B U L G A R I A N A C A D E M Y OF S C I E N C E S
INSTITUTE OF INFORMATION AND COMMUNICATION TECHNOLOGIES

Abstract of PhD Thesis

INNOVATIVE TECHNOLOGIES FOR INCREASING THE EFFICIENCY IN THE PRODUCTION OF TUBULAR FURNITURE

Petar Pavlov Panev

Supervisor: Prof. Dimitar Karastoyanov

Approved by Supervising Committee:

Prof. Lubomir Dimitrov
Prof. Pancho Tomov
Prof. Stancho Petkov
Prof. Vladimir Monov
Assoc. Prof. Nayden Shivarov

The results included in the dissertation were presented and discussed at an extended session of the Department of Embedded Intelligent Technologies, IICT-BAS, on January 18, 2022. It was decided that dissertation defense should take place.

The full volume of the dissertation is 133 pages. It consists figures, tables, applications. The list of references contains 100 titles.

The Defense of the PhD thesis had been held on ……., 2022 at …… in room ….., Block 2, IICT-BAS.

Keywords: *innovation, packaging, design, construction, productivity*

Introduction

The design of automatic computerized machines and the use of innovative technologies - controllers, power supplies and optimized software increases the reliability and productivity of operations in the production of components and products from pipes: preparation of heel and foot cup parts for table, welding, painting and packaging of the finished tubular product - table leg. The design and construction of innovative machines and lines complies with the standard for geometric requirements for the product ISO / TC 213, as well as the requirements for operational safety.

An overview, analysis and systematization of the factory for the production of tubular furniture and components has been made; a careful and thorough analysis of existing packaging and automatic machines and lines has been made. It is necessary to pay attention to the problems arising from the use of packaging materials. Marketing research of the various components of packaging has a good influence on the innovative technologies used, as well as the discrete processes and operations in packaging.

Existing methods and means for the production of elements for tubular furniture are presented: stamping of details and their design, welding and packaging of the entire product. The degree of suitability for automation friendliness and installation suitability was studied. Actual and desired performance and clocks are calculated. Different structural and layout options for packaging of finished products are presented.

Methodologies and approaches have been developed to design innovative machines that increase the productivity of tubular furniture - IAAM for welding a cup with a bolt, IAAM for laser welding of a pipe to a cup / bolt, AML for packaging all components for a table leg "Adils" and programmed the AM for automatic gluing of cardboard tape. Based on the compiled methodologies, the desired productivity of the AM is calculated; AM are designed according to the requirements for geometric accuracy, the normative requirements for safety of equipment in case of mechanical hazards and the software program for drawing Solid Works; all safety conditions for operation are met; equipment has been selected to design automated palletizing of table legs.

The results achieved after the construction of the automatic machines for cup- bolt welding, laser welding of tube to cup / bolt and packaging of all Adils table leg components are presented. The desired and actual productivity of the AM and the stroke of the production process are calculated.

The future projects for the development of a factory for the production of tubular furniture and components are presented.

Aim and tasks of the thesis

The dissertation deals with problems related to the production of tubular furniture and components, namely punching, welding and packaging. The aim of this paper is to study the progress and to initiate the introduction of new technologies to increase the efficiency and productivity of tubular furniture through modern research methods and innovative production tools.

Taking into account the performed analysis and the set goal, the following tasks are formulated:

1. After a detailed review to analyze the various methods and means of punching, welding and packaging of tubular furniture and components.
2. To study existing methods and means for the production of tubular furniture.
3. To design automatic machines to increase the productivity and quality of tubular furniture products.
4. Based on the projects, to design automatic machines to increase the productivity of automatic table leg machines.
5. To propose approaches and methodologies to increase the efficiency and productivity of automatic table leg machines.
6. To conduct experiments and simulations of various methods for design and construction in industrial environments.
7. The obtained results to be analyzed and tested.

Chapter 1

OVERVIEW, ANALYSIS AND SYSTEMATIZATION OF PROBLEMS AND SOLUTIONS IN THE PRODUCTION OF TUBULAR FURNITURE

1.1. Development over time of a factory for the production of tubular furniture and components (FPTFC)

In 1998 a "Factory for the production of tubular furniture and components" was established in the town of Lovech. Discussions and negotiations for the opening of contractual relations for the joint work with the company IKEA International Group of Sweden AB begin. They were realized immediately in the following year 1999.

The main activity of FPTFC is the production of furniture and components for the furniture industry, packaged and disassembled, compact for transport to different countries with its own stores of IKEA logistics. Metal products for furniture construction are ready for use by customers.

For the needs and development of the company (FPTFC) in 2002 a plant for the production of veneer and wooden spindles was established, and in 2010 a project was launched for the construction of a subsidiary factory for the production of pipes and profiles (FPPP).

1.4. Manufactured products in ZPTMK

1.4.1. When starting the factory

With the establishment of the factory began the production of beds with click-click mechanisms, with locking mechanism, bunk beds, camp bed and table legs. All mechanisms that are implemented in the beds are manufactured in the factory. The design and drawings for the production of all products manufactured in FPTFC are prepared by the designers of IKEA and provided to the designers of the plant for the manufacture and purchase of machinery for their production. Most of the products that are produced are made entirely of purchased raw materials and elements supplied by subcontractors of IKEA. The whole production is manual, but with the mastery of discrete technological processes and operations - basic and auxiliary, and so the young designers and technologists begin the first steps for their mechanization and automation.

1.4.2. Existing products

Over the years, some of the manufactured products have been discontinued, while others have improved dimensions, stability and automation of the technological process or completely newly created. Some of the biggest changes are Curry and Vika Kaj's legs. In addition to size and durability, they also change their names to Adils and Olov.

1.4.3. Production volume

1.4.3.1. Manufactured beds from 2000-2017

The total volume of manufactured beds is 7.8 million. until 31.12.2017. Over the years, one of the longest produced beds and with the largest volume is the product Beddinge with 5.4 million for the period.

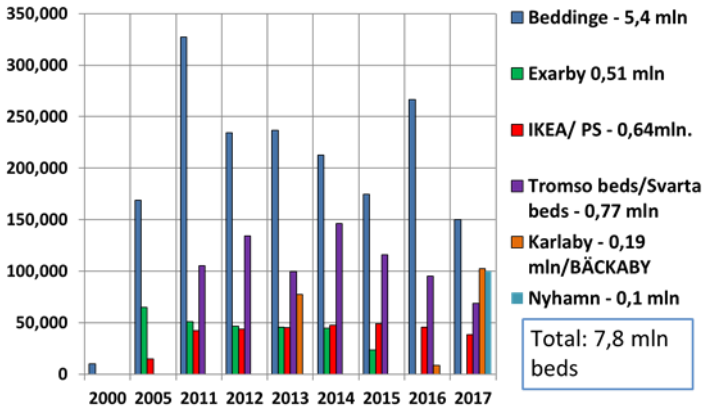


Fig. 1.21 Schedule of manufactured beds in the period 2000-2017

1.4.3.2.Manufactured legs 1999 ÷ 2017

The total volume of legs produced is 81.8 million. to 31.12.2017. From the data in fig. 1.22 It is clear that the longest and largest volume of production of Curry / Adils round legs is 71.5 million. This accounts for 87.4% of the total number of legs produced.

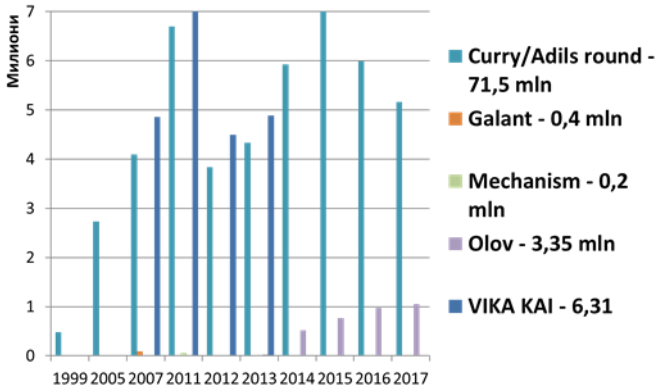


Fig. 1.22 Schedule of manufactured legs in the period 2000-2017.

1.5. Overview and analysis of types of packaging materials

In modern industrialized countries, much attention is paid to the commercial appearance of different types of packaging material. The consumer pays great attention to the attractive appearance of the packaging itself.

The following materials are used for decisive improvement of the packaging in our country: cardboard packaging; plastic packaging; packaging of metal; glass packaging; wood packaging, mixed, etc. [16, 17, 18, 19].

1.6. Ecology

- Innovative ideas

Ikea's idea is to create products that are made of natural materials - such as bamboo and natural cotton, as well as the packaging itself. It relies on materials that can be recycled and produced with the least amount of carbon emissions, so as not to pollute nature. Also, due to the reduced resources of the planet, it is time to start using them wisely, says Anna Granat, IKEA product development specialist [6].

- Recycling

At the heart of IKEA's philosophy is to limit and waste, as well as use a minimum of resources to achieve the maximum. In order to achieve this goal - saving resources, small steps are needed every day.

1.7. Conclusion

A detailed review and analysis of a factory for the production of tubular furniture from its launch in 1998 to the present day. The types of products that are produced and the technological equipment available at the factory are presented.

An overview and analysis of the types of film and corrugated packaging, the types of adhesive tape and the types of welding machines have been made. It relies on materials that can be recycled and produced with the least amount of carbon emissions, which will help reduce pollution. All analyzes are consistent with the imposition of innovative products that will be produced. A choice has been made for the application of innovative technologies, which will achieve high quality, reduce material costs, reduce operations and increase quality.

The following were selected as the most suitable materials:

1. The most suitable film is heat-shrinkable at high temperature - PE-HD. The chosen type of foil is polyolefin, which was chosen because of its qualities such as: low weight, low cost and flexibility.

2. Kraft paper, which is made from soft wood, is used for wrapping furniture legs. It was chosen because these fibers are not recycled fibers, this type of paper is more durable and more suitable for printing, which must be applied to the packaging. Profile E with a wavelength of 1.5 mm is the most suitable, due to its easier automation and folding by the machine on the runner.

3. For the needs of packaging and sealing of packages, both types of adhesive tape are used, depending on the ambient temperature. Solvent tape is used at higher temperatures, and Hotmelt tape is used during the colder months. This method of selection is more cost-effective for production. Both types of adhesive tape are preferred due to the lack of the unpleasant odor characteristic of acrylic tapes. Solvent tape is better for gluing on difficult surfaces and for more responsible applications.

4. The most suitable types of welding are MIG / MAG welding and laser welding, which is most suitable for process automation.

Chapter 2

EXISTING METHODS AND MEANS OF MANUFACTURING COMPONENTS FOR TUBULAR FURNITURE

Due to the high production volumes of table legs discussed in Chapter 1 and the smaller number of components in the finished product (giving a better opportunity for automation) compared to folding beds, we will focus on them in order to track the processes of its production and their productivity and assessing the possibility of increasing the productivity of the feet with innovative methods and tools.

2.1. Curry leg production, 1999

2.1.2. Technological process

2.1.2.1. Cutting the pipes

The cutting of a pipe ϕ50x1 mm is done manually on a band saw with automatic feeding of size 686 mm. 15 pieces of bundle pipes are fed at the same time - 3 rows of 5 pieces. After cutting, the resulting cuttings are sanded with wire brushes

The heel and the cup are punched on a RASKIN RT 85 punching machine. The sheets are first divided into two parts by hydraulic guillotine cutting of 500x2000 mm and 625x2000 mm. This operation is performed in order to lighten the sheet, due to its manual loading by the operators in the punching machine. Simultaneously with the punching of the cups, a central hole with a diameter ϕ 8,2 mm is drilled, and on the heels a central hole Φ 6,5 mm and 5 pieces Φ 5,5 mm for mounting the winches to the table top. The heels require additional operation - drawing the central hole and threading with hole M8 on a drilling table machine PN 161. Punched on average 2500-3000 pieces per day.

The finished punched parts go through a dry drum operation. It cleans the eyelashes obtained by cutting the details.

2.1.2.3. Welding of details

A. Cup with bolt

The cup is welded with a bolt on an instrument. They are placed in a row of 20 pieces. cups on copper mandrels with a hole in which a bolt M8x20 mm is placed. The bolts are pressed with sharp copper pins for better electrical conductivity and are welded manually with a MAG electric arc welding device with CO_2 in two places.

B. Cup / bolt with pipe

Welding a pipe to a cup / bolt is done by arranging the finished pressed pipes with cups in a basket with the bolts facing up. They are welded manually with an electric arc MAG device with CO_2 in four places at 45^o on each leg.

2.1.2.4. Painting

Before painting the prepared details, they must go through degreasing. Finished welded pipes are hung on racks, which are immersed in a bath with degreasing solution. Punched heels are also degreased by placing them in a basket with holes through which to drain the liquid. Due to the presence of residual dirt, the parts are wiped with a rag until completely cleaned and removed from the stands.

The cabin, the conveyor and the baking chamber for painting are designed and constructed by a team of the company. The prepared details are hung on stands on a step conveyor. After loading all the stands, the 5 m long painting booth is moved to the attached parts and the powder painting process begins, with the help of an operator with a hand gun. The already painted details are moved to the firing chamber, where the time and temperature are determined by the parameters of the powder paint. On average, the cycle lasts for about 20 minutes at a temperature of 190 ° C. With the help of robots, the finished parts are removed from the stands and transported to the next packing operation.

2.1.2.5. Packing

The Curry leg was packed in a 5-layer corrugated packaging. The delivered packaging is in the form of an unfolded treadmill, which is folded during packaging and transformed into a carton. At the top of the box, 4 legs are placed next to each other, separated by a folded sheet of paper so as not to scratch each other [37]. At the bottom is folded cardboard, in which are placed 4 pieces of heels, packed in a PE bag with a density of 40 μm, instructions, packed 20 screws and 4 plugs. After placing all the elements necessary for their installation on a table top, the corrugated cardboard is folded by two workers. To seal the box, a 50 mm wide corrugated tape is glued on top in the middle. 1 m of duct tape is required for gluing. The package is individual only for these 4 pcs. legs, and when purchased from the store can not be separated. They are arranged on a wooden Euro pallet, provided by IKEA with a size of 800x1200 mm. 102 boxes / 408 legs are arranged on one pallet. The packing capacity is 2000 pieces / shift.

2.2.1. Quantitative assessment of the suitability of the details for production automation

2.2.1.1. Study of the degree of suitability of the details for automation friendliness and installation suitability.

Before proceeding to the creation and development of options for the design of automatic equipment, it is necessary to check the degree of suitability of the parts for automatic packaging production. "Automatically, their friendliness and installation suitability will be studied according to the methodology of the Department of ADP" [50].

In Fig. 2.7 and Fig. 2.8 are shown the details involved in the automated curry packing process.

Fig.2.7 Details involved in the packaging process

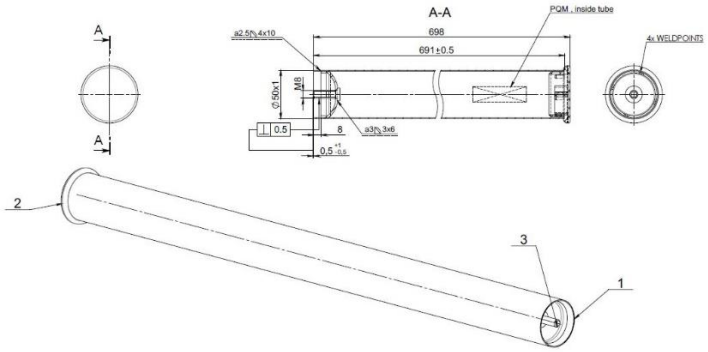


Fig. 2.8 Packing leg

When ready, complete self-packaging: heel, envelope with 5 pcs. screws and installation instructions (b4 = 52) and self-packing curry foot - pipe and plug (b7 = 52) the complexity category is K = 4 (fourth complexity category). Co-packaging automation is not appropriate: due to the complexity of automatic packaging, due to the complexity of automatic feeding, the parts are packed together manually.

If joint automatic packaging is used, the average total score of the first three parts will be Bcp1 = 35, and the category of complexity will still remain 4. It seems that the most favorable will be the separate power supply of all participating parts in automatic packaging, where the average total score is Bcp = 34 with complexity category K = 4.

2.3. Calculated Curry leg performance

From the marketing research conducted on international markets, the trend is to increase the production of curry leg. This forms a desired productivity of about Qgj = 7.5 million / year. On this basis, a technical and economic task is formed with a productivity of OAL Q = 1200 pcs / s. It is preferable to use productivity in the lower operating range in order to be able to have a margin to increase productivity due to increased demand for curry foot [53, 54, 55].

Given the complex economic situation on international markets, it is currently necessary to make calculations for a lower theoretical productivity (Q = 800 pcs / s). The competitive PAL, taken as a basis, has a lower theoretical tact, Table 2.3.

Table 2.3 Theoretical performance

произв.\показатели	Дрг	Ксм	ηизп	8x3600	Σф	Qг.г.и.	Qг.р.ч.	Qг.бр.	ΣQг.ж	τт=Ф/Qг.ж
бр/s	бр.	бр.		[s]	[s]	бр./год.	бр./год.	бр./год.	бр./год.	s /бр.
Q=800	1	1	0,7	8x3600	2520	800	80	1,6	881,6	2,86
Q=1200	1	1	0,7	8x3600	2520	1200	120	2,4	1322,4	1,9

The actual tact obtained for the automatic packaging machine were calculated at operating technological limiting times t_{P1} = 1.7 [s] and t_{P2} = 4.71 [s]. The actual tacts, broken down by month and year, are shown in Table 2.6.

Table 2.6. Actual performance

№ по ред	Време	При действителен такт τд=5,76[s/бр.]	Работни смени			При действителен такт τд=2,76[s/бр.]	Работни смени		
			1	2	3		1	2	3
			8h бр	16 h бр	24 h бр		8h бр	16 h бр	24 h бр
1	1 час	800 (437,5)	3 500	7 000	10 500	1200 (910)	7 304	14 608	21 912
2	1 седмица		17 500	35 000	52 500		58 432	73 040	109 560
3	1 месец		70 000	140 000	210 000		233 728	292 160	438 240
4	3 месеца		210 000	420 000	630 000		701 184	876 480	1 314 720
5	1 година		840 000	1 680 000	2 520 000		2 804 736	3 505 920	5 258 880

The obtained digital data, reflected in Table 2.6, do not satisfy the desired productivity provided in the feasibility study. Therefore, it is necessary to make experimental experiments - research on the time of adhesion of PVC packaging material. Obtained for $t_{рл}$ = 4.36 [s].

New productivity calculations were made for the obtained $t_{рл}$ and are presented in Table 2.7.

Table 2.7. Desired experimental performance.

№ по ред	Време	При действителен такт τд=5,41[s]	Работни смени			При действителен такт τд=2,7[s/бр.]	Работни смени		
			1	2	3		1	2	3
			8h / бр	16 h / бр	24 h / бр		8h / бр	16 h / бр	24 h / бр
1	1 час	~ 466	3 728	7 456	11 184	~ 933	7 464	14 928	22 392
2	1 седмица		18 640	37 280	55 920		37 320	74 640	111 960
3	1 месец		74 560	149 120	223 680		149 280	298 560	447 840
4	3 месеца		223 680	447 360	671 040		447 840	895 680	1 343 520
5	1 година		894 720	1 789 440	2 684 160		1 791 360	3 582 720	5 374 080

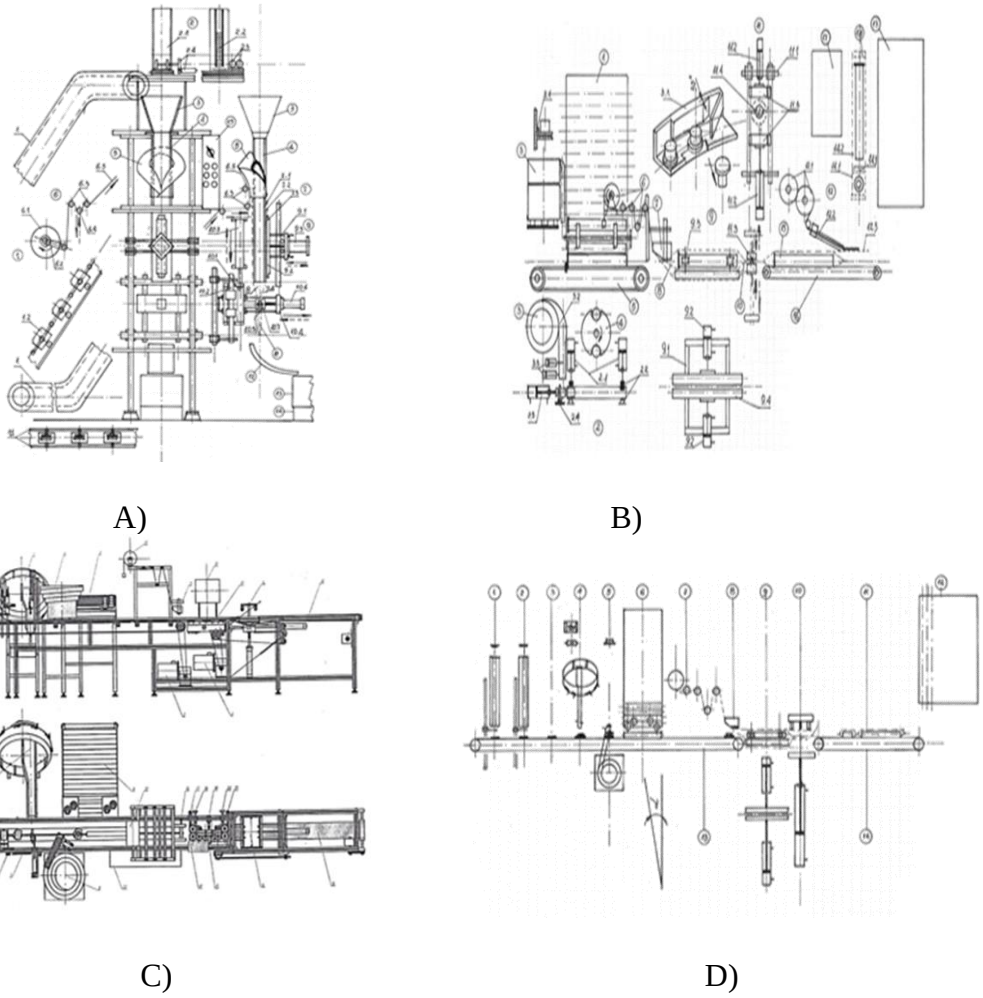
It will be appropriate to produce OAM for foiling the heel, screws and instructions and OAM for foiling the leg (tube and stopper). From the calculations made and the data obtained OAM fifth $t_{рл}$ = 5.41 [s / piece] and AOM foot $t_{рл}$ = 2.7 [s / piece]. With a desired productivity of 7,500,000 units / year. will be needed for foiling the heel 3 pcs. OAM, and for foiling a pipe 2 pcs. OAM. After mastering the production, you can think of a joint automatic foiling machine for the finished foot "Curry" - heel and tube together.

From the analysis of "automation friendliness" as well as installation suitability, it was found that automation for packaging is quite a difficult process. Therefore, competitive options must be developed in accordance with the conditions of the company.

2.2. Developed structural-layout variants

2.2.1. Structural layout of OAM

In Fig. 2.10 presents developed options for packaging the "Curry" leg and the components containing it.



A) B)

C) D)

Fig. 2.10. Structural layout options

2.4.2. Criteria and factors for choosing an option

It is difficult to determine the criteria, factors and parameters by which the choice of option is made. In compiling the proposed structural and layout options, the company was guided by the solutions of low-cost automation and use of the available element base [60].

1. CAR:

From Table 2.8 it is obvious that OAM produced by the company "CAR" - Germany has no data. Some of the necessary data for obtaining all the above criteria, factors and parameters are not given by the company that operates the existing equipment.

2. Option 1 + 2:

It is obvious from the table that the actual clock from OAM - 1 and OAM - 2 is:

$\tau_д = 5.41 + 2.7 = 8.11$ s.

Therefore, three OAMs will be needed - 1. They will be serviced by three operators and two general workers. For the three pieces of OAM 3 + 2 = 5 pieces are needed. staff. For the service of OAM 2 the number of operators is 2 and 1 total employee, the total service staff is 3.

For the service of the five OAM service staff increases to 8 people, of which a total of 5 operators and 3 general employees.

Table 2.8 Choise of variant

№ по ред	Наименование	Димензия	Варианти				
			ф „КАР" Германия	1	2	3	4
1	Qh – желано	бр/h	1200	1200	1200	1200	1200
2	τ^1 теоретичен такт	s/бр	3	2,86	1,91	1,91	-
3	Qh – теоретично	бр/h	1200	881,6	1322,4	1322,4	1200
4	τ^2 – действителен такт	s/ бр	3	5,41	2,7	2,7	3
5	Qh – действителен	бр/h	1200	~466	~933	~933	1200
5	P – потоци	бр	-	1	1	1	1
6	Участъци	бр	-	1	1	1	1
7	Работно налягане	[bar]	6	6	6	6	6
8	Разход на сгъстен въздух	l/min	-	1500	1500	2000	1800
9	Заемана площ	m^2	-	6	8	12	12
10	Управление		siemens	siemens	siemens	siemens	siemen
11	Материал за опаковка			ФЛЕКСОСИЙЛ HDPE			
	–ширина		280	280	280	2.0	2.0
	–дебелина		0,55	0,55	0,55	0,55	0,55
12	Работници	бр/cm	2	2	4	2	2
13	НГЕ	%	-	14,45	13,45	18,20	25
14	Елементна база	%	-	100% внос			
15	Материали		-	Ал.профили- Bosch БР"Техника"			
16	Срок на откупуване	месец	-	8	8	8	8
17	Заводска цена 1бр.	лева		2,50	2,50	2,50	2,50
18	Цена на машината	лева	-	40 000	40 000	50 000	50000
19	Годишна програма	бр/год.	-	7 500 000			

After operation and measurements, it was found that the machine is not profitable and this necessitated the construction and manufacture of a new OAM, which will eliminate unwanted shortcomings, as well as gluing the two packages. This creates a lot of difficulties in the commercial network. Just as they are placed in the boxes by the manufacturer, so they are provided in the malls. The box is opened and the customer picks up the package. This disadvantage of the new AOM has already been avoided.

3. Option 3:

The designed new OAM with clock τd = 3 [s]. It satisfies the actual productivity. At this productivity Qr = 7500000 pcs / year is achieved. package legs, per week productivity is Q = 150,000 pcs / seat. The service staff is 4 people. OAM is configurable. The new package of curry legs has a factory price of BGN 2.50 and facilitates sales in the retail network.

4. Option 4:

The value of the new OAM is BGN 50,000, which will be paid in less than 8 months. Packing is done in a common package, which greatly facilitates the process.

Option 3 and 4 have the same parameters and are implemented in production.

2.5. Conclusion

After a detailed presentation of the existing methods and means for the production of table tops, including the supplied raw material, the technological process of preparation of details, welding of individual components and the method of packaging, the following conclusions were established:

- According to the methodology of the Department of ADP, experimental studies have been performed for automatic power supply, accompanied by automatic orientation and storage of the orientation product K = 4 (fourth category of complexity);
- From the performed calculations for productivity it is established Qh = 1200 pcs / h;
- Competitive options for automatic packaging and installation have been developed, ensuring the necessary technical and economic efficiency;
- An analysis of the criteria, factors and parameters by which the most competitive option is selected;
- From the calculations made regarding the theoretical and actual clock, it was found that options 1 and 2 do not achieve the desired performance results and increase the cost of energy, compressed air, etc. Options 3 and 4 meet the required performance and the packaging is more compact - from 2 packages are packed in 1.

In conclusion, the market wants new products, new packaging, saving materials, energy and time. Therefore, a new market research and customer requirements have been launched, which will soon lead to the design of a new OAM to grow into an AL with a capacity of Qh = 1200 pcs / h.

Chapter 3

INNOVATIVE APPROACHES AND METHODS TO INCREASE THE EFFICIENCY AND PRODUCTIVITY OF AUTOMATIC MACHINES AND LEGS FOR LASSES

3.1. Requirements for new product design

After a detailed review and analysis of the existing process for the production and packaging of table legs, it was found that much of the technological process is done manually or semi-automatically, which makes it difficult to achieve the high productivity required by the IKEA market.

In addition, over time, some products are discontinued, others start production, and still others change the specifications of the size parameters of their constituent components or establish new packaging requirements (Chapter 1). This is also the case with the foot product in question in Chapter 2 - Curry Leg.

The joint talks between IKEA and the company after the global marketing stopped the change of the package sizes and the reduction of the sizes [60, 61].

The technical realization of this product is complete - both in overall dimensions and in the type of packaging and occurs in the following sequence: the new table leg is now renamed "Adils" and with a pipe diameter of 40x0.85 mm and length becomes L- 686 mm. The

requirement of the packaging designers is the following: each heel of the foot must be wrapped with corrugated cardboard, in which are also positioned the 5 screws, packed in an envelope and the installation instructions, which are -75x105 mm; in the specially obtained socket the pipe is positioned with the cup / bolt already welded to it and the stuffed plug; the already obtained set of all elements of the product is foiled with heat-shrinkable foil; it is labeled and arranged in a box.

For the design and construction of automatic machines and lines for complete production of Adils foot, it is necessary to create several methodologies and approaches in relation to parts made of metal and parts that are purchased (microcorrugated cardboard, shrink film, sliding plugs, screws, paper instructions, etc.) to force the manufacturers of these parts to be fitted. to be followed to build a competitive, efficient and highly productive technique. To this end, the steps below describe how to create an automatic machine to increase their quality of connection and packaging.

3.2. Methodology for automatic punching of the heel and cup

3.3. Study of the structure and methods in the design process

3.4. Innovative approach to machine design through Solid Works software

3.5. Approach to the preparation of technical documentation with accurate drawing

3.6. Approach to ensuring occupational safety

3.6.1. Ensuring safe and healthy working conditions for staff

3.6.2. Securing equipment in case of mechanical hazards

3.7. Methodology for the technological process of packaging

3.8. Methodology for achieving high productivity in packaging

3.9. Methodology for mechatronic increase of packaging productivity

3.10. Conclusion

Chapter 3 presents the requirements for a new design of the analyzed product - legs for table tops according to the requirements of IKEA. Methods and approaches for automatic preparation of components for the final product are presented:

- methodologies and approaches for innovative design, sizing and ensuring safe working conditions, both for staff and for safety of equipment;
- methodologies for technological process of packaging and ensuring high productivity; methodology for mechatronic increase of productivity in packaging.

The methods and approaches used help to design innovative automatic equipment, ensuring high quality and high productivity.

Chapter 4

SYSTEM APPROACH IN DESIGN AND CONSTRUCTION OF INNOVATIVE AUTOMATIC MACHINES AND LINES

4.1. Emerging changes in the industrial world

The digitalization of industrial production is changing the industrial world at a very rapid pace.

Solutions are being sought to achieve possible optimal performance. Ensuring the reliability of production processes with the use and application of new innovative, fundamentally new technologies, new materials, automation and robotics of modern industrial elements and components, techniques applied in solving problems in industry.

4.2. Desired changes in the production of tubular furniture

The new realities regarding the final cycle of product production are related to the automation of continuous and discrete processes and management in the considered industries. The main problem to be considered is the time factor, the importance of which in the business world is increasingly accompanied by the other factor investment decisions.

This determines whether the automation will be complete or gradual. The other number of changes in the dynamic development of the industry are intelligent information technologies, industrial internet, intelligent machine-building materials and technologies, etc. are related to the development of "Industry 4" and "Industry 5" [86].

A new IDEOLOGY has emerged, the products created by IKEA to be comfortable, light, created by new innovative technologies in practical and convenient packaging.

The unique thing in the design of IKEA is the combination of vision, functionality, quality, sustainability and affordable price. Improving production is the adopted innovative approach of IKEA is in the spirit of team suppliers, ie. innovative production for one with suppliers. The next stage is quality testing both in the manufacturing process and in the finished product.

The quality of the raw materials used in the manufactured products is not overlooked either.

4.3. Input raw material and preparation of punched parts

In connection with the facilitation of market conditions for the selection and purchase of a product from customers, which IKEA constantly maintains contact with, it is necessary to develop innovative automatic packaging lines for all manufactured and offered products on the market. This requires starting from the market requirements for packaging of IKEA Specification ISO-P0010 / 2010.11.12; Version AA-171373-8.

Table 4.2 shows the details and elements involved in the packaging. Problems have arisen in the automation of assembly processes and operations, basic and auxiliary, involved in the manipulation of parts / elements in the automatic packaging line [88-92].

In position 22 is given a package of microcorrugated cardboard, made of one cardboard Fig4.2. The box is obtained by manual manipulation and a box is obtained by means of glue.

But productivity is low. But it gave the ideology to be 2 cartridges. And all these details/ elements must meet the requirements of the IKEA standard.

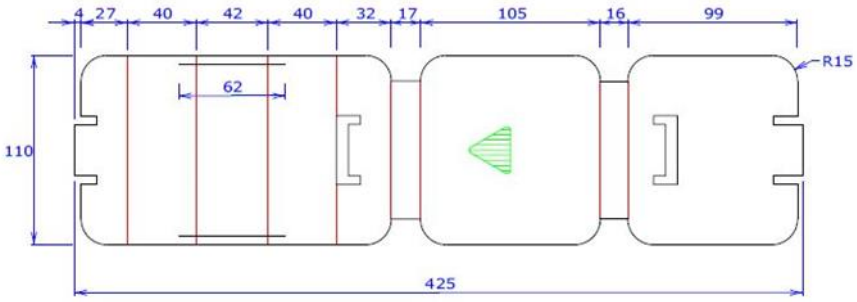


Fig 4.2 Hand cardboard made of micro corrugated cardboard

From the researches made in Chapter 1, the realized developments and the accumulated experience reflected in Chapter 2, the proposed innovative approaches and methods for increasing of efficiency and productivity for the development and construction of automatic machines and lines and analyzes matured ideology confirms.

All parts / components made of metal and some of the purchased ones need to be impeccably processed with high quality. Each of them has problems with their manipulation. How will the assembly packaging process be solved, the automatic supply of the positions with parts / components, what will be the choice of automatic shops, cutters, industrial manipulators, transport systems, grippers, glues, etc., which confirms the application of tight production.

Innovative should be developed: automatic assembly machine 1 (AAM1), automatic assembly machine 2 (AAM2), structural layout of the semi-automatic packaging line and built automatic packaging line.

In order to avoid the initial manual feeding of the sheet material, a new automatic machine with introduction of innovative elements was assembled. A new innovative machine with innovative elements was introduced for feeding a blank to the punch. It includes: unwinding device, straightening device, feeding device. In Fig. 4.3 shows the new fabrication of the heel and cup with bolt through basic and auxiliary operations.

The necessary raw materials are metal HR strips, steel grade DD11, with a size of 2.5x109 mm for the heel detail and 2.5x58 for the cup detail. They are manufactured in the subsidiary of the plant. The strip is placed on the unwinding device,

The combination of unwinding, straightening and feeding device (Fig. 4.4, 4.5, 4.6) help to increase productivity and automate production. In Fig. 4.7. an eccentric press with the feeder positioned is presented.

In both parts, operations are performed simultaneously, including sizing, drilling and indentation.

Due to the gaps obtained from the cutting of the part, they undergo another intermediate operation - grinding, including different in shape and size types of grinding bodies placed in vibro machines (poisoning) [93]. As the last the operation that is performed is threading in the middle of the part. In Fig. 4.8 shows a drawing of the detail "Heel", which includes one threaded hole M8 and 5 pcs. elliptical through-holes, and in fig. 4.9 drawing of a detail "Cup" [56, 57].

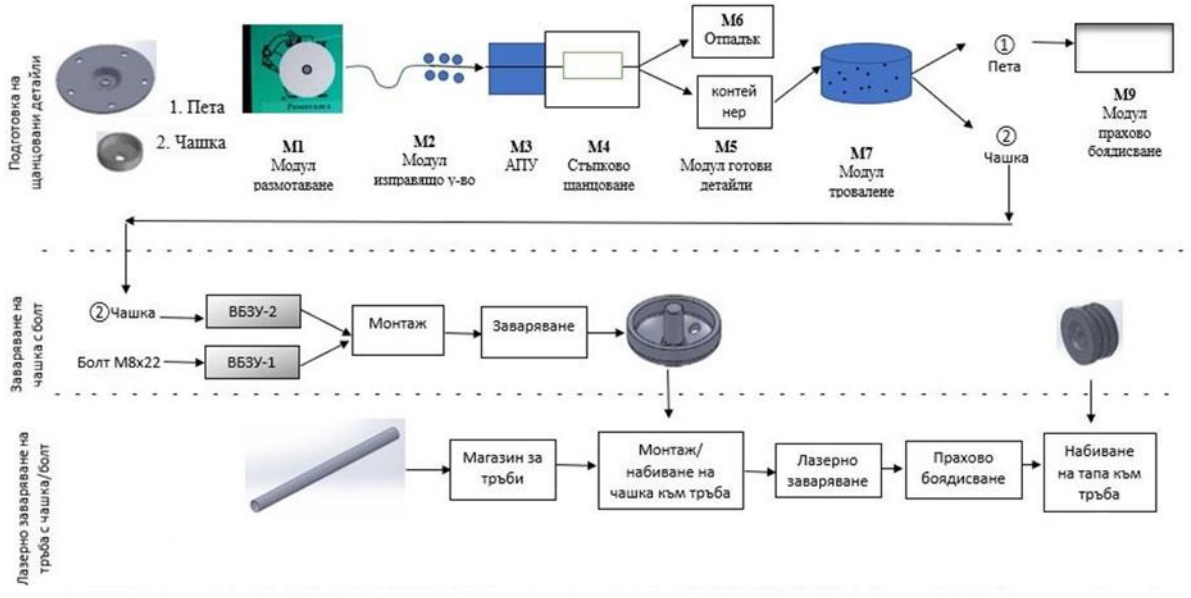


Fig. 4.3 Block diagram of a new technological process

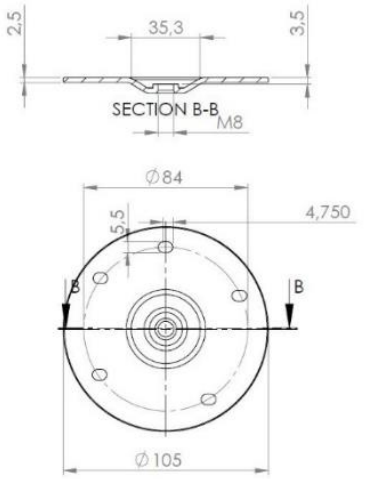


Fig. 4.8 "Fifth"

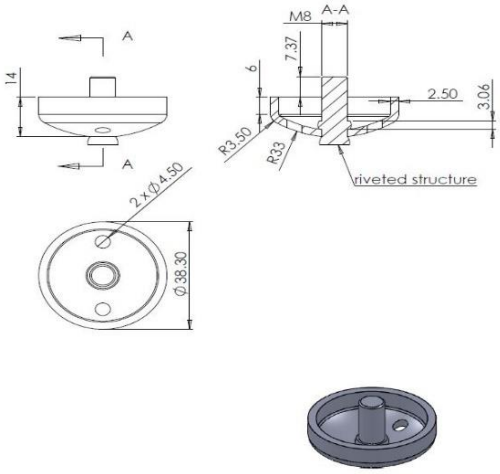


Fig. 4.9 Cup cup / bolt

4.4. Determining productivity

From the marketing works made in our own malls and on the international markets, as well as the continuous monitoring of sales, IKEA forms a desired productivity Q = 1200 pcs/h Q = 1000 pc /h Q = 720 pc /h, for table tops solidarity with the ambition of IKEA to produce products in accordance with the environment, meeting the requirements of the environment, the use of cost-effective packaging is adopted by the development of innovative two automatic assembly machines, semi-automatic packaging line and structural layout of the complete automatic packaging line with the proposed desired productivity of Q = 1200 pcs / h [94-99].

Calculations of the theoretical clocks for IAAM1, IAAM2, IPAOL and SKAOL have been made and to the desired productivity Qж have been added another 2% of the planned marriage. Initially, τ_1^T= 1206 pcs / h must be perceived for all four developments. However, due

to constructive, technological, power supply, orientation and especially the choice of working limiting operation, it was decided to develop them separately.

Thus, the ideology in accordance with the difficulties in the production of tubular furniture and the problem of packaging the product-legs for table tops was established. The calculation and determination of the times in the automation of the discrete production processes and basic and auxiliary operations was started. It refers on the one hand to the production of some of the metal parts, and the other to the participation of the purchased parts / elements, components reflected in table (4.2), but their construction must satisfy the developments to be adjustable.

It turned out that the basic packaging operation step 5 at position 5 is applied in drops on two paths on the feathers / drops on the lower box $t_{рл}$ = 3.94 s with $t_{прх}$ = 1 s and $\sum t_{из.ц.з}$ = 0.06s which is t = 5 [s]. At the same time, part of the diluent evaporates. This results in mutual adhesion.

The second problem. The purchased components and the installation instructions - paper and 5 screws in a PVC package at this stage is serviced by one operator.

Third problem. Combining operations - laser welding and welding control operation.

Fourth problem. Combining all operations with a thermal tunnel.

After calculating all working limiting working hours $t_{рл}$ proceed to the calculation, analysis and coordination of times for: idle moves $t_{прх}$; total, out-of-cycle, own - $\Sigma t_{соб}$, additional $\Sigma t_{доп}$ and repair $\Sigma t_{рем}$ for losses, after which they are listed in Table 4.3.

The actual clocks for each operating automatic technique are as follows: IAAM1 $\tau_1^т$= 6 [s], IAAM2 $\tau_2^т$= 3.57 [s], IPAOL $\tau_3^т$ == 5 [s] and SKIAOL $\tau_4^т$= 4 [s].

An innovative automatic assembly machine is duplicated to fulfill the company's production program.

The determined values for theoretical clock and performance are presented in Tables 4.3 and 4.4.

Table 4.3 Calculation of theoretical clocks

№ на вариант	$t_{р.л}$	$t_{пр.х}$	$t_{.ц}$	$\sum_{син}$	$t_{обр}$	$\sum t_{рб}$	$T_{ар.т}$	$t_{прен}$	$t_{бр}$	$\sum t_{доп}$	$t_{тр}$	$t_{ппр}$	$\sum t_{рем}$	$\sum t_{из.ц}$	$\tau_2^д$
	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
ИАММ1	5	0,7	5,7	0,05	0,05	0,1	0,1	0,05	0,05	0,2	0,05	0,05	0,1	0,4	6 детайла
ИАММ2	3	0,54	3,54	0,05	0,05	0,1	0,05	0,025	0,025	0,1	0,05	0,05	0,1	0,3	3,57
ИПАОЛ	3,94	1	4,94	0,01	0,01	0,02	0,01	0,005	0,005	0,02	0,01	0,01	0,02	0,06	5
СКАОЛ	2,94	1	3,94	0,01	0,01	0,02	0,01	0,002	0,005	0,02	0,01	0,01	0,02	0,06	4

Table 4.4 Performance calculation

№	АТ	$t_{р.л}$	$t_{пр.s}$	$t_{.ц}$	К=$\frac{1}{t\text{рл}}$		$Q\text{тех} = \frac{1}{\text{тр.л} + \text{тпр.х} + t\ \text{соб}}$	$Q_{тех}$	$Q\text{фак} = \frac{1}{t\text{р.л} + t\text{пр.х} + \sum t\text{соб} + \sum t\text{доп} + t\text{рем}}$	$Q_{фак}$
	-	s	s	s	s	бр./h	s	бр./h	s	бр./h
1	ИАММ1	5	0.7	5.7	0.2	720/1440	$Q\text{тех} = \frac{1}{5 + 0.7 + 0.1}$	620,8/1241	$Q\text{фак} = \frac{1}{5 + 0.7 + 0.1 + 0.1 + 0.1}$	600/1200
2	ИАММ2	3	0.54	3.54	0.333	1199.9	$Q\text{тех} = \frac{1}{3 + 0.51 + 0.1}$	1014,8	$Q\text{фак} = \frac{1}{5 + 0.54 + 0.1 + 0.1 + 0.1}$	1008
3	ИПАОЛ	3.94	1	4.94	0.202	728,744	$Q\text{тех} = \frac{1}{3.94 + 1 + 0.02}$	725,806	$Q\text{фак} = \frac{1}{3.94 + 1 + 0.02 + 0.02 + 0.02}$	720
4	СКАОЛ	2.94	1	3.94	0.254	913,706	$Q\text{тех} = \frac{1}{2.94 + 1 + 0.02}$	909,09	$Q\text{фак} = \frac{1}{2.94 + 1 + 0.02 + 0.02 + 0.02}$	900

4.5. Innovative automatic assembly machine 1 (IAAM1)

The official purpose of the innovative AAL is to perform two operations, installation of a punched metal cup with a bolt M8x20mm (purchased) and locking by electric arc welding in shielding gas. At the same time, it is adjustable.

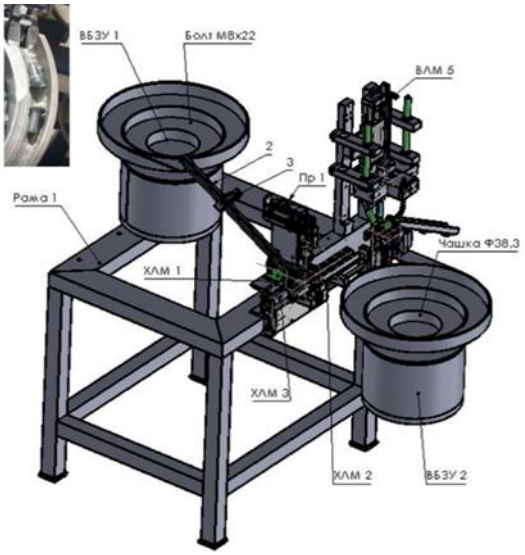


Fig. 4.10 Automatic machine 1- AM 1

4.6. Innovative automatic mounting machine 2 (IAAM 2)

The innovative automatic machine 2 fig. 4.13 is designed and constructed to perform sequentially the following steps:

Step 1. Installation operations - driving the welded part cup / bolt into the pipe;

Step 2. Control is carried out to check the compaction of the cup / bolt in the pipe, ensuring the next working position;

Step 3. Laser welding of the packed cup / bolt in the pipe. It is the limiting operation of AM 2 at an actual clock speed $\tau_д$ = 4 s / pcs, providing productivity $Q_п$ = 900 pcs / h .;

Step 4. Free;

Step 5. Testing of the weld with a load through a pneumatic cylinder providing a pressure of 800 kg .;

Step 6. Upon passing the test, the finished part is transferred through a groove into a container for finished products. If the test reveals: a bad welded cup / bolt with the pipe either does not fit in length, or the weld seam of the pipe cracks, the part is removed for scrap by means of a pneumatic manipulator in a scrap container. The automatic machine 2 is designed and made adjustable.

All operations performing installation, control, laser welding, free step, testing and pneumatic robot, removing the marriage are mounted on a main frame in which a 7-step linear conveyor is built.

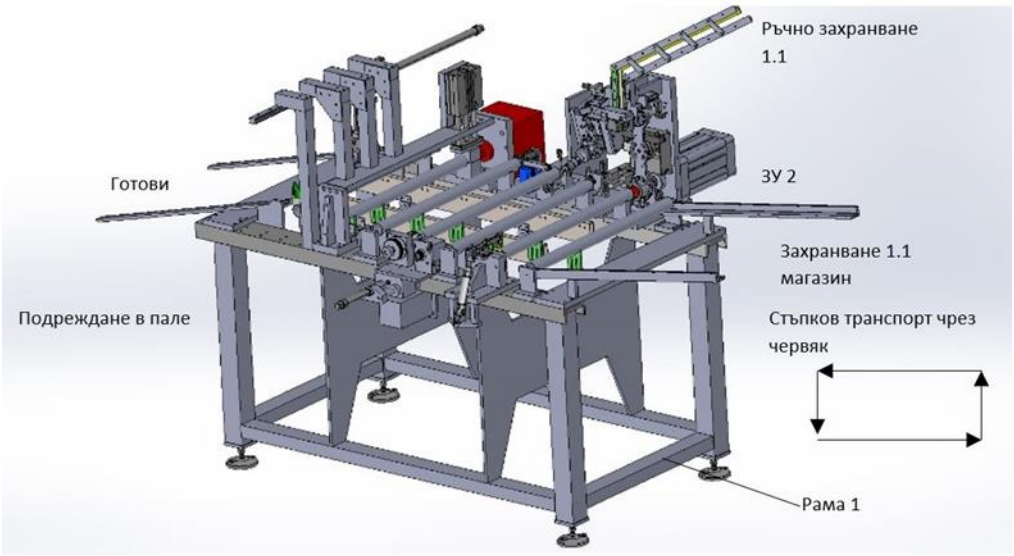
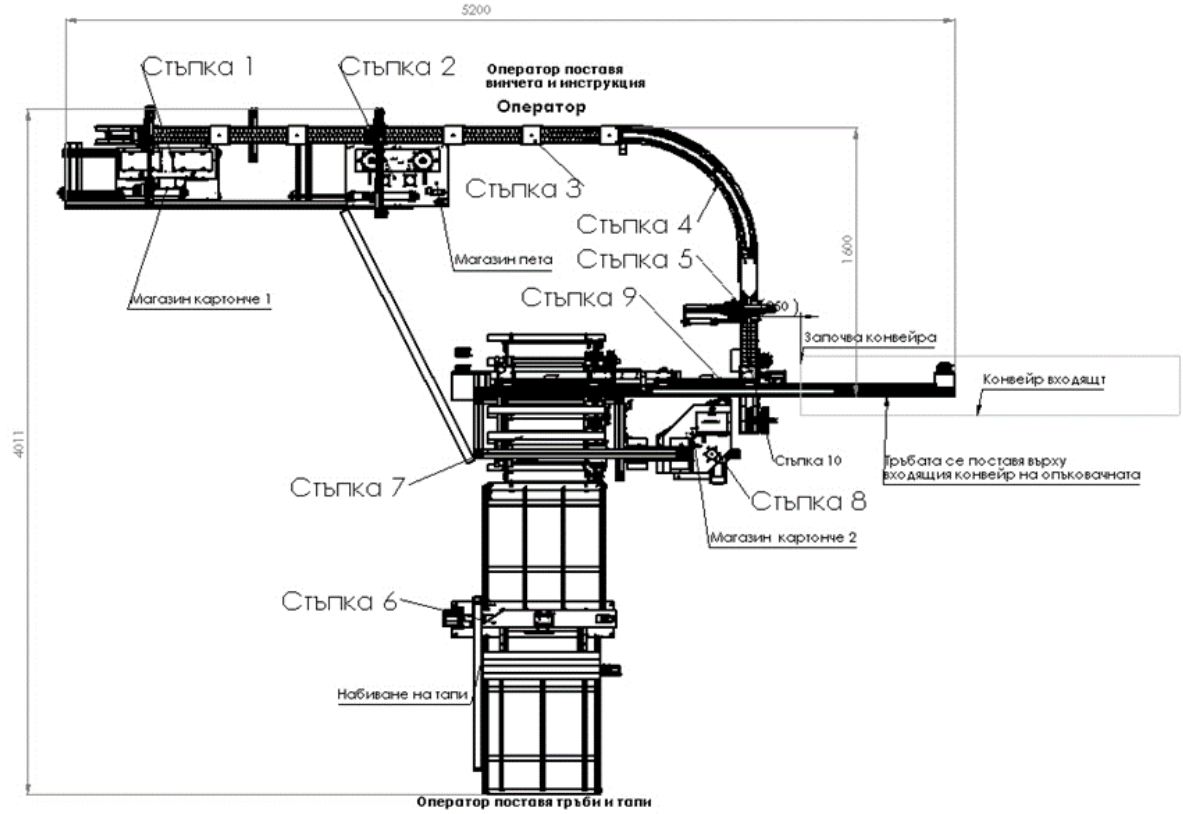


Fig.4.13. Automatic machine 2 (AM 2)

4.7. Innovative semi-automatic packaging line (IPAOL)

In Figure 4.21 shows the structural layout of a short, innovative, adjustable, semi-automatic Curry and Adils foot packaging line. The production of legs is mass. Joint installation of legs and top build tables. With the change of the interior design, the design of the tables also changes, which affects both the design and the tables.



Fиг. 4.21. Structural layout of a packaging line

4.8. Structural layout of an innovative automatic packaging line

The official purpose of the structural arrangement of the innovative automatic packaging line is to make two packages in a row, shown in fig. 4.34

Fig.4.34 Structural layout of IAOL

An operator manually arranges the finished product in corrugated boxes. In order to tightly arrange the packages in the boxes, they are rotated 180 ℃ through the package

4.2. Design and programming of a machine for automatic gluing of cartons with finished products

4.2.1. Machine preview with (HMI)

The basic principle of visualization is to recreate the operation of the machine and to show the basic processes for the execution of the cycle. Visualization of (HMI-Human-Machine Interface) human-machine connection represents the operation of the selected machine and can control its executive bodies manually. It also shows the operation of all sensors and monitors for alarms and alarm events [100].

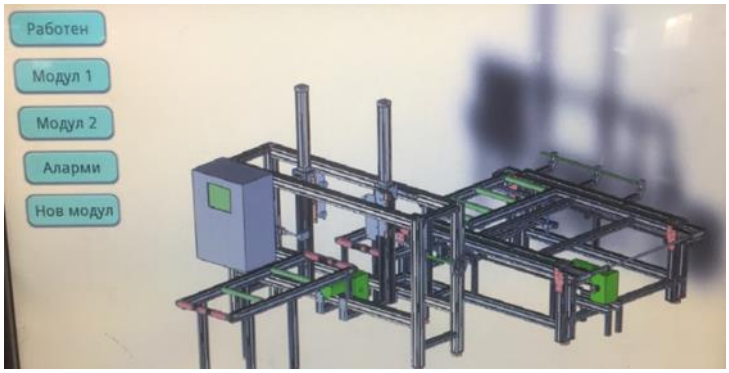


Fig. 4.37 Basic HMI visualization of an adhesive tape machine

4.3. Conclusion:

Chapter 4 presents the occurred and desired changes in the industrial world, which are summarized on the basis of marketing research. A new IDEOLOGY has emerged, the products created by IKEA to be comfortable, light, created by new innovative technologies in practical and convenient packaging. The most appropriate raw materials and tools that meet EU ISO standards have been selected to help achieve this goal.

Through the implementation and synergistic use of modules, an innovative punching technology has been created by means of an unwinding, straightening and feeding device. Synergistic use of technology increases the productivity of workpieces increases by approximately 35-40%.

Designed, developed and implemented in production through a software product are:

1. Innovative automatic assembly machine for welding parts cup with bolt;

2. Innovative automatic assembly machine for welding parts cup / bolt with pipe;

3. Innovative semi-automatic packaging line.

4. Structural layout of an innovative automatic packaging line.

The developed competitive structural assembly of an automatic packaging line for packaging in micro corrugated packaging of complete packaging (set) and Adils leg body with actual stroke τd = 4 s. For the packaging of the "ADILS" product the productivity is 24 pcs / min.

An innovative machine for gluing cartons with duct tape has been developed and programmed using the SCADA software program, which collects data and transmits it to other peripheral devices. It also shows the operation of all sensors and monitors for alarms and alarm events.

Chapter 5

Future projects

5.1. Innovative Leg

The project for an innovative leg, presented in order to eliminate some of the existing operations - punching a cup detail, welding a cup with a purchased bolt, welding a cup / bolt with a foot tube. The schematic diagram for the new innovative leg is as follows: A large thread is cut on the turret head directly on the outer diameter of the tube. In the same way a thread is cut on the punched drawn heel. In this way the connection of the two parts is done by rotating the pipe and the heel.

5.2. Shuttle welding department

It is planned to build a workshop for automated, robotic welding on the territory of the plant. With this innovative robotic welding system, high production, minimal errors and a small number of workers are achieved.

5.3. Conclusion

Thanks to the innovative technologies that are planned to be implemented, the operations in the technological process of making the finished foot detail for table tops are reduced. The introduction of a welding department increases the quality and reduces the number of employees involved in the welding process.

Both innovative technologies contribute to increasing the efficiency of production in the production of tubular furniture.

CONCLUSION

An overview for the production of tubular furniture and components has been compiled. The production process of tubular furniture during its stages of development is analyzed. Attention is paid to the types of products that are produced, as well as their volume. Based on the compiled analyzes, it is established that the products with the largest production volume are the legs for table tops. It is extremely important to preserve the quality of the products, as well as their packaging and transportation. From the analysis of packaging products and technologies, according to the quality requirements of IKEA, this type of products has been selected that are most suitable for automation, ecology and economic efficiency.

Based on the analysis made in Chapter 1, attention is paid to the technological process and raw materials for table legs. The product was chosen because of automation friendliness. Its components and its suitability for installation are suitable for automating the technological process. Four options for automation of the technological process are considered. Desired and actual productivity is calculated. Based on criteria and factors, options 3 and 4 have been selected, which cover the desired quality and volume.

On the basis of marketing research and increased requirements for packaging of products, the following characteristics need to be corrected: size, weight, type of packaging and name. Approaches and methodologies have been developed to design innovative machines with increased productivity, quality control, improved packaging, increased safety and reduced production costs.

New requirements for packaging materials that meet the needs of the developing world are presented. The delivery raw material used for the production of the new type of product is described. Based on the desired annual productivity, the theoretical tact is calculated and compared with the actual one. The resulting actual performance and actual clock meet the pre-set criteria. Four innovative machines have been designed, manufactured and implemented in the production to meet the increased requirements. The innovation of these machines consists of synergistic use of modules, implementation of Industry 4.0 and intelligent marriage management. The four innovative machines are as follows: automatic assembly machine for cup cup welding; cup / bolt laser welding machine; packaging line and structural layout of the packaging line.

Semi-automatic machine is designed and implemented in the production for automatic gluing of cartons with finished products. During the production cycle, the implemented elements from Industry 4.0 allow for: tracking of alarms and irregularities during the process; compiling a database with information on the quantity produced; compile and send a report to the cloud. The report contains monitoring data.

Innovative technologies contribute to the reduction of operations in the technological process. Using them increases productivity, quality, reduces costs, increases safety and contributes to environmental protection.

SCIENTIFIC AND APPLIED CONTRIBUTIONS:

The contributions to the dissertation are mainly of scientific and applied nature and are as follows:

1. The various methods and means for realization of processes of punching, welding and packing of tubular products are analyzed and systematized.

2. Existing problems, solutions and desired changes concerning the production of tubular furniture are discussed

3. The influence of ICT on the methods of production of tubular furniture is studied.

4. Innovative approaches and methodologies are proposed for the design of machines for automatic punching of the heel and cup of the table leg and for increasing the efficiency and productivity of automatic table leg machines.

5. Innovative methods have been proposed to increase the productivity of packaging.

6. Designed, developed and implemented in production is an innovative automatic assembly machine in two versions.

7. Innovative semi-automatic packaging line designed, developed and implemented in production.

8. A structural layout of an innovative automatic packaging line is proposed.

9. Experimental developments and simulations of various methodologies in industrial environment have been made.

10. Intellectual property is protected.

11. The developed automatic machines are in accordance with the European standards.

12. Methodological assistance was provided in mastering the principle of their work

13. The quality, volume and efficiency of the produced products have been increased

14. The results of the experiments are verified and analyzed in order to improve the quality of production and its productivity

15. Future projects are proposed - Innovative leg.

ACKNOWLEDGMENT

I had the honor to work under the guidance of Prof. Dr. Dimitar Karastoyanov, who supported and helped me over the years - thank you very much for his help.

I would also like to thank Prof. Galya Angelova for the opportunity to work with unique and modern research equipment in the Smart Lab at IICT-BAS.

Of course, I would also like to thank Assoc. Prof. Dr. Nikolay Stoimenov for the methodological instructions and guidelines he gave me.

I would also like to thank Prof. Dr. Todor Neshkov and Assoc. Prof. Dr. Lyuben Klochkov from the Department of ADP at the Ministry of Finance of the Technical University of Sofia for their support during all my years of doctoral studies.

Thank you all very much !!!

BIBLIOGRAPHY

[2] ИНОВАЦИИТЕ – ЕВРОПЕЙСКИ, НАЦИОНАЛНИ ПОЛИТИКИ, научен редактор проф. д.ик.н М. Петров, Фондация „Приложни изследвания и комуникации“ ARC FUND, 2008 г.

[6] https://www.ikea.bg/ (последно посетен 12.2021г.)

[7] IKEA Specification ISO – 0010/2010.11.12, Version AA-171373-8, замества AA-171373-7

[16] Видове опаковки, https://www.packit.bg/vidove-opakovachni-materiali.html (посетен декември 2021 г.)

[17] Интелигентно европейско опаковане - ProPack https://propackmagazine.bg (посетен декември 2021 г.)

[18] Булекопак А. Д., Основни изисквания към опаковките в Европа.

[19] PRO EUROPE, Ефективно опаковане – ефективно предотвратяване, 2008.

[37] Маркова Н., С. Стефанов, И. Илкова, Опаковъчна техника и технология, ръководство. Пловдив, 2008.

[50] Стоименов Н., Гьошев С., Панев П., Клочков Л., Автоматизиране на опаковъчните процеси и операции на крак „къри“. Част I: Оценяване степента на пригодност на детайлите участващи в автоматичното им опаковане. International Conference Robotics, Automation and

[53] Митев М., Клочков Л., „Възможности за автоматизиране на монтажните операции при опаковане на шоколадови бонбони“, XXI МНТК, Автоматизация на дискретното производство „АДП – 2012”, 20-23 Юни, Созопол 2012г., стр. 330-340, ISSN – 13 10 -3946 (2012)

[54] Илиева, Р., Клочков Л., „Резерви за повишаване производителността на автоматична опаковъчна машина“, Тринадесета национална научно-техническа конференция с международно участие “Автоматизация на дискретното производство” АДП 2004. Научни известия на НТС по машиностроене, год. XI, бр. 10 (78), София, октомври 2004, с. с. 389-394 , ISSN – 13 10 -3946 (2004)

[55] Stoimenov N., Karastoyanov D., Klochkov L., Study of the Factors Increasing the Quality and Productivity of Drum, Rod and Ball mills, 2nd Int. Conf. on Environment, Chemical Engineering & Materials, ECEM '18, Malta Sliema, June 22-24, 2018, AIP (American Institute of Physics) Publishing house, Vol. 2022, Issue 1, ISBN: 978-0-7354-1740-3, pp. 020024-1 - 020024-6 (2018)

[56] Ройдев М., Георгиева В., Стоименов Н., Клочков Л., Панев П., Разработване на автоматична линия за опаковане с еднократна опаковка, XXV МНТК Автоматизация на дискретното производство „АДП – 2016” 23-26 Юни, Созопол 2016г., ISSN – 13 10 -3946, 2016, стр.232-239.

[57] Panev P., Development of Automatic Packing Line for Single Packs. 8th International Conference on Mechanical Technologies and Structural Materials (MTSM 2018), Split, Croatia, September 27-28, 2018, 70, Croatian Society for Mechanical Technologies, Croatia, ISSN:1847-7917, 2018, pp. 149-152.

[60] PRO EUROPE, Ефективно опаковане – ефективно предотвратяване, 2008.

[61] Bocevska A., Neshkov T., Intelligent Manufacturing Systems, Heronpress, Sofia, 2014.

[88] H. Yu, X. Liu, X. Ren, Behaviour of longitudinal cracks on slab surfaces in V-H rolling processes, Steel Res. Int., 2 (2008), pp. 537-544, 10.2374/SRI07SP066-79-2008-xx

[89] M.Nioia, S.Celottob, C.Pinnaa, E.Swartb, H.Ghadbeigia, Journal of Materials Processing Technology, Volume 249, November (2017), Surface defect evolution in hot rolling of high-Si electrical steels, Pages 302-312

[90] S. Shainu, T.K. Roy, B.K. Dey, R.K. Sharma, N.C. Gorain, S. Dhar, C.V. Sastry, Study on Slab Surface Defects and Generation of FeO Type Slivers in Hot Rolled Coils Tata Steel Ltd., Jamshedpur (2008)

[91] S.-L. Lee, J. Choi, Deformation analysis of surface defect on hot rolling by 3-D FEM simulation, Rev. Metall. Cah. Inf. Tech., 105 (2008), pp. 127-135, 10.1051/metal:2008025

[92] Ivanchev I., Stoimenov N., Sokolov B., Testing of Concrete by Contactless Non-Destructive Tomographic Method, IEEE XXX International Scientific Symposium 'Metrology and Metrology Assurance' 2020 (MMA 2020), 7-11 September Sozopol, Bulgaria, (2020), E ISBN:978-1-7281-9719-7 pp. 1-6, doi: 10.1109/MMA49863.2020.9254250.

[93] Карастоянов Д., Стоименов Н., АБРАЗИВНО ТЯЛО, Полезен модел на Република България, рег. № 2964 U1/16.07.2018.

[94] Дащенко А. И., Белоусов А. П. Проектирование автоматических линий. Учебник. Высшая школа, М., 1983,

[95] „Проектирование металлорежущих станков и автоматический линий“, под ред. А.С. Проникова, М. Изд-во МГТУ или Н. Баумана, 2000

[96] Шаумян Г.А. „Комплексная автоматизация производственных процессов“, М. Машиностроене, 1973 г.

[97] Технология машиностроения, Под ред. А. М. Дальосково, М. Машиностроения, 1997 г.

[98] „Автоматизация на дискретного производства“, Под общей редакцией проф. Е. И. Семеонова и проф. Л. И. Волкчевича, М. „Машиностроение“, 1983, с. Техника, 1991, А 274010000-228

[99] Агрегатни машини, под общата редакция на ст.н.с Валентин Д. Грозданов, ДИ „Техника“, София 1984

[100] Dimitrov S., Dimitrov L., Dimitrova R., Nikolov S., EXAMINATION OF THE PROCESS OF AUTOMATED CLOSURE OF CONTAINERS WITH SCREW CAPS, International Conference on Information Technologies ICIT-2019: Information and Communication Technologies for Industry and Research, 7-8.02.2019, Saratov, Russia, © Springer Nature Switzerland AG, ICIT 2019, SSDC 199, pp. (502–514), 2019.