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DESIGN, STUDY AND OPTIMIZATION OF A SEMIAUTOMATIC PASTA COOKER FOR COFFEE SHOPS AND THE LIKE

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ABSTRACT

The advantage to have an automatic pasta machine that cooks dry semolina pasta automatically seems to be several, ranging from energy consumption to freshness and taste. However these machines have proved to be highly problematic. Several problems of pasta cooking machines are diffusively discussed. Also several automatic pasta machine patents are briefly described. The machine described herein is conceived for coffee shop where a hot water reservoir and an operator are available. This makes it possible to simplify the machine and improve the safety of use. Several technical solutions are analyzed in this paper. Energy concepts and concerns are also discussed. Different technical solution to achieve the best compromise between cost, functionally and safety are introduced. Several fashionable designs are analysed and introduced in this paper. At the end a very simple "rocket" patented machine is described. This machine can cook the special patented "geared spaghetti" in less than a minute and every other type of spaghetti in half the time indicated in the box. This solution seems to be the best compromise for taste, safety and performance.

Keywords: automatic pasta machine, coffee.

INTRODUCTION

Traditionally, at least since the time of the ancient Roman Empire, basic pasta dough has been made of durum wheat flour and water.

In the 14th and 15th centuries, dried pasta became popular in the navy for its easy storage. This allowed sailors to store dried pasta in ships when exploring the New World. For this reason, a century later, pasta was present around the globe during the voyages of discovery.http://en.wikipedia.org/wiki/Pasta-cite_note-Demetri-24.

Dried pasta is factory-made pasta because it is usually produced in large amounts that require large machines with superior processing capabilities to manufacture. Dried pasta is mainly shipped over to farther locations and has a longer shelf life. The ingredients required to make dried pasta include semolina flour and water. The dough is then extruded through dies and cut. Then the pasta is set in a drying tank so that it can be dried under specific conditions of heat, moisture, and time depending on the type of pasta that is being dried. Pasta needs to be dried at a low temperature for several days to evaporate all the moisture allowing it to be stored for a longer period. The final step is to package the pasta properly.. Dried pasta is placed in stainless steel buckets that are transferred to appropriate packaging stations to be portioned and sealed in plastic or cardboard packages. Usually dried pasta has a shelf life of three years. Once it is cooked, the dried pasta will usually increase in size by double of its original proportion. Good quality dried pasta has a slight rough surface and compact body that helps maintain its firmness in cooking, since it swells considerably in size when cooked. Durum flour and durum semolina have a yellow tinge in color. Italian pasta is traditionally cooked al dente (Italian: "firm to the bite", meaning not too soft). Outside Italy, dry pasta is frequently made from other types of flour (such as wheat flour), but this yields a softer product that cannot be cooked "al dente". The Italian Law divides dried pasta into three subcategories - (1) Durum wheat semolina pasta (*pasta di semola di grano duro*), (2) Low grade durum wheat semolina pasta (*pasta di semolato di grano duro*) and (3) Durum wheat whole meal pasta (*pasta di semola integrale di grano duro*). Pastas made under this category must be made only with durum wheat semolina or durum wheat whole-meal semolina and water, with an allowance for up to 3% of soft-wheat flour as part of the durum flour. For 100 gr. of pasta, 1000 gr. of water and 10 gr. of salt. As water temperature reaches the boiling point at sea level, the pasta is added. It has been found that as the spaghettis pass from their dry state to the cooked state, they not only become edible as desired, but also somewhat "sticky", that is acquire a tendency to stick on surfaces with which they come in contact. For this reason stirring is necessary to keep pasta separated. During cooking as starch is freed into to water, pasta becomes porous letting hot water inside. This process of hot water infiltration continues until the desired result. The use of superheated water accelerates the process up to halving the normal cooking time. The best solution is use 120°C water for a while and then let the pasta absorb water at 90°C up to end of the cooking process. The difficulty is to calibrate the process since its pasta temperature and not water temperature that controls the cooking process. This accelerated cooking process reduces the diffusion of starch into water. In this case salt should not be added to water, since the salty taste is given by the starch.

Brief review of pasta cooking machines by patents

The first significant patent is of 1921, US 1426050A. In this case a carousel system is used for automated pasta cooking at room temperature. In 1951, patent US 2649380A describes a pressurized cooking machine with one chamber. This device can be used for

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pasta but not exclusively. Patent US 3101995A describes a two chamber system, pressurized, isolated by the product canister. This very interesting solution, dated 1963 are not specifically for pasta. An "Apparatus for the sterilization of food products pat. US 3641917A -1967" describes an autoclave to cook pasta. In this case also sterilization takes place, adding this concept to the pasta machine. However this system is not fully automated. An automated, developed pasta machine is described in "Apparatus for the fast cooking, in hot water, of dosed quantities of foodstuffs in general US 3827344A" of 1972. In this pressurized, two chamber machine, the water is separated from the cooked item by a centrifugal system. "Automatic cooking and vending machine for boiled noodles US 3928045A", describes a vending machine that starts from pre-cooked pasta. The concept of the vending machine and the precooked pasta are interest. However, shelf life of precooked pasta, even at the temperature indicated by this patent of 1975 (5-10°C) is not long. “Apparatus for the fast cooking, in hot water, of dosed quantities of foodstuffs in general US 3937135A-1976" introduces the concept of tangential entrance to avoid sticking. "Heat efficient cooking apparatus US 4543878A-1985" introduces the concept of "The separating chamber, which is in the form of a vortex chamber", to add turbulence for sticking and stresses on the concept of compactness for energy saving. "Apparatus for cooking paste foods US 4718331A-1988" patent describes a two chamber pressurized system with an oil stabilized temperature heating system. The problem of constant temperatures is introduced in this concept. "Machine for rapidly cooking batches of spaghetti US 4803916A-1989" adds to the previous two-chamber patents the concept of computerized time control and of preheating of the system. In the "Apparatus for the fast cooking of pasta and the like US 4869160A-1989" patent, the concept of pressurized-three chamber-cooking is introduced reaching the minimum cooking time possible for dry pasta. "Three-phase process and machine for cooking foods as dry pasta, rice, legumes and the like US 4901632 A 1990" introduces an interesting gas operated machine that can provide 2 plates at a time. Even if technically controversial, some good ideas are introduced, like the use of gas heater instead of electricity and the three stage cooking system into two chambers. In" Machine to fast cook spaghetti and the like US 5172627A-1992 (revision of US 5033364-1991)" a two chambered pasta machine is used to cook in less than a minute a specialized type of spaghetti with a tiny hole. In "Rapid cooking apparatus for food, in particular pasta such as spaghetti US 5142966A-1992", several interesting concepts are introduced in the three chambers concept, along with an anti sticking system, with a conical posture of the dry pasta and an L-shaped fast exit to the intermediate chamber. The thermodynamics of cooking is extensively described along with the vapor handling system. In "Fast cooker of spaghettis, bucatinis, and the like US 5191829 A -1993" a system to avoid sticking of cooked pasta is introduced. "It has been found that as the spaghettis pass from their dry state to the cooked state, they not only become edible as desired, but also somewhat "sticky", that is acquire a tendency to stick on surfaces with which they come in contact." This problem is very important and a solution is introduced in this concept. In 1994 the L shaped system of discharging the high pressure cooked pasta is introduced in "Apparatus for rapidly cooking alimentary pastas US 5361682A"**.** The " Electrical pasta cooking device US 5586487A of 1996, introduces two design of a 3 stage pressurized home cooker, one that resembles a syringe sterilizer and the second an Italian coffee home machine. No provision is given for sticking; however, this problem can be overcame by adding a small quantity of olive oil into the water. "Apparatus for the discontinuous preparation of portioned pasta products and apparatus for portioning a predetermined amount of long-stemmed pasta products US 5630359A" of 1997 describes a compact mechanical arrangement for a vending or mass machine of the previous patents. The "Automatic pasta preparer US 5937741 A" of 1999 is an interesting solution with the problem that it is not sufficient to rise the cooked pasta out of the water, since vapor still cooks pasta afterwards. The 2002 patent "Cooking machine US 6360652 B1" introduces a concept of a 2 stage pressurized machine with ball valve to control the cambers. In this patent it is possible to find the interesting comment "The apparatuses taught in the relevant art have several drawbacks. While some apparatuses are designed to allow an influx of water into the first cooking chamber to stir the pasta being cooked, this frequently is not sufficient. As a result, individual pieces of pasta tend to adhere to each other. Additionally, due to the apparatuses' enclosed design, they are difficult to clean. While it is possible to run a cooking cycle without the pasta to flush the apparatus with water, simply filling the apparatus with water, without more, does not sufficiently remove food residue from the interior of the apparatus. An improved apparatus that will alleviate these problems is desired.” This is the problem of tiny bits of cooked pasta that are not removed from the chambers and are re-cooked in the next cycle. These bits spoil the taste of the pasta.” A cleaning cycle is introduced for this purpose and a additional "tangential" water nozzle is added to stir the pasta during cooking. These two ideas should prevent the sticking of pasta on the boiler walls and the following re-cooking. This solution didn't work satisfactorily since a second patent “Cooking machine US 6530307 B2 “was introduced by the same authors in the 2003. In this second patent the improvement is a swirl ring to improve cleaning by water. The same authors introduce in 2006 a simplified and improved version of the previous cooking machine "apparatus for rapidly cooking food in water with the assistance of steam and increased pressure; automatic self-cleaning pasta cooker US 7001637 B2". In 2004 two patents with different arrangement of cooking devices are introduced. In “Automatic apparatus for fast cooking dry food at atmospheric pressure US 6810790 B1" a four chamber pressurized device is introduced**.** While in "Automatic pasta-cooker for restaurants, spaghetti-houses and the like US 20040177766 A1" a double column

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arrangement is described. Both this patents use a vibrating loader that weights and loads the pasta inside the cooking chamber. Patent "Two-chambered automatic pasta-cooker US 7886656 B2 - 2011", introduces some concepts of turbulence and tangential entrance for anti sticking, that along with wall temperatures are not entirely new concepts. "Apparatus for rapid cooking of edible pasta US 7926416 B2 -2011" cooks the pasta with steam and it considers uniform temperature inside the chambers as fundamental. A home cooking machine is introduced in "Cooktop drain US 8616121B1-2013". This system is very compact and should increase the efficiency of the gas burner. However the vapor diffusion problem and the sticking are not considered. "Machine to fast cook raw food stuff including dry-goods such as pasta on demand US 20130263746 A1" of 2103 includes a cooling system for precooked pasta preparation. An Italian patent was introduced by the authors ("Italian title is Procedimento di cottura della pasta o del riso mediante shock termici" - Domanda # BO2010A000099) in 2010.

These patents introduce the cooking of pasta by several temperature shocks. The advantages of this technique are multiple. The first advantage it is possible to sterilize the pasta at the first thermal shock, this is important since the optimum maximum temperature is 120°C that is too low for sterilization, the second advantage is that it is possible to cook the pasta at temperatures higher than 120°C without making it stiff. This further reduces cooking time.

Patents on "pasta di grano duro" (Durum wheat whole meal pasta)

"Spiral shaped, dried pasta food composition and a method for making it US 5738896A" of 1998 introduces a method to "to reduce breakage of the noodles and to permit inclusion of noodles longer than the flexible package filling aperture and reducing the incidence of perforation of the package".

A Google Patent Search shows more than 2,000 patents for shaped pasta, mostly for marketing reasons. However Patent " Machine to fast cook spaghetti and the like US 5172627A-1992 (revision of US 5033364-1991)" a specialized type of spaghetti with a tiny hole introduces to cook in less than a minute. However this solution has the drawback that it is very difficult to cook the pasta "al dente" (eng. transl. "to the tooth") since, in this case it is necessary to keep a tiny filament uncooked inside the pasta. The tooth encounters this tiny resistance on bite and the "al dente" cooking level is attained. For this reason the authors introduced the "geared spaghetti" (Italian trans. "spaghetto dentato"), italian patent # BO2010A000100. This solution makes it possible to increment the surface to volume ratio, so reducing the cooking time. This type of section, shaped as a gear, has the necessary mechanical strength and it is easy to produce with the automatic machinery currently used for industrial "Durum wheat whole meal pasta" production. The presence in the geared spaghetto of a small core ensures the possibility to reach any type of cooking level, including also the "al dente".

Problems connected with automated pasta cooking machines

In this paper an automated pasta cooking machine is an apparatus for cooking portioned dry durum wheat semolina pasta in batches or portions. These portions are prepared by means of cooking in water, steam, and aqueous solution that may include a juice or a fat for consumption shortly afterward. The portions are prepared with an excess amount of liquid, with some of the liquid being discharged after the cooking process, in particular in the form of excess cooking water, and not being intended for consumption. Cooking is a wet cooking technique for preparing food by supplying heat with the aid of water. Cooking includes both boiling and simmering, that is to say cooking in water in the region of the boiling point, simmering at a temperature below boiling point, pressure-cooking and also cooking in steam.

The power requirement

"US 20110104349 A1 The described apparatus and the described method have long been used successfully in practice, in particular for preparing spaghetti and macaroni. The preparation interval for each portion of noodles is approximately 120 to over 150 seconds in the standby state in the case of the known apparatus, with the heating of the noodles in the water in the cooking chamber requiring approximately 90 to 120 seconds and filling of the empty cooking chamber with the noodles, emptying of the cooking chamber, removal of water from the cooked noodles, rinsing of the apparatus and opening and closing of the valves requiring approximately 30 seconds. In order to allow the most rapid possible heating of the water in the heating chamber and the cooking chamber, a high-power heating element with a power consumption of approximately 6000 watts is used, this requiring a high-voltage current connection to 360 volts and a fuse of 20 to 32 amperes." This type of power level is common for pasta. If you look at the Pastitaly-Meccanica H7 machine described also in patent US 7886656B2, the installed power is 8kW, while the standby power is 1kW. During cooking, after the first plate the energy requirement is 3kW. This type of machine, which produces an excellent plate of pasta in very short time, is the result of a long research in the pasta cooking field. These power levels are the minimum for an acceptable result in time (about half the time indicated by the pasta manufacturer) and energy consumption. Normally, in Italy, a common electric plug can reach a power of 2.5 kW, with a reachable maximum of 3.5 kW. That means that a special power supply is needed.

This data can be evaluated by simple calculation. The single cooking chamber machine starts from room temperature. The chamber is filled with spaghetti, then the pressurized water compresses the air inside and covers the spaghetti. In the process the chamber is heated up to the cooking temperature T_{max}. This temperature, that for sterilization reasons should be of 132°C [1] is held for a suitable time, then a little quantity of water is spilled out and a temperature of T_{min}= 90°C is kept for the final part

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of the cooking process. The minimum water quantity should be used in order to keep the energy required for the process to a minim.

Since the pasta from dry to cooked increases its mass of 2.57 times (data from INRAN, Italian Institute of nutrition), the minimum amount of water is about 3. This means that (1):

$$M_{wm}=M_p*3=0.18 \quad (1)$$

$$V_{vm}=M_w/\rho_w+M_p/\rho_p=0.00022 \quad (2)$$

The minimum vessel diameter is then

$$d_{vmin}=2*Sqrt[V_v/(L_{sm}*\pi)]=0.046 \quad (3)$$

For practical reasons the vessel diameter dv should be slightly higher and the vessel useful length Ls should be slightly increased to be sure that the spaghetti are fully immersed into water. Suitable values are d_v=0.06 and L_s=L_{sm}*1.2=0.153. The useful vessel volume is then V_v=0.00043. When high temperature water enters the chamber is compresses the air trapped inside and a part of the water becomes vapor, for this reason the chamber length should be increased of 50%. The minimum water temperature can be then calculated. The mass of water required for each portion is then given by (4)

$$M_w= (V_v-M_p/\rho_p)\ \rho_w=0.39 \quad (4)$$

The water should heat the spaghetti and remain at the minimum target temperature T_{max}. Its temperature T_f should be then higher than T_{max}. In ideal conditions, with the vessel and the air trapped inside at the T_{max} temperature and no dispersion, the minimum value of T_f can be calculated with (5).

$$T_f= (c_w\ M_w\ T_{max}+c_p\ M_p\ (T_{max}-T_p))/\ (c_w\ M_w) =140 \quad (5)$$

The minimum amount of energy E_j necessary to heat up the water is (6):

$$E_j=M_w\ c_w\ (T_f-T_t) = 205 \quad (6)$$

If the hot water is dispersed after the cooking process the energy wasted is calculated by (7), (8) and (9)

$$M_{tot}=M_w+M_p=0.45 \quad (7)$$

$$M_{pcooked}=M_p*2.57=0.154 \quad (8)$$

$$E_w=(M_{tot}-M_{pcooked})\ c_w\ (T_f-T_t)=94 \quad (9)$$

Slightly less than 50% of the energy is then wasted in the process.

The minimum power required to heat up the water in 1 minute is then

$$P_{min}=E_j/60=3.45\ kW \quad (10)$$

This figure is purely theorethical since the efficiencies are all considered equal to 1.

It is clear that in order to contain the energy costs it is important to find a way to recover the energy wasted in the process.

The weight and cost issue.

The Pastitaly-Meccanica H7 machine is a very optimized machine, still, its mass is 500 kg over a surface of about 1 m^2. This weight requires a floor that can hold this load level. Pneumatic and electric actuators, along with pressure vessels are included in this very high technology machine; this fact increases costs and maintenance problems. A water supply is also necessary, even if a water reservoir tank can be included in the machine. What it is badly needed is a drain line for waste water for hygienic reasons. Another problem comes from the hot pasta. A special dish is required since pasta is at 90°C. This very hot plate may be harmful for the careless user. For these reasons a professional use of the pasta machine in masses or restaurants is more convenient.

The cleaning issue

U.S. Pat. US 20090090247 A1 quotes " A drawback of said known apparatus consists in that, during the partial cooking carried out in the first chamber, the pasta can stick together thus forming lumps that do not break up even in the second chamber wherein a larger quantity of water is contained. For this reason, it may happen that the final product served to the client is not completely satisfactory for the presence in the dish of lumps of stuck pasta, and describes a method to clean the machine. This problem is common in pasta machine. Some already cooked parts of the previous plate are re-cooked in the following. The result, not harmful for health, is distressing for taste." The cleaning of the pasta machine is a also problem for hygienic reasons.

A possible solution: the café-coffee house pasta machine

Machines for coffee houses have several advantages. A well trained barman is behind the coffee shop counter, a coffee machine with high temperature, pressurized water is already available. The drain line for waste water is available. The number of portions of pasta to be served are in the order of tenth and not hundreds per hours like in masses, restaurants and vending machines. The use of precooked pasta is not convenient since the amount of plates served per day is unknown. Also the frozen pasta dish alternative is not so attractive for room occupied in refrigerators, limited shelf life and cost. This "coffee-shop-pasta-machine" should be small, easy to use, easy to clean and fast. The raw material is relatively inexpensive: dry durum wheat semolina pasta, hot water, sauce, salt and parmesan cheese. Sauce is available in precooked pots in different recipes and can be added to the cooked pasta. A drawback of this solution is that the single plate per day could be required. It can be served at any time of the day. It is common for this type of shops to stay open up to 20 hours per day.

The “standard” standard Italian coffee machine has a reservoir of more than 10lt of hot water (88 ºC ± 2 ºC), pressurized at 8-10 bar. It is kept warm and pressurized all day long. It has and additional module for cappuccino with water at 120°C. It is possible to recover the wasted water energy by installing an heat exchanger in the supply line between the water softener and the coffee machine boiler.

The thermo mechanical arrangement of the coffee-house pasta machine

First of all, only a type of pasta was chosen: the "spaghetti". This fact greatly simplifies the machine geometry and improved the product quality. "spaghetti" is the most common type of dry semolina pasta in Italy.

An initial solution is showed in Figure-1. Two vessels or reservoirs heat up water to 90°C and from 90 °C to the optimum feed temperature (T_f+Δ). Where Δ is the temperature drop between the reservoir and the cooking chamber. The two vessels arrangement makes it possible to recover the wasted energy immediately and more efficiently and to have the necessary amount of water at the ideal temperature for the single portion. In this case the cycle is the following. The pressurized cooking chamber is inclined forward to facilitate the charging of the dry semolina pasta. Dry semolina pasta is manually loaded into the machine. The operator starts the fully-automatic digitally-controlled cooking-process. The cooking vessel rotates to the vertical position and it is automatically closed. Water at T_f+Δ is flushed into the cooking chamber where it arrives at T_f. After a preset time, a little amount of water is spilled out of the cooking chamber to reduce temperature to 90°C and pressure around 1 bar. This spilled water heats up the 90°C reservoir. After a predefined time the excess of water is pumped out of the pressure vessel and this energy is recovered by an heat exchanger in the feeding line of the coffee machine. The cooking chamber is opened and then rotated forward completely to unload the cooked pasta into the plate. The pressure inside the cooking chamber is regulated by a discharge valve and a suction pump that eliminates the excess of water before unloading the machine. This arrangement is nearly ideal from the “cooking” point of view, and can be rearranged to a more pleasant and safe solution as depicted in Figures 2 and 3. The cooking time is half of what written on the "spaghetti" box.

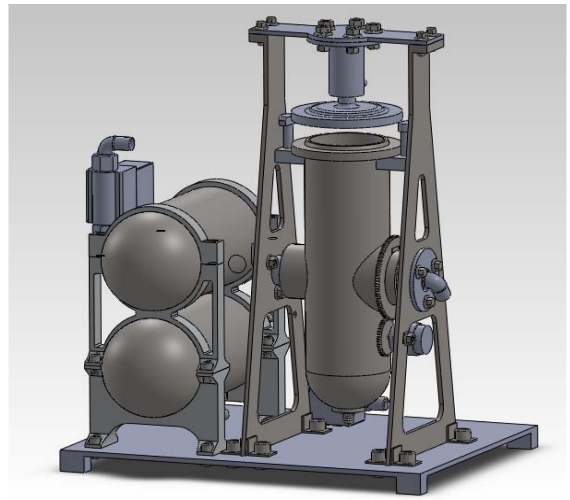

Figure-1. An initial version of the pasta machine [Rendering from the project of Michele Morara, Giacinto Pappalardo, Tommaso Scaramuzzino, Alessandro Tarozzi and Matteo Vecchi, "Course: Disegno Assistito al Calcolatore (Computer Aided Design)", Università degli Studi di Bologna, Instructor: Prof. Luca Piancastelli].

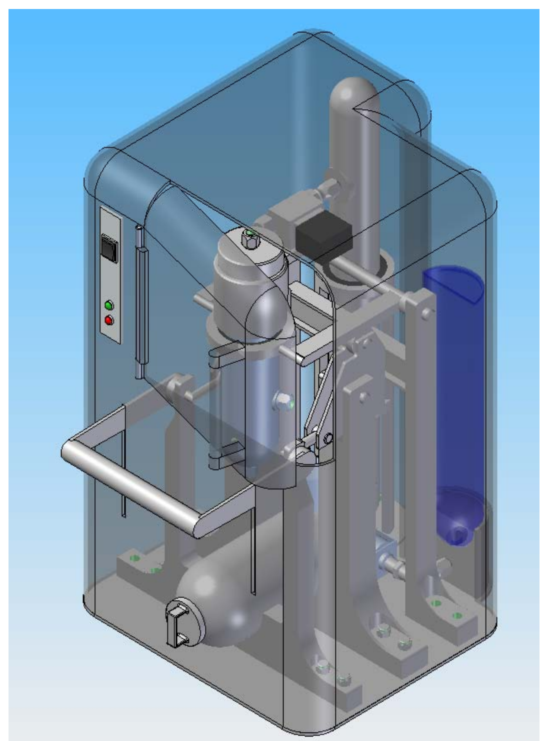

Figure-2. The pasta machine rearranged in a more functional design [Rendering from the project of Michele Morara, Giacinto Pappalardo, Tommaso Scaramuzzino, Alessandro Tarozzi and Matteo Vecchi,"Course:Disegno Assistito al Calcolatore (Computer Aided Design)", Università degli Studi di Bologna, Instructor:Prof. Luca Piancastelli].

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In the solution of Figure-2 the pivoting of the combustion chamber is manually actuated. An external chassis protects the operator from hot surface contact, prevents the opening of the machine when still in pressure and supports the user interface. A digital computer controls the fully automatic cycle. Once the cooking time of the pasta (half of the time indicated on the box) is selected, the dry semolina pasta is loaded and the on button is pressed the automatic cycle begins. The cycle ends with the lid open in vertical position. Then the light turns to green and operator can rotate the lever an discharge the plate of pasta. This design is very compact but has some shortcomings. The most important one is the safety concern due to the slots for the rotation lever. If something goes very wrong, hot steam may get out from the protection case and hurt the operator. This fact is unacceptable. Another concern is the design that is not familiar to the operator: it is a box. Drawings and patterns may soften the "box" appearance, but this design is far from ideal.

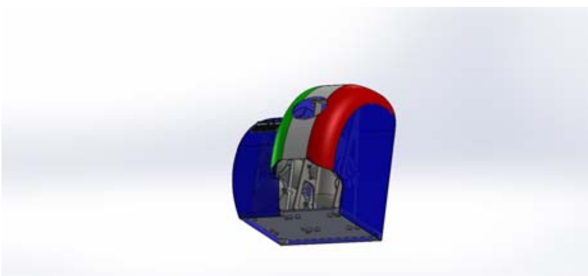

Figure-3. The more functional and familiar version of the Figures 1 and 2 pasta machine[Rendering from the project of Samuele Gasperoni, Emilio Frugieri, Luca Arlotti, Davide Aureli and Luca Casanova, "Course: Disegno Assistito al Calcolatore (Computer Aided Design)", Università degli Studi di Bologna, Instructor:Prof. Luca Piancastelli].

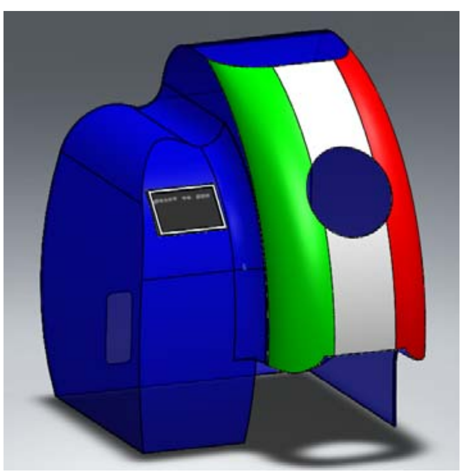

Figure-4. Another view of the skid of the machine of Figure-3.

Figures 3 and 4 show a very different skid for the Figure-1 machine. In this case the rotation of the cooking vessel is fully automatic. A circular hole on the chassis makes it possible to introduce the dry pasta. The cover of this hole may contain a commercial logo of the machine or of the pasta manufacturer. An inferior slot may contain a drawer with the plate of the pasta. On the left a display controls the pasta machine. This design is more familiar, it is copied by other-coffee machines. It is a common and well known design. The concept is to soften the impact of a whole new concept on the operator/buyer. The food machine looks like familiar. It looks like a machine that works. The operator/buyer may feel that only the "type of food" is new, but the machine is an old, beloved and reliable concept. This is obviously untrue, but the trick may work.

In this case the operator puts the dish in the drawer, then he closes the drawer. He puts the dry semolina pasta in the upper circular hole and then he closes the upper lid. Once the drawer and the lid are closed, the cooking time should be set and the start button has to be pushed, in order to make the machine start the cooking cycle. As in the previous machine the cooking chamber is rotated in an upward vertical position to close the lid. When the cycle ends the cooking vessel is opened inside the closed protective skin of the machine and it is fully rotated downwards to a downward vertical position. The cooked pasta is discharged into the dish by gravity. After a preset time the cooking chamber is rotated back to the "load" position. Only at this point, the safety on the lid and the drawer are released and the operator can open the drawer to extract the plate. A green light and a sound may inform the operator that the pasta is ready to be served. Before starting a new cooking cycle, the operator checks if the pressure chamber still contains parts of cooked pasta and, in this case he removes them. The removal can be mechanical of by flushing water inside the cooking chamber. The flushed water can be removed by the suction pump through a manually operated button. This machine is very safe. The only risk is to get burned during the loading and cleaning operations by the cooking chamber hot walls. Gloves may be required to protect the operator's hands.

This machine has some technical drawbacks. The first is the cleaning, that is not as easy as required. The second is cost. This machine is complicated with many critical components that require quality and performance. These facts mean unavoidably high costs.

The "rocket" pasta machine

The "rocket" pasta machine concept

A very simplified coffee house pasta machine is depicted in Figure-5. The hot water supply line comes directly from the coffee machine. This machine provides hot water at 90C or 120C at a pressure around 9 bar. It is then possible to load the spaghetti, warm up the machine with the 90C water and then cook the spaghetti at 120°C and 4 bar, then depressurize the cooking chamber by spilling a little amount of water, down to a temperature of

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105C and then finish the cooking process at 90C. The used water can be used to heat the fresh water that will refill the coffee machine. To keep the input line warm, an in line electric heater is inserted in the input water pipe to the machine. Energy can be than saved by discharging the water into an heat exchanger installed in the supply line of the coffee machine. The process can be controlled by a PLC and a simple electrically actuated automatic valve system. The cooked pasta is then extracted by the operator and put into the plate. The cleanliness of the machine is under the responsibility of the operator as the handling process of the warm dish.

Figure-5. The basic pasta machine [Rendering from the project of Francesco Licandro, Course: "Laboratorio di CAD (Laboratory of Computer Aided Design)", University of Bologna, Instructor: Prof. Luca Piancastelli].

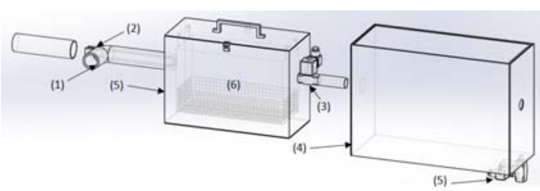

Figure-6. The pasta machine of Figure-5 partially disassembled.

From Figure-6: the supply line is depicted on the left (1). An in line electric resistance (2) to overheat the water is installed in the supply line (1). This resistance assembly includes also an electrically operated inlet valve. A drain valve (3) controls the pressure level and the temperature in the pressure vessel (5). A emptying valve (5) is installed in the bottom of the pressure vessel. The pressure vessel is contained in a insulated case (4). Inside the pressure vessel (5) it is possible to see the strainer 6.

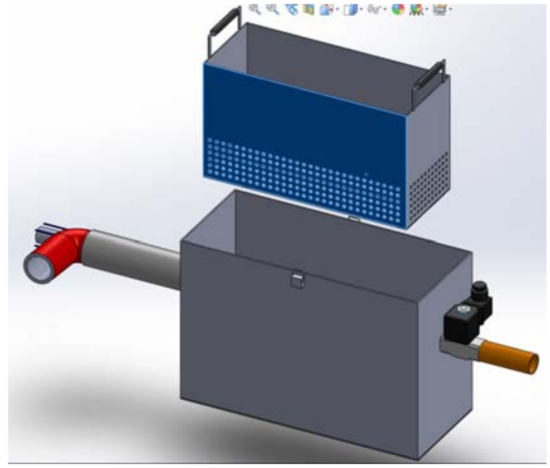

Figure-7. Another view of the basic pasta machine of Figure-5.

The operator loads the dry pasta into the strainer, then inserts the strainer inside the pressure vessel and closes it with the cover. Then he presses the PLC start button and the automatic cooking cycle begins. The water is taken from the coffee machine and the heat-up cycle begins. The machine is loaded with a mixture of water and vapor ant this mixture is kept for a suitable time. In this time the resistance is turned on. A second load of water is then loaded into the pressure vessel at 120°C and 4 bar. This temperature is kept for a suitable time that depends on the type of pasta. With the geared spaghetti this time is 10s. The pressure is then reduced to 1bar by discharging a little amount of water. Another time step is required to complete the cooking cycle depending if "al dente" or well done pasta is required. When the cycle finishes the operator opens the pressure vessel and takes out the strainer. This conceptually simple machine is difficult to use and has a disputable design. A new design concept is necessary. However the concept is very simple and cheap.

The rocket machine

A good pasta machine should be as fast as possible, should occupy as little room as possible and should resemble something of familiar. For this purpose the rocket machine was conceived (Figures 8 and 9). The rocket machine is again a single chamber machine fed with the hot water of the coffee machine. The concept is the same of the machine described into the previous paragraph (Figures 5, 6 and 7).

Figure-8. The rocket machine (outside) [Rendering from the project of Fabio Gordini Aglietti, Nicolò Carpinelli, Enrico Bezzi, Fabrizio Casadio, Course: "Disegno Assistito dal Calcolatore (Computer Aided Design)", University of Bologna, Instructor: Prof. Luca Piancastelli].

Figure-9. Cutaway section of the rocket machine.

The basic concept of the rocket design is that the pasta machine should be fast. In a coffee-house, the appearance is important. In fact, people usually shows off their new vehicles outside the coffee house to the friends. For pure commercial reason, coffee houses interiors are often trendy. A trendy machine is well accepted. In our case it should be fast...as a rocket. Also it should be as vertical as possible. Room is always required. The result is a vertical rocket. The upper handle is rotated horizontally, like when the operator makes a coffee. A familiar gesture for the coffe-shop man. The spaghetti are inserted vertically, also a familiar gesture. Then the "rocket" is closed. At this point it is possible to start the cooking process. After the green light turns on, the operator puts a plate under the rocket tail and rotates the bottom handle. The pasta is discharged into the dish. Both top and bottom handle are locked during the cooking process. A double closure system protects the operator from failure of the pressure vessel.

The vertical arrangement of the cooking chamber, which appears like a tube, makes it easier to clean the machine.

CONCLUSIONS

An automatic machine that cooks dry semolina pasta seems to be easy to design and very advantageous from the economical point of view. As a coffee vending machine the operator puts the coins push the button and otbtains a tasty plate of pasta. However these machines have proved to be highly problematic. A long refinement process hat put on the market some very good pasta vending machine. However their costs, the energy consumption and the necessity to have a water suppy and drain limit their diffusion.

Several problems of pasta cooking machines are discussed in this paper. Also several automatic pasta machine patents are briefly described.

A much simpler single-chamber pasta machine for coffee bar is then introduced in this paper.

The machine described herein is conceived for coffee shop where a hot water reservoir (120°C, 9 bars, 10lt) and a qualified operator are available. This makes it possible to simplify the machine and improve the safety of use. Also the production rate is much lower than vending of mass machines ranging to 1 to 50 portions per day.

Even in this extremely advantageous environment the problem is not easily solved. Several technical solutions are analyzed in this paper. Energy concepts and concerns are also discussed. Safety should be kept to an acceptable level even for a trained operator.

Different technical solutions to achieve the best compromise between cost, functionally and safety are introduced. The simpler the better concept is implemented. Several fashionable designs are introduced and analyzed in this paper. From an high technological, optimal expensive solution to an highly simplified "rocket" pasta machine.

This machine can cook the special patented "geared spaghetti" in less than a minute and every other type of spaghetti in half the time indicated in the box. This solution seems to be the best compromise for taste, safety and performance.

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Symbol	Description	Unit	Value
M_{wm}	Minimum water mass for single portion	kg	-
V_{vm}	Minimum water volume for single portion	m^3	-
ρ_w	Water density	kg/ m^3	1000
M_p	Dry spaghetti mass for 1 portion	kg	0.06
ρ_w	Dry spaghetti density	kg/ m^3	1500
d_{vm}	Minimum cooking chamber diameter	m	-
l_{sm}	Half spaghetti length	m	0.1275
d_v	Cooking chamber (vessel) diameter	m	-
l_s	Cooking chamber (vessel) height	m	-
M_w	Water mass for single portion	kg	-
T_{max}	Max cooking temperature of spaghetti	K	-
T_f	Max water temperature	K	-
C_p	water heat capacity	kJ/ kg °C	4.186
T_p	Dry spaghetti Temperature	K	298.15
C_p	Specific heat capacity of spaghetti	kJ/ kg °C	1.8
E_j	Minimum amount of energy to cook spaghetti	kJ	-
M_{tot}	Total mass inside the cooking chamber	kg	-
$M_{pcooked}$	Cooked spaghetti mass for 1 portion	kg	0.06
P_{min}	Minimum amount of power to cook spaghetti	kW	-

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