Development of Innovative Fully Automatic Processing System for High Energy Efficient Manufacturing of Commercial Cookware

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Abstract: *Cookware is one of the indispensable equipment for commercial kitchens. The very large size of commercial cookware (up to Ø1200 mm) requires precision manufacturing processes. In our current manufacturing process, the fact that different processing stations are separate from each other and the processing stages are dependent on the workers, carrying risks in terms of occupational safety (cutting with scissors, grinding, etc.), prevents the product from being obtained with high processing quality and causes high wastage rates arising from the manufacturing process. In addition, it creates negative effects in terms of efficient use of energy and production time, causing an increase in unit costs. Within the scope of this study, the design and prototype production of an energy-efficient and work-safe innovative processing system for commercial cookware, based on R&D systematic studies, is carried out by international standards (EN ISO 12100, EN 614-1, EN 12983-1, etc.) and the results of our current manufacturing process. As a result of this research, occupational safety risks and excessive process steps are reduced, product quality and efficiency are increased, and thus production costs and energy efficiency are increased. Results are promising for further optimization.*

Keywords: *COMMERCIAL KITCHEN COOKWARE, MANUFACTURING PROCESS, ENERGY EFFICIENCY*

1. Introduction

Cooking utensils (pots, pans, etc.) for industrial kitchens require high precision in production processes regarding product quality due to their very large size. Stainless steel materials are widely used in many products in the industrial kitchen area. Among the stainless steel types, especially AISI 304 (EN 1.4301), quality stainless steel material stands out with its various properties (mechanical properties [1], corrosion resistance [2] etc.) in the metal industry.

Various studies have been published on using stainless steel sheet materials for the food industry and their shaping in production processes (especially the deep drawing method) [3-14]. Various studies obtained from literature research on the subject are summarized below.

Daoyuan and his working group noted that stainless steel stands out as a widely used material for food contact in food processing equipment and various products. They emphasized that as a food contact material, it has advantages such as corrosion resistance, ease of manufacture, cleanability, relatively low cost, high strength, and hardness [3].

Junaidh and his work group evaluated the machining properties of AISI 340 quality stainless steel, which is in the austenitic stainless steel group, such as cutting force analysis, surface roughness analysis, and chip morphology of stainless steel by turning process using an uncoated carbide tool with four different cutting speeds and three different feeds. It has been stated that the correct selection and control of process variables can significantly improve the machining properties of AISI 304 austenitic stainless steel, depending on the cutting force, chip morphology and surface roughness. Junaidh and his work group emphasized that if the cutting speed increases, the cutting forces decrease as the feed rate increases. The surface roughness values decrease with increasing cutting speed. They found that tool wears increased with increasing speed but decreased with increasing feed. They also stated that helical chips were obtained at a lower feed value, which was more accessible to the machine. They emphasized that the correct selection and control of process variables significantly improve the turning machining performance of AISI 304 austenitic stainless steel [4].

Graphical representations of chips obtained when machining AISI 304 workpieces at various cutting speeds and feeds are shown in Fig. 1 [4].

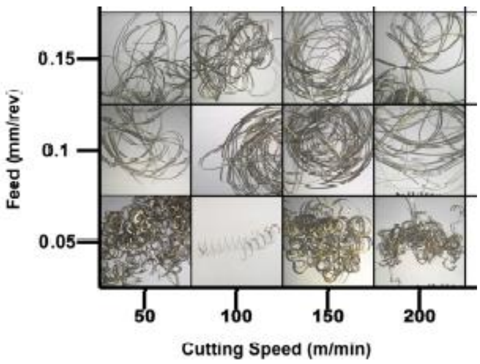

Fig. 1 *Graphical representation of chips obtained when machining AISI 304 workpieces at various cutting speeds and feeds (test conditions: depth of cut=0.5 mm, machining length=30 mm.) [4].*

Surjeet and his work group investigated the effects of cutting speed using uncoated tungsten carbide inserts in processing AISI 304 stainless steel material. They stated that the increase in cutting speed in the machining process helped to increase the degree of chip curl and the color of the chips changed as the cutting speed increased. They found that the chip color was slightly yellowish towards the dark metallic color at higher machining speeds. The appearance of stainless steel chip colors according to different cutting speeds is given in Fig. 2 [5].

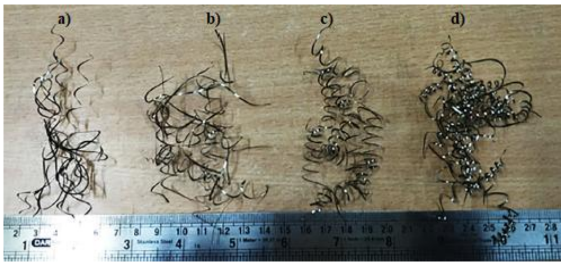

Fig. 2 *Chip shapes formed at different cutting speeds are a) 66 m/min, b) 146 m/min, c) 190 m/min, d) 247 m/min [5].*

Fig. 3 shows that the tool tip temperature increases gradually up to Vc = 146 m/min, and above this value, the tool tip temperature tends to decrease. They reported that the tool tip temperature was recorded as the highest value of 88.9°C at V = 190 m/min for all cutting speeds tested. [5]. The effect of cutting speed on cutting force and maximum tool tip temperature is shown in Fig. 3 [5].

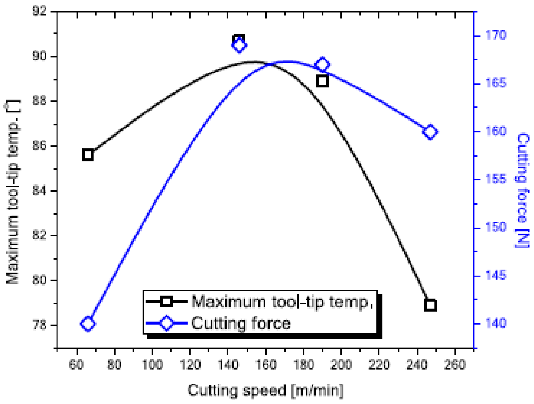

Fig. 3 *Effect of cutting speed on cutting force and maximum tool tip temperature [5].*

Jozic and his work group stated that energy consumption, use of cooling and lubricating oils (cutting fluid, amount of cutting fluid) during machining are the main factors that cause negative environmental effects. Therefore, it is crucial to reduce both aspects while improving the sustainability of the processing. They emphasized the importance of improving these factors while trying to improve the sustainability performance of the industrial sector. They stated that energy consumption could be reduced using the most suitable cooling techniques, processing parameters, and advanced processing tools in industrial applications [6].

Padmanabhan and his working group stated that improving process factors in sheet metal forming is an important activity to reduce production cost. They emphasized that it is essential to examine the effects on the deformation behavior of sheet metal to determine the optimal values of the process factors. They evaluated three important process factors on the deep drawing properties of a stainless steel axisymmetric vessel: die radius, cavity holding force and coefficient of friction. The finite element method combined with the Taguchi technique creates a refined estimation tool for determining the effect of generating process parameters. In this study, evaluations were made to determine the various effects of each process data handled with the Taguchi method [7].

Tiwari and his working group have studied the widespread use of deep drawing in sheet metal forming and various factors that can affect deep drawing to obtain a perfect product with deep drawing in manufacturing processes. The main factors that will affect the deep drawing process are temperature, sheet metal thickness, friction, blank holder force (BHF), pressure, lubrication type, etc. evaluated the features [8].

The above literature research has stated that many parameters affect high-efficiency manufacturing in sheet metal forming processes. Within the scope of this study, studies on the development of a uniquely designed, fully automatic processing system were evaluated in the face of the problems experienced in the production of traditional commercial cookware.

2. Methodology

AISI 304 stainless steel sheet is used to produce commercial cooking utensils (pots, pans, etc.). The chemical composition of the AISI 304 stainless steel material is given in Table 1.

Table 1: *Chemical composition (%) of AISI 304 quality stainless steel sheet.*

Elements	C	Si	Mn	P	S	Ni	Cr	N	Cu
Chemical composition (%)	0.022	0.50	0.90	0.033	0.003	8.12	18.36	0.049	0.04

The current manufacturing process for commercial cookware is given below;

- Circular cutting of stainless plates,
- Pressing the cut sheets with the deep drawing method (different diameters and depths),
- Fixing and cutting the edge of the stainless sheet in the guillotine shears,
- Circular cutting of excess allowances for sheet edge bending,
- Grinding burrs formed on circular cut edges,
- Transporting commercial cookware to a different press for bending the edges,
- Giving appropriate bending to commercial cookware in the press,

The stages of the current manufacturing process for commercial cookware are shown in Fig 4.

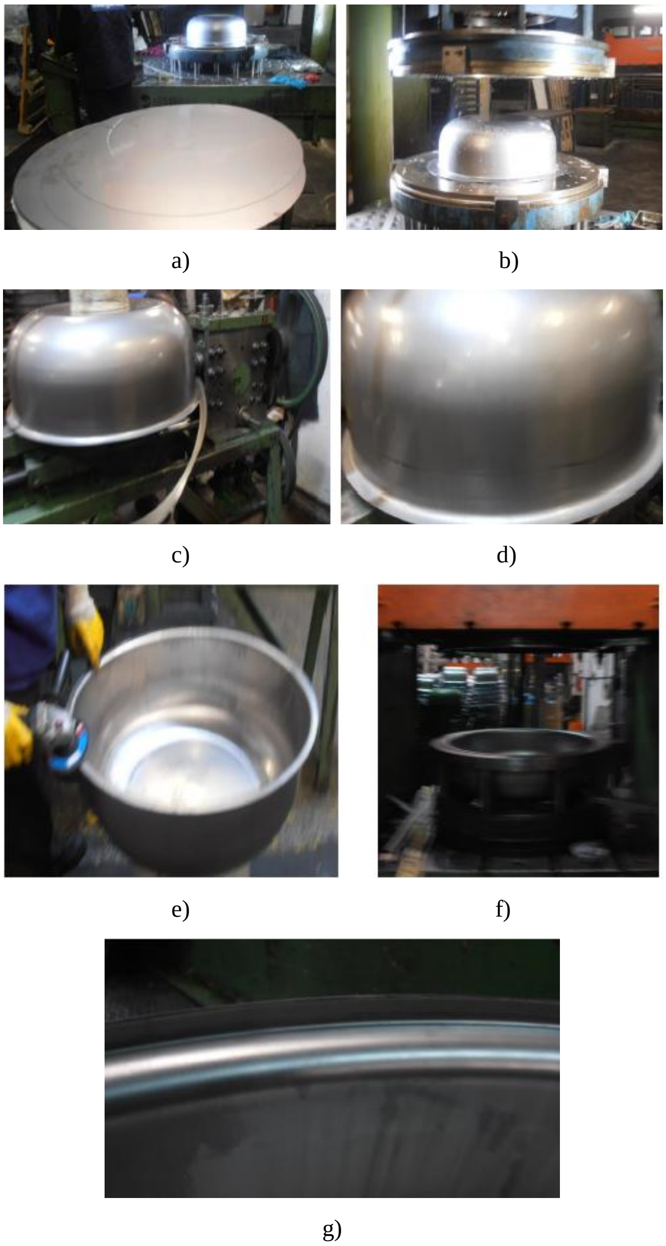

Fig 4. *Stages of the current manufacturing process for commercial cookware; a) Pressing the stainless steel circular plates (Ø350-1200 mm), b) Pressing the stainless steel circular plates, c) Circular cutting of the edges of the commercial cookware d) The image of the commercial cookware with circularly cut edges, e) Grinding circularly cut* commercial *cookware burrs, f) Placing the edge of the cut-out commercial cookware into a mold suitable for press forming, g) Commercial cookware mouth formed on the edges of the press.*

As shown in Fig. 4, commercial cookware produced with the traditional method causes energy efficiency losses due to many processing steps. In the current commercial cookware manufacturing process, the excess labor-related processes (cutting, grinding, etc.) poses a risk to worker safety. Automating the processes in the innovative commercial cookware manufacturing system will provide an advantage in occupational safety.

3. Experimental procedure

In our current manufacturing process of commercial cooking utensils, products are transported to 3 different stations after the press printing stage. This is done by placing it on the workstation, and the grinding process is also done manually by the worker. Occupational safety risks increase due to the worker-related process of this process and also create a negative effect on the increase in unit production costs. In the current manufacturing process, energy consumption values are also high due to 3 stations. The draft drawing of the innovative processing system developed based on the R&D systematic to overcome these problems, is given in Fig 5.

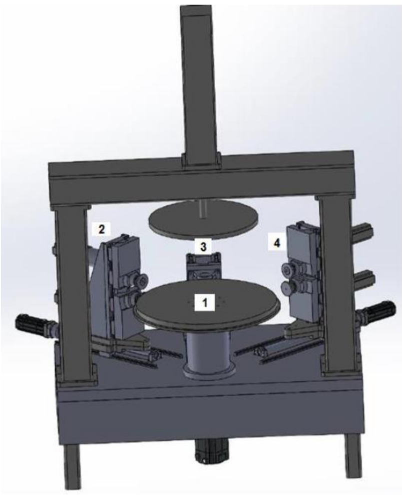

Fig. 5 *Innovative fully automatic processing system design for the highly energy efficient manufacture of commercial cookware.*

Within the scope of this study, the working process of the innovative fully automatic processing system for the high energy efficient production of commercial cookware is given below;

1. Placing and fixing the circular stainless steel sheet (between Ø350-1200 mm, in different thicknesses and depths) coming from the deep drawing press (applying compression force),

2. Rotating and cutting the edges coming out of the press with automation-controlled operation in different axes (at different rotation speeds, cutting angles, axial movements, etc.),

3. Automatic deburring with axial movements from the cut edges,

4. Obtaining commercial cookware with high occupational safety without worker-related risks by bending the cleaned edges (reverse forming - up/down, with different forces to be applied according to the material wall thickness).

With the innovative, fully automatic processing system, significant R&D gains have been achieved in manufacturing all commercial cookware, reducing production waste caused by traditional manufacturing methods and providing energy savings.

4. Conclusions

Within the scope of this study, it has been ensured that an innovative, fully automatic processing system with a unique design based on R&D systematics has been obtained in order to obtain energy efficiency, high occupational safety, and quality products in the manufacturing process compared to our current manufacturing process and to reduce production time. Various R&D gains obtained with the originally designed system are given below;

- In our current manufacturing process, 55 kW of energy is consumed only in the reverse forming press at the last stage, while the total energy consumption in 3 different workstations exceeds 75 kW. In the developed innovative system, gains were made in reducing energy consumption by at least 50%.

- In the current processing process of commercial cookware (Ø1100 mm), the processing time of commercial cookware has been reduced by approximately 2/3.

- In our current manufacturing process, commercial cookware is obtained by transporting and hand grinding to 3 different stations (cutting with scissors, edge round cutting and press forming processes). In contrast, the number of independent stations is reduced by providing 100% control over the innovative process with a single operational command.

- Innovative, fully automatic manufacturing system for the highly energy efficient production of commercial cookware, in line with international standards (EN ISO 12100, EN 614-1, EN 12983-1, etc.) In addition to increasing efficiency, product costs were reduced, and energy efficiency was achieved.

In our current manufacturing process, the molds that change according to the size are changed in the system to give the edges of the commercial cookware, whose edges are cut circularly, up/down inverted form. However, in the innovative system, the reverse form is provided with a single operation without needing these operations in the process.

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