sector. In the mechanical part, the transmission of two stepper motors is ensured by belt, pulley, and linear bearing systems. In order to provide this motion control, limiters were used. The food liquid is kept in a container and transmitted to the mouth of the pourer with the help of a hose, while the movable arms shape this pouring process. In Figure 1, the complete mechanical components of the system is shown. While the white food liquid container is located on the top, the moveable lever to which the container is connected can also be seen in the figure. As seen, the hose and belt systems are located behind the mechanism.

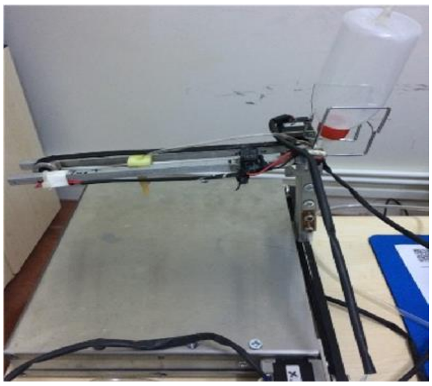

Fig. 1: Mechanical Part of the System

3.3. Stainless Plates

The 304 stainless steel plate used for the main lines and chassis of our machine was processed and assembled in accordance with our machine (Figure 2). The features such as being lightweight, giving results that we want in terms of durability, and being suitable for food use were among the main reasons for using this steel plate in our machine. In addition, its low cost stood out as a separate positive factor for us. The fact that the main frame of our machine is durable makes it possible not to be easily affected negatively as a result of any impact that the machine will face during the operation process.

Fig. 2: Stainless chassis of the machine

3.4. Movement and Transmission Elements

We used linear bearings so that our robot, which moves on two axes and also works with 3D printer logic, can perform the movements we want it to do on the axes without errors and smoothly. In addition, the linear bearing was the most logical choice because we used an induction shaft in the region where the bearing would move. The linear bearing where we use the SCE 10 UU model prevents axis leaks that may occur. In this way, the error rate that may emerge in the movements of our machine was minimized. Moreover, thanks to its lightweight structure, it did not create a disadvantage in the weight of the machine that we determined at the design stage. Figure 3 shows the selected bearing.

Fig. 3: Linear Bearing

Induction shaft: This shaft type with high strength works at full performance with the SCE 10 UU linear bearing that we use in our machine. In this way, our machine can move properly between the axes. The shaft used in the machine has a length of 270 mm and a diameter of 10 mm. The selected shaft is shown in Figure 4.

Fig. 4: Induction Shaft

In order to ensure the connection between the motors and the pulleys of our machine, a three-groove v-belt was used. Three-groove v-belts, which work in a full performance manner with specially processed pulleys, were used both because we did not use a process requiring high torque and because it was the best choice for movement between axes. In addition, the fact that v-belts have a long service life is another positive factor for our machine. In Figure 5, an example of a v-belt used in the system is shown.

Fig. 5: The v-Belt Used in the Machine

The pulley system used in the system was manufactured as a three-groove in accordance with this belt system; and this, in turn, minimizes the likelihood of the belt coming off due to the overload coming to the system.

3.5. Electronic Elements in the System

While two stepper motors were used in the system, the Toshiba Tb6560 stepper motor driver was used to control them. For fluidity, the air engine was used and the air pump control unit was used to control it. Limit switches were used for the notification of the limits of motor movements. These elements are controlled by an AT mega 328 microprocessor and power is provided to the system by a 12V DC power

supply.
Two stepper motors were used in the system: the Nema 14 and Nema 17 stepper motors. They provide x- and y-axis movement. Nema 17 moves the carrier arm on the x axis, while the Nema 14 motor moves the pouring mouth on the carrier arm on the y axis.

Fig. 6: Nema 17 Motor

It was decided that Nema 17, a type of stepper motor, was suitable for this project. In the system, one Nema 17 motor was used. In terms of its characteristics, the Nema17 operates at 4 V and 1.2 A. The purpose of use of it in hardware design with its holding torque of 3.2 kg-cm is to ensure the movement of the liquid pouring system and the X axis carrying the Y axis on it. This motor is shown in Figure 6.

Fig. 7: Nema 14 Motor

Nema14 is a kind of stepper motor and in the system, one Nema 14 motor was used. Nema 14 is powered by 2.7 V and 1000 mA. With its holding torque of 1.4 kg-cm, it provides the movement of the Y axis as integrated with the liquid pouring system in the hardware design. Figure 7 presents this motor.
To drive the Nema14 and Nema17 stepper motors used in the machine, two Toshiba Tb6560 Stepper motor drivers were used. This type of stepper motor driver, which can work with 24V and 3A, is suitable for 2, 4, and 6 phase stepper motors. A general view of the stepper motor driver is presented in Figure 8 and a connection diagram is shown in Figure 9.

Fig. 8: Tb6560 Stepper Motor Driver

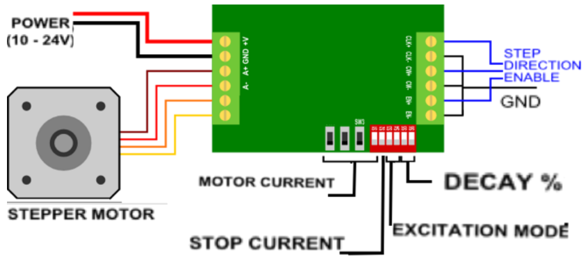

Fig. 9: Schematic Diagram for the connections of the motor driver

In order for the machine to transfer the food liquid onto the grill, an air pump powered by 220V and through which we can pour the food liquid was used. In this way, the movement of the food liquid on the axes of the designed system was ensured.
Another method is to perform this operation with a liquid pump. This pump, which was used to perform the spraying process that is the main task of Hexatar, provides the operation and stopping of the irrigation system by applying the start or stop commands that it received from the relay triggered by a pulse width modulation (PWM) signal. There are two hoses connected to this motor.

One of these hoses is located inside the fuel tank, while the other hose is fixed to the spraying apparatus. However, when we applied the literature [14] we examined, efficiency could not be achieved in terms of fluidity when we did not give the liquid to the container where it was in.

When tested with a DC 12 volt liquid pump, it was observed that no continuous fluidity could be achieved, and such a method was used to keep the air in the bottle constant. In Figure 10, a sample air pump motor is shown.

Fig. 10: Air Pump Motor

With the operation of the air pump, the food liquid was poured from the unit where it was located to the heater plate by the air pump control unit. This part is located in the control unit of the designed system and is controlled by the microcontroller board. This driver is shown in Figure 11.

Fig. 11: Air Pump Motor Driver

A power supply is an electrical device that supplies electricity to an electrical load. The main function of a power supply is to convert the electric current from a source to the correct voltage, current, and frequency to supply the load.

Therefore, power supplies are also sometimes called electrical power converters. A 12 volt 5 A power supply was used to supply all the electronic components in the system. All the necessary energy is supplied from this power supply. An example of the power supply used in the system is presented in Figure 12.

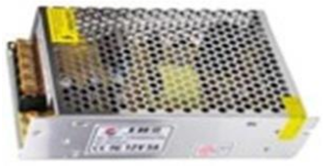

Fig. 12: Air Pump Motor Driver

To ensure that the internal components are in the correct position for the operation and to prevent operation when the access doors are opened, the Miniature Snap Action Switch can be used as components of devices such as copy machines, computer printers, convertible tops, or microwave ovens. A set of adjustable limit switches is installed on a garage door opener to turn off the motor when the door is in the fully raised or fully lowered position. A numerical control machine such as a lathe should have limit switches to define maximum limits for machine parts or to provide a known reference point for incremental movements. Therefore, in our system, we also used limiters to control movement limits in the system and obtain more useful results. An example of the limiter in the system is shown in Figure 13.

Fig. 13: The Limiters

Arduino Uno is a microprocessor development board based on ATmega 328 (Figure 14). The card has 14 digital input/output connections (of which 6 can be used as a P W M output), 6 analog inputs, a 16 Mhz crystal oscillator, a USB connection, a power connection, an ICSP connection, and a reset button. Connecting to the computer via the USB port is sufficient for the card to work. In addition, it can also be used with a battery or an adapter.

Fig. 14: Arduino Uno

In the machine designed in this study, we used AT mega 328. In order for the software created for the system to work simultaneously with the motor and drivers, the Arduino UNO-R3 was used. It was preferred both because of the variety of its code library and because it can be encoded very easily with the C codes. The card, which is also widely used in prototype projects today, has added practicality in terms of use in this project as well. In the study, this card was used as a processing and control card when driving the motors of the machine with the driver.

Another element of the system is the heater plate. It is the part where the food liquid that will flow through the liquid flow system with the air control unit will be cooked. Data related to food liquid is created on the computer interface in the system. A 220 V AC mains voltage was applied to supply the system. The heater plate (baking plate) was supplied as a ready-made product and added to the system. The heater plate used in the system is shown in Figure 15.

Fig. 15: Heater Plate

3.6. The Structure of the Software in the System

To control the motion system of the machine, the software developed within the Istanbul Gelisim University Technology Transfer Office (IGU TTO) was used in the software section. In the software system, the user data sent to the machine from the computer interface is directed by the TTO Pankek 4.1 interface software. The interface software used in the machine is comprised of six sections. The first is the “connection settings” section where the communications protocol is provided between the machine and the computer interface. The second is the “Manual Movement” section where manual position control of the machine is provided. In the third section, “Pancakes fluid flow control” is carried out by ensuring the manual control of the air flow system in the control unit. The fourth section is the drawing area where drawings will be created with the mouse. The fifth section is the “Incoming - outgoing data” section where outgoing–incoming data will be displayed during communication between the port and the machine and the possibility of manually sending codes can be provided. In the sixth section, on the other hand, there is an area where the created pancake data will be uploaded to the robot. The interface of the software used in the system is shown in Figure 16.

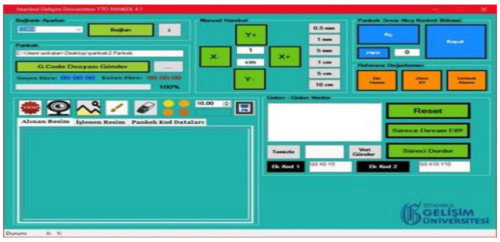

Fig. 16: Program Interface

As an example, when we type the inscription “İGÜ”, an image is formed in the program as in Figure 17.

Fig. 17: “IGU" Interface image

While writing, the cooking priority can be determined with the color options on the tab at the top of the interface. While the parts drawn in a dark color are cooked more, the ones drawn in light color are poured later so that they are cooked less. The resulting G codes of this writing appear as in Figure 18.

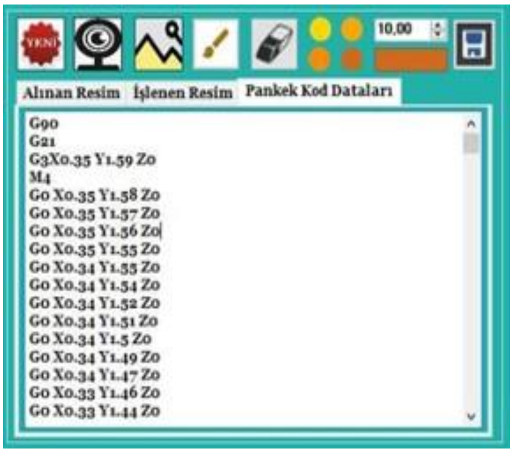

Fig. 18: G code view

It has been found that G-code instructions are mostly used in vertical machine tools and they are machine messages that tell motors where to move, how fast to move, and which path to follow [20].

3.7. The Principle of Operation of the System

After activating the power buttons on the system, the user makes sure that the microprocessor is working and its lights are on. The drawing program on the computer is run, the desired shape is drawn with the mouse, or the desired shape is transferred to the program. The heater plate is turn on and the pressure command is pressed with the control of the limit switches, then the pouring process of the food liquid is started. In case of any emergency, the printing process can be stopped via the program.

4. Conclusion and Recommendations

The control unit of the Food Liquid Machine can make axis movements in accordance with the air-flow system and liquid flow systems. In various tests conducted, it was observed that the software worked compatible with the control system and the air-flow system. In the project where the single-lever system was used for the first time on such machines, ease of use came to the fore, and it became easy to interfere with the product and the heater plate. However, it was noticed that the sensitivity of the liquid being poured was poor due to the mechanical system, and arrangements were made to prevent this. The system is shown in Figure 19.

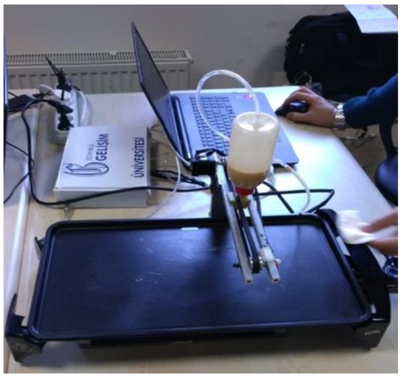

Fig. 19: Food liquid printing

In terms of arrangements, the height between the machine’s arm carrying the liquid pouring system and the heat plate was decreased. With the shortening of the arm length, the delay margin between the motion of the movement mechanism and the shape made by the liquid on the plate also reached an ideal level. For example, when the pouring height was reduced to four centimeter and the temperature was set to 180 degrees Celsius, the cooking time was recorded as 3 minutes. Another arrangement is that the liquid container previously located above the pouring mouth was placed on top of the conveying arm, and the pouring mouth and the chamber mouth were separated from each other. Thus, the liquid chamber performed a healthier pouring by not weighing on the movement arm and not creating vibration on the pouring mouth. In addition, we made a new addition to the pouring mouth, and we done this with 3D printer. Today, precision, reproducibility, and the variety of materials have shown that some 3D printing processes can be considered industrial production technology.

One of the main advantages of 3D printing is the ability to produce very complex shapes or geometries. There are no prerequisites for the production of any part printed on a 3D machine. A digital 3D model or a CAD (computer-aided design) file is enough. Considering these, it was profitable to produce the material by this method.

In terms of recommendations that can be made: The software part currently transfers what is drawn over the computer via cable. In the future, remote ordering logic can be placed wirelessly on devices such as phones, tablets, and computers. By covering the device with plexy, a protection shield can be created and a healthier pouring process can be performed. Cases and unit containers can be made on the machine by using plastic injection molds, the cost of which will not cause problems in mass production. Finally, it can be also said that if a linear bearing, which could not be purchased because of its high price, had been able to be used in the sleigh system, the movement mechanism would give a smoother result.

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