Design of an automatic sliding rack for injection moulding machine

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Abstract. Rubber processing manufacturing facility uses an injection moulding machine for its primary operation. This machine is fully automatic with one manual operation requiring two operators to push and pull the sliding tray during loading and unloading process. This work aims in eliminating the only manual operation by designing an automatic sliding rack system. As the weight of the sliding tray is 600 kg, it requires more effort from the operators resulting in fatigue. In few instances, minor injuries have been reported when the operators accidently get in direct contact with the finished components during loading and unloading. During the design process, rack and pinion mechanism is considered for the automatic sliding of the rack. The pinion is attached to the motor and the rack will push / pull the sliding rack as per the requirement. The design of all the components of the sliding rack system is performed in Unigraphics 2007. Also, the simulation studies shows that the cycle time is reduced from 9.67 seconds to 5.52 seconds. This shows the significant reduction in the cycle time.

1. Introduction
Injection molding machine, also called as an injection press, is a machine for producing thermosetting materials and thermoplastic materials into plastic products of different shapes by using plastic moulding dyes. Figure 1 shows the injection moulding machine with the mould tray in open condition.

Figure 1. Injection moulding machine with mould tray opened.
A time study to measure the cycle time (time taken to move the tray in and out in seconds) is done with three operators working in different shifts and the same is recorded in table 1. The mean cycle time is recorded as 9.67 s. To reduce the cycle time it is proposed to design an automatic sliding rack system.

Table 1. Cycle time for moving the tray in seconds.

| No. of trials | Operator 1 (s) | Operator 2 (s) | Operator 3 (s) |
|---------------|----------------|----------------|----------------|
| 1             | 8.92           | 8.52           | 8.7            |
| 2             | 8.97           | 8.63           | 8.91           |
| 3             | 9.11           | 9.03           | 9.11           |
| 4             | 8.89           | 8.91           | 8.85           |
| 5             | 9.34           | 9.13           | 8.9            |
| 6             | 9.21           | 9.25           | 9.29           |
| 7             | 9.49           | 9.30           | 9.83           |
| 8             | 9.87           | 9.41           | 9.45           |
| 9             | 9.98           | 10.09          | 9.82           |
| 10            | 10.11          | 9.92           | 9.94           |
| 11            | 10.31          | 10.34          | 9.97           |
| 12            | 10.05          | 9.99           | 9.93           |
| 13            | 10.94          | 10.5           | 10.15          |
| 14            | 10.98          | 10.61          | 10.32          |
| 15            | 10.81          | 10.72          | 10.87          |

2. Design of sliding rack system
The sliding rack comprising of sliding rack, rail bar, ejector plate and T-bar are designed as per the procedures [1-15] and its functions are discussed in following sections.

2.1. Sliding rack
Sliding rack holds the weight of the mould. When the force is applied on the sliding rack, the movement in the mould tray takes place. Any changes that has to take place for the variation in speed of the movement of mould tray, adjustments are done on the sliding rack. Due to this, rack gear will be provided on the bottom of the sliding rack. The 3-d model of the sliding rack is shown in figure 2.

![3-d model of the sliding bar](image)

Figure 2. 3-d model of the sliding bar.

2.2. Rail bar
A Rail bar consists of several cylindrical bearings which provide free to and fro movement of Sliding rack. It supports the movement of the sliding rack as it keeps the rack parallel to the ground while movement takes place. The 3-d model of the rail bar is shown in figure 3.
2.3. Ejector plate
The machine consists of two ejector plates placed parallel to each other. There are four columns in the machine, and each ejector plate is connected to two columns of the shorter side. Ejector plate holds the assembly of T-Bar and Rail bar. Ejector cylinder provides up and down movement to the ejector plate, therefore ejector plate carries the assembly of T-Bar and rail bar. Figure 4 shows the design of ejector plate.

2.4. T-bar
Rail bar is connected to the ejector plate with the help of a T-rod. Ejector cylindrical rod is connected to the ejector plate as shown in figure 5. Ejector cylindrical rod provides the movement to the ejector plate.
2.5. Push-pull bar
Push-Pull bar is an existing component of the machine as shown in figure 6 which, the operators have to push and pull the bar (Push-Pull bar) manually for the rack to move in and out. In modified design if electric motor fails, this bar can be used to continue the process until the motor is fixed.

2.6. Rack and pinion gear
The rack and pinion gear with pressure angle 20º is modelled as per the requirement and assembled as shown in figure 7.
3. Assembly of Sliding rack mechanism

All the components designed as per the requirements are assembled. The figure 8 depicts the three positions of the sliding rack. A pneumatic cylinder is connected to the rack which serves as ejector unit.

![Assembly of electric motor with rack and pinion gear.](image1)

**Figure 7.** Assembly of electric motor with rack and pinion gear.

![Assembly of sliding rack system.](image2)

**Figure 8.** Assembly of sliding rack system.

4. Simulation of the sliding rack system

The simulation studies are performed in Autodesk MAYA 2017. The following sequence of operations are considered during the simulation studies.

i. Part removal when the mould is completely opened

ii. Intermediate rack will then move downwards to match with the bottom plate

iii. Then the bottom platen along with ejector unit will move upwards, so that the mould closes

iv. Injection starts, part filling and curing

v. Mould opens and the ejector plate is lifted by the bottom cylinder rod arrangement

vi. The motor fitted to the rack will then function to pull the rack out. Part removed and the motor is rotated in opposite direction to push the rack in

The simulation model of the sliding rack system is shown in figure 8.
Figure 9. Simulation of the sliding rack system.

By simulation studies it is observed that the cycle time for opening and closing the mould is 5.52 seconds which has reduced the cycle time by 57.3%.

5. Conclusion
In this study the only manual operation in the injection moulding machine is eliminated by designing an automatic sliding rack system which reduces the cycle time by 57.3%. As a future scope this design can be fabricated and tested in the real time environment.

6. References
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