International Journal on Recent and Innovation Trends in Computing and Communication ISSN: 2321-8169
Volume: 3 Issue: 2 144 - 148

# An Overview of Human Powered Paper Corrugation Machine

R. N. Dehankar
Assistant Professor, Mechanical Engineering Dept
Anjuman College of engineering and Technology
Nagpur, India
*E-mail:dehankar3@gmail.com*

Dr. A. M. Langde
Professor, Mechanical Engineering Dept
Anjuman College of engineering and Technology
Nagpur,India
*E-mail:akashlangde@gmail.com*

A. P. Ganorkar
Assistant Professor, Mechanical Engineering Dept.
Anjuman College of engineering and Technology
Nagpur,India
*E-mail:apganorkar@rediffmail.com*

***Abstract*—** In Present scenario packing of any equipment / instruments is a big task for manufacturing industries for safety and handling point of view. One of the way-out for packaging is "Corrugated paper sheet boxes" (also called carton) is widely used for diverse packing applications. Many industrial goods and horticultural products are packed using corrugated paper boxes. The major raw material required for corrugated sheet boxes are papers.

Now a day's many machines are motorized / automatic as per market survey in various industries of corrugated box manufacturing units. Hence a new setup human powered flywheel machine introduce for paper corrugation.

Since invention Flywheel motor is being extensively used in various applications which are energized by the human e n e r g y. Such application includes b r i c k making machine, flour mill, forge hammer, chaff cutter etc. Because of increasing range of application flywheel motor is being the subject of i n t e r e s t of the researchers for the optimum use of human energy. In an attempt this paper presents the exhaustive literature survey on the flywheel motor focusing on the work done so far.

This study summarizes the reducing principle of design of corrugated box used in the goods packaging. Then it makes a term-by-term analysis on the selection of raw materials for paper boxes, the optimization, and the overall design of paper box, with special emphasis on the method to realize moderate packaging of goods.

***Keywords-*** *Flywheel Motor, Brick Making Machine, Chaff Cutter, Forge Hammer, Pedal Operated Flour Mill, Corrugated paper boxes etc.*

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## I. INTRODUCTION

Human powered brick making machine was first of its kind developed for the manufacturing of bricks (Modak J.P. J.P.1982, 1994, 1997, 1998) (1). and since then various processes are energized by the human power such as chaff cutter, wood turning, cloth washing, potter's wheel, flour mill etc (2). All these machines are operated by the human power. Human pedals the system with rate suitable to it, this energy is supplied to the processing unit through intermediate flywheel. Essentially The Machine consists of flywheel motor , driven bicycle mechanism with speed increasing gearing , which drives the shaft of process of process unit through clutch and torque amplification unit (Gupta 1977)(**1**).Ever increasing energy crises , increasing fuel crises, , busy schedules of load shading, unemployment in rural side of developing countries like India justify the need of human powered machines. Various parameters of these machines are optimized for easy operation by the operator and consequently make efficient use of human energy. In an attempt, this paper presents the exhaustive literature survey on the flywheel motor focusing on the numerous experimentation done on flywheel motor for optimizing its performance Corrugated box is a container(9) most extensively applied in goods packaging and transporting. It is made from paper, and machine-shaped from corrugated box board with hollow structure. Since 1903 when corrugated box was first accepted by legal freight classification organizations as the containers for freight transportation, the application history of corrugated box has been over more than 100 years. Because of its light weight, low cost, ease of assembly and disassembly, good sealing performance, certain cushioning and anti-vibration ability and easy recovery and waste treatment, corrugated box is widely applied in various fields.

## II. FLYWHEEL MOTOR

### *A.* Details Of Flywheel Motor:

Alexandrove 1981 stated that to power any machine by human energy, its driving power should be less than 75 watts but if any machine or process requiring more than 75 Watts and if process is intermittent without affecting and product, it can also be operated by human energy with the provision of intermittent energy storing unit such as flywheel (**3**). This stored energy is supplied periodically at required rate to process unit. This necessitates the use of flywheel in human energized machines and called as flywheel motor. From 1977 Modak J.P. and his associates are working on flywheel motor. A manually driven brick making machine was first of its kind in which manually energized flywheel motor is used for first time (**4**). Essentially the

flywheel motor consists of a simple bicycle mechanism, which drives flywheel by a human energy through pedaling and pair of speed increasing gears and clutch. (**3**). the schematic of flywheel motor with process unit is as shown in fig1.

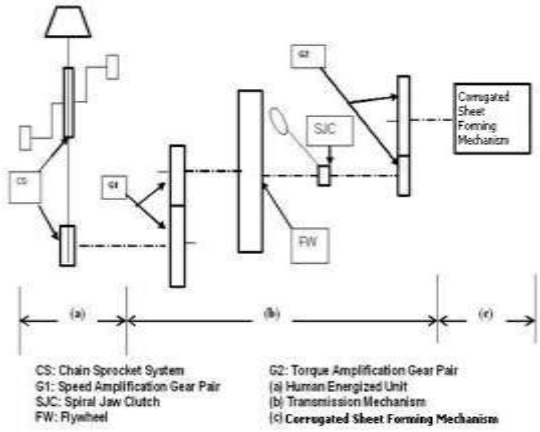


Fig.1. Schematic diagram of proposed mechanism for corrugated paper sheet making mechanism.

As shown in figure1 the mechanism „M" is energized by the rider by pedaling at big sprocket chain drive „BSC" there by converting the oscillatory motion of thighs into rotational motion of counter shaft „Cs". The pair of speed increasing gears connects the counter shaft „Cs" with the flywheel shaft „Fs" (**4**).Driver pumps the energy in flywheel at energy rate convenient to him (**4**). In this way, the muscular energy of human is converted i n t o kinetic energy and stored into flywheel by this man machine system and for its efficient use it is necessary to optimize its parameters (**4**).

*B. Perfromance Parameters :*

a.. The flywheel size and moment of Inertia:

The size of the flywheel and its moment of inertia also plays the vital role in the terminal velocity of flywheel. Modak J.P (1987) during the experimentation has observed that for the average person of 165 cm stature from age group 20-22 years m a x i m u m thigh oscillation is 40. (**5**). Therefore with the available chain drive for existing 22" bicycle frame the flywheel speed of 240 rpm was found appropriate enough from point of total speed rise from pedals to flywheel shaft (**5**). In order to store the maximum energy in flywheel irrespective of speed fluctuation, Modak J.P. (1987) has determined the size of flywheel (180-240 rpm) (**5**). During his research the Flywheel rim diameter is found to 82 cm which gives the weight of flywheel as 150Kg and 266 Kg for 240 rpm and 180 rpm respectively. Hence Modak J.P. (1987) suggested the flywheel with 150 Kg @240 rpm(**5**). Further Modak J.P. (1987) has also found that Moment of inertia has no effects on required driving torque at pedal and stores same energy for same frequency of thigh oscillation (**5**).

*b.Gear ratio :*

In order to provide the ease to operator it is necessary to reduce the harness effect of vibration and jerk at the process unit shaft. Hence Modak J.P. (1987) suggested the value of gear ratio as 4:1 so as to reduce the effect of jerk induced at process unit shaft as result of energy or momentum exchange during the clutch engagement. If lower value of gear ratio is to be used then flywheel speed should be maintained higher than 240 rpm (**5**).

c. *Improvement in Existing Bicycle Mechanisms*

For the efficient use of the system it is necessary to make maximum use of the human energy. But Modak J.P. has observed that among the 360° revolution of pedal only part of it produces the necessary useful torque. This is because of the limitation of existing bicycle drive .Modak J.P (1985) has established the relationship between the useful torque developed at the crank as function of crank position during its revolution (7).

Even when both the cranks are considered the useful driving angle is found to be 154°. (7).Consequently for improvement in maximum utilization of operators energy Modak J.P. suggested three modified mechanisms namely Quick return ratio one, Double lever inversion and Elliptical sprocket(**7**).Based on his mathematical modeling he concluded improvement of 18%,17%, and 38% in human energy utilization for Elliptical sprocket, Quick return ratio one, Double lever inversion and respectively. This performance of various bicycle drives then was experimentally verified by Modak J.P., Chandurkar K.C. (1987) and found almost matching with theoretical values (6).

## III. PAPER CORRUGATED BOX

*a.The principle of "light weight"*

Weight lightening of corrugated box can be realized through the selection and application of base paper, which is an important measure to achieve moderate packaging. This principle demands the selection of base paper characterized by low gram weight, high strength and weight lightening, which is mainly applied in the packaging of some large electrical household appliances and equipments. By considerably reducing the overall weight of the freight, it makes the handling and transportation more convenient. "Light-weight base paper" advocated currently has significantly lower gram weight of unit area of base paper than that of normal base paper, while its strength is comparable to that of normal base paper.

Therefore, this type of "light-weight base paper" will inevitably become the superior choice in the future. In 1950s, due to the backward development of China's paper making, the gram weight of box averaged between 320g to 360g, and the base paper used for the manufacture of export boxes and domestic sale boxes was of poor quality (12). There are

several opinions concerning the selection of "light-weight" base paper. According to one opinion, the ration of base paper should be as low as possible; while according to another opinion, there should be explicit requirements on the selection of "light-weight base paper", and at least one of the following three requirements, namely, processed by special techniques, manufactured by independent equipments, with gram weight of less than 150g, should be satisfied. There is a more widespread opinion: the ration of base paper should range between 100-180g/m2; indicators, such as ring pressure and breaking length should comply with certain standards (13).And, as to the aspects of base paper application in domestic, part of the electrical household appliances industry has adopted 3 layers of corrugated cardboard to replace 5 layer of corrugated cardboard previously used. For the outer and inner layer of corrugated cardboard, high-strength light-weight base paper is adopted, while for the middle layer, the high-strength corrugated cardboard. In this way, the consumption quantity of boxes was reduced tremendously, but with equal strength.

b. *High-strength corrugated honeycomb composite board*

High-strength corrugated honeycomb composite board in divided into two types, namely, laminated board of corrugated cardboard and honeycomb board, and composite board of corrugated honeycomb board (14). The laminated board of corrugated cardboard and honeycomb board is manufactured by arranging several pieces of continuous corrugated core papers cut into certain width in a parallel and vertical manner. Then waveform dislocation sticking is performed to form a structure similar to honeycomb (not a perfect hexagon), which is then glued to outer tissue and inner tissue. The corrugated core paper layer and flat paper layer are parallel to each other and glued together, with the prism perpendicular to the outer layer. For the corrugated honeycomb composite board glued together of more than two layers, the arrangement orientations of adjacent corrugated cardboard layers can be deviated from each other with a certain included angle (15). Since the corrugated core is "half-hardened", this type of high-strength corrugated cardboard has superior stiffness than honeycomb board, but its transverse stiffness is slightly lower than honeycomb. The board manufactured by this method is firm in overall structure, with high strength along various directions and balanced performance. Its load bearing capacity, pressure resistance, anti-rupture strength and cushioning performance have been significantly improved. Therefore, it proves to be an excellent substitute material for wood. The compressive strength as principle technical performance indictor of this high-strength corrugated composite box is as follows: when the pressure is 10560N, residual deformation ≤17.6mm [16]. When this high strength corrugated composite box replaces wooden box, not only its appearance and printing has been improved, but more importantly, it satisfies the environmental protection requirement, at a remarkably reduced cost.

*c.* Intensified sandwich corrugated cardboard

Intensified sandwich corrugate paper is called "corrugated cardboards of corrugation". Generally, two, three or five layers of corrugated cardboard are used as outer paper and inner paper (board), between which corrugated cardboard or corrugated paper-tube specially arranged is sandwiched to form wave-type sandwich layer (17). Reasonable structural design endows the intensified sandwich corrugated board with high strength. It is measured through testing that the total thickness of the board is 3.2cm (adjustable at will); corrugation density of sandwich layer is 38-40 prism/m; there are five layers of ordinary corrugated cardboard (C prism B prism) as outer layer(ration 780g/m2); three layers of ordinary corrugated cardboard(C Prism) as inner layers (ration 470g/m2); three layers of ordinary corrugated cardboard (B prisma) as sandwich layer(ration 680g/$m^2$ ), with a total ration of 1900-2000g/$m^2$[18] "Corrugated cardboard of corrugation" is an application of the mechanical principle of multi-azimuth support. It is made of high strength corrugated cardboard, which is deformed and arranged by special technique to form optimal mechanical structure. It can be applied in the manufacture of the packing box of six facades, by forming strong tubular matrix. Its superiority is mainly manifested in its ability to prevent damages to the objects contained in the box, especially for the packaging of large-volume, heavier, fragile and pressure susceptibility items. Moreover, because of its compact structure, seamless, absence of nails, fold ability and forming ability, the overall packaging cost can be reduced by about 30%, and its appearance and integrity are also improved. Therefore, this kind of structure is very applicable for the packaging and transportation of large electrical household appliances and electromechanical equipments.

d. *Network-structured corrugated cardboard*

The inner layer of network-structured corrugated cardboard is made of corrugated paper. The adjacent corrugations are perpendicular to each other or at certain angle, and the lattice network is formed by adhering the prisms at the intersection points between corrugations. The layer number is determined according to specific need, and the network-structured corrugated cardboard and its products are obtained by covering it with cardboard. In contrast, the corrugated cardboard and its products of conventional structure have good performance in bearing the load along the direction of prisms. However, its load bearing capacity

along other directions is relatively poor. By modifying the original structure of corrugated cardboard, the good load bearing capacity along the prism direction is fully utilized. Its impact resistance and flexibility, as well as its overall load bearing capacity, i.e. anti-puncture capacity, impact resistance, ring pressure resistance, and edge crush strength, can be improved by increasing its thickness. Since corrugated paper is used to replace the original sandwich paper, the weight is reduced while its thickness is increased. Therefore, anti-puncture capacity, pressure resistance, ring pressure resistance, edge crush strength and flexibility are improved. If applied to the design of five-layer corrugated cardboard, this method can save 296g of paper per square meter of cardboard, with a 13% reduction in cost. Moreover, the cost and freight charges are lowered, and labor intensity of transport workers is also lessened.

## IV. OPTIMISATION OF VARIOUS PARAMETERS IN FLYWEEL MOTOR

Because of the wide range of applications the flywheel motor is being the constant subject of researchers for the performance improvement of the system through parameter optimization. For this various experimentation is done on the flywheel motor. To determine the various dynamic responses ,Modak J.P. and Bapat A.R.( determine the various dynamic response such as force exerted on pedal/crank, measuring crank angle w.r.t. frame, measuring angle between pedal w.r.t. ground, Human input energy measurement (R). Modak J.P. and Bapat A.R. (1994) formulated generalized experimental model for flywheel motor (16). They established the functional relation between the terminal angular velocity (W) and other dependent variable such as moment inertia (I), Gear ratio (G), Human input energy (R), Effectiveness of mechanism ($E_M$). From this functional relation, for a particular time period of oscillation (T), the terminal velocity at the end of pedaling can be determined. (16)

Further during experimentation Modak J.P. and Bapat A.R. (1994) also find the variation of terminal velocity (W) with G, I, and $E_M$. Determined the valued of G, I, and $E_M$ depending upon the objective of study which are shown in table. (16)

| Obj. Funct. | I(Kg/m ) | $E_M$ | G |
|---|---|---|---|
| Max WT | 0.25<br>5 | 1 | 4 |
| Max Energy | 0.25<br>5 | 1 | 4 |
| Max Effectiveness | 0.255-1.061 | 1 | 2-4 |

Modak J.P. and Bapat A.R. (**1**) conducted experiments for various combination of m o m e n t of inertia (I) & (G)and determined the variation of pedal force ($F_t$) with position of crank angle. Modak J.P. and Bapat A.R. (**1**) also found that of moment of inertia (I) of flywheel should not between 1.4 to 2.4 Kg/$m^2$ because during this variation pedal force ($F_t$) and load torque to overcome has a maximum value. Furthermore in order to minimize frictional losses the gear ratio (G) should be taken 3.8 and moment of inertia (I) should 1.06 Kg/$m^2$.

## V. OPTIMIZATION OF OVERALL DESIGN OF CORRUGATED BOX

Design optimization refers to the optimization made by designers according to the theory of meeting specific properties, so that different configuration complying with new standards will be obtained

a. *Forming Process.*

The forming process of corrugated boxes has significant impact on the quality of corrugated box. Groove, slotting, printing, and gluing all need to be optimized in actual operation. First, the strength of corrugated box is associated with the width and depth of press mark line of cardboard. Excessive width and depth of press mark will lead to the rupture of inner paper; while insufficient width and depth lead to the non-fundability of the corrugated box. Therefore, investigation has to be made into the groove process of corrugated cardboard, so as to determine the optimal operational parameters. Second, the printing process is another factor affecting the load bearing strength of corrugated box. Research shows that with the increase of printing pressure, the contraction and deformation will occur to corrugated cardboard; its compressive strength declines until the crush of the corrugated box. It is thus necessary to adopt the smallest printing pressure possible while ensuring good printing appearance. Third, the slotting and gluing process optimization also need exploration, since the compressive strength of corrugated box dramatically decreases with the deepening of the slotting; inadequate dosage of adhesive leads to the weak cohesion. As a result, adhesive failure is very likely to happen under pressure, leading to crushing and the decline of compressive strength. On the other hand, excessive dosage will bring about glue overflow, which affects the appearance of the products; or, it will result in cohesion between corrugated boxes, with a waste of production cost (22).

*b. Optimization of size and proportion*

To ensure moderate packaging, the arrangement number and arrangement orientation of the packaged commodities, as well as the internal and external size of the corrugated box can be optimized during the transportation(23) (24). In actual

practice, various kinds of cushioning pads are placed inside the corrugated box to prevent the packaged commodity from being damaged. By this means, the volume of commodity after packaging is usually larger than that of the commodity itself, sometimes by 5-10 times. In this case, prodigious waste is incurred with a several-fold increase in consumption quantity of corrugated cardboard. Therefore, much can be done in reducing the size of corrugated box in accordance with the reducing principle of corrugated box (25).

## VI.CONCLUSION

Thus the exhaustive literature survey on flywheel motor with its process unit is carried out. Firstly it was developed for the manufacturing of lime fly ash bricks later on various applications is developed such as chaff cutter, potters wheel; forge hammers etc .Because of its numerous advantages flywheel motor is finding the importance in the rural side of developing countries like India. And hence it is necessary to optimize its performance parameters. In an attempt lots of experimental and numerical models are developed which are already discussed. The effect of multiple operators with alteration in the mechanisms s u c h as gear ratio can also be analyzed as future work for the flywheel motor.

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