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AUTOMATION OF PTFE HANDLING SYSTEM FOR MOULD FILLING OPERATION

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Abstract: PTFE resins are highly sensitive to the contaminations like dust, moisture, etc. A small amount of contamination results in rejection of final product. Hence, intensive care needs be taken while handling these resins. A case study was conducted at an industry which supplies vital components used in pumps, valves, etc. This industry processes fluoropolymers, like PTFE, PFA, FEP, ETFE, etc. There was more human intervention while handling PTFE resins. Objective of this study was to reduce human intervention while handling these resins in the selected industry. In this, an attempt was made to design new handling system consisting of hopper and automatic weighing mechanism. The proposed system was designed to handle batches of resins in various quantities depending on the mass. The hopper of 200 litre capacity with supporting structure was designed and recommended. Solenoid actuated valve was used to control flow of resins. The system was controlled with Arduino Uno R3. In this work, interface of Arduino with load cell of 20 kg capacity, 20×4 LCD, and keypad was used. It was observed that by reducing human intervention, 80% reduction in mould filling time could be achieved by the proposed system.

Keywords: Polytetrafluoroethylene, PTFE, mould filling

1. INTRODUCTION

Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer of tetrafluoroethylene which has numerous applications. The well-known brand name of PTFE-based polymer is Teflon by Chemours. Chemours is a spin-off of DuPont, which originally discovered this compound in 1938. Being hydrophobic, non-wetting, high-density and resistant to high temperatures, PTFE is an incredibly versatile material with a wide variety of applications. PTFE is well known for its non-stick properties. Teflon™ PTFE 807 NX is a free-flowing PTFE granular resin designed for compression or automatic molding and ram extrusion (low back pressure). It offers an excellent combination of properties that are characteristic of Teflon™. There are certain properties of PTFE 807 NX granular resins because of which it gets contaminated [1-3]. It happens mainly when it comes in contact with the air. Due to the dust, dirt particles and moisture, it gets contaminated. If granules get contaminated by such particles, it causes the rejection of final product.

The rejection due to contamination in the selected industry was almost 2% because of manual handling of PTFE resins. Hence, it was necessary to decrease the material handling by using suitable automation. Preforming was easier when the resins were uniformly between 21–27°C. As the temperature gets reduced, it becomes difficult to mould the resins without cracks because of condensed moisture. Higher temperatures inhibit flow and promote lumping. Thus, the storage conditions should be set accordingly. Cleanliness is a critical requirement for successful use of Teflon™ PTFE 807NX [4-6].

2. EXISTING MECHANISM FOR FILLING MOULDS

PTFE resins come in form of boxes of 50 kg, 100 kg, 150 kg, etc. from the supplier. After arriving at the filling section, boxes are stored at 230C for 2 days. For filling moulds, charge weight in the range of 5 gm to 2 kg is required. First, granules are taken in 10 kg container manually and then they are put in another container on weighing machine and poured into the moulds. But while weighing, granules are manually handled many times for correct charge weight. This causes contamination in the granules due to hand contact and air contact. While filling large size mould, operator needs to weigh charge weight many times as different sections of moulds have different charge weight. This whole process is time consuming and produces contaminations, hence affecting the production and quality of product.

The main problem associated with the current filling system was more material handling. Due to more material handling, resins got more contaminated and resulted in the final contaminated product. In spite of taking intensive care for cleanliness in the filling room compartments, contaminations in the final products could not be reduced. Also more handling of resins consumed more time, hence reducing the productivity. To reduce the material handling, the company wanted to design automatic or semi-automatic weighing system along with the one shift resins capacity hopper. This system should be contamination free, with low air contact, less time consuming, and low handling should be associated with it.

The study was concerned with filling room 02 as shown in Fig.1, in which moulds of charge weight ranging from 80 gm to 3.9 kg were filled. In this room, resins used to fill moulds were PTFE 807 N X resins. Dimensions of filling room 02 were 180 cm × 150 cm × 217 cm (length × width × height). Height of the filling room could be increased up to 300 cm.

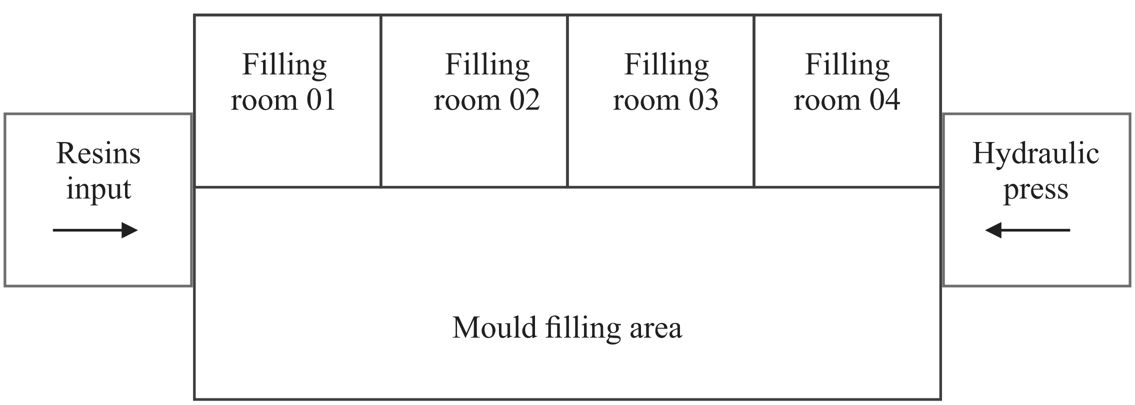

Fig.1: Filling room layout

3. DESIGNS OF MECHANICAL COMPONENTS

The different mechanical components of the proposed system like hopper, frame, stand, weighing components, etc. were designed as per the standard design procedure as discussed in the following sections [7, 8]. Fig. 2 (d) shows the schematic view of the stand holding the complete assembly. Fig. 2 (a) shows the design of the hopper. Fig. 2 (b) and (c) shows the design of the weighing system component and frame respectively.

3.1. Hopper

The hopper is the top most part of this mechanism. The material used for design of the hopper was mild steel with PTFE coating. The diameter of upper part of the hopper was 1100 mm and the total height of the hopper was 760 mm as shown in Fig. 2(a). The thickness of the sheet used for hopper was 2 mm.

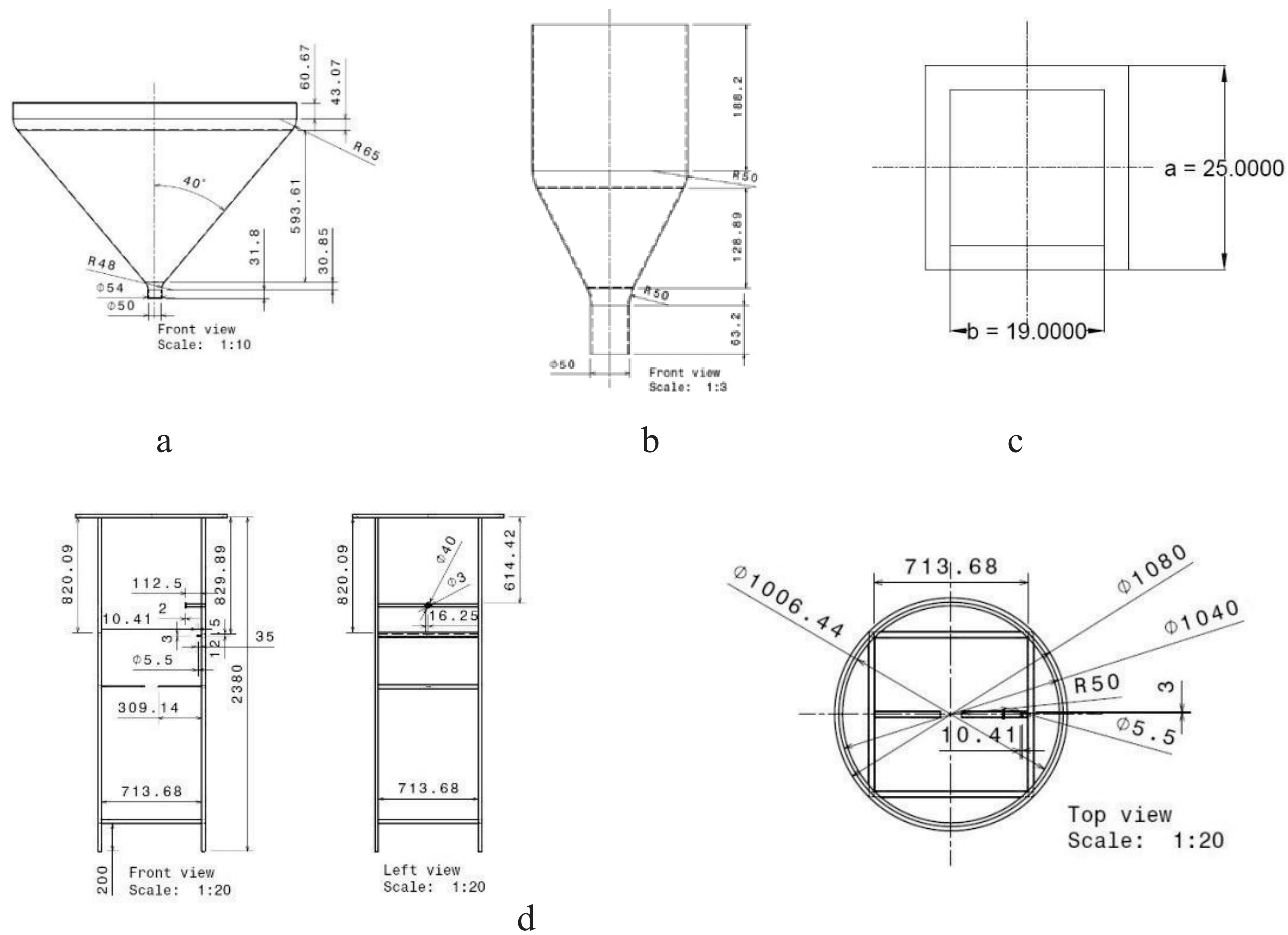

Fig. 2: Schematic view of (a) hopper, (b) weighing system component, (c) frame (d) stand

3.2. Weighing System Components

The material considered for designing the weighing system component as shown in Fig.2 (b) was mild steel with PTFE coating. It was designed to handle volume of 7.22 litre. The diameter of the upper section is 200 mm and complete height of the cylindrical part was 200 mm. The outlet diameter of bottom cone was calculated as 50 mm and the height of the bottom cone was calculated as 100 mm.

3.3. Frame

The frame for this system was designed by considering material as mild steel. The thickness of the frame components was 3 mm. The total weight of 205 kg could be accommodated on the stand. The length of the leg was kept as 2.38 m as shown in the Fig. 2 (d). The left hand side view, front view and the top view of the stand are also shown in the Fig. 2 (d). Remaining important dimensions of all the components can be seen in Fig.2.

3.4 Valves

Two valves were used in this design. First was solenoid actuated valve and another was manual operated butterfly valve. At the outlet of the hopper solenoid actuated valve was used for quick closing and opening action. Butterfly valves were used at the outlet of the weighing pot.

4. ELECTRONIC CIRCUIT COMPONENTS

For the automation of the designed system, electronic circuit was built with the help of different components like Arduino Uno R3, load cell, driver IC, etc. These components and their detail specifications are discussed in the following sections.

4.1. Arduino Uno R3

Arduino is open-source electronics prototyping platform based on flexible, easy-to-use hardware and software as shown in Fig. 3. It is intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. It was used to build the prototype of the actual system. It was programmed to weigh the PTFE granules in exact quantity.

4.2. Load cell

Fig. 4 shows the load cell selected for the proposed system. The load cell was of 20 kg capacity having Wheatstone Bridge-based sensor. The size of load cell was 55.25 mm x 12.7 mm x 12.7 mm. The compensated temperature range was -10°C to +40°C and operating temperature range of -20°C to +55°C.

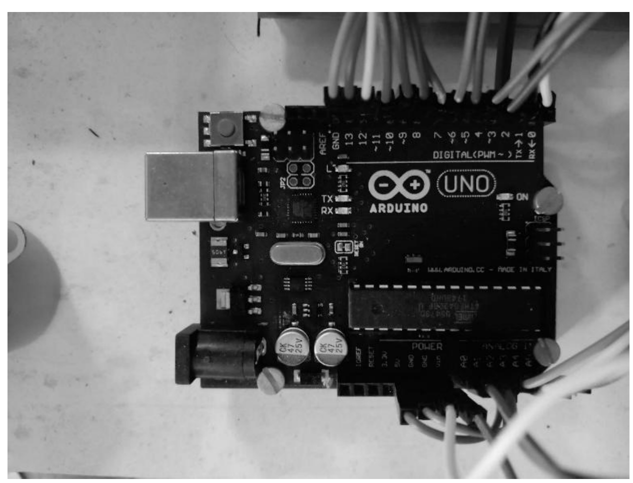

Fig. 3: Arduino Uno R3

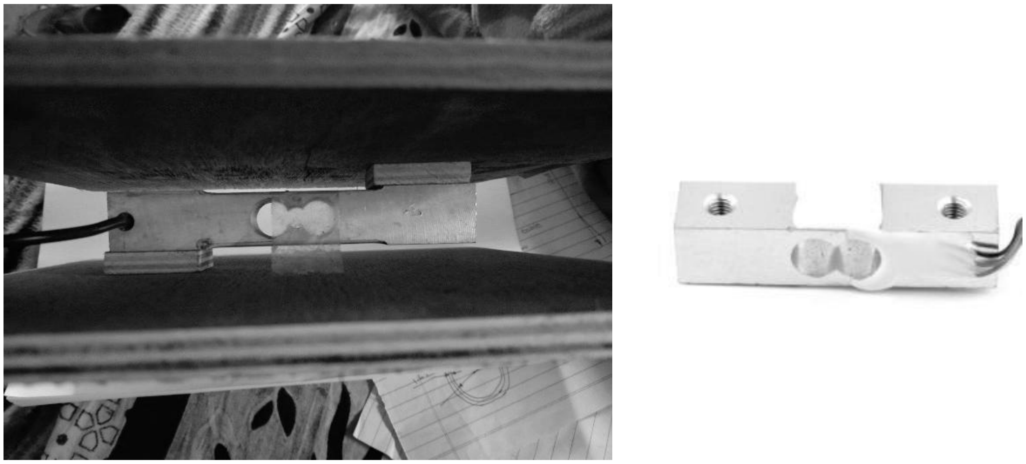

Fig. 4: 20 Kg Micro Load Cell.

4.3. HX711 Module

For interfacing 20 Kg load cell to the Arduino, HX711 Load cell amplifier module was used as shown in Fig. 5. HX711 is a precision 24-bit analog to-digital converter (ADC) designed for weigh scales and industrial control applications to interface directly with a bridge sensor.

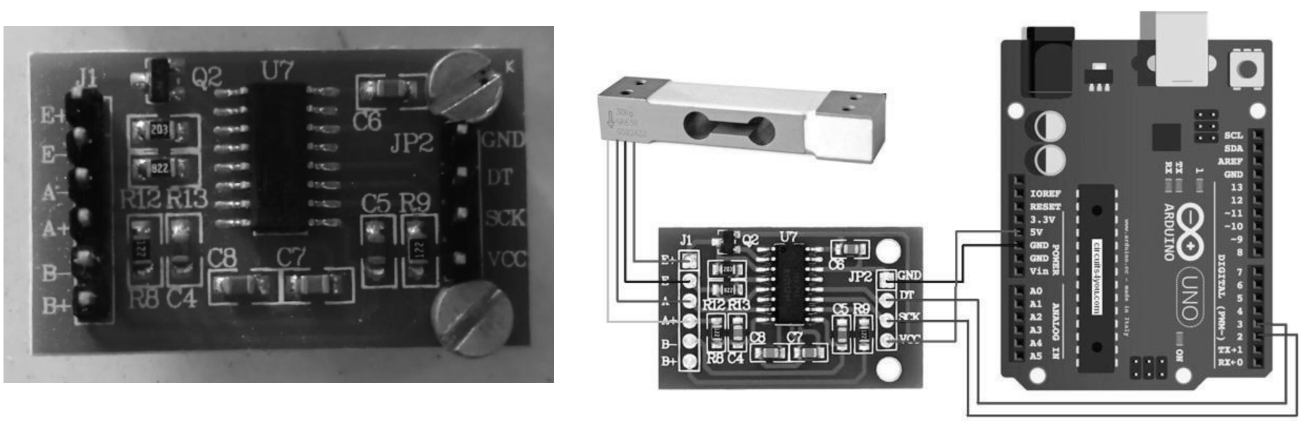

Fig. 5: HX 711 module and Connecting diagram with load cell

4.4. ULN2003 driver IC

ULN2003 is a high voltage and high current Darlington array IC as shown in Fig. 6. It contains seven open collector Darlington pairs with common emitters.

4.5. LCD Display and Keypad

A Liquid-Crystal Display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals. The display as shown in Fig. 7 (a) was used for building the proposed system. A matrix keypad arrangement as shown in Fig. 7 (b) was used to reduce the pin count.

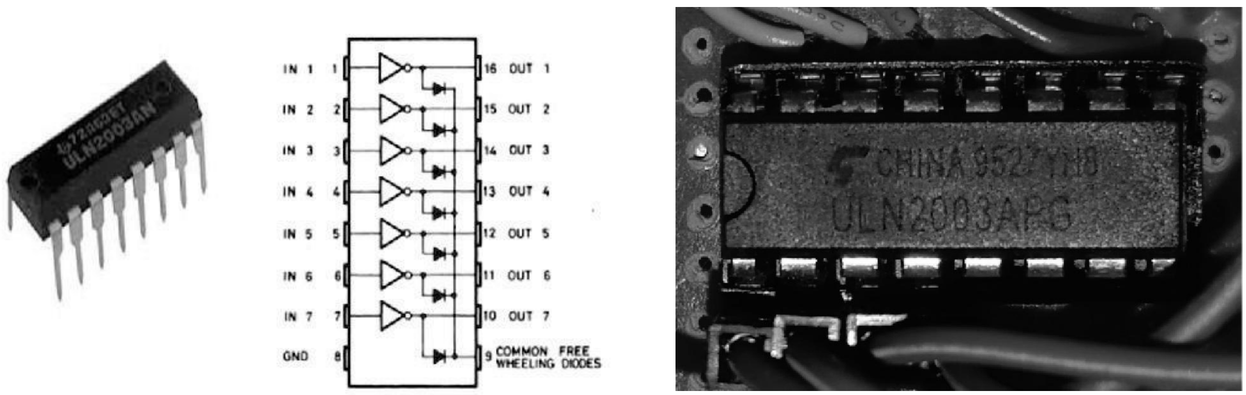

Fig. 6: ULN2003 driver IC

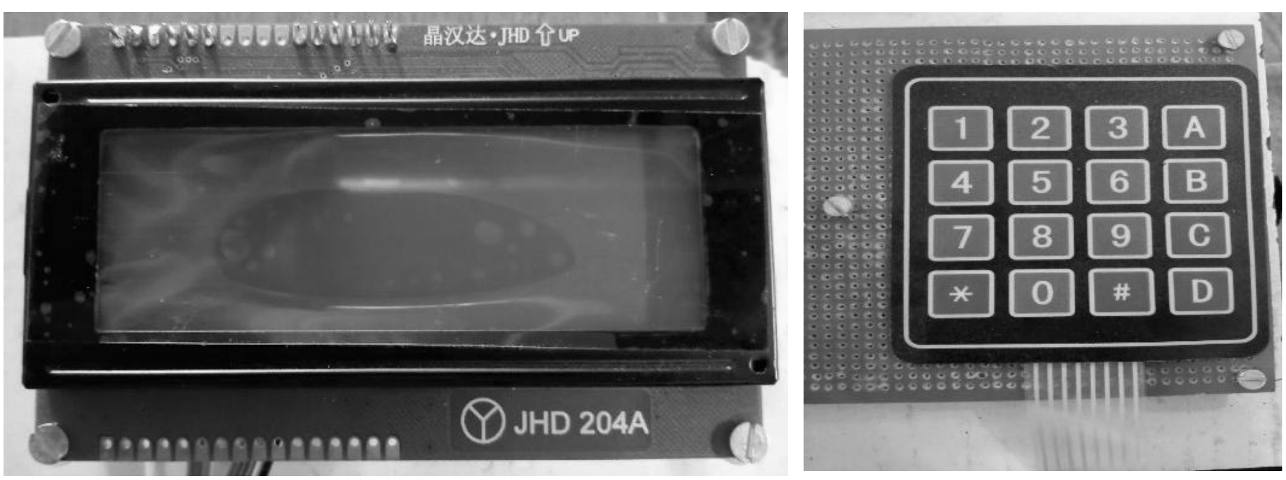

Fig. 7: (a) LCD Display (b) Keypad

4.6. Solenoid Actuator

It is an electromagnetic device that converts electrical energy into a mechanical pushing or pulling force or motion. Solenoids can be used to electrically open doors and latches, open or close valves, move and operate robotic limbs and mechanisms, and even actuate electrical switches just by energizing its coil. The solenoid actuator as shown in Fig. 8 was used.

5. WORKING OF THE PROPOSED MODEL

All the above explained components were used and the electronic circuit as shown in Fig. 9 was built. This was used to weigh the PTFE granules to exact amount. The total amount of resins required for one shift was calculated and then the first step was to store resins in the hopper as per requirement of that shift. As the system was turned on, the display showed the welcome message. The operator had to feed required weight of resins through the keypad and followed the instructions shown on the display as shown in Fig. 9. An Arduino received the input given by the operator, read it, and displayed on the LCD. Then the key for weighing needed to be pressed. As start weighing key was pressed on the keypad, solenoid valve was operated by an Arduino. Further process was continued. Here, in the prototype, the stepper motor was used instead of solenoid actuator.

As the solenoid valve was operated, the resins started falling in the weighing container, which was placed on the load cell. Load cell sent the analog signal to the ADC (HX711 module), which amplified and converted it into digital signal and sent to Arduino. As the Arduino got required signal as fed by the operator, it stopped operating solenoid actuator and the valve got closed. Thus weighing of PTFE resins was done. To fill these resins into the moulds, operator had to operate butterfly valve. When the valve got opened, the resins started falling into the moulds through flexible pipe. Thus the filling operation was achieved without any manual intervention. This prototype system was tested with high accuracy and was suggested to the industry with the complete design of actual sytem.

Fig.8: Solenoid Actuator

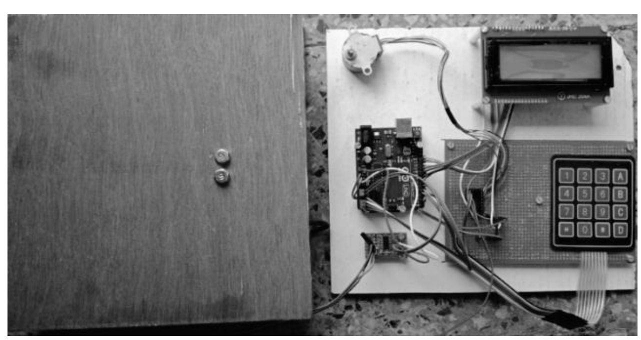

Fig. 9: Complete electronic circuit

5.1. Effectiveness of Proposed System

This system can be effectively implemented in reducing the rejection of product. This proposed system also requires less handling time. Another advantage of this system is that it is completely enclosed. Existing system in the industry had lot of human interferences for handling as well as weighing. The proposed system provides complete enclosure in handling as well as weighing, again in this proposed system handling and weighing is fully automatic.

Then checking the effectiveness of proposed system is done by calculating the time required for old system and new proposed system. This calculation was done for the various sizes of the hoppers. For example, if one considers hopper outlet to give mass flow rate of 30 gm/s, for DN 50 size, time required to flow required weight from upper hopper will be $[\frac{300}{30}] = 10$ s. Similarly for some other sizes, moulding time required in second was calculated and given in Table1.

Table 1: Time required for flowing charge weight

Size	Charge weight in grams	Time required in seconds
DN 50	300	10
DN 80	540	18
DN 100	900	30
DN 125	1100	37
DN 150	2000	67
DN 200	2750	92
DN 250	3400	114
DN 300	5000	167

Now one shift capacity of hopper is 150 Kg. Loading hopper of 150 Kg (150000 grams) takes 5 minutes (300 sec). Time required for weighing of resins is same as time required to fill weighing container. Flow rate at outlet of weighing container is 200 gm/s. For DN 50 size mould time required to fill mould after weighing, $[\frac{300}{200}]\, 1.5 \approx 2$ s.

Table 2: Time required for mould filling

Size	Charge weight in grams	Time required in sec
DN 50	300	2
DN 80	540	3
DN 100	900	5
DN 125	1100	6
DN 150	2000	10
DN 200	2750	14
DN 250	3400	17
DN 300	5000	25

Considering DN 50, calculations are as follows,

- Total number of moulds can be filled = $[\frac{150000}{300}]$ = 500
- Hopper filling time = $[\frac{300}{500}]$ = 0.6 ≈ 1 s per mould
- Time for weighing = 10 s per mould
- Time for filling of mould = 2 s per mould

Table 3: Comparison of time required between old and new system for mould filling

Size	Number of moulds can be filled in one shift	Time for loading the hopper (s)	Time required to operate electronic system (30 s/mould) (s)	Time required for weighing (s)	Time required for filling mould (s)	Time required by new system (min)	Time required by old system (min)
DN 50	500	300	500*30 = 15000	10*500 = 5000	2*500 = 1000	$\frac{6300+15000}{60}$ = 355	5*500 = 2500
DN 80	277	300	277*30 = 8310	18*277 = 4986	3*277 = 831	241	1939
DN100	166	300	166*30 = 4980	30*166 = 4980	5*166 = 830	185	1660
DN125	136	300	136*30 = 4080	37*136 = 5032	6*136 = 816	171	1360
DN150	75	300	15*30 = 2250	67*75 = 5025	10*75 = 750	139	525
DN200	55	300	55*30 = 1630	92*55 = 5060 sec	14*55 = 770	130	550
DN250	44	300	44*30 = 1320	114*44 = 5016	17*44 = 748	124	440
DN300	30	300	30*30 = 900	167*30 = 5010	25*30 = 750	116	300

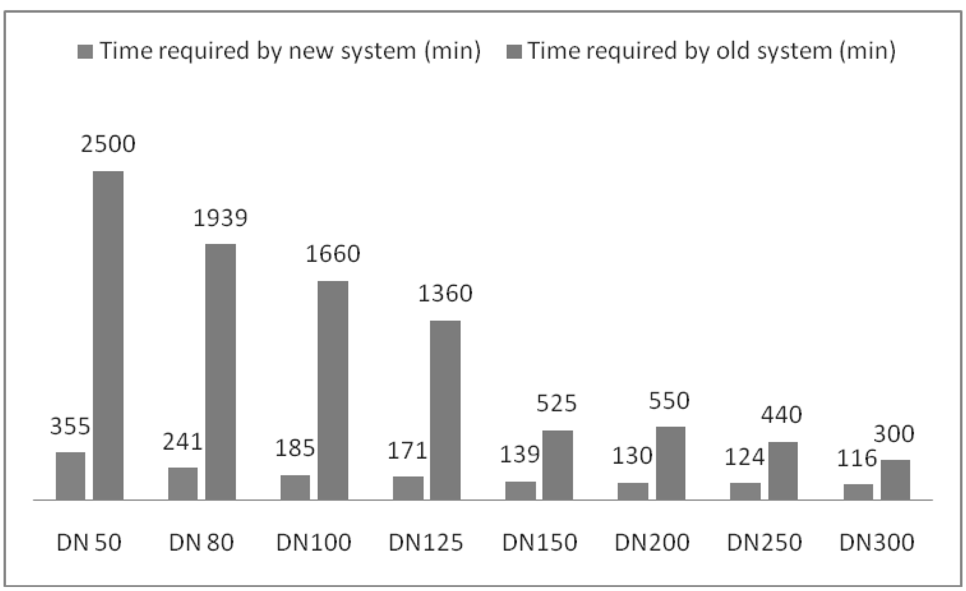

Fig. 10: Chart showing time required for new system and old system for mould filling

Thus from Fig.10, it is clear that, the time required for mould filling by the old system gets reduced. The new proposed system can save sufficient time because of automation and reducing the human intervention. If one considers the percentage wise reduction in time as shown in Table 4, then one can get 61% to 89% time reduction because of this new proposed system.

Table 4: Time reduction

Size	Time reduction
DN 50	$\frac{2500 - 355}{2500} = 0.858 = 85.8\ \%$
DN 80	87.5%
DN 100	88.85%
DN 125	87.42 %
DN 150	73 %
DN 200	76.36 %
DN 250	71.81 %
DN 300	61.33 %

6. ASSEMBY OF THE PROPOSED MODEL

The components as per the design procedure followed in previous sections were assembled as shown in Fig. 11 and Fig. 12. This shows the drafting of assembled model. The front and left hand side views of the complete assembly are shown in the Fig. 11 and the top and bottom views of the complete assembly are shown in the Fig. 12.

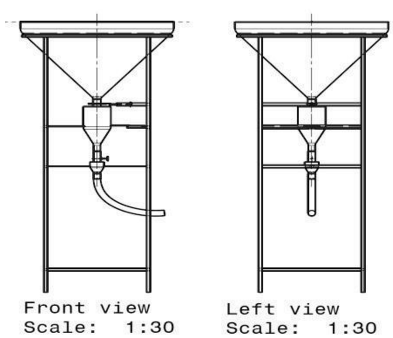

Fig. 11: Front and Left hand side view of assembly

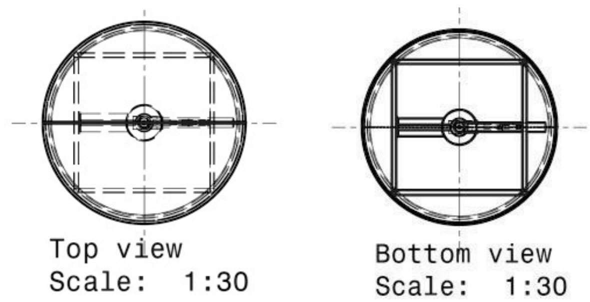

Fig. 12: Top and Bottom view of the assembly

7. CONCLUSIONS

The PTFE resin handling system and Hopper were designed for the selected industry. The proposed system is able to decrease handling time of PTFE material by using suggested automation. Hopper of volume 200 litre and automatic weighing scale capable of weighing granule up to 6 kg was designed. Outlet valve of weighing pot was intentionally kept manually operated to enable operator to open valve when mould was ready to fill. An operator can adjust the flow rate of granules coming out of weighing system, so that he can distribute granules in mould uniformly. One operator can operate two such systems simultaneously, this reduces manpower requirement. Up to 61% to 89% reduction in time can be achieved in mould filling enhancing the overall productivity. Once the granules are loaded in the hopper, it does not come in contact with air and human interface gets eliminated. The system can be improved in future so that operator can feed assigned mould part number instead of giving charge weight every time. Smart phone interface can also be implemented in the system using wireless modules.

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