

Design and Analysis of Fourth Inversion Punching Mechanism

Dr. K.R. Senthil Kumar¹, A. HemaKumaran², B. Ashok Niranjana³, R. Dhananjayan⁴

¹Professor, Dept of Mechanical Engineering, R.M.K. Engineering College, Kavaraipettai, Thiruvallur, India

^{2,3,4}UG Student, Dept of Mechanical Engineering, R.M.K. Engineering College, Kavaraipettai, Thiruvallur, India.

Abstract - Fourth Inversion Punching Mechanism is mainly based on improving the efficiency of the existing normal punching mechanism by reducing the time taken for total operation thereby increasing productivity. In normal punching mechanisms, by rotating the crank once, one reciprocation of the punching ram is achieved. But by employing the fourth inversion mechanism, two reciprocations of the punching ram can be obtained with the single rotation of the crank. The fourth inversion of four bar mechanism coupled with the crank is utilized in the work. Thus, by rotating the crank once, two punching actions of the punching ram and thereby reducing the overall time required for the process is achieved.

Key Words: Punching Mechanism, crank, Kinematics

1. INTRODUCTION

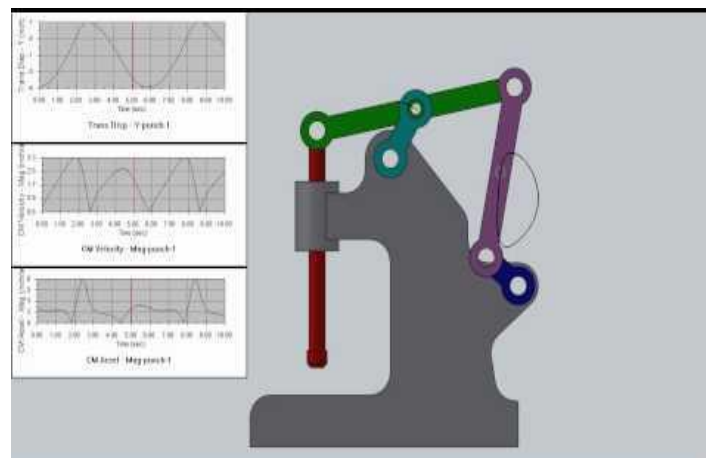
Punching is a type of forming process which involves forcing a tool called a punch, through the workpiece to create a hole by shearing. The punch press, a type of machine press is used to carry out this process. The punch after passing through the workpiece, it is made to ram into a die. The scrap slug formed from the hole is deposited into the die in the process. In some cases, this slug can be recycled and reused. Most of the time, it is discarded as a waste.

Punching is the cheapest method to create holes in sheet materials in medium to high volumes of production. Some of the other processes related to punching are stamping, blanking, perforating, drawing, lancing and bending etc. Blanking is the process in which a specially shaped punch is used to create multiple usable parts from a sheet of material. Slugging is the operation of punching in which the punch is stopped as soon as the metal fracture is complete and metal is not removed but is held in the hole itself. In hot punching, the work is punched while it is hot. It is mostly used in Metal forging applications.

2. FOURTH INVERSION PUNCHING MECHANISM SHORTCOMINGS IN THE EXISTING PUNCHING MECHANISM

In the existing punching mechanism, for one rotation of the crank, only one reciprocating action of the punching ram is obtained. Hence, for the shearing of hard materials, it takes a very long time to complete the required operation. Also the productivity is greatly affected in

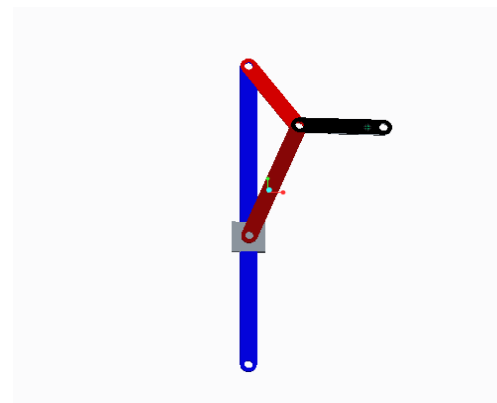
industries. Though, the existing mechanism is necessary to keep the press tool from experiencing increases stress and distortion it needs slight modifications to reduce the time of operation and improve the productivity. The existing mechanism is shown in the figure



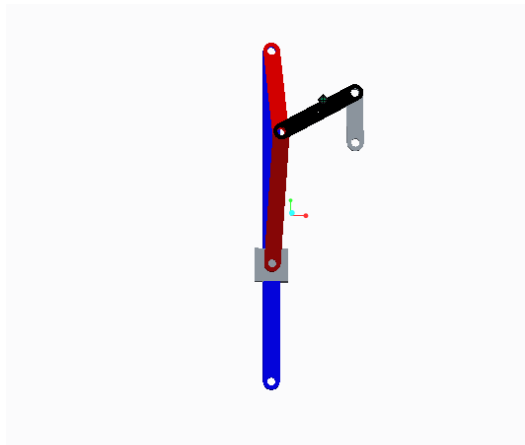
NORMAL PUNCHING MECHANISM

3. DESIGN AND SIMULATION OF FOURTH INVERSION PUNCHING

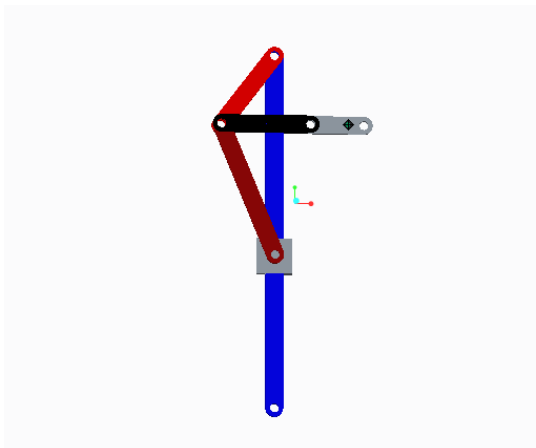
In order to overcome the shortcomings of the existing punching mechanism, a new mechanism has to be devised. Thus, the idea of developing such a mechanism which will help to reduce the operation time is evolved. The “Fourth Inversion Punching Mechanism” is mainly based on improving the efficiency of the existing normal punching mechanism by reducing the time taken for total operation thereby increasing productivity.



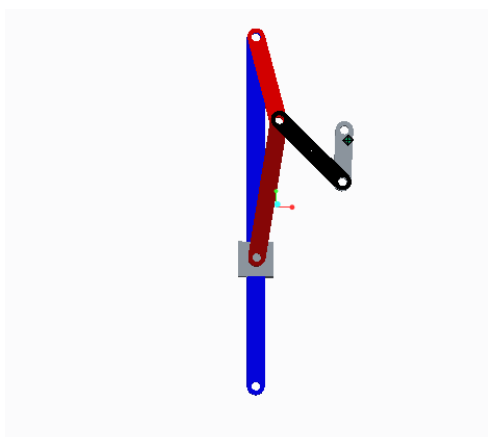
POSITION1



POSITION 2



POSITION 3



POSITION 4

In normal punching mechanisms, by rotating the crank once, only one reciprocation of the punching ram is available. But by employing the fourth inversion mechanism, two reciprocations of the punching ram can be obtained with the single rotation of the crank.

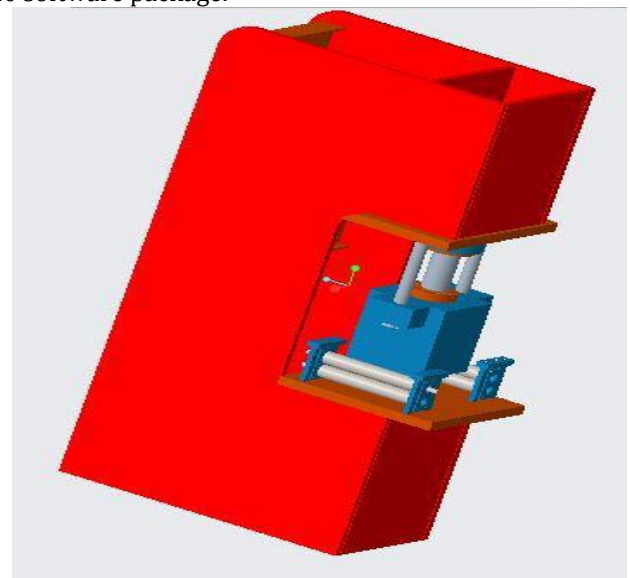
The fourth inversion of the four bar mechanism coupled with the crank is used. Thus, by rotating the crank once, two punching actions of the punching ram and thereby reducing the overall time required for the process is procured.

The design of the mechanism was carried out using the CREO 3.0 Software and the subsequent simulation was also carried out using the same.

The mechanism can be well explained by referencing the designs which will help to visualize the mechanism and provide a better perspective of how the mechanism works. The following images showing the designs of the mechanism at various positions will help to provide a clear idea about the mechanism

4. FINAL ASSEMBLY

The final assembly of the punching press incorporating the fourth inversion punching mechanism is as shown in the following figure. The assembly was carried out using CREO 3.0 software package.



FINAL ASSEMBLY

5. THEORY AND CALCULATIONS

LAMI'S THEOREM

Lami's theorem is an equation relating the magnitudes of three coplanar, concurrent and non-collinear forces, which keeps an object in static equilibrium, with the angles directly opposite to the corresponding forces. According to the theorem,

$$\frac{A}{\sin \alpha} = \frac{B}{\sin \beta} = \frac{C}{\sin \gamma}$$

where A, B and C are the numerical values of three coplanar, concurrent and non-collinear forces, which keep the object in static equilibrium, and α, β and γ are the angles directly opposite to the forces A, B and C respectively.

FORCE RESOLUTION THEOREM

Another important theorem regarding the calculation of torque and force for the mechanism is the force resolution theorem. It states the process of substituting a force by its components so that the net effect on the body remains the same is known as resolution of a force. For each force, there exists an infinite number of possible sets of components.

Suppose a force is to be resolved into two components. Then:

- When one of the components is known, the second component can be obtained by applying the triangle rule
- When the line of action of each component is known, the magnitude and the sense of the components are obtained by parallelogram law

According to the principle of resolution,

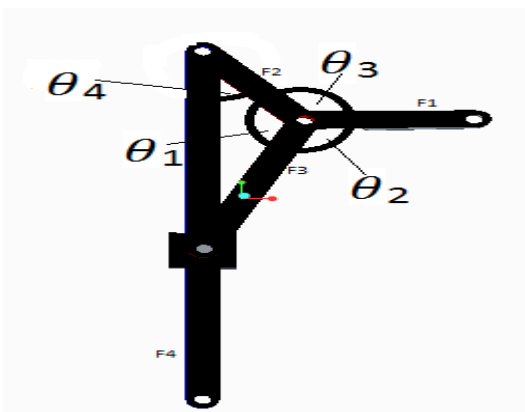
The algebraic sum of the resolved parts of a number of forces in the given direction is equal to the resolved part of their resultant in the same direction.

Thus, by the application of Lami's theorem and the principle of resolution of forces. The required calculations for the work can be made.

The following parameters are required to be found,

1. Punching force
2. Torque applied

Considering the following figure showing the fourth inversion punching mechanism,



LAMI'S THEOREM APPLIED TO THE MECHANISM

Considering Lami's theorem

$$\frac{F1}{\sin\theta1} = \frac{F2}{\sin\theta2} = \frac{F3}{\sin\theta3}$$

Therefore,

$$\implies F2 = \frac{F1 \cdot \sin\theta2}{\sin\theta1} \dots\dots\dots (1)$$

Now by the principle of force resolution,

$$\implies F4 = F2 \cdot \cos\theta4$$

Therefore, from equation (1)

$$\implies F4 = \frac{F1 \cdot \sin\theta2 \cdot \cos\theta4}{\sin\theta1} \dots\dots\dots (2)$$

Therefore,

$$T = F1 \cdot r$$

TO FIND PUNCHING FORCE

1. Shearing Force:

To pierce a hole in the given part, the shearing force is given by,

$$Fs = \text{perimeter of part} \cdot t \cdot \tau$$

Where, t - Thickness of part

τ - part material Shear strength

2. Stripping Force:

Stripping force is required to remove the strip from the punch after the cutting operation. It is given as 10% of Total shear force.

$$\text{Stripping Force} = 10\% \text{ of total shear force}$$

3. Total Required Force:-

Total force require for cutting is given as;

$$T.F. = T.S.F. + \text{Stripping Force} \dots\dots\dots (3)$$

Now,

Therefore the total force required will be equal to the force developed on the punching ram, that is,

$$(2) = (3)$$

Hence,

$$T.S.F. + \text{Stripping Force} = \frac{F1 \cdot \sin\theta 2 \cdot \cos\theta 4}{\sin\theta 1} \dots\dots\dots(4)$$

Therefore, by doing reverse calculation the necessary torque required for the operation can found. For better understanding of the process a sample calculation can be made with some random dimension to find the punching force and torque required and can be compared with those required for the existing mechanism

6. SAMPLE CALCULATION

- Punching a hole of diameter 20mm and thickness of 40mm

1. Shearing Force:

To pierce a hole in the given part, the shearing force is given by,

$$F_s = \text{perimeter of part} \cdot t \cdot \tau$$

Where, t- Thickness of part

τ -part material Shear strength

Thus,

τ -Shear strength of aluminum=207Mpa=207N/mm²

$$\begin{aligned} F_s &= (2 \cdot \pi \cdot r) \cdot t \cdot \tau_{\text{alu}} \\ &= (2 \cdot \pi \cdot 10) \cdot 40 \cdot 207 \\ &= 520.247\text{KN} \end{aligned}$$

2. Stripping Force:

Stripping force is required to remove the strip from the punch after the cutting operation. It is given as 10% of Total shear force.

$$\begin{aligned} \text{Stripping Force} &= 10\% \text{ of total shear force} \\ &= 0.1 \cdot 520.247\text{KN} \\ &= 52.0247\text{KN} \end{aligned}$$

3. Total Required Force:-

Total force require for cutting is given as;

$$T.F. = T.S.F. + \text{Stripping Force}$$

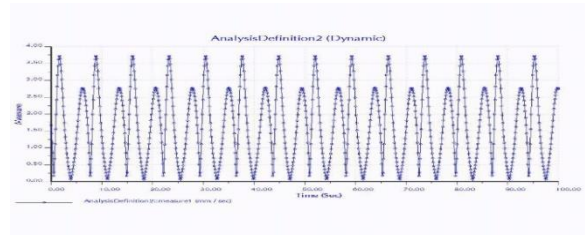
$$\begin{aligned} &= 520.247\text{KN} + 52.0247\text{KN} \\ &= 572.27\text{KN} \end{aligned}$$

Thus by comparison, the force required is much smaller compared to the existing mechanism. Hence, the mechanism helps in increasing the efficiency of punching.

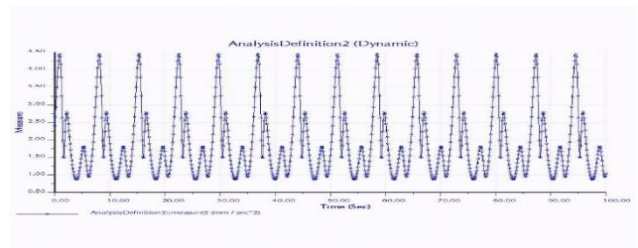
7. VELOCITY AND ACCELERATION ANALYSIS

The position, velocity and acceleration analysis of the mechanism was carried out using the CREO 3.0 software. The respective graphical representations generated using the same are thus given below. The following graphs are generated with reference to the datum point present on the connecting rod part of the four bar mechanism.

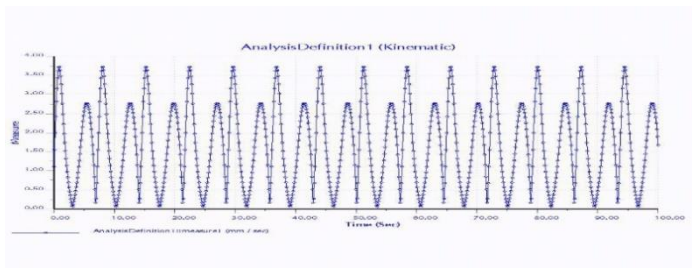
DYNAMIC VELOCITY



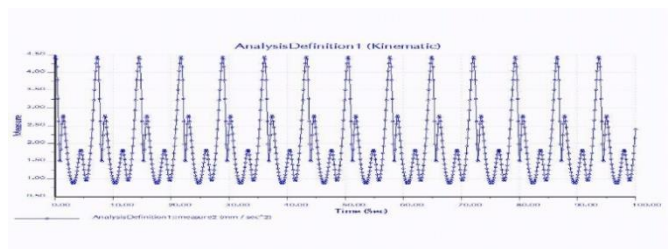
DYNAMIC ACCELERATION



KINEMATIC VELOCITY



KINEMATIC ACCELERATION



Thus, the position, velocity and acceleration analysis are carried out using the CREO 3.0 Software and the respective graphs are generated using the same and are shown above.

ADVANTAGES AND APPLICATIONS

ADVANTAGES

The Fourth inversion punching mechanism provides the following advantages as below,

- Productivity is improved in industries
- Operation time is greatly reduced.
- Harder materials can sheared faster since two punches are produced for single crank rotation.
- Effort is reduced since only fewer crank rotations are required.

APPLICATIONS

This mechanism can be employed in punching operations achieve two punches for a single crank rotation. Since this mechanism is basically a conversion of rotary motion to linear motion, it can be applied to the applications involving the conversion of rotary motion into linear motion such as the following,

- Machine tools such as shapers
- Oil pumping applications

8. FUTURE SCOPE

ENHANCING TOOL LIFE

Since the mechanism produces two punches for a single rotation, it is necessary to enhance the tool life to withstand the rapid punching. The following are the efforts that can be taken to increase the tool life.

- Maintaining Punches

Regular maintenance is an important

Drawing back the punch head to a consistent 40 to 45 Rockwell hardness C (HRC) makes it less brittle and prone to breakage. Factor in extending punch life and reliability. Taking the extra time for punch regrinding is well worth the effort and helps to improve the tool life.

- Minimize Head Breakage
- Increasing the Size

Using the largest, shortest (stubbiest) punch design adds stability to the point diameter that pierces the hole, resulting in longer tool life.

- Use of backplates

Using backing plates behind the punch pads or retainers that match punch head hardness helps to prevent the punch from working into the die and minimizes vibrations.

- Providing Proper Shear angles

Sharpening a punch with shear angles can be tedious. Multiple surfaces need to be maintained, and convex or concave surfaces require extra time. Shear angles significantly reduce the shock and recoil within the punch.

Reducing shocks not only increases tool life, but also reduces press wear and tear. Reducing recoil minimizes punch head breakage and protects the die from slug pulling.

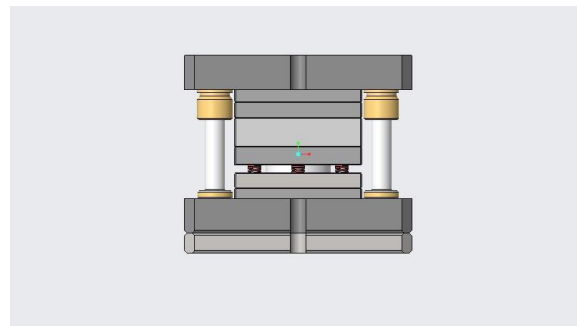
- Using Speciality coatings

Inexpensive, general-purpose coatings are prone to flaking and tend to wear out fast. For better results, coatings such as TiCN can be used that are specifically engineered to maximize the life of punches. Like tool steels, a superior coating can be well worth the investment in the long run.

- Using Solid punches

For the punching of HSLA materials, Use of solid punches will make them less prone to damage.

9. TOOL DESIGN



TOOL DESIGN USING CREO 3.0

RESULT

The work provides an improvement to the existing mechanism by providing two punching actions for single rotation of the crank. Also, the design and simulation of the mechanism was carried out using the CREO 3.0 Software and also the position, velocity and acceleration mechanisms was also carried out and the respective graphical representations were provided.

The proposed mechanism discussed in the work can be applied in the industries to increase the productivity and to reduce the total operation time. Also with suitable study it can be extended to all kinds of punching mechanisms and with suitable tools, it can be used for shearing of all kinds of work piece materials.

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