Ashok Kumar Prasad, 2024, 12:6
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology

An Open Access Journal

Development of a Simplified Mechanical Bale Making Machine Using Raw Jute

Ashok Kumar Prasad[1], Subrata Kumar Mandal[2], Atanu Maity[3], Arun Baiju V.G[4], Avi Chakraborty[5], Anindya Majumdar[6]

CSIR-Central Mechanical Engineering Research Institute, Durgapur, India[1,2,3,4,5]

Jute Corporation of India Limited, Kolkata, India[6]

Abstract- The raw jute plays an important role for the socio-economic and ecological condition of India from long time since when the people uses these products for their different purpose. It is bio-degradable and recyclable in nature having unique characteristic of absorbing atmospheric CO2 and releasing O2 gas to atmosphere, this will helps a lot for the purification polluted air. The bales obtained from raw jute were usually transported to the mills and warehouse for stacked used for production purposes. Considering all the drawback of the existing machine, compact size, manually operated bale press machine has been designed and developed at CSIR-CMERI. The basic requirement of stress analysis and effort has been calculated with reference to the capacity of the male adult worker. The required effort to rotate the handle is 190N, and as per design calculation the value obtained is 215.82N as the force applied workers. The equivalent stress and maximum shear stress was calculated based on the applied efforts it comes to around 114MP and 65 MP respectively also the value of analysis of von-Mises stress comes to 428MPa. Hence it is found that from the calculated values obtained the lead screw and the body structure is found to be under safe condition.

Keywords- socio-economic, recycle, Bale press, Effort, Power screw, Stress, analysis

I. INTRODUCTION

Jute is a rain-fed crop with a requirement of very little amount of fertilizer or pesticides. The manufacturing is focused in basically in Bangladesh and India, in India it is spread in the state of West Bengal also in some other states. The jute fiber mainly comes from the stem and ribbon (outer skin) of the jute plant the fibers were then manually extracted after retting. India, Pakistan, and Chinaare are the massive shoppers of neighborhood jute fiber, while Britain, Spain, Ivory Coast, Germany and Brazil import uncooked jute from Bangladesh. The literature survey says that India is the world's biggest producer of jute fibre. The Jute is an important natural fibre for the cash crop in India, next to cotton with respect to its use. Jute is a natural fibre and mostly grows in the Ganges delta region of Bangladesh, China, Myanmar and Thailand and India. As per the study it is found that the cultivation of jute fibre in these regions are presently decreasing day by day. The solution of these decrease in production non scientific cultivation, so its production could be enhanced by the application of new scientific method of cultivation and also production of diversified jute items to catch the market1. In exchange and industry jute crop is recognized as raw jute and it performs a vital function in the country's economy2.The raw jute was originally considered as a source for most of the packaging industries. But it has now emerged as a versatile cloth for numerous applications, such as fabric industries, paper industries, construction, and automobile industries it can be used as a soil saver and furnishing cloth

etc. The Jute is considered to be bio-degradable in nature and also as a renewable resource. It is regarded as an environment friendly crop and it helps in maintaining the surroundings and also ecological balance. Now-a-days, the entire world is concerned about the control of environmental air pollution and ecological degradation. For this they are trying to relocate out an actual answer to mitigate these problems. As an answer, it is observed that more use of natural fibers like raw jute will clearly assist in improving the prospect of the crop in future. The demand of Jute lies in its availability, inexhaustible volume and at a comparatively less cost-effective than any other similar materials. The jute has a special property that it can be easy blended with other natural and artificial fibers. Hence it may be stated that, in future the jute will be the only substitute materials in place of plastic in many countries. The research is being carried out on independent review of Bangladesh Development which focuses on economic, technological as well as workers related issues3. The production rate of Jute in West Bengal areas is very high and it is having very good demands in the entire world due to its better quality4.The Jute Corporation of the India (JCI) has been

Involved in collection of raw jute and processed this raw jute using the bale press making machine to convert it into bale for ease of transportation and stacking in the godown. The finished jute bales are then transported to the different parts of the country as per the requirement.

As per the survey it is found that the Jute Industries in India are using very old machines to convert the raw jute into final bales. The machine which is being used is very cumbersome, requires more efforts as manpower and more manpower to make a complete bale within a predefined size and shape. The operation of bale by using the old machine is completed in two stages, so it consumes more time and hence the rate of production is low. Thus, there is a need for the development of a new bale pressing machine, which will be easy to operate, the operation could be completed in a single machine, requires less manpower and maintenance cost. This will definitely helps in boosting up the operator of the bale making and also enhance the living standard of the workers.

II. PROBLEM DESCRIPTION AND WORKING OF THE DEVELOPED MACHINE

India is the biggest manufacturer of raw jute and jute products; it stands the second position in exporting after Bangladesh. Average production of raw jute is approximately between 45 lakh bales bales per year. There are about 70 working jute mills at present in India; most of them are situated in West Bengal.

The processing of raw jute to bale making is a step by step process which requires a dedicated specialized bale making machine. The typical stages to convert the raw jute to a complete bale involves the following steps first collection of raw jute from the field, then filling of raw jute in the machine in a rectangular chamber or box, when the complete raw jute is filled up then it is pressed by applying the required pressure through a piston on the raw jute by mechanically rotating the handle in clockwise direction. After applying the pressure when the required size is reached then the next steps is to create the knotting operation throughout the bale for 8 tines, after the completion of knot the piston is slowly released by reverse rotating the handle.

The bale is now ready and it is taken out by opening one side door. Using the available machines at JCI, to complete the same process requires more manpower and time consuming. Considering these issues a new machine has been designed and developed at CMERI, Durgapur, it is basically horizontal type and mechanically operated. Here the pressure to compress the raw jute is being applied by revolving the handle through screw jack mechanism and all the operation are completed in a single setup.

III. MATERIALS AND METHODS

1. Calculation of the Force Requirement for Pressing Operation

The maximum force applied by person for rotating the handle attached with the screw jack to move the pressing head forward to compress the jute fiber is calculated by using the formula as shown in Fig.1.The relevant data are given in Table1

Fig.1 Standard Table for the calculation of force for compressing

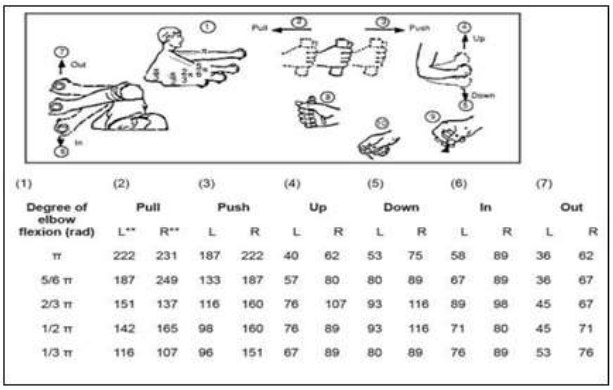
Table1: Force calculation data

Sl.No	Specification	Value
01	The compressive force to press the raw jute	5Ton
02	Mean diameter	60mm
03	Pitch of the thread	9mm
04	Gear Ratio	0.85
05	Type of thread	Trapezoidal
06	Pressure angle	14.5^0

Based on the above calculation it is found that the required max force exerted by one person for rotating the wheel is equal to 190.6 N. Hence considering for two workers to rotate the handle simultaneously to move the pressing head forward along with the power screw, the total force required will be equal to 381N. from the calculation the required comes to around 381N, hence it can be said that the value of calculated force is found to enough for rotating the handle easily to move the pressing head forward for pressing the raw jute to convert it into bale from raw jute.

Selection of Human Hand Pressing Capabilities

The Fig.2 shows the typical strength of applied by a human with respect to force exerted by the arm, hand and thumb/finger together. It is clear from the figure that the magnitude of force applied by hands in upward and downward direction is different. The right hand usually exerts a force of about 62 to 107N in upward direction where as 75 to 116N in the downward direction. The similar case is with left hand also. Thus it may be clear that the selected force is sufficient by two workers together in rotating the handle, and this rotational movement will be enough to convert it into linear movement i.e in forward or reverse direction of the lead screw which will be utilized to compress the raw jute fiber to convert it into a finished bale.



(1)	(2)		(3)		(4)		(5)		(6)		(7)	
Degree of elbow flexion (rad)	Pull		Push		Up		Down		In		Out	
	L**	R**	L	R	L	R	L	R	L	R	L	R
π	222	231	187	222	40	62	53	75	58	89	36	62
5/6 π	187	249	133	187	57	80	80	89	67	89	36	67
2/3 π	151	137	116	160	76	107	93	116	89	98	45	67
1/2 π	142	165	98	160	76	89	93	116	71	80	45	71
1/3 π	116	107	96	151	67	89	80	89	76	89	53	76

Fig.2 Arm, Hand and Thumb/Finger strength (5th percentile Male data)

IV. DESIGN AND ANALYSIS OF THE MODEL DEVELOPED

1. Design of the Prototype

After selection by survey a concept model is being prepared, based on the concept model a 3D CAD Model has been developed with dimension of the complete machine as shown in Fig.3a in our case we have selected square thread power screw as shown in (Fig. 3b) considering to withstand high pressure exerting by tools or exerted maximum load on bearing part. Thus in the whole assembly this may be considered as the main critical parts of the prototype. The design calculation was carried out with the developed 3D model and then analysis of whole parts is being carried out to find out the strength of the selected member. The design analysis was carried out in three steps: first developed modelling of the critical parts, then preprocessing and then final analysis of all the components step by step. In order validate the

design standard the integration is conforming to Indian Standards into the version together with the forces, pressure and strain. After completion of this analysis, the developed model is divided into a large number of interconnecting elements which will result in an appropriate meshing of each member and each element shows its individual mechanical and material properties. The resulting data thus obtained is used to predict the resultant effect of forces at meticulous points on the model, principally the load bearing area like joints etc.

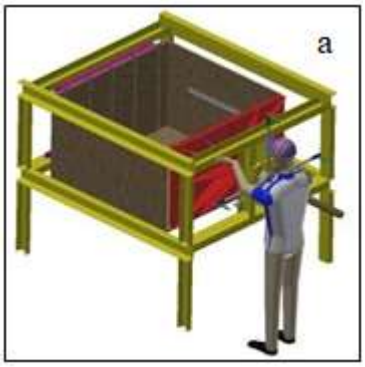


Fig.3 3D CAD Model: a) Developed prototype

b) Lead screw or power screw

2. Analysis of the Elements

The analysis of the critical members is very important to check whether the selected element fails during actual working condition when the required load is applied. Design analysis was carried out by applying the vertical loads on each element to check whether the selected elements will bend when the force is applied during actual working conditions. As mentioned earlier the maximum compressive force required to press the raw jute is approximated to 5 kN, with factor of safety taken as 1.5, the maximum load of 6.5Ton or 64.765kN has been considered in this case for experimental purpose. The resultant analysis of result shows that the size of the power screw selected is quite enough to take the applied load without producing any deformation during the repetitive process of operation of the prototype.

3. Design of Power Screw

The power screw, which may be called as lead screws are used to convert the rotary motion into linear motion as shown in Fig. 4 (a-c). By choosing with accurately sized threads, it is capable of taking huge mechanical advantage and can raise or move huge loads. In this study, we have selected the square thread, having mean diameter dm = 60, as it is having the maximum strength. The standard pitch length has been selected as 9 mm for this purpose. This is selected by considering the amount of pressure will be applied on the arm. If the pitch length is selected higher, then for rotating the handle one has to apply much more force for each revolution of the power screw. While the total number of revolutions is being kept minimum to reduce the operation time, if the number of revolutions will be more than the workers were experiences fatigue more frequently. The force required to compress by using square thread is similar to lifting a weight against a wedge. The mean diameter and force acting on plane is shown in Fig.4d, the selected square thread and force analysis at the interface of the lead screw and nut while lifting and lowering the load is depicted in Fig.4e and 4f respectively.

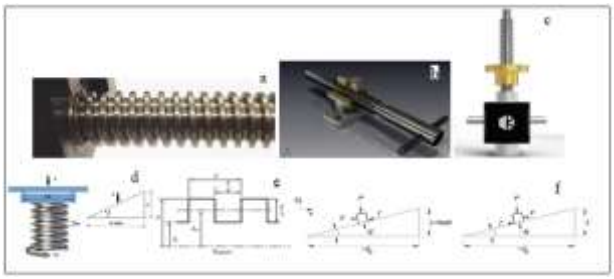


Fig.4 Power screw details6: a, b, c- Power screw and its application in a screw jack, d-Mean diameter with Force acting on plane; e –square thread; f – force analysis in lifting and lowering a load

Governing equation for the force required[7-8]

$$P = \frac{F(l + \pi f d_m)}{\pi d_m - fl} ----(i)$$

Where, F= Compressive force, f = Friction Co-efficient, d_m= Mean diameter, l = lead = n.p n = No of thread start, P = Pitch of the thread

when a collar is attached with the screw to take the axial load, it will generate frictional moment. So, the torque required to rotate the handle is given by Equation [9-10]

$$T_R = P\frac{d_m}{2} + Ff\frac{d_c}{2} + M_C \text{ NM} \text{ ------ (ii)}$$

Table 2: Calculation of force exerted by two labors

Sl.No.	F, compressive Force (Ton)	Mean Dia, (d_m) (mm)	Pitch length (mm)	Arm length, l (m)	Thread angle (deg)	Force per Person in Kgf
1	7.0	60	9	1	14.5	21.98
2	6.5	60	9	1	14.5	20.41
3	6.0	60	9	1	14.5	18.84
4	5.5	60	9	1	14.5	17.27
5	5.0	60	9	1	14.5	15.70

Where d_c= Mean collar diameter = 70 mm, and M_o= Moments due to bearing, where the value is Mo = 20.6 Nm as per SKF bearing data[10]. In this study, SKF 33033 bearing was considered which can withstand a standard radial load of 1.1 kN and axial thrust of 68.67 kN, d_c =70 mm, M_o=20.6 Nm. T_R must be overcome by the workers utilizing their arms with rotational movement. Following data has been considered as: F= 6.5Tonne, Arm length = 1m and assuming that 2 nos. of labors is working simultaneously. The calculations are depicted in Table2.

From the Table.2 as well as from the literature survey[11] it is clear that a man can exert an upward force of 62N to 107N and downward force of 75N to 116N. Hence the combined effect these forces are 21.98 or 22Kgf = 215.82N, this is the maximum amount of force exerted by a worker by hand movement. It is assumed from the above calculation that an Indian labour is having the capability to exert this amount of force to operate any hand rotating machine, under this maximum loading condition.

Stress Analysis of Critical Part (Lead Screw)

The complete bale press machine was developed with the main structural parts, few angles, channels etc. and power screw to compress the entire jute to make bales. Thus, this power screw or lead screw was considered as the main critical component of the entire machine. The stress analysis is also been carried out for this critical part.

Following are the observations [9]:

- The body of the screw will be subjected to torque as T_R which will result in twisting of screw as

  Follows:

  $$\tau = \frac{16T_R}{\pi d^3} \text{ --------- (iii)}$$

- In addition to this, the screw will be subjected to the compressive force along the central axis as

  Follows:

  $$\sigma = \frac{4F}{\pi d} \text{ (iv)}$$

- The bearing stress will be developed in thread-nut areas to act at the base of the thread:

  $\sigma_B = \frac{2F}{\pi d_m n_t p}$ ----------(v) Where , n_t = No of thread engaged with the nut

It was found from the experiment, that the 1st

thread will takes only 38% of the total applied load, following 25%, 18% by the 2nd and 3rd respectively. The 6th and 7th thread remains stress free. Hence

$$\sigma_B = \frac{2\ x\ 0.38\ F}{\pi d_m\ p} \text{----------(vi)}$$

As per the calculation it is found that 1st thread is taking maximum load during analysis of the lead screw, and we have considered the maximum loading of the 1st thread. By application of the stress during experiment it has been observed that by the application of this amount of load, the 1st thread remains safe and there is no sign of any bending throughout the thread length. The thread is also subjected to the bending stress at the root of thread, which is given by the equation.

As the1st thread is taking maximum load, hence during our analysis we have considered the maximum loading condition of the1st thread. By the application of the stress during experiment it has been observed that by the application of this amount of load, the 1stthread remains safe and there is no sign of any bending throughout the thread length. The thread is also subjected to bending stress at the root of thread which is given by the equation.

$$\sigma = \frac{6F}{\Pi d_r n_t\ p} = \frac{6\ x\ 0.38}{\pi d_r\ p} \text{ --------- (vii)}$$

V. RESULTS AND DISCUSSION

Design and Development of the Working Prototype

The design was first developed based on the discussion with the Jute Corporation of India as their requirement. Then after finalization of the design the drawing of the all the members of the prototype is being developed. Then accordingly the bill of materials for hardware, structural members and other parts were developed. Then based on the drawing it was supplied to the manufacturing shop for the fabrication of the components and structural members. The structural members were then first cut according to the given length and joined by welding one by one after checking its proper alignment and accuracy. But before welding some members the hole is first drilled then welding operation is performed as it is not possible to do the drilling and other operations after welding. After welding of the members its accuracy is being checked for the right angle. The gap of the C channel and angles were also properly maintained. In the box chamber where the raw jute is feed its one side is fixed and other side is movable. So in the other side of the door the hinge is welded at the middle from the main body structure, it is welded in such a way so that when will be opened it does not touch the ground. After this operation the top cover is welded and hinge is also attached with it so that it will be opened when the operation is completed. The lock pins are attached with welding for the locking of the top cover and movable doors. A special locking arrangement is a being provided in the structural members so that it will resists the applied force when the jute is completely compressed otherwise there is chance of breaking of the members.

This complete working prototype has been developed at CSIR-CMERI based on our developed design. The each structural member was undergone failure analysis to find out that any of the selected members may fail during the actual application of the applied force as shown in Fig.5a.The pressing head was made with special nut and casted bracket attached to lead screw with a cylindrical bearings. The length of the lead screw is around 600 mm (Fig.5b). The pressing head will move forward and backward as per the rotation of lead screw along with the rotating of handle (Fig 5c). For the collection of the raw jute before pressing operation the wooden structure attached with the wooden frames all side. When the 150 Kg of raw jute is completely filled up in the box chamber, then it is covered with the top covers which is locked by the locking pins. Then for pressing operation the attached handle is rotated by two skilled persons, when the handle is rotated clockwise the pressing head will move forward and the rotation continue till the pressing head reaches the max limit as per the attached scale (Fig.5d). The tying and knotting operation is being performed in the pressed

position. Now the jute bale is completely ready and it was taken out from the machine by opening the one end of the side structure of the machine, and by rotating the handle in the counter clockwise direction, which is hinged with the main structure. The finished bale (Fig. 5e) is now can be moved to the stockyard.

Finite Element Analysis of the Designed Structure

The finite element method is a numerical method which can be used for the accurate solution of a complex engineering problem. The basic idea in the FEM is to find out the solution of a complicated problem by replacing with a simpler one. In FEM the solution region is considered as built up of many small, interconnected sub regions called finite elements. This finite element model contains information like geometry, materials, excitations and constraints about the device to be analyzed. The way FEA obtains the temperature, stresses, field or other desired unknown parameters in the FE model is by minimizing energy functional. The minimum of the functional is found by setting the derivative of the functional with respect to the unknown grid point potential to zero. Thus the basic equation for FEA is

$$[K]\{\delta\} = [Q]$$

Where 'K' is the stiffness matrix, δ is the deflection and Q is the transverse load. Both static and dynamic behaviour analysis can be done with Fem analysis. With the rapid progress of computing technology, FEA is merged with CAD software packages and along with linear analysis non linear analysis can also be performed which offers a better and more accurate solution in many cases. The principal steps in FEA are as follows.

Pre-processing: A model of the part to be analyzed is constructed in which the geometry is divided into a number of discrete sub regions or elements, connected at discrete points called nodes with definite constraints.

Analysis: The step for the analysis is as follows.

- Divide the solution region into small interconnected sub regions.
- Assume an appropriate solution in each piece of elements.
- Derive overall equilibrium condition of the continuum or domain after assembling elements equation.
- Apply boundary conditions & obtain field variable and stress over the whole region.

Post Processing: A typical postprocessor display overlays colour contours representing stress levels on the model, showing a full-field picture similar to that of photo elastic experimental result.

Model Analysis and Result

The model of the lead screw was developed using 3D Cad software. This model was then analyzed using the finite element analysis software to find out the maximum and minimum stresses and displacement. The analysis result shows that the value of Von-Moises stress comes to around 4.283x105 N/m2 or 428 MPa, which is much lower than the yield strength of the selected lead screw. Hence with this analysis it can predict that the designed lead screw is safe with the application of load.

Specifcation of the Bale

The final specifications of the developed working prototype is: Overall dimension: 2000 x1300 x1625 mm (L x W x H); Capacity: 16 bales in eight hours (max.); Weight of the finished bale: 150 kg; Dimension of the finished bale: 1200 x 700 x 450 mm; Manpower required: 02 nos: Time to make a bale: max 20-25 mins.

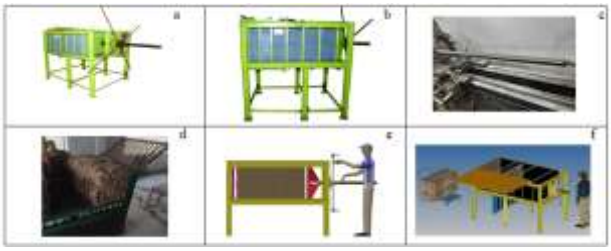
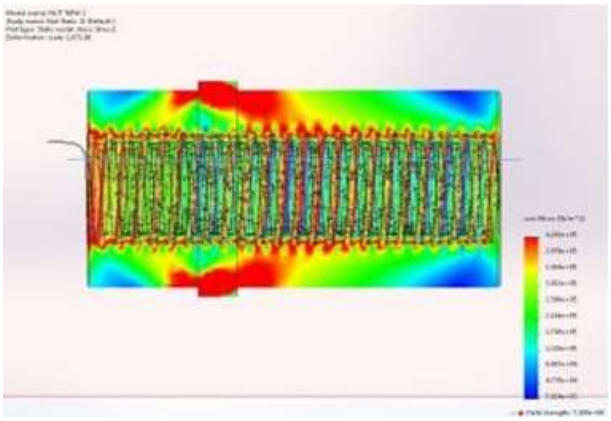


Fig.5: a & b-Working prototype; c-Manufacturing of Lead screw; d –Pressing Bale (Compression) e – Pressing of raw jute; f –Finished bale;

Failure Analysis of the Lead Screw



The lead screw is also subjected to failure analysis to identify its failure at a particular location screw by applying the required load. It is found from the result of the failure analysis that with this applied load there is no significant changes occurred throughout the full length of the lead screw. Hence with this result of the failure analysis it can be say that the selected material and design is totally safe with the application of the required load.

VI. CONCLUSION

There are many presses available for the operation of the different types of materials and for operations. But this developed considering that minimum efforts requirement and less manpower and it will run without electricity or hydraulic power it is purely a mechanical type jute bale pressing machine. The developed machine is having a capacity of 16 bales in 8 hours. The design analysis is performed of all the critical part i.e. the lead screw or power screw. Based on the analysis it was found that the design was safe by applying a compressive load or force of 6.5Ton to get the required bale size from the 150Kg of raw jute. As India we observed from the literature review that India is the largest producer of raw jute for making the different type so items, so it can be said that with this development of mechanical type bale press machine the jute industries will benefitted by utilizing this machine for transforming the Bale from the available raw jute. The develop machine will help in increase the rate of production. So this will ultimately helps to enhance the living standard of the families who were involved in the jute industries.

REFERENCES

1. Islam M S & Alauddin M, World Production of Jute: A Comparative Analysis of Bangladesh, International Journal of Management and Business Studies, 2(1) (2012): 14-22.
2. Karthik G & Ramya N, SWOT Analysis of Indian Jute industry, Indian Streams Research Journal, 2(10) (2012): 1653-1660.
3. Khondake G M, Rahman T & Sahan A, Jute Manufacturing sector in Bangladesh, Opportunities, Challenges and Policy option. Occasional paper 78, Centre for Policy Dialogue (CPD), Dhaka-1209, Bangladesh, 2009.
4. Ray Kamal, Economics of summer paddy - Jute substitution: A profile of environmental cost.Asian Journal of Research in Social Science & Humanities 2(3) (2012): 134-150.
5. Human Engineering Design Data Quest. Department of Defense Human Factors Engineering Technical Advisory Group, 2000. Washington, DC USA.
6. Carvill J, Power screw: Mechanical Engineer's Data Handbook, 1993. Butterworth-Heinemann. ISBN: 978-0-08- 051135-1 DOI: https://doi.org/10.1016/C2009-0-24207-3.
7. Childs P R N, Fastening and Power Screws, Mechanical Design (Third Edition), Butterworth-Heinemann, 2021, Pages 371-412, ISBN 9780128211021, https://doi.org/10.1016/B978-0-12-821102-1.00010-X.
8. Rattan S S, Theory of machines (2014). Tata McGraw-Hill Education, ISBN 9789351343479.
9. Budynas R G, Shigley J E & Nisbett, J K, Shigley's Mechanical Engineering Design (2011). India: McGraw-Hill, ISBN 9780071077835.
10. https://www.skfbearingselect.com. Accessed on 21Nov.2022.
11. https://msis.jsc.nasa.gov/sections/section04.htm. Accessed on 22Nov.2022.