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A Case Study :

Formulation of the approximate generalized data based model for oilseed presser using human powered flywheel motor as an energy source

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ABSTRACT

Human Powered oilseed presser presses the oilseed and extract the oil which can be used for eating purpose or even in small laboratories where we can take different test on oil. A machine has been fabricated which will perform this pressing operation not by electric power but by human power. The human power is sufficient which could easily be converted into work [1 to 12]. In this paper an approximate generalized data based model for a human powered oilseed presser was developed by varying some independent parameters during experimentation.

Key words : Human powered, Flywheel motor, Energy, Oil seed presser

Modak and his associates [1 to 12] had developed human powered process machines which could energize process units needing 3 to 7 hp and which had intermittent operation.

This machine system comprise of three subsystems (1) energy unit (2) mechanical power transmission system (3) process unit. Energy unit comprise of an arrangement similar to a bicycle, a speed raising gear pair and a flywheel. The flywheel size is one meter rim dia, 10 cm rim width and 2 cm rim thickness. A flywheel is with 6 armed constructions each arm is with elliptical cross section. Mechanical transmission comprises of spiral jaw clutch. (1) or other clutches [4,5] and torque amplification gear pair. Process units tried were for brick making [1, 6, 7] wood turning [8]. Algae formation [9] wood strips cutter and smiths hammer [10] and electricity generation [11] could be looked upon these models design data for designing such system.

A young operator with a slim stature and 165cm height speeds up flywheel to 700 to 800 rpm in a minute's time. After pedaling is stopped and then clutch is engaged connecting this human powered flywheel through torque amplification gears to a process unit. The stored energy in the flywheel around 2800 kgf-m gets exhausted within 3 to 10 seconds in operating a process unit depending on its process resistance. This amounts energizing of a process unit in the range 3 to 12 hp. Recently Modak [10] had proposed the concept of, when to use human powered flywheel as an energy source or on load operation of the process unit depending on the operating characteristic of the process unit. In view of this, fertilizer mixture using human powered flywheel motor as an energy source was developed. Its approximate generalized experimental data based model was evolved. This model was evolved applying methodology of experimentation proposed by Schenck [03].

Scope of present research:

Scope is to establish design data for low and medium capacity oil seed presser energized by human powered flywheel motor. With the help of this design data the specific unit for a low medium capacity presser could be designed. The utility of such presser will be for small farmer and oil extractor for bringing about low cost automation. Thus, result of this project will be useful (1) Partly as an aid to a low/ medium capacity farmer for eating oil, cake of oil seed after extracting oil will be used as healthy food for the cows, oxes etc. (2) Alternatively to low profiled entrepreneur who could execute the business of extracting the oil. As the work was ultimately useful for low profiled farmer in present context of lot many cases of suicide of farmers in India this scientific research effort was likely to be useful in lessening the severity of this socio economic problem. Low profiled farmer will be benefited by the proposed work. Other similar systems will be needed by large number of low profiled farmers who may need such an oil seed presser but with different capacities remaining within same concept of Human Powered oil seed presser in future to be adopted for various other agricultural operations. This would add to enhancement of technology for low profiled farmer from the point of view or human powered

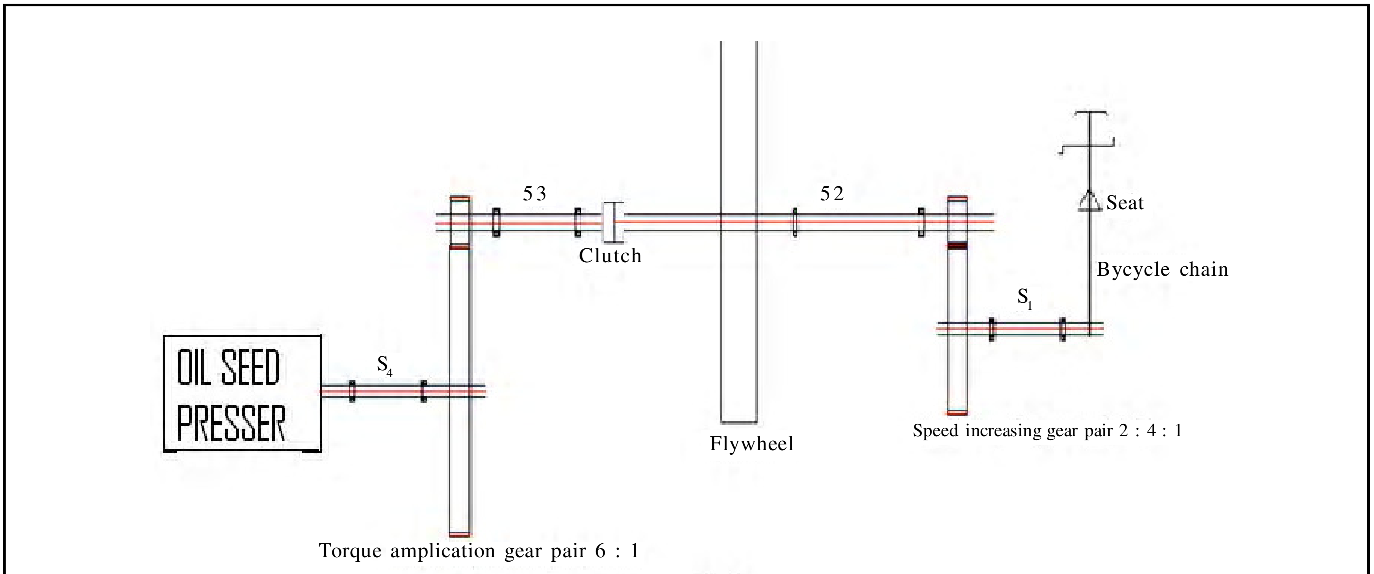

Fig. 1 : Oil seed presser

mechanization of agricultural operation.

Operation of the human powered oil seed presser:
Operation:

The oil seed by weight is admitted in the barrel through the hopper provide on the barrel. Then operator sits on the seat (S) and peddles the bicycle mechanism. Initially the operator has to put in somewhat more driving torque to overcome the inertia during initial acceleration phase of the motion. Once the steady speed of the motion is reached, the torque input gets reduced. This torque now just balances all the resistances such as frictional resistance and smaller inertia resistance. Time process resistance is offered by the screw shaft with oil seeds. This torque can be nominated as steady demand torque of this system.

There is a provision of operating the system at six different speeds by properly choosing the gear ratio of a torque amplification gear pair provided on the screw shaft..

Need for formulating generlized experimental data based mode:

In view of foregoing it is obvious that one will have to decide what should be the minimum human energy to be supplied to the system for getting appropriate oil seed pressing in minimum time. This would be possible if we have a quantitative relationship amongst various dependent and independent variables of the system. This relationship would be known as the mathematical model of this man machine system. It is well known that such a model for the man machine system cannot be formulated applying logic (12). The only option with which it is to formulate is an experimental data based model (12). Hence, in this investigation it was decided to formulate such an experimental data based model. In this approach all the independent variables are varied over a widest possible range, a response data is collected and an analytical relationship is established. Once such relationship is established, the technique of optimization (15) could be applied to reduce the values of independent variables at which the necessary responses can be minimized or maximized. In fact determination of such values of independent variables is always the puzzle for the operator because it is a complex phenomenon of interaction of various independent variables such as geometric parameters of the barrel and screw shaft (base diameter of screw shaft, max. diameter of screw shaft, length of taper, diameter of barrel, pitch of helix) variable speed of the rotation of shaft, the amount of oil seed taken, the operator where as the response variables would be time of pressing, instantaneous torque on the shaft, quantity of oil exhaust, quality of oil, quantity of residue gathered.

It is well known that mathematical modeling of any man machine system is possible applying methodology of experimentation (14). The same is adopted in the present work.

The approach adopted for formulating generalized experimental model suggested by Schenck [1963] is step wise indicated below

– Identification of independent, dependent and extraneous Variables.

– Reduction of independent variables adopting dimensional analysis

– Test planning comprising of determination of test envelope, test points, test sequence and experimentation plan.

– Physical design of an experimental set-up.

– Details of Formulation of Approximate Generalized Data Based Model.

Design of experimentation:

Formulation of dimensional equation:

Reduction of variables through dimensional analysis: The various independent and dependent variables of this machine process with their symbols and dimensional formulae are given in Table 1,

Dimensional equation for response variable load torque

$$T_{shaft} = f_1 (d_b, d_m, L_t, D, \omega, P, E, g, G, T_c, S, Q_r, t, T_s) \text{——} (1)$$

$$\pi_1 = E^{a1} g^{b1} \varpi^{c1} d_b$$

$$M^0L^0T^0 = (ML^2T^{-2})^{a1} (LT^{-2})^{b1} (T^{-1})^{c1} L$$

For M $\quad 0 = a_1$

For L $\quad 0 = 2a_1 + b_1 + 1 \qquad b_1 = -1$

For T $\quad 0 = -2a_1 - 2b_1 - c_1 \qquad c_1 = 2$

$$\pi_1 = E^0 g^{-1} \varpi^2 d_b$$

$$\pi_1 = \frac{\varpi^2}{g} d_b \qquad (a)$$

$$\pi_2 = E^{a2} g^{b2} \varpi^{c2} d_m$$

$$M^0L^0T^0 = (ML^2T^{-2})^{a2} (LT^{-2})^{b2} (T^{-1})^{c2} L$$

$$\pi_2 = \frac{\varpi^2}{g} d_m \qquad (b)$$

$$\pi_3 = E^{a2} g^{b3} \varpi^{c3} L_t$$

$$\pi_3 = \frac{\varpi^3}{g} L_t \qquad (c)$$

$$\pi_4 = E^{a4} g^{b4} \varpi^{c4} D$$

$$\pi_4 = \frac{\varpi^2}{g} D \qquad (d)$$

$$\pi_5 = E^{a4} g^{b5} \varpi^{c5} P$$

$$\pi_5 = \frac{\varpi^2}{g} P \qquad (e)$$

$$\pi_6 = E^{a6} g^{b6} \varpi^{c6} T_c$$

$$M^0L^0T^0 = (ML^2T^{-2})^{a6} (LT^{-2})^{b6} (T^{-1})^{c6} (ML^{-1}T^{-2})$$

For M $\quad 0 = a_6 + 1 \qquad a_6 = -1$

For L $\quad 0 = 2a_6 + b_6 - 1 \qquad b_6 = 3$

Table 1 : Variables, symbols, dimensional formuley

Sr. No.	Description of variables	Types of variables	Symbols	Dimensions
1.	Base dia. Of screw shaft	Independent	d_b	L
2.	Max. dia. Of screw shaft	Independent	d_m	L
3.	Length of Taper	Independent	L_t	L
4.	Diameter of Barrel	Independent	D	L
5.	Speed of Rotation	Independent	ω	T^{-1}
6.	Pitch of Helix	Independent	P	L
7.	Input energy to Machine	Independent	E	ML^2T^{-2}
8.	Accn. Due to gravity	Independent	g	LT^{-2}
9.	Gear ratio of torque amplification	Independent	G	$M^0L^0T^0$
10.	Crushing strength of material process	Independent	T_c	$ML^{-1}T^{-2}$
11.	Avg. size of oil seed	Independent	S	L
12.	Quantity of raw material admitted per cycle	Independent	Q_r	M
13.	Instantaneous time	Independent	t	T
14.	Crushing strength of material of screw	Independent	T_s	$ML^{-1}T^{-2}$
15.	Load Torque	Dependent	T_{shaft}	ML^2T^{-2}
16.	Quantity of oil exhaust	Dependent	Q_o	M
17.	Time of cycle	Dependent	t_c	T
18.	Quantity of residue gathered	Dependent	Q_c	M
19.	Quality of oil	Dependent	Q_t	
20.	Prime time	Dependent	ω_p	T

For T $0 = -2a_6 - 2b_6 - c_6 - 2$ $c_6 = -6$

$$\pi_6 = E^{-1} g^3 \varpi^{-6} T_c$$

$$\pi_6 = \frac{g^2}{E\varpi^6} T_c \quad \text{(f)}$$

$$\pi_7 = E^{a7} g^{b7} \varpi^{c7} S$$

$$\pi_7 = \frac{\varpi^2}{g} S$$

$$\pi_8 = E^{a8} g^{b8} \varpi^{c8} Q_r$$

$M^0L^0T^0 = (ML^2T^{-2})^{a8} (LT^{-2})^{b8} (T^{-1})^{c8} (M)^1$

For M $0 = a_8 + 1$ $a_8 = -1$

For L $0 = 2a_8 + b_8$ $b_8 = 2$

For T $0 = -2a_8 - 2b_8 - c_8$ $c_6 = -2$

$$\pi_8 = E^{-1} g^2 \varpi^{-8} Q_r$$

$$\pi_8 = \frac{g^2}{E\varpi^2} Q_r \quad \text{(h)}$$

$$\pi_9 = E^{a9} g^{b9} \varpi^{c9} t$$

$M^0L^0T^0 = (ML^2T^{-2})^{a9} (LT^{-2})^{b9} (T^{-1})^{c9} (T)^1$

For M $0 = a_9 + 0$ $a_9 = 0$

For L $0 = 2a_9 + b_9$ $b_9 = 0$

For T $0 = -2a_9 - 2b_9 - c_9 + 1$ $c_9 = 1$

$$\pi_9 = E^0 g^0 \varpi^1 t$$

$$\pi_9 = \varpi t \quad \text{(i)}$$

$$\pi_{10} = E^{a10} g^{b10} \varpi^{c10} S$$

$M^0L^0T^0 = (ML^2T^{-2})^{a10} (LT^{-2})^{b10} (T^{-1})^{c10} (ML^{-1}T^{-2})$

For M $0 = a_{10} + 1$ $a_{10} = -1$

For L $0 = 2a_{10} + b_{10} - 1$ $b_{10} = 3$

For T $0 = -2a_{10} - 2b_{10} - c_{10} - 2$ $c_{10} = -6$

$$\pi_{10} = E^{-1} g^2 \varpi^{-6} T_S$$

$$\pi_{10} = \frac{g^2}{E\varpi^8} T_s \quad \text{(j)}$$

$$\pi_{01} = E^{a01} g^{b01} \varpi^{c01} T_{Shaft}$$

$M^0L^0T^0 = (ML^2T^{-2})^{a01} (LT^{-2})^{b01} (T^{-1})^{c01} (ML^2T^{-2})^1$

For M $0 = a_{01} + 1$ $a_{01} = -1$

For L $0 = 2a_{01} + b_{10} + 2$ $b_{01} = 0$

For T $0 = -2a_{01} - 2b_{01} - c_{01} - 2$ $c_{01} = 0$

$$\pi_{01} = E^{-1} g^0 \varpi^0 T_{Shaft}$$

$$\pi_{10} = \frac{g^2}{E\varpi^8} T_s \quad \text{(k)}$$

$$\frac{T_{shaft}}{E} = f_1\left[\left(\frac{\varpi^2}{g} d_b\right)\left(\frac{\varpi^2}{g} d_m\right)\left(\frac{\varpi^2}{g} L_t\right)\left(\frac{\varpi^2}{g} D\right)\left(\frac{\varpi^2}{g} P\right)\right]$$

$$\left[\left(\frac{g^2}{E\varpi^6} T_c\right)\left(\frac{\varpi^2}{g} S\right)\left(\frac{g^2}{E\varpi^2} Q_r\right)(\varpi t)\left(\frac{g^2}{E\varpi^6} T_S\right) G\right] \quad \text{(A)}$$

Similarly, Dimensional equation for response variable Quantity of oil exhaust

$$\frac{Q_0\, g^2}{E\varpi^2} = f_2\left[\left(\frac{\varpi^2}{g} d_b\right)\left(\frac{\varpi^2}{g} d_m\right)\left(\frac{\varpi^2}{g} L_t\right)\left(\frac{\varpi^2}{g} D\right)\left(\frac{\varpi^2}{g} P\right)\right]$$

$$\left[\left(\frac{g^2}{E\varpi^6} T_c\right)\left(\frac{\varpi^2}{g} S\right)\left(\frac{g^2}{E\varpi^2} Q_r\right)(\varpi t)\left(\frac{g^2}{E\varpi^6} T_S\right) G\right] \quad \text{(B)}$$

Dimensional equation for response variable time of cycle,

$$\frac{Q_0\, g^2}{E\varpi^2} = f_2\left[\left(\frac{\varpi^2}{g} d_b\right)\left(\frac{\varpi^2}{g} d_m\right)\left(\frac{\varpi^2}{g} L_t\right)\left(\frac{\varpi^2}{g} D\right)\left(\frac{\varpi^2}{g} P\right)\right]$$

$$\left[\left(\frac{g^2}{E\varpi^6} T_c\right)\left(\frac{\varpi^2}{g} S\right)\left(\frac{g^2}{E\varpi^2} Q_r\right)(\varpi t)\left(\frac{g^2}{E\varpi^6} T_S\right) G\right] \quad \text{(C)}$$

Dimensional equation for response variable Quantity of residue gathered

$$\frac{Q_0\, g^2}{E\varpi^2} = f_4\left[\left(\frac{\varpi^2}{g} d_b\right)\left(\frac{\varpi^2}{g} d_m\right)\left(\frac{\varpi^2}{g} L_t\right)\left(\frac{\varpi^2}{g} D\right)\left(\frac{\varpi^2}{g} P\right)\right]$$

$$\left[\left(\frac{g^2}{E\varpi^6} T_c\right)\left(\frac{\varpi^2}{g} S\right)\left(\frac{g^2}{E\varpi^2} Q_r\right)(\varpi t)\left(\frac{g^2}{E\varpi^6} T_S\right) G\right] \quad \text{(D)}$$

Test planning:

This comprises of deciding test envelope, test points, test sequence and experimental plan [3] for the deduced sets of independent pi term.

Table 2 : Independent Pi terms

Sr. No.	Description of Pi Terms	Equation of Pi terms
1.	Pi terms relating to geometric variables of oil seed presser	$(\pi_1\pi_2\pi_3\pi_4\pi_5) = \frac{\varpi^{10}}{g^5}(d_b, d_m, L_t, D, P)$
2.	Pi terms relating to crushing strength of material process and material of screw	$\frac{\pi_6}{\pi_{10}} = \frac{Tc}{Ts}$
3.	Pi terms relating to average size of oil seed	$\pi_7 = \frac{\varpi^2}{g}S$
4.	Pi terms relating to quantity of raw material	$\pi_8 = \frac{g^2}{E\varpi^2}Q_r$
5.	Pi terms relating to instantaneous time	$\pi_9 = \omega t$
Dependent Pi Terms		
Sr. No.	Description of Pi Terms	Equation of Pi terms
1.	Pi terms relating to load torque	$\pi_{01} = \frac{T_{shaft}}{E}$
2.	Pi terms relating to quantity of oil exhaust	$\pi_{02} = \frac{Q_0}{E}\frac{g^2}{\varpi_2}$
3.	Pi terms relating to time of cycle	$\pi_{03} = \omega t_c$ -
4.	Pi terms relating to quantity of residue gathered	$\pi_{04} = \frac{Q_0}{E}\frac{g^2}{\varpi_2}$

Determination of test envelope:

The test envelope comprises of complete range encompassed by the individual independent Pi term. So, it is now necessary to ascertain the complete range over which the entire experimentation is to be carried out. In this test, we can calculate the ranges only for first five pi-terms. The remaining pi-terms involve the response variables that can only be estimated during experimentation. The ranges for various pi terms are ascertained below.

Range of Pi terms relating to geometric variables of oil seed presser:

This pi term is associated with geometric variables of oil seed presser. This oil seed presser has d_b, d_m, L_t, D, and P as geometric parameters. By assigning the combination of ($d_{b,}$ $d_{m,}$ P) (25, 39, 35) (25, 39, 40) (25, 39, 45) (27, 39, 45) (25, 37, 45) (27, 41, 45) (30, 39, 45) (25, 41, 45) (27, 37,45) Length of taper L_t = 210mm Dia, of barrel D = 43mm N = 200, 300, 400, 500, 600 rpm

This range comes out to be (54.977 to 5016625.6)

Range of Pi terms relating to crushing strength of material process and material of screw:

This pi term is related to crushing strength of material process and material of screw

Keeping Ts constant take value of Tc (08, 10, 10, 12, and 15)

Range of Pi terms relating to average size of oil seed:

This function of pi-term is related to average size of oil seed. By assigning the different speed of N = 200, 300, 400, 500, 600 rpm. This range comes out to be 44.69S to 402.40S.

Range of Pi terms relating to quantity of raw material:

This function of Pi term is related to quantity of raw material. For input energy first calculate the moment of inertia then find range of this pi term.

This range comes out to be 1.235 x 10^{-6}/I to 5.005 x 10^{-4}/I

Range of gear ratio:

This pi-term is related to the gear ratio used during the experimentation according to the load and quantity of oil seed. The gear ratio tried is 1:1, 2:1, 3:1, and 4:1.

Determination of test points:

The spacing of the test points within the test envelop is selected not for getting a 'symmetrical' a 'pleasing' curve but to have every part of our experimental curve map the same precision as every other part. Thus, the concept of proper spacing is now replaced by permissible spacing of the test points. Similarly, for all other pi terms the test points are decided by permissible spacing rather

Table 3 : Shows the instrumentation specification

Sr. No.	Instrument	Specification
1.	Computer	Pentium 4 RAM1GB, HDD 80 GB,
2.	Printer	Laser Printer Hp 1505
3.	A-D Card	PLC-812 Analog Channels 16 single input –ended resolution 12 bit input range, conversion speed 30 KHz
4.	Tachogenerator	12 volt DC, 0-1000 RPM
5.	CRO	20MHz

than by the proper spacing.

Determination of test sequence:

The choice of test sequence is decided by nature of experimentation *viz.,* reversible or irreversible. In fact all tests basically are irreversible in the sense that no piece of apparatus returns to an identical previous configuration after same use. But if the changes brought by testing are below the level of detection such tests could be assumed as reversible. [3] The independent variables are varied from one extreme to another in a sequential plan or in a perfectly random fashion in a random plan. The sequential plan is essential for irreversible experiments where randomization is not practicable.

Physical design of an experimental setup:

It is necessary to evolve physical design of an experimental set up having provision of setting test points, adjusting test sequence, executing proposed experimental plan, provision for necessary instrumentation for noting down the responses and independent variables. From these provisions one can reduce the dependent and independent pi-terms of the dimensional equation. The experimental set up is designed considering various physical aspects of its elements. For example if it involves a gear, then it has to be designed applying the procedure of the gear design. In this experimentation there is a scope for design as far as oil seed presser is concerned from the strength considerations. Actually the oil seed presser is designed from the consideration of the dimensions having influence on user’s fatigue from ergonomic considerations. The other dimensions of the oil seed presser are designed using previous mechanical design experience and practice.

Experimental set up can be designed for the above stated criteria so that the general ranges can be set properly within the test envelope proposed in the experimental plan. The procedure of design of experimental set up however cannot be totally followed in the field experimentation. This is so because in the field experimentation, we are carrying out the experimentation using the available ranges of the various independent variables to assess the value of the dependent variable.

Selection and calibration of instruments for measurement of dependent and independent variables:

The instruments are to be selected for measuring various dependent and independent variables..

In this experimentation, the measurements to be made are as follows:

– Linear dimensions

– Variation of angular velocities of flywheel and the auger during mixing process

– Quantity of oil and residue.

– Variation of torque on screw shaft during pressing process

The selection of instruments for various measurements is discussed below:

Linear measurements:

For linear measurements, vernier calipers, micrometers, or scales are used. It is estimated that the maximum possible error of measurement is equal to one half, the least count of the measuring instrument

Angular velocities:

For measurement of angular velocities, tachogenerator is used and the variation of speed will be recorded on computer through encoder. This pattern of variation of angular velocity will also give the exact mixing time. Table shows the specifications of tachogenerator and the encoders used.

Variation of torque on auger shaft:

The variation of torque on the auger shaft during mixing process will be evaluated as shown in Appendix.

Calibration of Tachogenerator:

Tachogenerators are calibrated to decide their accuracy over the range in which they are used. Tachogenerator calibration chart was drawn. Magnitude of slope of this curve helps to indicate angular velocity of shafts using the computerized instrumentation.

Conclusion:

From the interaction made with small oil extractor and manufactures of oil extractor, literature cited and the cursory survey conducted in Vidarbha region of state of Maharashtra following conclusion were drawn.

– The design data, economic viability and feasibility, low cost of fabrication will help them to start small scale industry.

– Workers experience postural discomfort while performing the task. They were not aware as to what extent ergonomic intervention can elevate their drudgery. Secondly, the relationship between various inputs such as (ingredients, Geometric dimensions) and outputs as (Time of pressing, human energy, productivity of oil) of the system is not known to them quantitatively.

The data in the present work was collected by performing actual experimentation. Due to this the finding of the present study are seemed to be reliable.

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