Gastronorm Container Production with Automatic Pressure Compensation System Machine Providing Energy Efficiency with Industry 4.0

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Abstract: *With the developing food industry applications, the use of gastronorm containers is also increasing rapidly. It is widely used to transport, cook, preserve and serve gastronorm containers and food products. In line with international standards (EN 631-1, EN 631-2, etc.), the production process becomes more complex as the depth of gastronorm containers increases (from 20 mm to 200 mm / 6 different depths) and the process steps increase. Due to the errors arising from the process stages, there is an increase in the number of rejects, and thus energy efficiency is adversely affected. An automatic pressure balancing system design has been developed in accordance with the workflow in gastronorm container manufacturing with deep drawing technology. Providing the elimination of excess pressure steps and heat treatment needed in deep gastronorm containers (sizes and depths respectively: 1/2 200 mm, 1/3 150 mm, 1/3 200 mm, etc.), as well as the unique design of the integrated deburring machine, a significant innovation with industry 4.0 application has been imparted. Thus, in addition to the increase in product quality, it contributed to reducing unit costs by reducing high waste rates below 5%.*

Keywords*: GASTRONOMY CONTAINER, ENERGY EFFICIENCY, INDUSTRY 4.0*

1. Introduction

With the development of production techniques in recent years, results in the field of industry 4.0 are gaining momentum. The design principles of Industry 4.0 appear as a collection of necessary conditions that enable the digital industrial transformation to offer its unique advantages (for example, economy, environment, etc.) [1-3].

Industry 4.0 first emerged in Germany in 2011 to increase the intensity and efficiency of the manufacturing industry. With the increasing complexity, demands, and competition in the international market, customized product requirements are the main challenges for companies [4].

Industry 4.0 will potentially impact manufacturing systems with rapid digitalization developments and technologies such as IoT, big data, and artificial intelligence. The scope of industrial revolutions is given in Fig. 1 [4].

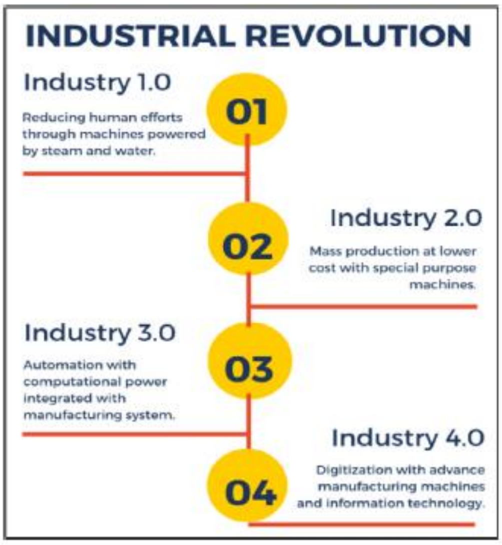

Fig. 1 *Scope of industrial revolutions [4].*

The advanced use of sensors, programmable devices, and industrial robots within the scope of Industry 4.0 is shown in Fig. 2. The use of technologies was rated on a 0 to 4 Likert scale (value 0 indicates not used at all or very little, 4 indicates advanced usage). It has been reported that the history of these technologies is at most 15 years, and their applications are increasing in large companies engaged in production [5].

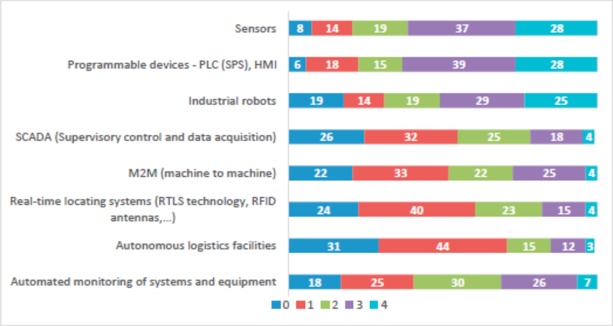

Fig. 2 *Usage level of Industry 4.0 components [5].*

The forming method is widely used due to its high material handling efficiency and production speed. Most forming processes control the geometry of the final products with tools. With process parameters, devices are used to shape/deform the final geometry of the workpiece. Therefore, part geometry and surface quality can be significantly controlled [6].

Product properties are affected by the interface between the tool and the workpiece. The relationship between the product and the tooling is shown in Fig 3 [6].

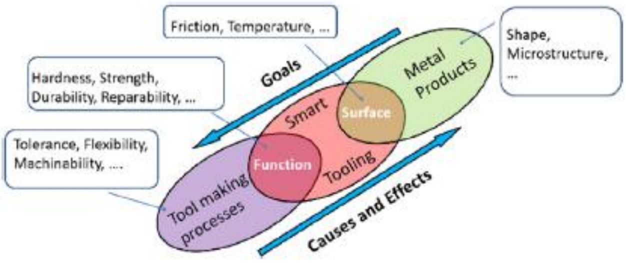

Fig. 3 *The relationship between the product and the tooling [6].*

Cao and the working group emphasized that an essential feature of Industry 4.0, or digital manufacturing, stands out with its structure that encourages the development of new solutions and the optimization of forming processes, as well as allowing the use of product information in real time. They also evaluated the functional requirements of the metal forming tool on dimensional accuracy, surface performance, wear resistance, fracture and fatigue strength, repairability, and cost. A Diagram of the relationship between critical elements in tool development for metal forming is given in Fig. 4 [6].

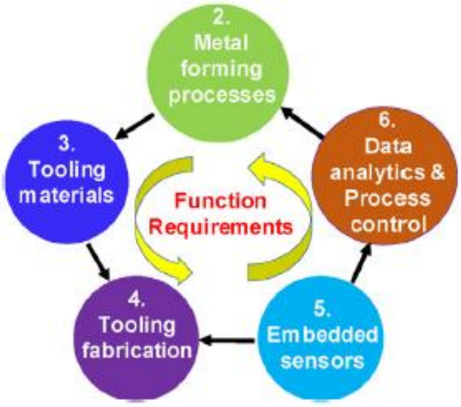

Fig. 4 *Diagram of the relationship between critical elements in tool development for metal forming [6].*

The fifth wave, cyber-physically-enabled circular economy in metal forming mitigation activities, is given in Fig. 5. It has been interpreted as transforming the economy from a linear path to a circular one (design/production-distribution-using-reuse-disposal). The realization of this vision in metal forming requires the contributions and integrations of various disciplines [7].

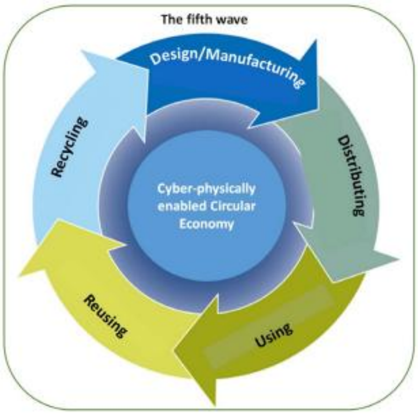

Fig. 5 *The fifth wave in metal forming for light weighting—the cyber-physically-enabled circular economy. [7].*

Many studies have been carried out regarding the parameters affecting the deep drawing process of sheet metals [8-15]. Various studies on this subject are summarized below.

Tiwari and his working group evaluated the deep drawing method among metal forming processes. They reported that the deep drawing method is used extensively in the industry and is the most challenging process to obtain a perfect product. However, they emphasized that the material waste is shallow if the appropriate parameters are determined in the deep drawing process. In this way, it is a very cost-effective process. While evaluating various parameters (temperature, thickness, friction, blank holder force - BHF, pressure, shape of the blank, lubrication, punch speed, drawing force, radii) affecting the deep drawing method, other factors (drawing ratio, slope of die) are also evaluated. and blank holder, deep drawing depth) [8].

Ikumapayi and his working group stated that the deep drawing process has a wide range of applications compared to other metal-forming methods. Many industries include beverage and food cans, kitchen sinks, cooking utensils, engine oil pans, solenoid assemblies, automotive fuel tanks, and fire extinguishers. They are reported to be widely used. In terms of defects and disadvantages in deep drawing manufacturing, they also explained the defects of wrinkling, ironing, tearing, earing, galling, and surface marks [9].

Deep drawing is a sheet metal forming process widely used in industry to produce box-shaped and other complex curved hollow-shaped sheet metal parts. Parameters affecting the deep drawing process and display of various failure forms are given in Fig. 6 [10].

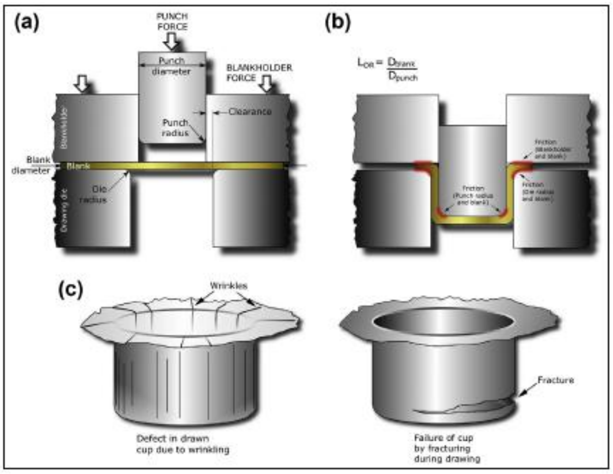

Fig. 6 *Parameters affect the deep drawing process and display of various failure forms. (a) Deep drawing process and fundamental parameters, (b) Deep drawing of sheet material, and (c) Display of various failure forms [10].*

The formability process is defined as the ability of the sheet metal to undergo plastic deformation in a certain way without defect. Various parameters affecting formability are given in Fig. 7 [11].

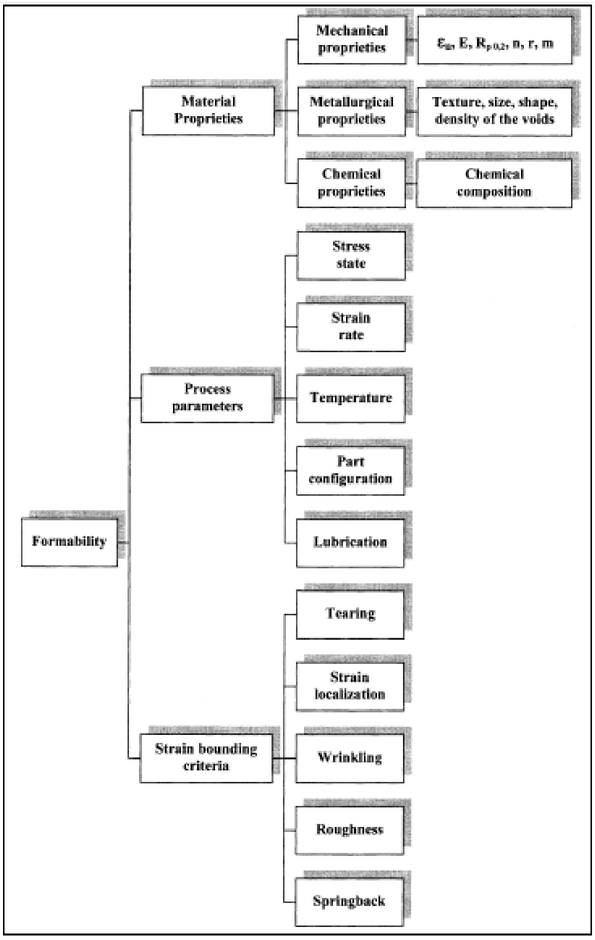

Fig. 7 *Various parameters are affecting the formability of sheet metal. [11].*

Photographs of stainless steel gastronorm containers produced in different sizes according to the EN 631-1 standard are shown in Fig. 8.

Fig. 8 *Photographs of stainless steel gastronorm containers.*

Standard gastronorm containiers depth dimensions are 25 mm, 40 mm, 65mm, 100 mm 150 mm and 200 mm. Standard gastronorm container sizes are shown in Fig. 9.

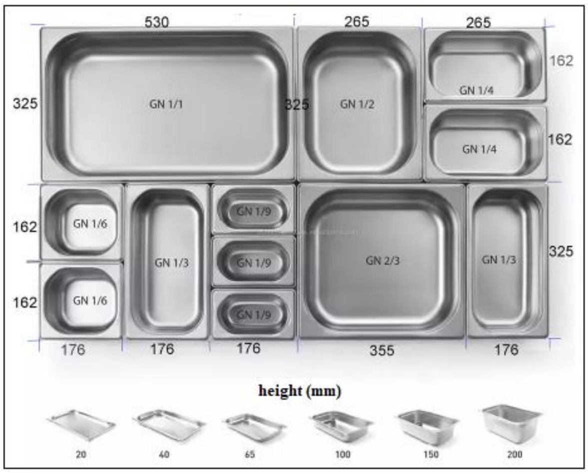

Fig. 9 *Dimensions of stainless steel gastronorm containers (EN 631-1).*

2. Methodology

The current production process of stainless steel gastronorm containers consists of many stations, and the number of faulty products increases with the human factor. In addition, the possibility of tearing the products increases with going deeper (for example, 150 mm and 200 mm) in gastronorm container products. In this case, additional heat treatment should be applied to the products. This way, the amount of gastronorm containers obtained per unit of time due to the production process is negatively affected. To eliminate these negativities, studies were carried out to develop an innovative system with a pressure compensation system machine and deburring system in line with Industry 4.0.

AISI 304 stainless steel is the most suitable material for deep drawing in terms of the high strength and mechanical properties (% elongation) of gastronorm containers. The properties of AISI 304 stainless steel used are given in Table 1.

Table 1: *The properties of AISI 304 stainless steel.*

Chemical Properties							
Elements	C	Si	Mn	P	S	Cr	Ni
Composition (%)	0.044	0.605	0.79	0.029	0.003	18.231	9.088
Mechanical Properties							
Elongation (%)	55						
Tensile Stress (N/mm^2)	622						
Yield Stress (N/mm^2) %0.2	265						

As indicated in Table 1, although the elongation value of AISI 304 stainless steel material is 55%, it is suitable for deep drawing. Still, because the current manufacturing method consists of several stages, it is necessary to prevent adverse effects.

Various defective product images most frequently encountered in gastronorm container manufacturing in the current production process are given in Fig. 10.

Fig. 10 *Gastronorm container production defect types a) material tearing, b) wrinkle, c) short edge, d) failure to open, e) Nylon/PVC scrape, f) trace (chip mark, mold mark).*

There are many defects in manufacturing stainless steel gastronorm containers (Figure 10). If these error types are not eliminated, the labor, material, and time losses caused by the current production method negatively affect product costs.

3. Experimental procedure

By Industry 4.0, the production of stainless steel metal sheets (AISI 304) and gastronorm containers in different sizes and depths according to international standards (EN 631-1 & en 631-2) has been carried out on the innovatively developed system with an original design, which includes pressure compensation system machine and deburring systems as a whole.

The efficient operation of the innovative system has been ensured by simultaneously transferring the data obtained from the sensors to the control panel during the effective operation of the entire system.

Following Industry 4.0, stainless steel gastronorm containers are manufactured using digital interaction with sensor systems at all process stages. Firstly, the stainless steel sheet material (AISI 304) is drawn to a certain depth in the first part of the automatic pressure compensation system. After this process, it is possible to go down to a greater depth (max. 200 mm) at the second station.

At the third station, the edges of the gastronorm containers are cut automatically with the cutting mold. As a final operation, the burrs formed on the edges of the stainless steel gastronorm containers are removed and flattened.

4. Conclusions

Within the scope of R&D activities, it has been ensured that stainless steel gastronorm containers (different sizes and depths), which are widely used in the commercial kitchen industry, are produced efficiently with an innovative system uniquely designed and compatible with Industry 4.0.

With the pressure compensation system under Industry 4.0 in the deep drawing process, producing AISI 304 stainless steel gastronorm containers at high depths (150-200 mm) without the need for a heat treatment process is ensured.

With the pressure compensation system, the production of stainless steel gastronorm containers has primarily eliminated the waste rates (wrinkling tearing, earing, ironing, galling, product thickness homogenization, etc.) compared to the many existing productions (waste rates below 5%).

Following international standards (EN 631-1 & EN 631-2), it has been achieved to obtain energy-efficient stainless steel gastronorm containers in the innovative system.

With the innovative production system in line with Industry 4.0, significant improvements have been achieved in producing stainless steel gastronorm containers in terms of quality products and unit production times, as well as working opportunities with high occupational safety.

Acknowledgment

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