Analysis of changes in paper cutting forces during the cutting cycle in single-knife guillotine

Rusin Agnieszka, Petriaszwili Georgij
Warsaw University of Technology, Institute of Mechanics and Printing, Division of Printing Technologies, Warsaw, Poland

Abstract: *Paper presents the results of changes in the three components of cutting forces of paper stacks cutting during the cutting cycle in single-knife guillotine. The changes of the three components of cutting force at different stages of cutting cycle were analyzed.*

Keywords: *paper stack, cutting force, three components measuring, cutting cycle*

Preface

Paper cutting operations are widely applied in the implementation of the printing process: before printing – to trim the stack to the desired format at single-knife cutting machines, as well as the treatment of the final book blocks – a three-knife guillotines. Until recently, slicing the paper was to be regarded as secondary and auxiliary. But today applied to the much more attention, as it is proven that the correct cutting is largely dependent on the smooth running of other technological operations, which has a large impact on the quality of the product and the cost of printing. In most guillotine cutter mechanism realize saber movement, which is considered the most perfect. However, the cutting process is characterized by relatively large values of cutting force, which is working with blunt knives repeatedly increasing and causing deterioration of the quality and accuracy of cut, and increases the load on the machine drive. The modern guillotines works with higher dynamic load, that's why the aim of the investigations is: the comprehensive analysis of the cutting process in the cutting cycle of guillotine by using the stand built on the base of high speed guillotine. Such research enable them to determine the actual distribution of cutting forces in the cycle high-speed single knife cutting maschine.

Backgrounds

Cutting is a very complex process, because its course is dependent on many factors related to the material being processed, tool, machine and cutting conditions. Among the first major research work process of cutting stacks of paper work needs to be replaced research of Dittrich, Mordowin and Ginzburg [1,2,3]. These studies indicate that the evaporation of a knife in a stack of paper produced localized compressive stress, which is always greater than the pressure of the clamping beam. Knife when going into stack causes the deflection and deformation of fibers around the cutting edge of the knife, resulting in compressive stress and stretching. When the tensile stresses strength of the fibers exceed the limit, the sheet tears . The value of cutting force depends on many parameters, of which the most important are: the width of cutting, sharpness the knife, knife blade angle, movement angle of the knife, the type of cutting material, and more. Most of these parameters has been determined experimentally by special bench tests in the 50-s and 60-s by Ginzburg (1957), Dittrich (1965). In recent years, the research of cutting process of stacks was performed at the Institute of Printing Science and Technology (IDD) in Darmstadt by Neumann, Desch, Spiehl, Dörsam (2009–2012) [4].

When cutting a wedge-shaped knife is inserted into the stack causing complex deformation of the stack and intersection sheets of paper by cutter blade. The vertical component of the movement of the blade in the stack causes the deflection of layers of paper under the knife and the separation of the fibers near the edge, and the horizontal component of motion causes kerf (cutting) sheets of paper. The ratio of the friction force truncated stack under pressure beam and force bent sheet under the knife to the frictional forces of the shifted stack contributes to the deflection blade by cutting in the direction of pressure beam and in the direction of the sliding parts of the stack. The cutting of the paper is characterized by the appearance of the following forces: the resistance of the stack move of the knife in a vertical line, the resistance of the paper to move the knife in a horizontal line, the friction force edge of the cut-sheet under the pressure beam, pressure deformed sheets under the pressure beam on the knife, the friction force shifted stack of cut. The cutting force can be described by using three components: in a vertical plane F_y, a horizontal plane F_x and square with this plane – a component F_z. The first component F_y is the largest. The horizontal component F_x depends on cutting and friction resistance of the paper. The component F_z is the smallest. To assess the actual distribution of cutting forces in the cycle cutter knife used construction of three-component knife-dynamometer and enhanced data acquisition system.

Experimental researches

The researches was made by using a special measuring station and a single knife cutting machine Adast MM58-1 (Czech Republic). A cutting system enable to do research into a different parameters of knife motion. A special dynamometer, which is used for research into component cutting force, acts as a measuring device [5]. There was also used the National Instruments (USA) measuring system for cutting forces registration. Investigations were carried out with the main variable parameters: max cutting width of the paper stack – 100 mm, variable working speed of the guillotine – 10 ÷ 100 cycles/min, variable angle of the main knife movement – 20^o ÷ 70^o and others.

On the basis of the structure a dynamometer, developed to study a single knife cutting machines (Poludov, Georgievsky, Ivaschenko, 1977), designed and manufactured measuring head - cutting the dynamometer bench. Dynamometer consist of two elastic octagonal rings on which strain gauges were mounted. Connection were made to form measuring the Wheatstone bridges. To measure the changes in the forces are tensometers, respectively, glued together in the bridge circuits (Fig. 1). Tensometers 1y, 2y, 3y and 4y are sensitive only to vertical force component trimming, Tensometers 1x, 2x, 3x and 4x – the horizontal, and Tensometers 1z, 2z, 3z and 4z - the front component (Fig. 2). Tensometers in the electrical bridge circuits are connected so that the potential at the input of the bridge depends only on the size of each of the components of force trimming and does not depend from the place it of application of on a knife edge. The tests of cross sensitivity calibration of any components of the knife-dynamometer have shown that the effect of each component to the other is not greater 1.5%.

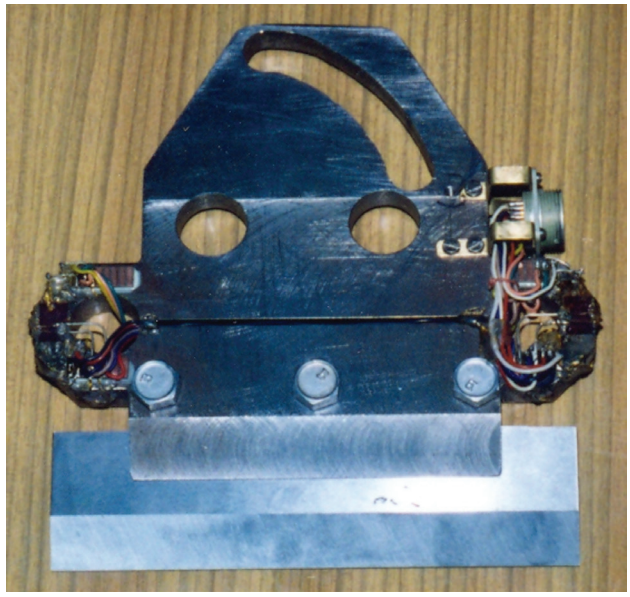

Figure 1: View the knife-dynamometer

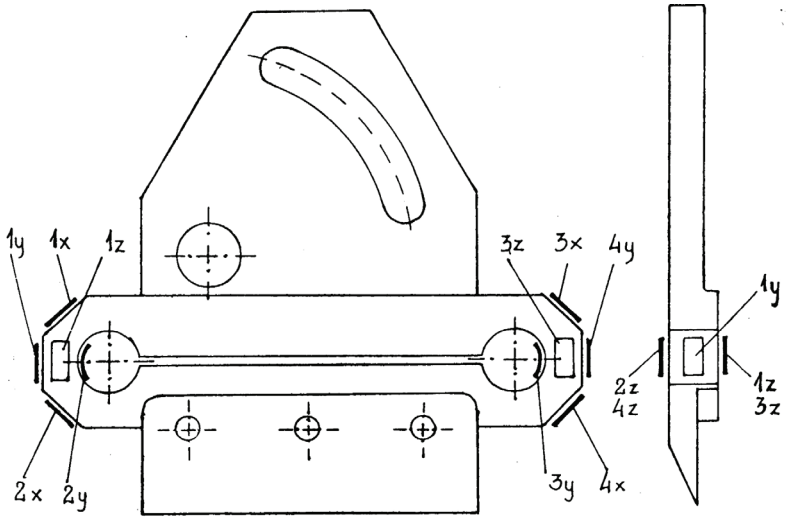

Figure 2: Construction of three component dynamometer (knife is not shown)

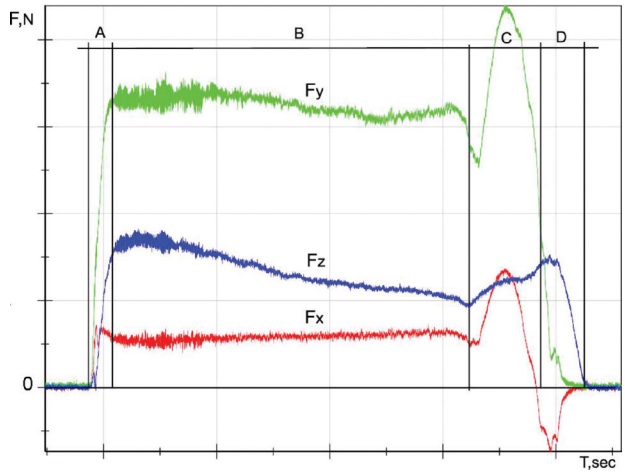

Figure 3: Typical data measured curves of three components of cutting force during the cutting cycle

Figure 3 shows a typical data measured curves of three cutting force components during cutting cycle of single-knife cutting machine. The research which has been made shows that every curve of cutting force changes can be divide into characteristic segments. A segment (A) is characterized by the fast increase in forces (shows a deformation of the top of stack and a knife penetration). A length of it depends on the height of pile and an angle of penetration. The second segment (B) is related to the cutting process. It is characterized by a vibration changes of the force value. The third segment (C) has a characteristic, that shows the increase the force (Fy and Fx) when the knife contacted with the cutting stick. Then, forces are decreasing and segment (D) shows the end of the process, knife is coming back from the stick (negative value of the Fx appeared).

The results of the investigations and planned further researches could explain deeper the phenomena occurring in the process of paper cutting.

References

1. Dittrich, H., (1965), Schneidemaschinen – Ausgewählte Beitrage, Leipzig
2. Mordowin, B., (1948) Ob usiliach rezanija i dawlenijach priżyma stopy w bumagorezalnych maszynach. Izd. MPI, Moskwa. (Russian)
3. Ginzburg, W., (1957) Isledowanije procesa rezanija na odnonożewych bumagorezalnych maszynach. Sbornik WNIIPM N3, Moskwa. (Russian)
4. Neumann, J., Desch, M., Spiehl, D., Dörsam, E., (2012) Measuring forces appearing while cutting a stack of sheets with the aim to improve post press process. IARIGAI. Advances in Printing and Media Technology. vol. XXXIX, pp. 253–260.
5. Georgievsky, I., Poludov, A., Ivaschenko, B., (1977) Izmerenie sil rezania w bumagorezalnych maschinach. Poligrafia, 1, pp. 30–31. (Russian)