Design Process Involved in Developing Mechanism of linear Motor Operated Multiple Spray Operations Spray Gun

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Abstract: Normally spray operation has been carried out in various processes such as air spray, High volume low pressure spray, air less spray, air assisted air less spray, electrostatic spray, ultrasonic spray etc. To carry out the spray operation in different processes different types of spray guns are used. Sometimes different types of spray operations are needed to finish the task of a certain product. In that case two or more types of spray guns are use to fulfill the requirement which is costly. On the other hand in automatic spray application, pneumatic system is used to trigger the spray gun. But the main disadvantage of pneumatic system is to position the fluid flow control valve as desired. This system needs more control knobs and highly skilled operator to carry out the quality spray operation. By addressing this issue a spray gun is designed in such a way that it can be accumulated four types of spray processes such as air spray, High volume low pressure air spray, air less spray and air assisted air less spray and the triggering operation has been carried out by specially designed sensor less DC linear motor. CATIA software is used to design the total spray gun model. In the first phase all the component of the spray gun such as spray unit, spray unit holder and shaft assembly, air control unit, triggering lever, motor housing, motor, and cover plate have been designed and then assemble all components to get the total spray gun model in the second phase accordingly. This paper is focused on to discuss the complete design processes involved in developing this especially dedicated spray gun and its operating mechanism.

Key word: mechanical design, spray gun, liner motor, multiple sprays.

INTRODUCTION

The transformation of bulk liquid into sprays and other physical dispersions of small particles in a gaseous atmosphere are of importance in several industrial processes. These include: combustion, process industries, agriculture and many other application in medicine and metrology. During the past decade there has been a tremendous expansion of interest in science and technology of atomization, which has now developed into a major international and interdisciplinary field of research. It is becoming increasingly important for engineers to acquire a better understanding of the basic atomization process and to be fully conversant with the capabilities and limitations of all the relevant atomization devices (Lefebvre, 1989). Presently there are four major processes of spray application: air atomization conventional air spray, high volume low pressure (HVLP) atomization, airless atomization and air assisted airless atomization. In air spray atomization fluid emerging from a nozzle at low speed is surrounded by a high speed stream of air. Friction between the liquid and air accelerates and disrupts the fluid stream and causes atomization. On the other hand, in the airless atomization process a high pressure forces fluid through a small nozzle. The fluid emerges as a solid stream or sheet at a high speed. The friction between the fluid and the air disrupts the stream, breaking it into fragments initially and ultimately into droplets (GRACO; Hund J.P.).

The manual and automatic spray guns are used to carry out the different types of spray application process and researchers have developed verity of new and innovative spray guns. Brief descriptions of some innovative spray guns are as follows:

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A modular spray gun that can be configured and built to operate using a selectable spray processes. The modular spray gun includes a gun body, an extension and a selectable spray atomizing component. The basic gun body and extension are used to configure a spray gun that can operate as an air spray gun, an airless spray gun, an AAA gun or an HVLP spray gun. The modular extension can be selected to allow circulation and noncirculating operation. The modular extension also permits a variety of spray nozzle assembly to be mounted thereon depending on the selected spray process to be used with specific gun. The modular gun body allows selective connection of an atomizing air supply and additional components specific to a particular spray process. An indicator device and or relief valve is provided for spray guns using an HVLP spray process to provide an indication that the spray gun is in compliance with maximum nozzle air pressure limit usually less than 10 psi. A new air valve seal assembly is also provided (Hartle et al., 2002).

An improved HVLP spray gun which operates from an air source and an improved nozzle are discussed here. The HVLP gun has a fluid nozzle including a first integral, laterally extending portion including pressure reduction orifices which are calibrated, relative to a fluid passage in the nozzle, so that the spray gun operates as an HVLP spray gun. This spray gun is especially lightweight, having a reduced trigger force needed to operate and can be used to spray all types of coating materials including corrosive waterborne paint (Weinstein and Seitz, 1998).

A spraying system for delivering a plurality of fluids for applying to a surface is focused in this invention. This spraying system includes a nozzle assembly having a fluid tip, a body with a central orifice, an air cap having a set of passages in communication with a set of orifices and a set of conduits contained at least partially within the set of passages, and a plurality of fluid circuits in communication with the nozzle assembly. One of the fluid circuits is adapted to deliver an adhesive, one of the fluid circuits is adapted to deliver an activator, one of the fluid circuits is adapted to deliver atomization air and one of the fluid circuits is adapted to deliver fan air from the nozzle assembly. This spray system also includes the controller to operate the system (Dingler D.W. 2001).

A spray gun is easily convertible between a number of configurations. A removable fluid insert may be placed in interchangeable spray heads with the fluid insert being either a pressure fed device which depends downwardly from the front end of the gun into a pressurized cup or via a connection to a pressurized fluid source or may have an upwardly directed insert which will take fluid from gravity cup. A simple air swivel also adds ergonomic benefits (Anderson et al., 2000).

A high volume, low pressure spray gun for use with air atomizable liquids includes a gun handle and a gun barrel. A plenum is defined in the gun barrel. A valve seat defined in the gun barrel communicates with the plenum. A supply air inlet in the plenum feeds supply air into the plenum. An aperture in the plenum directs air flow out of the plenum. A first outlet defined in a wall of the aperture directs fan air flow out of the aperture and second outlet defined in the wall of the aperture directs atomizing air flow out of the aperture. A third outlet, which is located in the plenum, directs atomizing air flow out of the plenum. The third outlet is located on one side of the valve seat and the second outlet is located on the other side of the valve seat. With this construction, the valve may selectively close one of these outlets and restrict atomization air flow out of the plenum. At the same time the fan air flow is shut off (Scholl, 2000).

From the above descriptions it can be concluded that still there are verity of ways of thinking to modify the spray guns and their functionality. From this point of view a spray gun is designed in such a way that it can be used in four different spray application processes such as air spray, HVLP air spray, airless spray and air assisted air less spray without dismantle the internal system. CATIA software is used to design the total spray gun model. In the first phase all the component of the spray gun such as spray unit, spray unit holder, shaft, air control unit, triggering lever, motor housing and cover plate have been designed and then assemble all components to get the total spray gun model in the second phase accordingly. This paper is focused on to discuss the complete design process involved in developing this especially dedicated spray gun.

2. Mechanical Design of Spray Gun:
2.1 Design of Spray Unit:
Spray units comprise fluid nozzles, air nozzles, assembly cap, and paint housing. In this propose design, fluid nozzles, air nozzles, and assembly caps are going use the standard commercial one. Two units of spray housing are designed for air spray and airless spray accordingly. Figure 1 shows the spray units of the spray gun.
Fig. 1: (a) Air spray assembly
These two units of spray housing are held to the spray gun body with a holder. The holder is attached at the holding places of the paint housing. Three air passages are provided in this model to fill the requirement of the amount of air which is used for atomization. Four air releasing holes are provided to atomize the paint according to the painting process. All the features are similar in both units but the configurations are different because airless system needs almost double pressure compare to air spray. The needle valve passage and the ball valve passage are designed in such a way that these can hold the valves properly without leaking the paint. The valves are kept through the passage with rubber shielded hollow nuts.

To select the proper materials and dimensions of the paint housing, analyses can be carried out by considering the paint housing as a pressure vessel. Deflection theory and failure theory can also be used in these analyses.

### 2.2 Design of Spray Unit Holder and Shaft:

Spray unit holder is designed to hold the two units of spray unit. Fig. 2 shows the spray unit holder and the shaft arrangement.

There are two links of this holder and they are $90^\circ$ apart from each other. One end of the holder links are held the spray units and other ends are attached with a shaft. The shaft is kept in position in the spray gun body by the help of bearings and can rotate only $90^\circ$ in either side. This rotation is provided to the shaft to adjust the position of the spray unit during the desired painting operation. Since the high pressure fluid is flown through the spray unit therefore high force is subjected at the ends of the holder links where the spray units are held and the holder links are behaved like a cantilever beam. Therefore beam theories can be use to analyses this part to get optimum dimensions and material. The shaft is subjected to bending moment and torque. Therefore, should fatigue be considered in the analysis of the shaft. To investigate the feasibility of manufacturing of this part, rapid prototyping has been carried out.

### 2.3 Design of Spray Gun Casing:

Spray gun casing is designed that can be hold almost all the major components as desired such as spray unit, spray unit holder, triggering lever, air passing piping system and linear motor. Fig.3. shows the spray gun casing.
As the Figure shown the front upper part is allocated for the spraying system and lower part is allocated for the housing for the linear motor. A rotation passage is provided to ensure the smooth rotation of the spray units with needle and ball valve. Shaft rotation control housing is provided to adjust the rotation of the shaft as well as adjust the positioning of the spray unit. This can also be used to hold the shaft properly. The top part of the casing is designed to hold the pin of the triggering lever and also provided the passage for air passing pipes. The motor housing is designed in such a way that cylindrical shaped linear motor can be accommodate smoothly.

2.4 Design of Air Control Unit:

Referring to Fig. 4, the air control unit comprises air control unit casing, air passage block, rear cover plate, air valve, air passage protector, tube adjusting system and upper cover plate.

Fig. 3: Spray gun casing

Fig. 4: Air control unit
Air control unit casing is designed in such a way that it can hold the air valve, air control system and tube adjusting system. The upper part of this housing is designed to accommodate the air control system and tube adjusting system and the lower part is designed to hold the air valve. Three control knobs are used to control the air flow and tube adjustment. The side control knobs are used to control the air flow as desired for the air spray, HVLP air spray, air assisted air less spray system. The rear knob is used to position the tubes into the spray unit. Three tubes are used to maintain the amount of air flow as desired for the above mentioned spray systems. These three tubes are attached with the rear knob in such a way that by rotating the knob the tube adjusting system can be moved back and forth. This back and forth movement of the pipes has been provided to facilitate the locking system of spray units which will restrict the rotation of spray unit when it comes to the position of spray operation. Spring operated air valve is designed in conventional way as designed for the other conventional spray guns to allow the air to flow inside the system. The main difference between this air valve and the commercial air valve is that this air valve can also used to operate the triggering system of this proposed spray gun. The needle of the air valve is attached with rear part of the triggering lever. Due to the spring force the triggering lever will be held in position as well as to hold the needle or ball valve of the spray system since the needle or ball valve is attached with front part of the triggering lever. The attaching knob and the valve seat of the air valve are so designed that these can be attached in the housing and operated properly.

2.5 Design of Spray Gun Casing Cover Plate:
Spray gun casing cover plate is shown in Fig. 5. This casing is designed to cover the linear motor and hold the linear motor firmly. This casing is provided an air supply channel to allow the air to flow into the air control housing. The front upper part of the casing is designed to hold the air control unit.

![Fig. 5: spray gun casing cover plate](image)

2.5 Design of Triggering Lever:
The triggering lever plays the vital role for spraying operation. This triggering lever is designed in such a way that the lower part of the lever is connected to the linear motor which will provided the thrust to lever with the help of the connector link. Pin joint is provided between the lower part of the lever and the upper part of the connector link. Lower part of the connector link is attached with the shaft of the linear motor. The upper part of the lever is attached with the needle of the air valve and the upper front part is attached with the needle valve or ball valve of the spray unit. During the painting operation, linear motor provides the thrust to triggering lever and due to the pin joint the lever moves backward by compressing the air valve spring and allows the air to flow inside the system. Since the lever is displaced, it will displace the needle valve or ball valve position on the other hand opens the nozzle and painting operation is performed. Fig. 6. shows the triggering lever and connecting link.

3. Basic Structure of Linear Motor
Referring to Fig. 7. shows the internal component of the sensor less DC linear motor. This linear motor comprises four coils, four permanent magnets, a shaft, two linear bushes a back yoke and two cover plates. The cylindrical shaped linear motor is attached with the triggering lever by the connector link. The motor is design in such way that it can produce required amount of force. This newly design linear motor is used the especial permanent magnet which produce the radial magnetic flux. Production of radial flux reduces the longitudinal dimension of the motor. A motor driver is used to operate the linear motor.
4 Proposed Spray Gun:

Figure 8 and 9 shows the internal system and proposed designed spray gun respectively. Two spray units are used to fill the requirement of four types of spray system such as air spray, HVLP air spray, airless spray, and air assisted airless spray without dismantle the internal system. The spray units can be rotated 90° either side. An especially designed linear motor is used to trigger the spray gun instead of pneumatic system. A single air control unit, an air control valve, a triggering lever are used to carry out the spraying operation. All the components are housed in a single casing. This will be reduced the cost of the spray gun. All the designed components are prototyped to test the functionality of the spray gun.
Conclusion:

Two spray units are used to full fill the requirement of four types of spray system such as air spray, HVLP air spray, airless spray, and air assisted airless spray without dismantle the internal system. The spray units can be rotated 90° either side. A special designed linear motor is used to trigger the spray gun instead of pneumatic system. A single air control unit, an air control valve and a triggering lever are used to carry out the spraying operation. All the components are housed in a single gun body. During the painting operation, the spray unit is positioned by rotating the holder shaft. Once the spray unit is in position that ensures the rear end of the needle valve or the ball valve is inside the passage the triggering lever. After getting the position of the spray unit, the air flowing piping system is inserted into the spray unit by rotating the rear knob of the air control unit which will protect the rotational movement of the spray unit. Now the sensor less DC linear motor is activated to produce the thrust to the triggering lever and due to the pin joint the lever moves backward by compressing the air valve spring and allows the air to flow inside the system. Since the lever is displaced, it will displace the needle valve or ball valve position on the other hand opens the nozzle and painting operation is performed. For air less spray system air supply will be stopped. In order to execute the system, at least 7 bar to 9 bar air pressure and at least 6 bar fluid pressure are needed for air spray system. For air less system at least 35 bar of fluid pressure is necessary. In order to execute the linear motor at least 0.4 A DC input current is necessary.

REFERENCES

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