EXPERIMENTAL RESEARCH OF PAPERBOARD CREASING IN DIE-CUTTING PRESS WITH SCREW-NUT MECHANISM FOR DRIVE OF THE MOVABLE PRESSURE PLATE

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Abstract: *The paper reports experimental research of torque values during paperboard creasing in the die-cutting press with the screw-nut transmission as the drive mechanism of the movable pressure plate. The purpose of the study is to get experimental data for analytical calculations of the proposed drive mechanism of the pressure plate at the stage of its design for substantiation of its practical implementation for the production of cut-outs of paperboard packaging. Experimental research of paperboard blanks creasing allows getting dependencies of torque values on parameters of paperboard and regimes of experimental bench working. Results of experimental research allow getting trustworthy and systematised information about torque values depending on the thickness of the paperboard, the paperboard fibres direction and pressure plate displacement velocity. The article shows the workability of the designed device with the screw-nut transmission in the drive mechanism of the movable pressure plate.*

Key words: *cardboard, die-cutting press, creasing, pressure plate*

1 INTRODUCTION

Paperboard packaging manufacturing is a complex of different operation that forms the technological process. These operations can be divided into two groups – prepare and basic operations (Rehei 2011). In all the cases the technological process provides the die-cutting operation regardless of the type of packaging (Emblem H. 2012), (Coles R. 2011). This operation foresees the cutting of packaging cut-outs from paperboard blank simultaneously with creasing of fold lines and, if necessary, perforation and embossing can be performed.

Modern die-cutting equipment provides performing of several technological operations for paperboard packaging manufacture. The key part of automatic die-cutting equipment is the press. The most common are flatbed die-cutting presses.

The press section accomplishes the technological operation of die-cutting. In die-cutting presses, for pressure plate drive, are used special lever mechanisms. have carried out the analysis of existing mechanisms design of pressure plate drive in die-cutting equipment and equipment from other industries, which perform operations that require overcoming a significant technological load at the end of the movement of the executive link. As it has been noted by the authors, the work of such mechanisms is based on wedging effect, which provides sufficient effort value of pressure plate with comparatively little loads on driving links (Khvedchyn 2014).

For today, it is proposed many schemes of die0cutting presses designs. In several studies (Kuznetsov 2012), (Kuznetsov 2017), (Lin 2015), (Shakhbazov 2020) had been proposed and researched mechanisms of the drive of the movable pressure plate of flatbed die-cutting press. During researches the authors had shown significant advantages of proposed mechanisms. However, the majority of proposed drive mechanisms are characterized by the non-parallel movement of the pressure plate during its kinematic cycle. These mechanisms are, also, complicated and difficult during set-up operations. Therefore, it has been proposed the new design of drive mechanism of die-cutting press, in attempting to overcome existing drawbacks (Behen 2020). Authors proposed the use of screw-nut transmission for drive mechanism of movable pressure plate. The analytical researches of die-cutting technological process with use of such a mechanism have shown the availability for the use of presses of this type in the industrial manufacturing of the paperboard packaging. However, researches mostly consider loads that occur during cutting the contour of the package cut-outs despite the fact that the technological operation of die-cutting provides also the creasing of fold lines. Given this, there is a need to study the process of creasing on presses with screw-nut transmission in the drive mechanism of movable pressure plate for confirmation of their operability and efficiency during paperboard packaging manufacturing.

Creasing is a converting process in which the die creates a fold line on the stock material. However, creasing reshapes the material to have an inward bending bulge between two parallel stress points. Having two stress points increases the flexibility of the material at the crease and reduces the amount of stress on the material at each point when it is folded. Creasing is an operation of applying a straight groove on a sheet of paperboard for further its folding (Kirwan 2013). Running the creasing operation is possible only with the use of paper or paperboard with a mass of a square meter of more than 175 g. The proper creasing quality is one of the important factors of ensuring the efficiency of packaging manufacturing and achieving high-quality indicators of the final product. As it has been said, during the creasing operation the necessary residual deformation must be created in the paperboard blank, which provides forming clear fold contours excluding the damage of the surface layer of the front side. Insufficient residual deformation of paperboard causes the necessity of extra load applying during the process of forming a bulk package. It can also cause damage to the printed layer. During the process of forming a bulk package, the fold is provided by the destruction of the elastic component of the paperboard and achieved by creating a complex stress-strain state in the paperboard. The paper-board needs to adapt to the shape of the creasing rule and retain the desired geometry of the crease.

Creasing is one of the most important steps in forming the box process. The creasing procedure comprises mainly 2 steps. It begins by setting the paperboard sheet on a female die and then a male ruler is punched into the female die. This forms the creases in the paper or paperboard (Huang 2011). The forces formed to misshape the paperboard in a planned way and the deformation is permanent. The result is a reduction in the bending resistance of the crease.

During creasing of paperboard blank, it is needed to understand paperboard behaviour and its deformation in process of fold lines creation. In article (Panthi 2016) creping process of fibre material based on creasing technology has been studied. The authors have analysed mechanical characteristics of paperboard blanks and developed schemes of creping based on the extensibility of paperboard. Basically, the authors have used a quantity strategy for the elaboration of the corresponding contour of regularities. Besides pattern design, it has been made few analyses with the aim to find out the results of different patterns. The authors have made microscopic analysis of paper-board blank, established its tensile properties, stiffness, tensile strength and fat barrier. However, these researches are focused mainly on the study of creping patterns and the force research during creasing was given a secondary role. Additionally, such research-es have not characterised paperboard behaviour during packaging manufacture.

For prognostication of paperboard behaviour during its creasing, the process of creation of a complex deformation is needed to be researched. To this end, in the work (Nygårds 2010) the authors have used a simplified model of the material. According to this model, paperboard has been presented in the form of interconnected fibres The model allows to simulate the fibre structure of an industrial sample of paperboard, although it includes much less material. In conducted researches paperboard appears as a combination of continuum and interface models. The simulation results obtained by the authors based on finite element analysis have been confirmed by experimental researches. The proposed material can be used to investigate the paperboard properties and their relation to the creasing behaviour. The obtained results are useful for the understanding deformation process of paperboard during its creasing. The main purpose of the creasing operation is to form residual deformation of paper-board for a decrease of local stiffness of the material to ensure to avoid damage to the surface layer of paperboard. Based on the simulation results, both stratifications between the components of the paperboard and plastic deformation inside the layers have been got with high engineering accuracy, which has allowed us to understand paperboard behaviour during its creasing and to provide a qualitative creasing process.

The crease formation can be analysed and simulated as a structure, with the purpose to predict the macroscopic mechanical behaviour of the creased paperboard during folding (Dai 1998).

Paperboard is a widely used material in industrial processes, in particular for packaging purposes. Packages are obtained through a forming process, in which a flat laminated sheet is converted into the final 3-D solid. In work (Giampieri 2011), a constitutive model for the mechanical response of crease lines is proposed and validated based on experimental tests. The model has been implemented in an interface finite element to be placed between adjacent shell elements and is intended for large-scale computations of package forming processes. The proposed model is macroscopic and interprets in a phenomenological way the complex phenomena occurring at lower scales. For this reason, it requires only a relatively small number of parameters to be characterized and can be considered to be 'simple'.

The work (Mentrasti 2013a) has carried out the results of the experimental investigations on samples obtained from industrial cartons. The results prove that the bending behaviour of a creased paperboard under large rotations is heavily dependent on a number of events out of the control of the structural analyser: the crease depth and the moisture content, primarily.

In paper (Mentrasti 2013b) authors have theoretically re-searched the erection process of the typical car-ton corner with 5 creases. The finite rotation kinematical analysis of the mechanism is presented, assuming the versor of the inter-mediate crease, as a 2-dof Lagrangian parameter. The main aim of the research is to increase the reliability of the reconfigurable robots manipulating origami-type cartons in the packaging industry demands an accurate characterization of mechanical behaviour of the creased paperboard, with the aim is to point out the possible criticalities of the erection process. However, these results are interesting during paperboard packaging manufacture in process of creasing and folding the packaging.

Laminated paperboard is often used as a packaging material. The quality of the folds depends on two converting processes: the manufacture of fold lines (creasing) and the subsequent folding. In article (Beex 2009), the authors have proposed a mechanical model in a finite element framework is proposed to predict and understand the behaviour of a three-layer laminated paperboard during creasing and folding. To discover general mechanisms and to provide a reference for comparison with predictions of the mechanical model authors have conducted experimental researches using a manufactured test bench. During researches, authors have got values of theoretical calculations that match the experimental data quite well. This data is important during the design of the new die-cutting press. Nevertheless, experimental researches have been conducted in conditions that do not accurately resemble an industrial creasing process.

The paper (Deganutti 2018) has shown the individual evaluation of measurements of the bending moment on the crease and uncreased paper-board. It has been shown in industrial testing the impact of Scott Bond on the creasing process and RCS values. High Scott Bond values impair the internal delamination necessary for good creasing at the same time should be controlled so that there is no delamination during the conversion process. Also, the authors have performed X-ray microtomography were performed to investigate the structure of the creased and folded area.

In work (Nygårds et al. (2009) is shown laboratory creasing device to capture the most important properties of a commercial rotary creasing tool and conducted experimental research with the use of a commercial paperboard blank. The authors have made simulations of the creasing process. The multiply paperboard was modelled as a multi-layered structure with a cohesive softening interface model connecting the paper-board plies. The paperboard plies were modelled by an anisotropic elastic-plastic material model. These results made it possible to capture the essence of the paperboard deformation and damage mechanisms. However, this research does not consider the parameters and features of the industrial creasing process and die-cutting presses.

In the analysed scientific works the process of deformation of a paperboard blank in the course of load application, which is similar to the creasing load during paperboard packaging manufacture is investigated in detail. However, these studies do not take into account the peculiarities of the industrial manufacture of paperboard packaging. Researches of the creasing process are conducted in the direction of modelling of a complex deformed state of the paperboard blank and prognostication of paperboard behaviour during its processing.

The use of the die-cutting press, with screw-nut transmission as a drive mechanism of movable pressure plate, for paperboard packaging manufacture, as for today, is researched only partially and mainly aimed at the process of cutting the cut-outs of paperboard packaging. Therefore, there is reason to believe that for further improvement and development of technology of paperboard packaging manufacture there is a need for thorough experimental researches of the die-cutting method for cut-outs manufacture with screw-nut trans-mission as a drive mechanism of the movable pressure plate.

The purpose of the study is to justify of practical implementation of a new die-cutting press scheme with drive mechanism with the use of screw-nut transmission and also determinate of technological loads depending on variable parameters of packaging manufacture technological process.

To achieve this goal, the following tasks need to be solved:

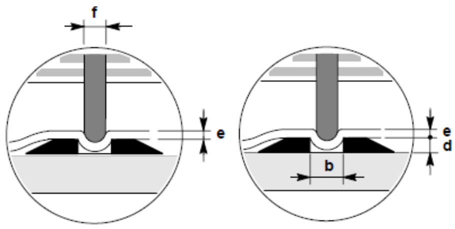
- to design, manufacture and assemble an experimental test bench with screw-nut transmission as a drive mechanism of movable pressure plate and experimentally check the possibility of practical implementation of the proposed scheme (Behen 2020) of the die-cutting press;
- detect the impact of technological parameters on loads that arise during paper-board blanks creasing.

2 DEVICE, MATERIALS AND METHODS

For obtaining the relief of the product, that is, the formation of fold lines crease rulers with different configurations are mainly used. The complicated design of packaging and low tolerances needs strict conformity of the crease ruler to the material that is processed and causes high requirements for the quality of the rulers themselves.

At the same height of cut rulers, the paper-board creasing with some thickness demands the appropriate thickness of the crease ruler and its height, the thickness of the creasing matrix and the width of its canal. Because of the fact that the thickness of the paperboard can change almost infinitely, to reduce the range of these elements, manufacturers recommend the use of crease rulers with parameters that are the same for a certain narrow range of paperboard thickness changes.

For experimental research of the die-cutting process on the proposed experimental bench was chosen the most common material for making packaging – paperboard. The most common paperboard for packaging is the Folding boxboard (FBB) (Emblem 2012), (Kirwan 2013) which has inner plies of mechanical pulp and outer plies of chemical pulp. For experimental research was chosen paperboard blanks of a local manufacturer with thickness of 0,3 mm (250 gsm), 0,45 mm (350 gsm), 0,5 mm (370 gsm), 0,6 mm (440 gsm), 0,7 mm (500 gsm). The thickness of paperboard blanks was measured and controlled during the experiments according to the recommendations of ISO 3034:2011. For experimental research, paperboard blanks have been conditioned at a temperature of 23° C and relative humidity of 50% for four hours.



a) b)

Fig. 1. Dependency of the crease ruler thickness (a) and crease matrix parameters (b) on paperboard thickness e

According to recommendations (Autoplatine 2006), the thickness f (fig. 1 a) of the crease ruler depends on the type and thickness e of the material that is processing. The width b of the crease canal (fig. 1 b) of the creasing matrix is selected depending on the thickness and type of paperboard and also on the fibre's direction relative to the tool.

Table 1. Recommendations of the choice of parameters of the crease ruler depending

Paperboard thickness e, mm	Recommended thickness of crease ruler f, points (1 point = 0.35 mm)
0.1 – 0.8	2
0.6 – 2.0	3
Corrugated cardboard	2

Each crease canals need to be centred relative to the crease ruler. The creasing canal width that is perpendicular to the paperboard fibres direction need to be 1.5 times larger than the thickness of the paperboard sheet e plus the thickness f of the crease ruler:

$$b = (1.5 \cdot e) + f \quad (1)$$

Canals parallel to the paperboard fibres direction are slightly narrower, in practice, such canals are 0.1 mm smaller than the previous ones:

$$b = (1.3 \cdot e) + f \quad (2)$$

It is needed to admit, the different behaviour of the paperboard during its processing, which depends on its type, thickness and other influential parameters, causes some differences in the real conditions for obtaining quality creasing from the recommended. The thickness of the crease canal is chosen equal to the thickness of the paperboard (d = e). To get quality creasing and ensure the minimal creasing effort the height of crease rulers is less than the height of the cutting rulers by the thickness of the paper-board blank, in case of the use of crease matrix.

Given the recommendations, to conduct experimental studies and obtain reliable values of loads that arise during paperboard blank processing are applied creasing crease rulers of type SR with the thickness of 2 points (0.7 mm) and height that corresponds to the thickness of the paperboard blank and also crease matrix with parameters corresponding to the paper-board blanks.

For experimental research had been designed and manufactured experimental bench, as has been shown in the article (Ternytskyi 2021). This test bench includes screw-nut transmission in the drive mechanism of the movable pressure plate. This bench (Fig. 2) provides strictly parallel displacement of the pressure plate during the working cycle of the press.

The experimental bench is driven by stepper motor 1 (Fig. 2) with a worm gearbox (not shown in the figure), and driveshaft 2 connected to it. On the drive shaft, 2 is placed the crank 3 that is connected by a connecting rod 4 to a gear wheel 5. The gear wheel 5 is mounted on a vertical shaft and installed into thrust bearings 6. The movement from the gear wheel 5 transferring to gears 7 and 7` which are fixed on vertical screws 8 and 8`. On screws 8 and 8` are placed nuts 9 and 9` of ballscrew that is fixed to the movable pressure plate 12. By nuts 9 and 9` the motion of screws transforms into the reciprocating motion of pressure plate 12. To guarantee the strictly parallel movement of pressure plate 12 is used cylindrical guides 10 and 10` with linear displacement bearings 11 and 11`. On the movable pressure plate 12 is placed and fixed an adjustment plate 13, that additionally provides high-quality of cutting the paperboard blank. A base plate 14 with die-cutting forme 15 is fixed to amount 16 of the experimental bench. Mount 16 of the experimental bench has the needed rigidity. The use of a stepper motor for the pressure plate drive allows smooth adjustment of kinematic parameters of pressure plate movement.

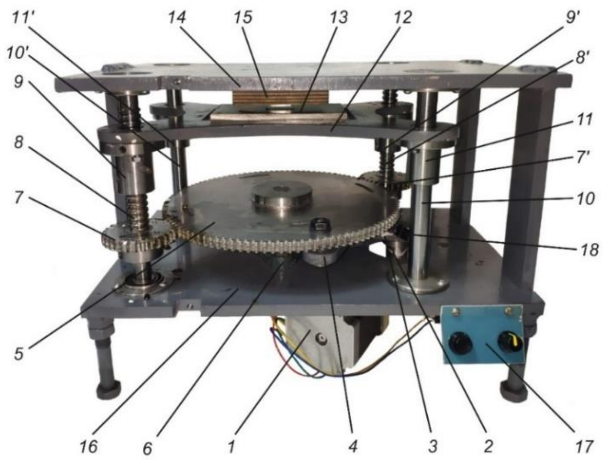


Fig. 2. Photo of the experimental bench for research on die-cutting process with use of screw-nut transmission in drive mechanism of pressure plate (Ternytskyi 2021): 1 – stepper motor, 2 – drive shaft, 3 – crank, 4 – connecting rod, 5 – gear wheel, 6 – thrust bearing, 7, 7` – gears, 8, 8` – vertical screws, 9, 9` – nuts, 10, 10` – cylindrical guides, 11, 11` – linear displacement bearings, 12 – movable pressure plate, 13 – adjustment plate, 14 – base plate, 15 – die-cutting forme, 16 – mount.

The experimental bench works as follows. Paperboard blank is put onto the adjustment plate 13, which is connected to movable pressure plate 12. Movable pressure plate 12 moves backwards in the vertical direction and presses the paperboard blank to die-cutting forme 15. The forme 15 is fixed on the base plate 14 which is rigidly connected to amount 16 of the experimental bench. The drive of movable pressure plate 12 was carried out from a stepper motor 1 through drive mechanism. From stepper motor 1 imparts rotational motion to the drive shaft 2. On the drive shaft 2 is fixed crank 3 that transfers the motion to gear wheel 5 by a connecting rod 4. The drive gear wheel 5 has reverse-rotating motion that is provided by the configuration of four-bar linkage mechanism. The reverse-rotating motion from drive gear wheel 5 in-stalled in the mount 16 of the device in the bearing unit 6 through driven gears 7 and 7` transfers to vertical screws 8 and 8` on which are fixed driven gears. On screws 8 and 8` are placed nuts 9 and 9` of ballscrew that is fixed to the movable pressure plate 12. Thus, the movable pressure plate 12 get the needed backwards displacement. In order to avoid skew of the plate 12 during its movement in the mount 16 of the experimental bench guide rods 10 and 10` is in-stalled and to the plate 12 is fixed linear dis-placement bearings 11 and 11`. The experimental bench is controlled by control panel 17 that allows setting the required motor speed. To perform measurements of loads that arise during creasing of paperboard blanks, on the drive shaft 2 a module of measuring sensors 18 is placed.

The experimental bench design shows the possible realisation of the pressure plate drive mechanism with the use of a screw-nut transmission with a leadscrew that provides the necessary displacement of the pressure plate (Ternytskyi 2021).

To get reliable loads values that arise during paperboard creasing with the use of the proposed drive mechanism of the pressure plate is used a strain gauge measure method that provides the needed precision of measurements. To measure torques on the drive shaft of the experimental bench according to recommendations (Schicher 2002) are placed strain gauges which change their resistance depending on values of loads. From the measured electrical resistance of the strain gauge, the number of technological loads may be inferred. For measurements are used foil strain gauges N2A-06-

T007R-350 with an electrical resistance of 350 Ohm and a base of 100 mm. According to recommendations (Hilal Muftah 2013), strain gauges are glued on the drive shaft 1 of the experimental bench (a mechanism) at an angle of 45° to the axis of the shaft and 90° relative to each other. The connection of the strain gauge bridge to the measuring equipment is provided by a specially designed mod-ule 2 for processing and wireless data transmission. This kind of module gathering, processing and wireless data transmission (Knysh 2019).

To establish the compliance of ADC data with the real torque values has been done the calibrating of the measuring equipment. The real values of torque on the drive shaft of the experimental bench are determined by known load values.

The experimental bench makes possible getting torque values that arise during paperboard creasing. The design of the experimental bench provides the displacement of the movable pressure plate by 80 mm. The use of a stepper motor enables the smooth adjustment of the movement speed of the pressure plate.

3 RESULTS

Obtained results of experimental researches of torque values, that arise in the drive shaft of the experimental bench during creasing of paperboard blanks have been processed according to the described methods and presented in the form of graphs (Figs. 3 and 4). The abscissa axis shows the time which corresponds to the operation period of the drive mechanism of the movable pressure plate.

Figs. 3 and 4 have shown typical graphical dependences obtained experimentally which shows the change of torque values on the drive shaft of the pressure plate mechanism during the kinematical cycle of mechanism work. The graphs show two cycles of pressure plate drive mechanism work – without creasing and during creasing process of paperboard blank. The change of torque values on the drive shaft of the pressure plate drive mechanism during creasing of the paper-board blanks with the thickness of 0.7 mm (500 gsm) with CD and MD of paperboard against crease ruler at a speed of drive shaft rotation 30 rpm. The kinematic cycle of work of the experimental bench begins at point A. From this point inertia forces on the drive shaft of the experimental bench begin to increase, reaching a maximum value at point B. After these loads caused by the inertia of components of the experimental bench gradually decrease and reach the minimum value at point C, which is the point of the end of the kinematical cycle of work of the experimental bench. Segment A–C shows the change of torque values without the creasing operation of paperboard blanks. In this segment, the torque on the drive shaft of the experimental bench changes because of inertia forces taking into account the friction in the components of the combined mechanism, the gaps in the kinematic pairs, the characteristics of the drive, the noises of electronic devices.

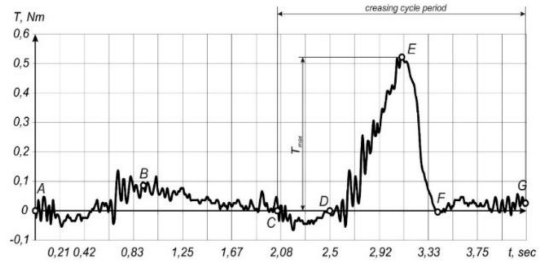


Fig. 3. Graph of torque change on the drive shaft of the drive mechanism during paperboard blanks creasing MD for paperboard FBB with the thickness of 0.7 mm

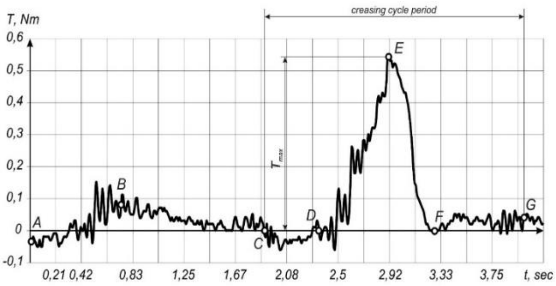


Fig. 4. Graph of torque change on the drive shaft of the drive mechanism during paperboard blanks creasing CD for paperboard FBB with the thickness of 0.7 mm

Point C is also the beginning of the second kinematical cycle of work of the experimental bench during which the creasing of paperboard blanks take place. At point D on the graph, the crease ruler touches the card-board blank and the creasing process begins. This is accompanied by an increase in the torque value to reaching a maximum value at point E. During the creasing of paperboard blanks, because of the use of the creasing matrix, complex deformation appears.

Then the pressure plate changes the movement direction and begins to move away from the base plate and torque values on the drive shaft of the experimental bench gradually decrease to their disappearance, which corresponds to the point F on the graph. The pressure plate continues its movement to reaching the extreme position (segment F–G). In this segment can be seen the change of torque values caused by inertia forces of the experimental bench components.

The experimental data were processed according to the method described above and the torque values are presented in the Table 2.

Using the values from Table 2 graphs that show dependencies of torque values that arise during paperboard blanks creasing in experimental bench has been built (Fig. 5). The analysis of diagrams allows revealing the dependence of torque on the thickness of a paperboard blank, and the impact of paperboard fibres direction relative to the crease ruler.

Table 2. Results of experimental research of torque on the drive shaft of mechanism that arises during paperboard blanks creasing

Crank speed, rpm		10		20		30	
Paperboard fibres direction		MD	CD	MD	CD	MD	CD
Torque, Nm	0.3 mm, 230 gsm	0,26	0,28	0,24	0,28	0,25	0,27
	0.45 mm, 350 gsm	0,38	0,39	0,37	0,40	0,4	0,41
	0.5 mm, 370 gsm	0,43	0,46	0,42	0,44	0,42	0,42
	0.6 mm, 440 gsm	0,5	0,51	0,47	0,51	0,48	0,5
	0.7 mm, 500 gsm	0,6	0,6	0,59	0,59	0,56	0,56

The experimental research has provided obtaining the dependence of torque value on its speed parameters. As can be seen from Table 2 the crank speed change, and therefore the creasing process speed, has an insignificant impact on the torque value. In the range of speeds that were studied (10–30 rpm), observing the torque value change on around 3–5%. So it can be stated that the speed of the cranck of the drive mechanism of the experimental bench does not impact the torque value during creasing of paperboard blanks, unlike torque values during cutting the paperboard blanks (Ternytskyi 2021).

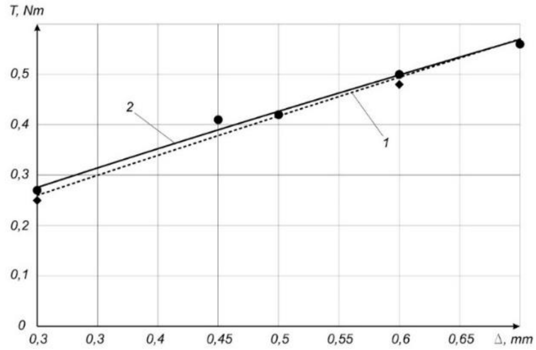


Fig. 5. Dependence of creasing torque of paperboard blank thickness measured on the drive shaft of experimental bench: 1 – CD, 2 – MD

Analysing the graphs of the torque values on the drive shaft that arise during paper-board blanks creasing has been established that the thickness of the paperboard blank causes an increase in the torque value. Because of the appearance of the complex deformation in the paperboard blank and the anisotropic properties of the paperboard, there is no directly proportional dependence of the torque value on the thickness of the paperboard blank.

The increase of thickness of the paperboard blank twice, from 0.3 mm to 0.7 mm, causes the increase of the torque on the drive shaft of the experimental bench more than 2 times during paperboard cutting MD (from 0.26 Nm to 0.6 Nm) and CD (from 0.28 Nm to 0.6 Nm).

The torque value change on the drive shaft of the experimental bench dependence on the paperboard thickness can be described by empirical dependencies. Empirical dependencies of creasing of paperboard blanks on their thickness for paperboard FBB with crank speed 30 rpm:

during creasing in MD:

$$T = 0{,}77 \cdot \Delta^{0{,}85}, \quad (3)$$

during creasing in CD:

$$T = 0{,}79 \cdot \Delta^{0{,}93}. \quad (4)$$

The total dispersion S2 characterised the scatter of experimentally observed points to medium value, is 0.98 for the dependence of creasing torque on the paperboard thickness for creasing in MD and 0.97 during creasing in CD. Following the residual dispersion and the correlation coefficient, it can be stated that empirical dependence is close enough to experimental data.

The functional dependence (empirical dependence) describes the experimental values of the variables and accurately reflects the general trend of change of dependence except for measurement faults and random deviations. Mathematical models of torque values during paperboard blanks creasing dependence on paperboard thickness together with paperboard cutting allows getting physical characteristics that correlate the stress and strain of paperboard and analytical calculations of the drive mechanism at the stage of its design.

4 SUMMARY AND CONCLUSION

The experimental bench with the screw-nut transmission in the drive mechanism of the pressure plate has been proposed. It allows smooth changing of the speed of the drive shaft and as a result velocity of pressure plate dis-placement. The experimental research provides the study of torque values on the drive shaft with detection of the impact of paper-board parameters on the loads that arise during creasing operation. Methods of measurements and data processing allow getting reliable values with minimal faults.

Values of creasing torque values have been established. Moreover, the impact of paper-board blanks thickness and speed of drive crank of pressure plate mechanism on torque values are revealed.

The analysis of torque value, which appears on the drive shaft of the pressure plate mechanism in experimental bench, dependence on the speed of its work has shown that in range of 10–30 rpm the increase of the rotation speed of the drive shaft, and hence the movement of the pressure plate, do not affect the value of torque.

It has been established that paperboard blank thickness does not impact the nature of the torque values change, which arise during the creasing of paperboard blanks on the drive shaft of the experimental bench. The direction of the fibres of the paperboard blank relative to the crease ruler has no significant effect on the amount of creasing torque. It can be observed an increase of creasing torque value of only 7% on average during creasing in CD compared to creasing in MD.

The increase of paperboard thickness from 0.3 mm to 0.7 mm causes the increase of torque value of technological operation of creasing 2.2 times during creasing in MD (from 0.25 Nm to 0.56 Nm) and 2 times during creasing in CD (from 0.27 Nm to 0.56 Nm). This explains by consisting of a paperboard of intertwined and interconnected plant fibres containing cellulose and the greater density in the CD of paperboard.

Mathematical models of torque values during paperboard blanks creasing depending on paperboard thickness allows getting physical characteristics of stress and strain of paper-board and analytical calculations of the drive mechanism at the stage of its design. The functional dependence describes the experimental values of the variables and accurately reflects the change of dependence except for measurement faults and random deviations.

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