# Design of new type biomass pellet forming machine with plunger roller and ring-die at room temperature

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**Abstract**

Bio-energy has become the fourth major energy resource after oil, coal, natural gas energy on account of the properties of green, clean, and renewable. And biomass densification is an important technology which makes the biomass resource be low cost and high value. But for current biomass forming equipment, there exist common shortcomings of high energy consumption, low efficiency, serious wear of forming parts, and etc. In this paper, a forming mechanism of a new type biomass pellet machine with plunger roller and ring-die was proposed, which using the mesh extrusion pressure between plungers and forming cavities (or called holes) to make the loose biomass material densification. It could avoid direct contact and intense friction of forming parts and biomass materials out of the holes. So the energy consumption of the materials in ineffective forming process was reduced and the wear of forming parts was effective alleviated. Then the new type biomass pellet forming machine was designed according to the requirements by Solidworks after force analysis and theoretical calculation, and a prototype was built with the whole power 22 kW and production capacity 450 kg/h. Compression experiments were done finally on the prototype. It was shown that the forming quality of solid pellet fuel tended to be stable after 30 minutes' running and the pellet density could reach more than 0.8 g/cm$^3$. So it represented that the designed pellet machine had a good practical operation and met the design demands.

*Keywords:* forming technology of biomass densification, pellet forming mechanism with plunger roller and ring-die, pellet fuel

## 1 Introduction

Energy shortage and environmental pollution are common serious problems currently restricting the development of world economy and the society. So it is the necessary way for the future to develop renewable and green energy, which means a low-carbon, sustainable and scientific development [1]. Although biomass materials are widely distributed with a good renewability and richness in natural resources, its greatest inadequacy lies in the scattered distribution, the low original density, and low energy density [2], which severely limits the direct utilization of biomass energy. So technologies should be developed to convert bio-materials into a new form fuel with high unit energy density.

Biomass densification is an important kind of technologies to achieve the target of the biomass resource utilization with low cost, high value and efficiency at present. The process of biomass densification is that compress biomass material (mainly residues of forest felling, thinning, processing and agriculture) physically at heating or room temperature into solid fuels shaped as columnar, cube, or pellet with high unit density after the pretreatment of drying, crushing and etc. [3]. The unit density and combustion value of the solid fuels after processing could respectively reach 0.8~1.4t/m$^3$ and 16~21MJ/kg in terms of kinds of biomass materials such as agricultural straws, grasses, woody resources like wood chips and sawdust. Combustion efficiency could be as high as 90%, and the conversion cost is low as well [4].

So far, there are many kinds of biomass forming machine, but an objective reality that the high power consumption (≥100kw/h per ton) and quick wear of main forming parts (≤1000h) still exists, which restricting the development of biomass solid fuels. To overcome shortcomings in traditional forming machines, a completely new type of biomass pellet forming mechanism with plunger roller and ring-die was designed after deeply studied the densification of biomass material in this paper, which effectively avoided the extrusion and friction of biomass material out of forming cavities. It would greatly reduce the power consumption of densification, and prolong the service life of forming molds.

## 2 Design of biomass pellet forming machine with plunger roller and ring-die at room temperature

### 2.1 THE WORKING PRINCIPLE OF THE FORMING MECHANISM

A new forming mechanism with plunger roller and ring-die was presented after deep study on compression and shaping process of many kinds of biomass forming machines, shown in Figure 1, which was similar to a pair of inner meshing gears. It depended on the mesh extrusion pressure between plungers circumferentially on the roller and forming cavities uniformly distributed in the ring-die to make the loose biomaterials densification. Compared with the traditional rolling ring-die forming mechanism, shown in Figure 2, it avoided direct contact between the ring-die and the roller,

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reduced mutual extrusion and friction between the roller and bio-materials out of the forming cavities and alleviated the force of forming parts. Therefore, it could effectively reduce the power consumption of biomass forming and wear of forming parts to improve the service life [5].

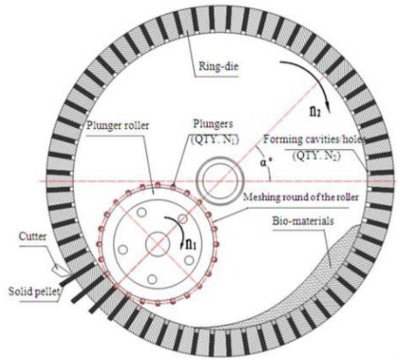



FIGURE 1 The working principle of biomass pellet molding mechanism plunger roller ring-die

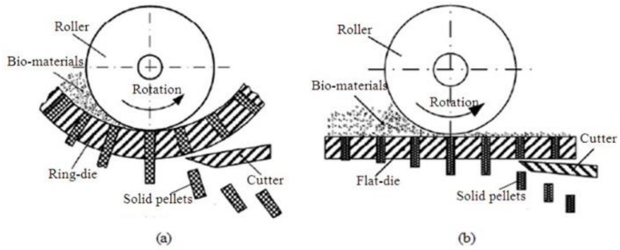
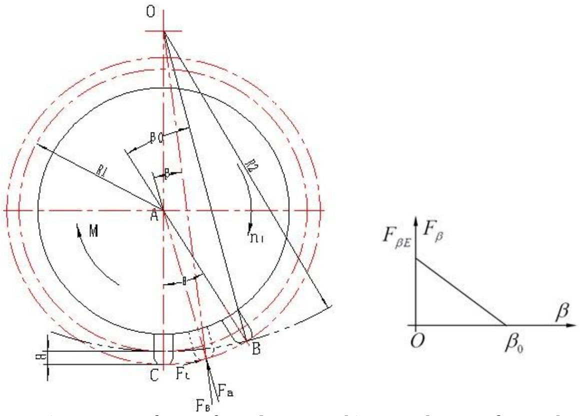



FIGURE 2 The traditional rolling ring-die forming mechanism

All of the plungers and forming cavities were uniformly distributed along circumference in the Figure 1. Let the quantity of plungers and forming cavities of each row separately be $N_1$ and $N_2$, the revolving speed of plunger roller and ring-die be $n_1$ and $n_2$ in turn. Then when the four parameters matched the following equation, the movement between the plungers and forming cavities was similar to the meshing motion of the gear: $\frac{N_2}{N_1} = \frac{n_2}{n_1} = \left( \frac{Z_2}{Z_1} : gear \right)$.

## 2.2 FORCE ANALYSIS OF PLUNGER RING-DIE FORMING PARTS

Figure 3 was the force schematic of plunger roller. In the Figure 3a, the plunger roller was rotated at speed of $n_1$ driven by torque ($M$) after bio-materials filling into the forming holes in the ring-die. The plunger began to mesh with forming hole at the position of $B$, that is to say, bio-materials in the hole were squeezed by the plunger. When rotated to the position $C$, the plunger reached a maximum depth of engagement with $H$ mm, and it would gradually withdraw from the hole with the continual rotation of roller. It was thought that the top end of the plunger was subject to the action of force $F_\beta$ to the centre of the ring-die $O$ when the materials was squeezed because of the larger radius of ring-die compared with roller. The angle between $F_\beta$ and the centre line of the roller was $\beta$. $F_\beta$ could be decomposed into the radial force of the roller $F_\alpha$ and the tangential force $F_t$, so $F_t$ would be the resistance to the rotation of roller. It could be simplified to a static force process due to the short residence time in the meshing zone BC of the plunger and higher rotating speed of the roller.




a) Extrusion force of single plunger

b)Force change of $F_\beta$ at the top end of plunger

FIGURE 3 The force schematic of the plunger roller

$O$ and $A$ were the rotation centre of the ring-die and roller respectively. Point $B$ and $C$ were the entry and exit points of engagement separately. $R_1$ and $R_2$ were radius of roller circle and ring-die inner circle in turn. $M$ was the driving torque, and $n_1$ was the rotating speed of the roller. $\theta$ was the central angle of the roller at the mesh zone of plunger and forming hole. $\beta$ was the angle between axes of plunger and hole and the maximum was $\beta_0$ (i.e. at the position of B). $F_\beta$ was the force of the plunger, and $F_a$ and $F_t$ were the radial and tangential force of the roller respectively, while the maximum was $F_{\beta E}$ at the position of $C$. $H$ was the maximum insert depth of plunger.)

For ease of calculation and analysis, $F_\beta$ was simplified as a linear growth in the Figure 3b, and the following Equations could be obtained.

$$F_{\beta E} = P_0 \frac{\pi D^2}{4}, \quad \beta_0 = \cos^{-1} \frac{R_2^2 + (R_1 + H)^2 - OA^2}{2R_2(R_1 + H)}, \tag{1}$$

where, $P_0$ was the maximum extrusion pressure per unit (MPa), $D$ was the diameter of the forming hole.

Equation (2) can be calculated from Equation (1).

$$F_\beta = F_{\beta E} - \frac{F_{\beta E}}{\beta_0} \beta. \tag{2}$$

Decompose $F_\beta$ into radial force $F_a$ and tangential force $F_t$, and Equation (3) can be received:

$$F_t = \sin\beta F_\beta, \quad F_a = \cos\beta F_\beta, \tag{3}$$

where resistance torque produced by the tangential force to the roller is:

$$T = \sum_{\beta=\beta_0}^{0} F_t \cdot (R_1 + H) = (R_1 + H) \sum_{\beta=\beta_0}^{0} \sin\beta \left( F_{\beta E} - \frac{F_{\beta E}}{\beta_0} \beta \right) = (R_1 + H) F_{\beta E} \left( \frac{\sin\beta_0}{\beta_0} - 1 \right). \tag{4}$$

The resultant of all radial force to the roller was $R_a$:

$$R_a = \sum_{\beta=\beta_0}^{0} F_a = \sum_{\beta=\beta_0}^{0} \cos\beta F_\beta = F_{\beta E}\left(\frac{\cos\beta_0 - 1}{\beta_0}\right). \tag{5}$$

Plungers would squeeze the bio-materials in the range of angle $\theta$, and $\theta$ was received through the geometric relationship in the Figure 3a:

$$\theta = \cos^{-1}\frac{OA^2 + (R_1 + H)^2 - R_2^2}{2OA\cdot(R_1 + H)}. \tag{6}$$

Bio-materials were extruded by more than one plunger when the roller rotating because several ones were circumferential distributed per row on the roller. So let the number of meshing pair between plunger and forming hole which took part in squeezing simultaneously be $\omega$:

$$\omega = \frac{\theta}{2\pi / N_1}, \tag{7}$$

where, $N_1$ was the number of plungers per row on the roller and ω should be an integer.

So the resistance torque and the resultant radial force are:

$$T^{total} = \omega Ts, \ R_a^{Total} = \omega R_a. \tag{8}$$

Equation (9) can be obtained integrating Equations (4), (5) and (8).

$$\begin{aligned} T^{Total} &= \frac{\theta}{2\pi / N_1}(R_1 + H)P_0\frac{\pi D^2}{4}\left(\frac{\sin\beta_0}{\beta_0} - 1\right), \\ R_a^{Total} &= \frac{\theta}{2\pi / N_1}P_0\frac{\pi D^2}{4}(\cos\beta_0 - 1)\frac{1}{\beta_0}. \end{aligned} \tag{9}$$

Bio-materials in each forming hole were extruded by appropriate plunger from the position $B$, and it reached the maximum depth $H$ when at the position $C$. During the process, extrusion force increased gradually from 0 to maximum $P_0$ with the degree of the materials compression. Curve 2 in the Figure 4 showed the actual force change. To measure the complicated friction resistance between bio-materials and hole wall in compression process, relationship of extrusion force and deformation was simplified as a positive correlation, shown in curve 1 of the Figure 4.

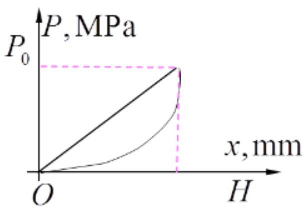



FIGURE 4 The relationship between deformation and pressure of bio-materials in one forming hole

Curve 1 and 2 were the linear simplified and actual relationship respectively between deformation and pressure of bio-materials in straight forming hole.

According to the forming theory of open straight hole [6, 7], it was known that the radial force generated by bio-materials in the mould, friction per unit length of straight hole wall, and the total friction are:

$$P_r = \varepsilon P, \tag{10}$$

$$dF_f = fP_r ds = 2\pi Df\varepsilon Pdx, \tag{11}$$

$$F_f = \int_0^H dF_f = 2\pi f\varepsilon D\int_0^H Pdx = \pi Df\varepsilon P_0 H. \tag{12}$$

The value of the total friction $F_f$ based on curve 1 in Figure 4 was slightly larger than the actual friction of the straight hole for more safe and reliable.

Similarly, the total friction of the ring-die was expressed in the Equation (13) because there were several (the number was $\omega$ ) forming holes working for extrusion simultaneously at forming zone $BC$:

$$F_f^{total} = \omega F_f = \omega\pi Df\varepsilon P_0 H. \tag{13}$$

In Equations (10)-(13), $\varepsilon$ is a side pressure coefficient and $f$ was friction coefficient of materials and forming hole (usually to be 0.1-0.7) [8].

Equations (1)-(13) are the approximate static calculation results for pressure of plunger and forming hole per row. If the row number of plunger and forming hole was $N$, the force of forming mould should be $N$ times.

## 2.3 GENERAL DESIGN OF THE FORMING MECHANISM WITH PLUNGER ROLLER AND RING-DIE

The pellet forming machine was mainly composed of transmission system, forming parts, enclosure bodies and frames, and so on, where, the key points of the design were the transmission system and size of the roller and the ring-die.

### *2.3.1 Design of the transmission system*

Figure 5 was the design of the transmission system. It was known that the ring-die spur gear 2 and the roller spur gear 1 with their shafts were in rigid connections respectively. The ring-die and the roller were mounted on the frame by the bearings, and the idle gear with its shaft was mounted on the frame as well.

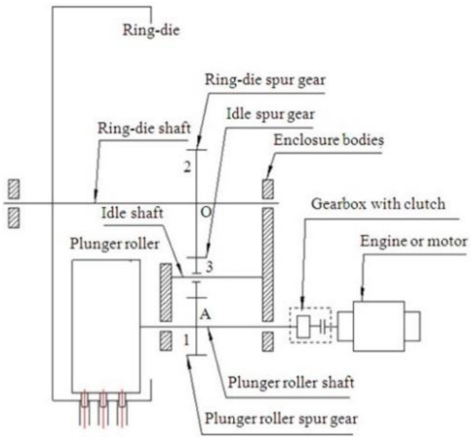



FIGURE 5 The general design of the new biomass pellet forming mechanism

The engine power was transported to the roller shaft through the clutch, which driving the roller rotation. Then the ring-die parts rotated by the gear transmission system 1-3-2, and finally turned round together with the plunger roller at a certain ratio. The running speed of the forming mould could be changed by gearbox in real time according to the actual forming conditions of the materials' characteristics to improve the forming fuel quality and productivity.

Considering the transmission system and design demands, spur gears parameters of the roller and the ring-die could be determined finally referred to size of the same type of pellet forming equipment existing on the market, shown in Table 1.

TABLE 1 The spur gears' design parameters of the plunger roller and the ring-die

| $Z_1$ | $Z_2$ | $Z_3$ | $m$/mm | $i$ | $R_1$/mm | $R_2$/mm | $OA$/mm |
|---|---|---|---|---|---|---|---|
| 24 | 60 | 24 | 3 | 2.5 | 132 | 330 | 198 |

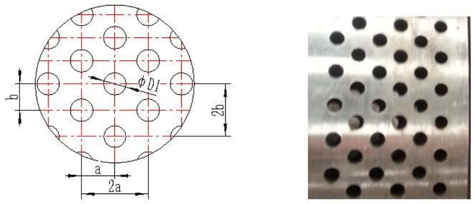
### *2.3.2 The design of the key forming parts*

1) Design of the ring-die parts: according to the design requirements, the productivity ($Q$) of the new type forming machine was greater than or equal to 450 kg/h. The rotation speed of the ring-die was elected to be $n_2$, which was equal to 240r/min, to ensure the forming mould working under lower shock load. The layout of the forming straight hole in the ring-die was shown in Figure 6. In the figure, two adjacent rows of straight holes were symmetrical and staggered distribution, which could increase the hole wall thickness and its strength. And the pressure of the roller and the ring-die could be relatively more dispersion at the same time when the bio-materials in the forming holes were squeezed in turn by each row of plungers on the roller. So it was benefit to the smooth operation of the mould. As the diameter of pellet fuel was already determined ($D$ was 8mm according to the design demands), the diameter of the forming hole ($D_1$) should be 8.5 mm in order to ensure the enough buckling strength of the extrusion plunger body in the same size, and offset the transmission error caused by gear backlash and machining error.

The number of holes per row would be determined based on the productivity of design requirement:

$$N_2 = \frac{4\times 10^6 Q}{60\pi N D^2 H \rho n_2 \zeta} \approx 114.9\,, \tag{14}$$

where, $Q$=500kg/h, $N$=6, $D$=8mm, $H$=6mm, $\rho$=0.9g/cm$^3$ (density of pellet), $n_2$=240r/min, $\xi$=0.167.




a) Layout of forming holes in the ring-die b)Actual forming holes

FIGURE 6 The straight forming hole layout of the ring-die

Let the number of holes per row ($N_2$) be 120, and the design parameters of the ring-die was listed in Table 2.

TABLE 2 The structure parameters and dimensions of the ring-die

| **Inside Diamete r/mm** | **Outside Diameter/ mm** | **Number of Rows/N** | **Number of holes per row/N2** | **Hole Diameter D1/mm** | **Space in rows/mm** |
|---|---|---|---|---|---|
| φ660 | φ760 | 6 | 120 | φ8.5 | 12.5 |

2) Design of the plunger roller parts: the number ratio of plungers and holes per row must be equal to the speed ratio of the roller and the ring-die because all the plungers on the roller and the corresponding straight holes in the ring-die needed precision engagement. Based on the data in the Tables 1 and 2, the number of plungers ($N_1$) per row on the roller should be 48 ($N_1$=$N_2$/$i$). Like the layout of forming hole in the ring-die, the plungers were circumferential uniform distributed. The position and space of the two adjacent rows were same as the forming holes. The design parameters of the plunger roller parts were expressed in Table 3 and the structure was in Figure 7.

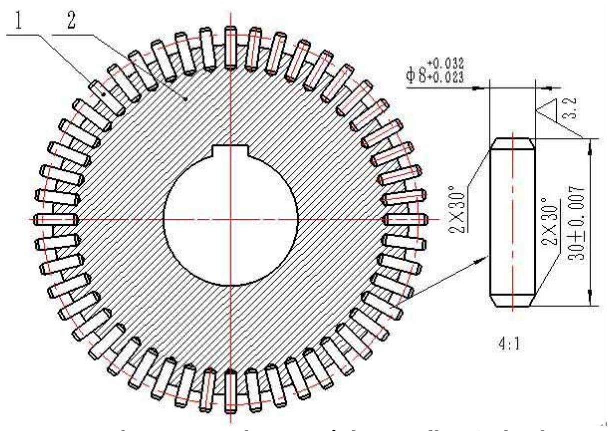
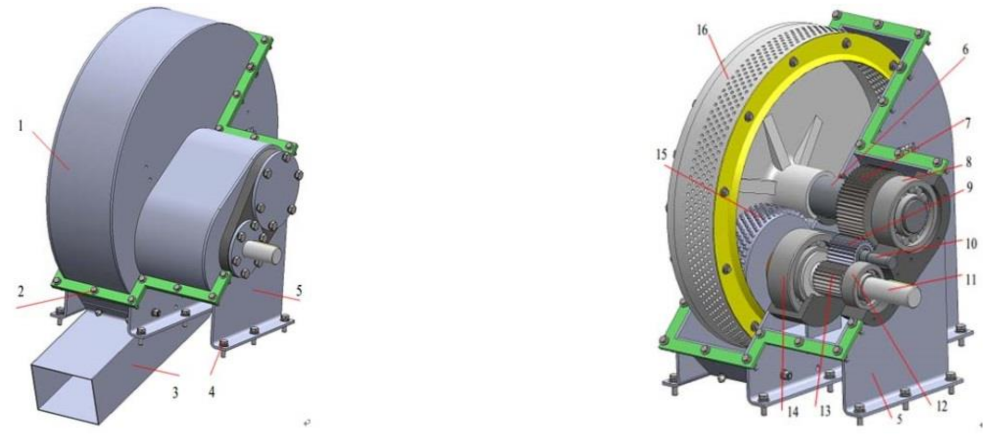



FIGURE 7 The structure schematic of plunger roller. 1) The plunger body 2) The roller body

TABLE 3 The structure parameters and dimensions of the plunger roller parts

| **Mesh Circle Diameter of the Roller /mm** | **Mesh Depth of the Plunger /H/mm** | **Row of the Plunger /N** | **Number per Row/$N_1$** | **Diameter of Plunger/D/mm** |
|---|---|---|---|---|
| φ264 | 6 | 6 | 48 | φ8 |

According to the above design of several parts and reference of similar equipment on the market, the new biomass pellet forming machine with plunger roller and ring-die was designed completely, shown in Figure 8.




a) Appearance of the forming machine b) The internal structure of the forming machine

FIGURE 8 Complete design of the new type biomass pellet forming machine 1) Upper enclosure body. 2) Enclosure body connecting bolts. 3) Outlet hopper. 4)Forming machine fixing bolts. 5) Lower enclosure body. 6) Ring-die shaft. 7) Ring-die spur gear. 8) Ring-die bearings. 9) Idle spur gear. 10) Idle shaft. 11) Plunger roller shaft. 12) Right plunger roller bearings. 13) Plunger roller spur gear. 14) Left plunger roller bearings. 15)Plunger roller 16) Ring-die

## 2.4 POWER CALCULATION FOR THE FORMING MACHINE

The other parameters of angle and force could be calculated based on the Equations (1)-(13) and the design parameters of the forming parts. And the total weight of the plunger roller parts and the ring-die parts could be obtained as well on the foundation of design, listed in Table 4.

TABLE 4 The other parameters of angle and force for forming parts

| **θ/°** | **$\beta_0$/°** | **$T^{total}$/N·m** | **$R_a^{total}$/N** | **$F_f^{total}$/N** | **$G_P$/N** | **$G_R$/N** |
|---|---|---|---|---|---|---|
| 22.05° | 13.02 | 119.7533 | 11258.133 | 21191.5 | 592.7435 | 1977.64 |

**Note: $\beta$ was the angle between axes of plunger and hole and the maximum was $\beta_0$.**

Table 5 shows the bearing types for both side support of ring-die and plunger roller respectively.

TABLE 5 Bearing types

| **Right side of ring-die** | **Left side of ring-die** | **Right side of plunger roller** | **Left side of plunger roller** |
|---|---|---|---|
| NJ2316E | NJ2316E | NJ2310E | NJ2319E |

Let frictional coefficient μ and friction arm $d_m$ of the rolling bearing to be 0.006 and $(d_i+D_0)/2$ apart, then the rolling friction torque of the couple forming parts would be get in the Equation (15), and the power consumption of the friction torque in Equation (16) below:

$$T_1 = \mu(G_1 + R_a^{total})d_{m1}\,,\; T_2 = \mu(G_2 + F_f^{total})d_{m2}\,, \tag{15}$$

$$P = \frac{Tn}{9550}\,, \tag{16}$$

where, $P$ – power consumption (kw); $T$ - torque (N·m); $n$ - rotation speed (r/min); $d_i$ - inner ring diameter of bearing (mm), $D_0$ - outer ring diameter of bearing (mm).

The calculations of resistant torque and power consumption for the couple forming parts were listed in Table 6.

For probably fieldwork, a chipping equipment (power was $P_2$=3 kW) was installed at the feed inlet to improve the application performance of the forming machine. So the total power consumption of the whole machine was calculated below.

TABLE 6 The resistant torque value and power consumption of forming parts

| | **Resistant torque / *N·m*** | | | ***n*/rpm** | ***P*/kW** |
|---|---|---|---|---|---|
| | $T^{total}$ | $T_{1,2}$ | $\sum T$ | | |
| Roller part | 119.753 | 10.488 | 130.241 | 600 | 8.1827 |
| Idler part | – | – | – | 240 | – |
| Ring-die part | – | 17.376 | 17.377 | 240 | 0.4367 |
| | | | | **$P_1=\sum P$** | 8.6194 |

Note: Speed of forming mould n was calculated according to the theoretical productivity $Q$=450 kg/h

$$P_0 = k\frac{P_1+P_2}{\eta} = 1.3\frac{3+8.6149}{0.85} = 17.8\text{ kW}\,, \tag{17}$$

where, $P_0$ was the power of the whole forming system with unit kw, $k$ was the power factor ($k$=1~1.1 when $P_0 \le 5$kW, $k$=1.1~1.2 when $P_0$=5~10kW and k =1.2~1.4 when $P_0$>10kW), and was selected to be 1.3 according to the power calculation. $\eta$ was the total efficiency of the transmission system ($\eta$=0.80~0.90), and was selected to be 0.85.

It could be known from Equation (17) that total power consumption of the new pellet machine with productivity 450 kg/h was about 39.6 kW/t theoretically, much less than that of traditional forming equipment on the market (about 80~100 kW/t) [9].

A multi-cylinder diesel engine with type of ChangChai ZN3850Q, was chosen finally in the light of lighter weight at the same power to make the machine with enough power reserve. And the main parameters were listed in the Table 7.

TABLE 7 The main parameters of ChangChai ZN385Q diesel engine

| Number of cylinders | Engine displacement | Rated power | Idle speed | Maximum torque | Fuel consumption | Cooling | Shape size | Weight |
|---|---|---|---|---|---|---|---|---|
| Unit | L | kw/ rpm | r/min | N.m /rpm | g/kw.h | – | mm | kg |
| 3 | 1.617 | 22/2400 | 800 | 91 /1800 | ≤220 | Water cooling | 614×492×628 | 185 |

## 3 Forming test on the prototype of the new biomass pellet forming machine

A prototype of the new biomass pellet forming machine was assembled completely after design and machining, shown in the Figure 9, which included a drum chipper directly mounted on the side panel of lower enclosure body for integration fieldwork operation. And the machine and engine were fixed on the frame by bolts.

FIGURE 9 The biomass forming system with plunger roller and ring-die at room temperature 1) Frame. 2) Forming mechanism. 3) Drum chipper. 4) Clutch lever. 5) Gearbox lever. 6) Changchai ZN845Q diesel engine. 7) NJ130 Gearbox. 8) Clutch

### 3.1 UNLOAD TEST

Unload test must to be done before the actual operation to keep normal meshing of each couple of plungers and forming holes. The test was conducted according to the following steps.

Firstly, started the forming machine by hand. The transmission must be in "neutral", and turned the roller shaft slowly by manually to run the forming mechanism. Any sound like metal friction and knocking must be noticed during the rotation. After several times of manual rotation, friction between plunger and entrance to forming hole would be well fit.

Then, started the diesel engine, and unload test with multi-speed running would be done.

1) The forming machine was idle run driven by the engine at the speed of about 1000 r/min with the first gear engagement, and maintained the speed of 10 minutes to make the forming pairs mesh fully at high speed.

2) Adjusted the engine to the speed of 1800 r/min with maximum torque and the second gear engagement, the ring-die parts would be run at fastest speed of the design about 240 r/min. Kept the state for 10 minutes to observe the actual operation situation, and the results showed well run.

3) Increased slowly the speed of the engine to the maximum 2400 r/min, namely, the ring-die parts would be run at speed of about 320 r/min. Kept the state for 10 minutes to observe the actual operation situation, and the results showed normal working.

It was known from the above unload test results that the designed forming machine could run well at different speeds after low speed running.

### 3.2 COMPRESSION TEST

At the beginning of work, the state of the new and traditional forming machine was similar. Loose bio-materials entering into the forming parts would directly drop out with the centrifugal force of rotation due to the open end of the forming hole. With the continuous supplement, bio-materials were gradually compacted to densification under the combined action between the friction produced by hole wall and the extrusion pressure of plunger. The larger density of the pellet, the greater of friction and extrusion pressure. After stable run for a period of time, steady-state balance was developed of the friction and extrusion, when the forming density of bio-materials tended to be stable, and reached the maximum. Then the solid pellets were constantly squeezed out.

Compression tests were done with sawdust and paper scraps at the condition of 12% moisture content and ≤2mm granularity as test materials [10, 11]. Adjusted the speed of engine at about 1600 r/min with the first gear engagement, that is, the ring-die part was run at 100 r/min. After 10 minutes feeding, bio-materials (sawdust) in forming holes would be dense gradually and begin to be squeezed from the holes, seen in Figures 10a and 10b. The pellet density was lower (about 0.4-0.5g/cm$^3$) for the poor particle binding force at the moment in Figure 10c. With the growth of work time, the pellet production quality had been improved greatly and tended to be stable, when the pellets density could reach 0.8-0.9 g/cm$^3$ finally shown in Figures 10d and 10e. Figure 10f was the paper pellets produced at the engine speed of 1000 r/min, the density of which was measured to be 0.85 g/cm$^3$.

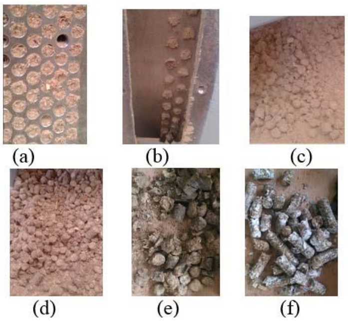



FIGURE 10 The compression experiments of the new biomass pellet forming machine a) Material extrusion condition at the entrance end of forming holes after 10 minute sawdust feed. b) Discharge condition at the outlet end of forming holes after 10 minute sawdust feed. c) Biomass pellet product after 10 minute sawdust feed. d) Biomass pellet product after 20 minute sawdust feed. e) Pellet fuel made by sawdust after 30 minute operation. f) Pellet fuel made by paper scraps after 40 minute operation

## 4 Conclusion

At present, there exist common shortcomings of low efficiency, high energy consumption, serious wear of forming mould, and etc., general existing in current biomass forming equipment's. In this paper a forming mechanism of a new type pellet machine with plunger roller and ring-die was proposed, which using the extrusion force of mesh between plungers circumferentially on the roller and forming cavities uniformly distributed in the ring-die to make the loose biomaterials densification. It could avoid direct contact and intense friction of forming parts and materials out of the holes. So the energy consumption of the materials in ineffective forming process was reduced and the wear of forming parts was effective alleviated. Then the new type biomass pellet forming machine was designed according to the requirements by CAD/CAE system (SolidWorks), and a prototype was built with the power 22 kW and production capacity 450 kg/h. Unload and compression test were done finally on the prototype. It was shown that the machine could run well at different speeds when idle load, the forming quality of solid pellet fuel would tend to be stable after 30 minutes' continuous operation and the pellet density could reach more than 0.8 g/cm$^3$. So it represented that the new pellet machine had a good practical operation and met the design demands. The test results ensured feasibility and practicability on the mechanism of plunger roller and ring-die forming machine.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