"DESIGN AND DEVELOPMENT OF A TWIN SCREW OIL EXPELLER FOR PONGAMIA PINNATA SEEDS"

COLLEGE : R. V. COLLEGE OF ENGINEERING, BENGALURU
DEPARTMENT : MECHANICAL ENGINEERING
GUIDE : CHANDRAKUMAR R
KRUPASHANKARA M. S
STUDENTS : AMRUTHRAJ M
BHARATH H B
CHETHAN H S
S KAMINI

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Introduction:

The existing single screw press expeller can process only 25 – 30 kg of Pongamia pinnata seeds per hour in three or more passes, with low oil yield of about 18 percent. The increase in demands cannot be met by a machine with this low yield. Hence, this project was aimed to design and develop an oil expeller which meets the increased demand by increasing the productivity of the expeller.

In response to the defined limitations of existing technology, various concepts were generated such as flourmill, sequential type, reverse worm and twin screw. The students of batch 2013 of Department of Mechanical Engineering, R V College of Engineering performed experiments on Reverse worm concept and results were obtained with increasing yield but also with increasing retention time. Hence, Experiments were performed on the existing expeller and other generated concepts.

Since there is no oil expelling technology involving twin screw for non-edible seeds, experiments were performed using twin screw extruders used in polymer industry. The results from the experiments were compared based on productivity and the twin screw extruder which processed 80kg of seeds in one hour meets the project objective and hence, twin screw concept was selected. The separation of oil from cake was a challenge in twin screw extruder. This problem was solved by incorporating an innovative design named slotted twin barrel cage. In order to prove the functioning of slotted twin barrel cage, a slotted barrel cage which incorporates a design similar to that of the slotted twin barrel cage was designed and fabricated for a single screw oil expeller. The twin screw oil expeller was designed in detail using CATIA V5 and analyzed using ANSYS 14.5.

Objectives:

1. To study the theory behind oil expelling process and analyze the practical problems associated with existing oil expeller.
2. To develop a concept design that can extract oil:
   i. With high through put of 80 to 100 kg/hour
   ii. Increase in Oil yield.
3. Validate the generated concept of oil expeller.

Methodology:

To understand the drawbacks of the present oil expeller – the Technical and the Performance parameters affecting the process were studied. Research papers on twin screw technology, factors affecting oil recovery, journals on properties of Pongamia Pinnata seeds were read. A report on biodiesel by Department of Science and Technology and various university theses were studied to understand the various expelling process and to understand the significance of the components used in oil expulsion.

After understanding the process of oil expelling, new concepts were generated along with the drawings. Each concept was then evaluated for its technical, economical and production feasibility. Depending on the various deciding factors, the concept was screened for the further development.

Preliminary experiments on Twin Screw extruder were carried out to understand various difficulties in oil expulsion and conclusions drawn from these experiments led to the design of twin screw oil expeller.

By considering various factors such as throughput, power requirements and material selection, the detailed design of machine is started. It includes twin screw shaft designs, Barrel designs, Slotted Barrel cage design, Torque Calculations, base frame design. Part modelling was done using CatiaV5 followed

by assembly of the machine. After designing the parts, it is analysed in Ansys14.5 (Workbench) so as to assure that the design is safe.
Since the cage bar concept as used in single screw expeller cannot be used for twin screw expeller, a slotted barrel cage for single screw expeller was designed, analysed and fabricated so as to validate the twin screw design.

Results and Discussions:
The results of various preliminary experiments, the results of finite element analysis of the designs and the results of experiments performed on slotted barrel cage are discussed.
Results of Preliminary Experiments
In this section, the results of preliminary experiments performed using various concepts are discussed.
Existing Expeller
It can be inferred from the experiments conducted on existing expeller that, the single screw oil expeller requires at least three passes in the first hour of operation in order to expel oil from the seeds because the oil expeller should achieve a temperature of at least 80 degree Celsius and a compression ratio of 16:1 to 18:1. These two conditions should be simultaneously achieved along with moisture content of 8% in the seeds at the time of feeding for effective oil expulsion. For the oil expeller to reach the temperature 80 degree Celsius is due to the heat generated between various moving parts while the oil expeller is processing the seeds. Hence, there is no external heating required. The extraction efficiency of this machine is very less as the compression ratio is around 15:1.
Combination of Flour Mill and Existing Single Screw Oil Expeller
By using the flour mill, the first pass i.e., to crush the seeds was eliminated and the experiments were performed. It can be inferred from the experiments conducted on flour mill attachment to existing expeller that, the first batch of 30 kg of seeds was stored for about a day and then was fed to the oil expeller. Even though these powders were fed for about 3 to 4 passes no traces of oil was found. After the addition of 1.8 litres of water to these powders, oil was obtained. This is because initially the moisture content of the powders was not sufficient therefore, the oil could not be expelled even after 3 to 4 passes. This implies that the moisture content plays a very important role in the oil expelling process. The second batch of 30 kg of seeds was fed to the oil expeller within two hours of being powdered. The oil was obtained in the first pass itself without any addition of water. Thus, it can be inferred that powders loses the moisture content faster than the whole seeds. Therefore, the storage of powdered seeds should be avoided and the powders should be utilized within few hours.
Reverse Screw Oil Expeller
It can be inferred from the experiments conducted on reverse screw oil expeller that, the reverse screw oil expeller processed only 18 kg of seeds in hour and in one pass. The retention time in processing the seeds for oil expulsion is high in this case as the seeds progresses till it encountered the reverse thread and got crushed. These crushed seeds progressed forward through the clearance provided between the crest diameter of the shaft and barrel. The crushed seeds progressed to the pressing region and the oil was expelled. The time in all these operations were high hence the throughput rate was only 18 kg/hr, whereas the extraction efficiency of the machine was better than the flour mill concept and existing single screw oil expeller.
Twin Screw Extruder
Experiments were conducted on a polymer machine i.e., twin screw extruder.Throughput rate of powders and whole seeds are tabulated in table 1.

Table 1 Throughput Rates of Whole Seeds and Powdered Seeds

Speed (rpm)	Throughput rate (kg/hr)	
	Seeds	Powder
500	18.46	38
750	27.69	65
1000	42.35	82

It can be inferred from the experiments conducted on twin screw extruder that, the first configuration of the shafts was the default polymer processing configuration. In this configuration, though the oil was not expelled, the soft cake was obtained with traces of oil in it at lower rpm. This is because of the conveying and kneading action of the screw elements. At higher speeds, dry cake was obtained as the temperature exceeded 110 degree Celsius. The second configuration of the shafts consisted mainly

of mixing and kneading elements. At lower speeds, briquettes as shown in figure 1 were obtained and at higher speeds burnt cake was obtained. The temperature increased rapidly even at lower speeds because of rapid missing and kneading action which exceeded 110 degree Celsius, and at higher speeds temperature exceeded 140 degree Celsius which evaporated the oil and burnt the cake.

Figure 1 Briquettes

The third configuration of shafts mainly consisted of conveying elements, when the chopped pieces of seeds were fed to this configuration, the oil was expelled therefore, experiments were performed using powdered and whole seeds. At lower speeds the oil got expelled along with soft cakes and at higher speeds the oil got expelled alongside briquettes. This was because the effect of kneading was less and conveying was more.

Comparing the results obtained from the preliminary experiments on the concepts generated, twin screw extruder had the highest throughput than the other concepts as shown in figure 2. Twin screw also processes seeds in a single pass where the seeds were crushed as it was conveyed. Since the twin screw concept meets the objective of the project, the twin screw concept was selected for designing the oil expeller.

Hence, a twin screw oil expeller was designed in this project in order to obtain high throughput of at least 80 kg of seeds. An innovative solution of slotted twin barrel cage was proposed and designed for effective oil separation.

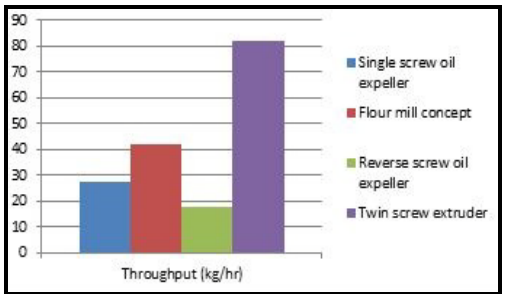

Figure 2 Throughput Graph of Generated Concepts

Results of FE Analysis

The analyses of the designs were carried out; the maximum stress of each design is below the yield stress value of the material. The maximum deformation of each component is very less or negligible and factor of safety of each design is greater than 1. Hence the designs are safe. The analyses results of all the designs are tabulated in the table 2.

Table 2 Analyses Results of the Designs

Sl No	Component	Maximum stress (MPa)	Maximum Deformation (mm)	Factor of safety
1.	Twin screw shaft	169.97	0.086	1.47
2.	Configuration 1 barrel block	217.23	0.067	1.15
3.	Configuration 2 barrel block	148.63	0.031	1.68
4.	Slotted barrel cage	205.9	0.0311	1.214

Results of Experiments Performed On Slotted Barrel Cage

The experiments were carried out using slotted cage. The seeds were fed to the expeller. In the first pass, 20 kg of seeds were effectively crushed. In the third pass, the machine had attained a temperature of 80 degree Celsius and the oil got separated effectively for about 18 minutes.
It can be inferred from the experiments performed using slotted barrel cage that, the slotted barrel cage successfully operated for 18 minutes effectively separating the oil. The ineffectiveness of separating oil after 18 minutes was because of the slot width of 0.3 mm which was cut instead of 0.5 mm due to cost constraints. Another reason for ineffectiveness of the slotted barrel cage was the expansion of the material at higher temperatures of 90 degree Celsius, the material used was mild steel which has high coefficient of expansion. Though the slotted barrel cage successfully operated for a limited time, its function to separate oil effectively was proved. One additional advantage of using slotted barrel cage is that it is an effective replacement for the cage bar design as assembling the cage bars takes about 3 to 4 hours every time the cage bars were removed whereas it takes only about a minute in order to assemble the slotted barrel cage within the barrel. Therefore, by utilizing a material with lower coefficient of thermal expansion and by providing slots of width 0.5 mm while fabricating slotted twin barrel cage, the slotted twin barrel cage will successfully separate oil continuously. Figure 3 shows the exploded view of the expeller.

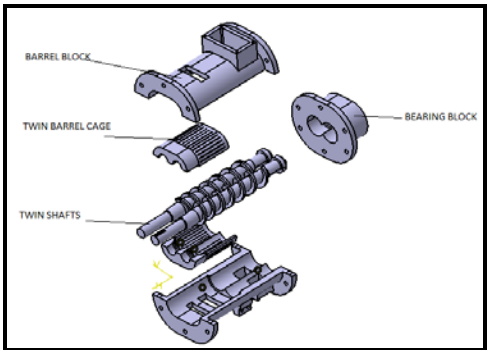

Figure 3 Exploded View of Twin Screw Barrel Block

As discussed in the previous sections, it is clear that the twin screw oil expeller which was designed will extract oil by processing atleast 80 kg of Pongamia pinnata seeds in one hour and in one pass. From the results discussed, it is clear that the slotted twin barrel cage will separate oil effectively.

Conclusions:

Since present day automobile fuels are depleting at an alarming rate, there is a huge necessity of replacing the fossil fuels with alternative sources that are also relatively less harmful to the environment. Thus, a development in the oil expeller plays a very important role in increasing the feedstock availability for biofuel. In this project, an effort has been made to understand the features of the existing oil expeller, and include design modifications to improve the process. So far only single screw expellers are in use in the market. To improve the throughput as well as to reduce the time of operation, a twin screw expeller is designed to meet the increasing demand for bio-fuels.
The new twin screw oil expeller design is aimed to accomplish expelling of oil in a single pass. The design also contributes towards decreased human intervention and increased throughput of at least 80 to 100 kg/hr. Further, the decrease in pitch at the rate of 3 mm/pitch and decrease in depth of screw thread at the rate of 1 mm/pitch reduces the L/D ratio to 5.1 which achieves the desired compression for effective oil recovery. This also makes the expeller compact in size. The problem associated with the oil separation is solved by utilizing slotted twin barrel cage in the expeller.
The design of the second configuration barrel block can be utilized for different shaft lengths and different diameter of shafts up to 80 mm by making small changes to the barrel. Hence, the barrel of second configuration can be utilized for R&D purposes and any seed of different physical properties can be processed in this configuration.
Thus, designed twin screw oil expeller after fabrication would expel oil effectively at a rate of at least 80 kg/hr in a single pass.

Scope for future work:

The twin screw expeller is designed and the fabrication needs to be carried out. Before fabrication, further work is to be done in the following areas:

- Market survey of twin screw gearbox fabricators
- Fine tuning of the design of barrel configuration 1
- Further research can be carried in non- conventional methods of oil extraction such as microwave technology and solvent extraction method
- Further research can be carried out on increasing the yield of oil
- Further research can be carried out to expel oil from potential oil seeds such as Neem, Castor etc., by modifying the twin screw barrel configuration 2 designs.