Application of Jaw Type Flexible Clutches in Human Powered Machine: A Literature Review

Nitin Sawarkar1, *, K S Zakiuddin2, Roshan Umate3, Rajkumar Chagde4

1, 2Department of Mechanical Engineering, Priyadarshini College of Engineering, Nagpur, Maharashtra, 440019.
3 Jawaharlal Nehru Medical College, Datta Meghe Institute of Medical Sciences, Nagpur, Maharashtra
4 Department of Mechanical Engineering, Yeshwantrao Chavan College of Engineering, Nagpur
*Corresponding Author E-mail: nitinsawarkar304@gmail.com

Abstract. This article presents the topical progresses in the arena of an approach to articulate an experimental databased model for jaw type flexible clutches. The developing countries are facing very acute problems of the energy crisis. It has become essential to use human energy for energizing the manufacturing process machine. This kind of machine necessitates a flexible clutch for torque transmission. Due to the intricate impact phenomenon, flexible clutches cannot be deliberate without experimental data. Therefore, the experimentation methodology and experimental setup to evaluate the performance of torque transmitted by the clutch have been augment. It is obliging for selection of the optimum clutch-type for various applications in low powered processing machines. This study of analysing suitable material can be useful for the comparative study of Jaw type flexible clutches and their transmission ability. Mathematical model and Artificial Neural Network (ANN) development are essential, to evaluate the belongings of altered components and to make forecasts about behaviour.

Keywords. Jaw Type Flexible Clutches Torque, Human Energy, and Artificial Neural Network.

1. Introduction

In today's industrial environment, equipment system designers are exacting higher speed, torque, transmission efficiency, greater flexibility for clutches. As the technology advances, the need for flexible clutches is becoming more and more acute. Clutches used in engineering machineries to connect or disconnect the cause of influence [1]. It used in machineries for transmission of speed and torque. The researchers have executed the analysis of the various type of clutch, but a comparative study of Jaw clutches and their transmission ability not yet been studied. Therefore, this research mainly focused on Jaw Type Flexible Clutch (JTFC) and requisites torque output. The benefit of JTFC are having optimistic engagement and can transfer great torque with no-slip, when united [2]. Which impart in no heat generation during operation. The precise machining of teeth on two splits to ensure perfect contact stretches an adequate operation of the JTFC. Friction clutches are moderately greater as compared to JTFC for the same power transmission [3]. The spiral and square JTFC comprise of sloping and square teeth respectively, which lock into mating recesses in pebbledash members. The Experiments carried out on the setup for various values of load torques and observations fed to the computer by using the instrumentation system. The experimentation performed by changing
independent physical quantities and responses gathered, to generate design data by performing experimentation involving independent parametric variation. Due to the nonlinear structure and intricate phenomenon, Artificial Neural Network (ANN) development is necessary [4, 27]. The significance of this grid decided by relating the output from the network with output from the mathematical model and experimental response as per the observed data.

2. Material And Methods
The material selection is significant for any potential concerns that definite materials may present. This will make the process of engineering design analysis easier in the culmination. Tirasuntarakul [2] developed a micro triggering device, which used a single motor to drive multi degrees of freedom. The torque transmission is vital in the progression. The magnetic jaw clutch is designate to create high conceivable torque and bi-directional rotation of the module. To control the operation of the magnetic jaw clutch used a controller design. Experimental setup is required to determine the accurate results of output torque. Overrunning clutches can also be used in various application if requires one direction torque transmission.

Yusuke [3] developed, “a single degree of freedom combined drive mechanism using regenerative servo clutches”. This is consists of a regenerative brake and a differential gear mechanism. It can control the transferred torque by regulatory the regenerative brake torque. The main factor of the dynamic condition is the output torque imposed. Whereas Jaw type flexible clutches provides both directional torque transmission. It is compact in size and low cost as compared with an exploited clutch.

2.1. Human Powered Flywheel Motor
Human Powered Process Machines for several rural-based production activities developed by Chandak [4] as shown(Fig.1). The evolved machine system comprised of an energy entity, clutch, torque escalation gear-pair, and a process unit.

![Diagrammatic Arrangement of a HPFM](image)

In this comparison between neural prediction and empirical prediction with experimental findings has carried out. According to him, clutch plays an important role in Human Powered Flywheel Motor and various low powered machines. No-slip occurs during power transmission therefore, no heat generation during the operation. A comparative study of these types of clutches can provide inheritance while selecting a clutch for essential torque output.

2.2. Selection of Dependent and In-dependent Variable
According to Mishra and Srinivasan [5], “clutch-to-clutch shifts are existing in automatic transmissions, motivating the need for formal and robust methods for controlling these shifts”. The off-
going clutch controlled to imitate a one-way clutch, which ensures reduced overall variation in the output shaft torque and smooth coordination of the two clutches, during the torque phase. Thereafter the oncoming clutch is control to ensure subsequent driveline oscillations, engagement at lock-up, and ensuing in a reduction of shock. The shift control intentions encountered by the proposed valuation and control strategy in the presence of significant model uncertainty. Thus, validating the practical effectiveness and robustness.

The Dependent and independent variables play avital role while designing a mathematical model for the clutch. The various independent and dependent variables identified for the designing and formulation of a mathematical model for jaw type flexible clutch listed in table 1.

| Sr. No | Description                     | Variable Type | Symbol | Dimensions   |
|--------|---------------------------------|---------------|--------|--------------|
| 1      | Load Torque (T_L)               | Independent   | N-m    | ML^2T^-2     |
| 2      | Speed of Shaft (n)              | Independent   | rpm    | T^-1         |
| 3      | Length of Jaw (L)               | Independent   | m      | L            |
| 4      | Width of Jaw (W)                | Independent   | m      | L            |
| 5      | Depth of Jaw (D)                | Independent   | m      | L            |
| 6      | Diameter of Hub (d)             | Independent   | m      | L            |
| 7      | Modulus of Elasticity (E)       | Independent   | N/m^2  | ML^-1T^-2    |
| 8      | Radius of Jaw measured from the center (r) | Independent | m | L |
| 9      | Acceleration due to Gravity (g) | Independent   | m/sec  | LT^-2        |
| 10     | Bearing Friction Constant (b_F) | Independent   | -      | ML^2T^-1     |
| 11     | No of Jaw (N)                   | Independent   | -      | M_0L_0T_0    |
| 12     | Period of Operation             | Independent   | sec    | T            |
| 13     | Input Power (P_i)               | Dependent     | watts  | ML^2T^-3     |
| 14     | Driving Torque (T_d)            | Dependent     | N-m    | ML^2T^-3     |

To find the optimum shape constraints that deliver the mark stiffness curve, the shape optimization is important. After solving the optimization problem with the differential development method, optimum shape parameters of the cushion disc had found for N. Kaya et.al. [6] and Martin Steinberger et.al. [7], two case studies. Continuous variable transmissions play an important role in mechanical systems. Oday I. Abdullah et.al [8] states that in the process of power transmission, clutch is a necessary factor. It is essential to investigate the stresses of the clutch to avoid failure. The effort presented deformations during the steady-state period of the rigid clutch disc and the mathematical modelling of computing the stresses. In this research, response equated to the reference model and new model intended. The numerical results showed that by adjusting design parameters, the stresses of the clutch could be control. Zakiuddin et.al. [9], worked on The Pedal Operated Energized Flywheel Motor. “It has established functional feasibility and economic viability of pedal-powered process machines of 3 to 7 h.p. capacity”, evaluated in their study.

According to the investigation, an experimental setup is required to determine the accurate result due to complexity in design. Rothabart [10] and Schenck [11] proposed a classical plan of experimentation, by which the experimentation mainly carried out. In such a plan all but one of the independent terms
are to be maintain at their planned fixed level values and said the independent term is to be varied over its wide range as decided by the test points, taken one at a time. Jaw clutches also called a positive clutch because of the positive engagement between two parts of the clutch. It is useful for driving in both directions. The design of the Jaw clutch should base on strength consideration. Cast Iron is mainly use as a good quality material for this type of clutches [11].

2.3. Assortment of Artificial Neural Network Paradigm for Experimentation
According to ANN study paradigm[12-15], in the field of mechanical engineering, ANN has extensive application. From the origin of the mechanical engineering arena to the manufacturing, machine design, and operation, ANN technology is ubiquitous. Due to the hasty evolution of technology, mechanical engineering is extensively considered as a basic chastisement in the routine life. However, the technology based on mechanical engineering has several disadvantages such as the inconsistent system. The AI can promptly exchange the input and it can process it in a timely manner such that the output is not pretentious. It can also make meritorious verdicts for this defect. It is recognized that selecting a proper ANN parameter plays a significant role in verdict. The artificial neural network designated parameters are, coatings in the network, neurons, training approaches, learning procedure, transfer functions used, and performance function.

2.4. Experimentation System
Modelling of performances of such systems over Artificial Neural Networks comprises the routine of the above paradigm applicable. All the network factors have their own choices of parametric statistics [18, 20]. It is significant to differ a single parametric figure of associated network parameter for respective set of experiment, keeping all other figures of ANN parameters constant, to perceive the effect of parametric value, the subsequent parameter on ANN prediction [15-17].

3. Experimental Model to Investigate Jaw Type Flexible Clutches
For accurate engagement, two halves on the shafts is essential to mounting appropriately [23]. It requires greater exactitude in machining compared with toothed disks for trouble free meshing [24]. The engagement causes noise and fierce shock due to metal contact. JTFC clutch is consists of two robust disks with jaws that can apt with each other. The right part is fastening to the input shaft and other mounted over load shaft. Motion could be transmitting by direct intervention between the projections on parts of the clutch.

![Figure 2. Schematic Representation of Experimental Setup](image)

The Energy Unit consists of Electric Motor and Speed Control Unit on the left side of the setup as shown (fig. 2). The Input Shaft (IS) had connected with the Energy Unit. The Load Shaft (LS) has mounted on another side of the system. Both Input and Load Shaft has supported with the Bearings. Input Shaft and Load Shaft connected through Jaw Type Flexible Clutch (JTFC). The clutch consists of Two Parts. The first part attached to the driving shaft (Input shaft) and another attached to the driven
Shaft (load shaft) which consists of a jaw integral with the outer periphery. The Hand Lever mounted on the one part of the clutch to engage and disengage the Input and Load Shaft. The Speed in rpm selected as a first fixed independent term. As per the experimental plan, the load torque will be varied over its range [29]. Similarly, the experimentation performed for different levels of speed. This Process repeated for testing various Jaw Type Flexible Clutches [30].

4. Result and Discussion

“The clutch failed when the perilous load was reached and the beam buckled” [1]. Occurrence of the clutch dynamics is having non-linearity so the model formulation done using an artificial neural network to curtail the imprecision [25]. The output of this network evaluated by comparing it with the mathematical model intended data and the experimental data. ANN model can work very meritoriously for problems approximation. Requires more iterations, exercise and simulation time with the higher neurons size while lower size of neurons gives a deprived performance of the network in the hidden layer. This leads to result in overfitting thereby governing the forecast of ANN. Consequently, in the hidden layer optimum value of neuron size selection is protuberant. “For Human Powered Flywheel Motor with three independent variables, the neuron size of 50 originate to be optimal” [4]. According to Oday I. Abdullah [8], von mises stresses induced in the clutch disc which is ranges from 163.6 to 421.6 n/mm² for 0.040 to 0.187 mm displacement respectively. “The corresponding values of reliability and coefficient of determination for Human Powered Flywheel Motor of the proposed ANN model is found to be 96.68% and 0.95 respectively”[4]. The stiffness of the clutch plays an important role in part life. The stiffness ranges from 0.0023 to 0.124 mm has been analized by N. Kaya[6]. By taking these all factors into consideration final model has been formulize for analysis.

The evaluations have been made for two jaw clutch assembly with three material. The comparative study of structural steel, grey cast iron and stainless steel is as following.

Table 2. Results of Two Jaw Type Flexible Clutch Assembly with three type of materials.

| Type          | Total Deformation | Stress     |
|---------------|-------------------|------------|
| **Results (Structural Steel)** |                  |            |
| Minimum       | 0. mm             | -249.93 MPa|
| Maximum       | 0.60127 mm        | 245.69 MPa |

| Type          | Total Deformation | Stress     |
|---------------|-------------------|------------|
| **Results (Grey Cast Iron)** |                  |            |
| Minimum       | 0. mm             | -246.83 MPa|
| Maximum       | 0.34774 mm        | 242.85 MPa |

| Type          | Total Deformation | Stress     |
|---------------|-------------------|------------|
| **Results (Stainless steel)** |                  |            |
| Minimum       | 0. mm             | -249.93 MPa|
| Maximum       | 0.60127 mm        | 245.69 MPa |
According to the Fig.3, Grey Cast Iron (GCI) is having less deformation. As per shear stress result, there is no much variation. But GCI is having better results than other two. With the experimental data of a JTFC, the model analysed qualitatively for variables like driving torque and torque transmission efficiency. During experimentation, an attempt has made for the quantitative analysis of the model for all response variables. Model represents the degree of interaction of numerous independent variables. The torque transmission efficiency varies with load torque but varies contrariwise with the speed of the clutch shaft. The load torque greatly varies by the independent variable like input power and driving torque. This experimental setup will also be useful for testing any type of clutch by some trifling variations.

5. Conclusion
The various type of Clutches used for various applications in the industry [2]. The analysis of the various type of clutch has been executed by the researchers [29, 30] but a comparative study of Jaw clutches and their transmission ability not yet been studied. In a conventional loom mechanical clutches used on main shaft of the machine. Until the motor attains its required torque and speed, the drive to the loom is disengaged. Similarly, Feed roller drive on a card, Yarn under winding in ring spinning, Lap roller drive on sliver doubling machine, etc. As far as the Mechanical type of Flexible Clutches is concerned, they have some obvious shortcomings such as a) While transmitting torque, the clutch should not absorb more energy, b) Impact phenomenon is very complex and hence cannot studied without experimental data [5].
It is quite possible to overcome the shortcoming. Thus, Jaw Type Flexible Clutches considered as the better option among the other [26, 27]. Experimentally it established the functional viability of various possibilities for these clutches. Therefore, it decided to generate design data to analyse the Jaw type of flexible clutches by performing experimentation involving independent parametric variation. Mathematical model development is essential, to study the properties of different components, to explain a system and to make predictions about performance. Formulation of design-databased model for jaw type flexible clutches has augmented. The Models if one optimizes then for minimization of responses, the best set of designed variables would accomplish.

References

[1] Gregory M. Roach, Larry L. Howell, Evaluation and Comparison of Alternative Compliant Overrunning Clutch Designs, Journal of Mechanical Design, Transaction of ASME, Provo, Utah, Vol.124, pp.485-491, 2002.
[2] Narongsak Tirasuntarakul, Arbitip Dheeravongkit, Torque Analysis of a Micro Actuating Mechanism Driving Multi Degree of Freedom via Single Motor, 3rd International Conference on Control, Automation and Robotics, IEEE Transaction, 978-1-5090-6088-7117, pp.529-532, 2017.
[3] Yusuke Sugahara, Kensuke Kikui, Mitsuru Endo, Jun Okamoto, Daisuke Matsuura, and Yukio Takeda, A Human-Powered Joint Drive Mechanism Using Regenerative Clutches, RSJ International Conference on Intelligent Robots and Systems (IROS), IEEE Transaction, 978-1-5386-2682-5, 6337-6342 Vancouver, BC, Canada, 2017.
[4] Pawan Chandak, Arati Lende, Jayant Modak, Modeling of Human Power Flywheel Motor through Artificial Neural Network-A Novel Approach, Elsevier, Procedia Computer Science, 125, pp.77-84, 2018.
[5] Kirti D. Mishra, K. Srinvasan, Robust Control and Estimation of Clutch-to-Clutch Shifts, Elsevier, Control Engineering Practice, Vol.65, pp.100-114, 2017.
[6] N. Kaya, S. Kartal, T. Cakmak, F. Karpat, A. Karaduman, Shape Optimization of Clutch Cushion Disc Using Differential Evolution Method, Proceedings of the ASME, International Mechanical Engineering Congress and Exposition, Houston, Texas, pp.1-9, 2015.
[7] Martin Steinberger, Christian Milwisch, Walter Rosinger, Martin Horn, A clutch-based transmission for mechanical flywheel applications, Proceedings of the 19th World Congress, The International Federation of Automatic Control Cape Town, South Africa. August 24-29, 2014.
[8] Oeday I. Abdullah, Josef Schlattmann, Emir Pireci, Optimization of Shape and Design Parameters of the rigid Clutch Disc Using FEM, FME Transactions, Vol.41, No.4, pp.317-324, 2013.
[9] K.S. Zakiuddin, J.P. Modak, Application of pedal operated flywheel motor as an energy source for fodder chopper, International Journal of Agricultural Engineering, Vol. 3 No. 2, pp.251 -256, 2010.
[10] Mechanical Design and System Handbook, Second Edition, by Harold A. Rothabart, Published by Mac-Graw-Hill Book Company.
[11] Hilbert Schenck, Jr., Theories of Engineering Experimentation, McGraw Hill Book Company, New York, USA, 1961.
[12] S. N. Shvanandam, S Sumathi, and S. N. Deepa, Introduction to Neural Network using Matlab 6.0, 2017, McGraw Hill publisher.
[13] Stamiotis V. Kartaplopoulos, Understanding Neural Networks, and Fuzzy Logics, 1996, Wiley-IEEE Press, ISBN: 9780470546826.
[14] Neural Network Toolbox TM 7 User’s GuideR2010a.
[15] P. A. Chandak, A. R. Lende, J. P. Modak, A literature review on fundamentals & methodology of development of mathematical model through artificial neural network, International Journal of Computer Application, Issue 4, Volume 1, 2014.
[16] S. M. Sheikh, K. S. Zakiuddin, History of Human Powered Oil Expeller: A Literature Review, Springer Nature Switzerland and A G, B. Zhang and M. Ceccarelli(Eds.): Explorations in the History and Heritage of Machines and Mechanisms, HMMS 37, pp. 77–88, 2019.
[17] M. Sohail Pervez, K. S. Zakiuddin, Literature Review on the Development of Rice Milling
[18] Siraj Mohamad Ali Sheikh, Zakiuddin Syed Kazi, Design & Development of Human Energized Oil Expeller Machine, International Journal of Recent Trends in Engineering & Research, Volume 02, Issue 06, pp.342-345, 2016.

[19] J.J.Bos, J.Mangus, N.Bellamy, A Comparison of Clutch Types for Naval Propulsion, ASMETurboExpo2018, Turbomachinery Technical Conference and Exhibition GT 2018, Oslo, Norway, pp.1-8, 2018.

[20] V.N.Bhaiswa, J.P.Modak, M.P.Singh, Dynamic Analysis of Lobe Coupling by Formulation of an Approximate Generalized Experimental Data Based Model, International Journal of Scientific and Research Publications, Vol.01, Issue 01, pp.1-5, 2011.

[21] Yonggang Liu, Datong Qin, Hong Jiang, Yi Zhang, A Systematic Model for Dynamics and Control of Dual Clutch Transmissions, Journal of Mechanical Design, Transactions of ASME, Vol.131, pp.061012, 1-10, 2009.

[22] Jignesh Patel, Kausral Ajmera, Raghav Thanki, Rohit Maitar, Design and Theoretical Analysis of Single Plate Clutch by Varying Friction Lining Materials, International Journal of Advance Engineering and Research Development, Vol.2, Issue 11, pp.68-72, 2015.

[23] Shakebuddin M, Khandelwal K.K, Langde A.M, Hussain H., Experimental Data Based Model for Process of Manufacturing Utensils Using Human Powered Flywheel Motor as an Energy Source, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X, 14-16, 2014.

[24] M. Sohail Pervez, K. S. Zakiuddin. "Chapter 8 Literature Review on the Developments of Rice Milling Machines", Springer Science and Business Media LLC, 2019.

[25] Harrsh Kumar Dubey, M.P. Singh, J.P. Modak, Rahul Makade, "A review on the advancement of human powered flywheel motor (HPFM) in India and its application for rural empowerment", Materials Today: Proceedings, 2020.

[26] Yusuke Sugahara, Kensuke Kikui, Mitsuru Endo, Jun Okamoto, Daisuke Matsuura, Yukio Takeda. "A human-powered joint drive mechanism using regenerative clutches", 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2017.

[27] "Computing in Engineering and Technology", Springer Science and Business Media LLC, 2020.

[28] "Advances in Mechanism and Machine Science", Springer Science and Business Media LLC, 2019.

[29] Pranav R Morchapure, KS Zakiuddin, Nitin S Sawarkar, “Investigation of Flexible Clutches Over a Wide Range”, Int. Journal of Innovations in Engg. and Science, Volume 5, No.10, pg.15-19, 2020. DOI: 10.46335/IJIES.2020.5.10.4

[30] N S Sawarkar, K S Zakiuddin, O Noman, P Palsodkar, “Analysis of Three Jaw Type Flexible Clutch”, Zeichen Journal, Vol.6, Issue 11, pg.180-188, 2020.