Review on Gyratory Mechanism of Spraying Machine for Cylindrical case

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Abstract-*The role of a liner spraying machine is to spray the liner material on the interior surface of the cylindrical case. The attention must be given to the consistency of the thickness of the spraying material. The present machine used is stodgy as not much development has been done on it before. Thus the aim of this paper is to review a gyratory mechanism, which turns the motor to carry out the spraying process, taking into consideration that the cylindrical case may be of different diameters. This paper states the desirable mechanism which fulfils the objective of a machine that is adaptable, flexible and takes less space and is easy to assemble and disassemble.*

Keywords-- Adhesive, Case-bonded, Chemical Migration, Insulator, Liner, Motor, Propellant, Primer.

I. INTRODUCTION

The liner plays an important role in a rocket motor. It only assists in predicting the performance of the rocket motor but also holds the propellant and the insulator under various environmental conditions. It is essential that the composition of the liner be based on the same binder system used in the formulation of the propellant. Besides carrying out the function to provide a limited fire protection effect, thus providing a protective shield for the insulator, a liner with a thin layer is applied to make sure that a compatible bond is created and maintained between the propellant and the insulator in the rocket motor.

It is essential for the rocket motor bond lines to be monitored during the fabrication process and thereafter correct the imperfections in order to minimize defects. Solid Rocket Motors consist of layers of preferably similar materials contained under a rigid outer case making them a rather complex and highly stressed integrated structure. Therefore their reliability depends directly on the integrity of bonds between these layers. A basic structure of an SRM is shown in Figure 1.

Solid rocket propellants can be classified as cartridge-loaded propellants and case-bonded propellants. Cartridge-loaded systems are comparatively simple and are preferable for defence payload-carrying capacity and large sizes are required. The case-bonded motor primarily consists of a motor case, an insulator, a liner, and a propellant as major subsystems.

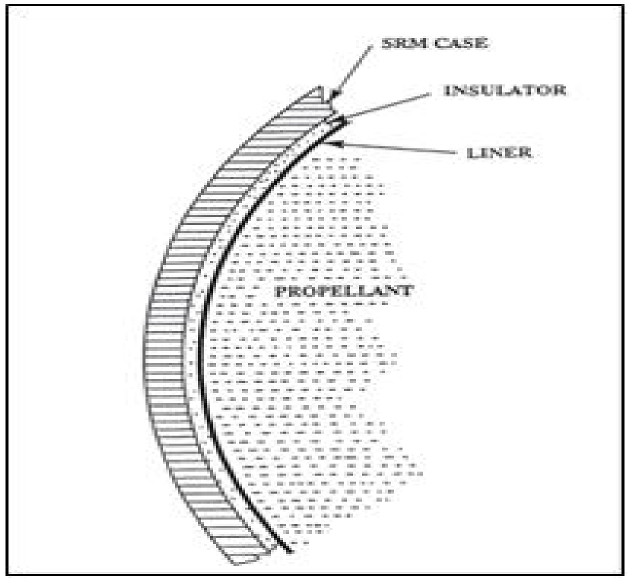

Figure 1: Generic Solid Rocket Motor Casing Structure

II. METHODOLOGY

i. Obtaining Necessary Input Specifications from Industry

Initial part was to obtain inputs from the industry to understand the kind of problem they were facing in their machine.

The specified areas where work had to be done were discussed and worked upon. The inputs that were provided to us are listed below:

- Length of motor casing : 3000mm
- Range of diameter of the casing: min 200mm & max 500mm
- Range of RPM of casing : min 20 & max 50
- Density of material of casing : 7850 kg/m3
- Casing material : Mild Steel (MS)

ii. Breaking Down the Mechanism

The rotating mechanism of the Liner Coating Machine consists of various elements. It was difficult to think of a solution for the machine as a whole. So, we had to break it down to different elements and work on each element individually for final design. At final stage, we will compile all the designs of the individual components together.

iii. Literature Survey

At initial stage, it was very hard to find the research papers on ‘Liner Coating Machine’. So we divided machine into various elements and we found research papers on each of those elements.

iv. Roller Wheel Design

Roller wheel design consists of various aspects like material of the wheel, wheel diameter and the distance between the wheels. We got the friction material from literature survey which can be applied over the wheel periphery to optimize its coefficient of friction (μ) and specific wear rate. We also found out the distance between two rolling wheels for minimum and maximum casing diameters. We also have to find out appropriate diameter for the roller wheels which will support the casing and transmit the required torque.

v. Mechanisms

So far, we have worked on three mechanisms. Out of which, the first mechanism consisted of a turn-buckle and a handle to rotate it; but due to the bulkiness of the mechanism, we stopped considering it. The second mechanism consisted of a lead screw but dew to the compilations that came along with it we have finalised our third solution that consists of a spring, four links and two sliders.

vi. Design of Bed

The entire mechanism will rest on a bed, thus providing support for the whole structure, simultaneously providing the necessary height, which is an ergonomic requirement for the operator.

vii. Design of Mountings

Mountings are requires to mount various elements of the mechanism on the bed and the mechanism itself.

viii. Design of Transmission Mechanism

The input speed from DC motor is 2000 RPM and speed range of the machine is 20 to 50 RPM. So, we have to design a transmission mechanism for this speed reduction. Preferably, pulley and belt combination will be used because of its simplicity; but we are also looking whether Continuously Varying Transmission (CVT) will be compatible or not.

ix. Design of Springs

The mechanism we are working on has three springs. The two springs relatively larger in size are connected between the slider links and the inner links while the third spring is connected between the 2 inner links. We have to optimize the stiffness of the material, so that the axis of rotation will be aligned irrespective of different diameters of the casing.

x. Design Compilation and Analysis

During the final stage, we will compile the design to make it one. Also, we will carry out an analysis of each component along with carrying out an analysis of the assembled mechanism. For analysis, we will use analysis software like ANSYS, Hyper mesh, etc.

III. ANALYSIS AND NATURE OF FORCES

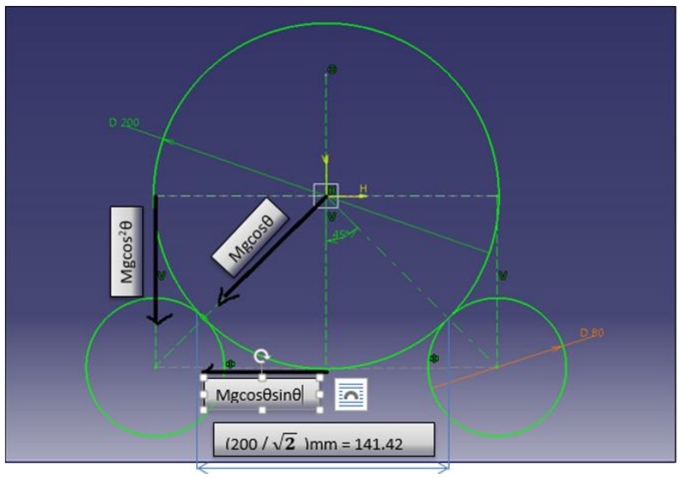

Figure 2: Force Diagram between Casing & Roller Wheels

In the above image the two smaller circles represent the roller wheels on which the rocket motor with a certain thickness and mass will be placed. There will be four roller wheels out of which one will be driving and other three will be driven. So the image represents the default magnitude and direction of the forces.

A. Space

The length of all the rocket motors is three meters. The diameter of the rocket motors is in the range of 200 mm to 500 mm. The whole mechanism is to be fitted in a space of approximately five meter length and three meter width with a constant height of the axis of rotation of the rocket motor from the ground. So the bed dimensions will be 5X3 m.

B. Weight

The mechanism has to be designed such that it can rotate rocket motors with diameters ranging from 200mm to 500mm. The thickness of each rocket motor is 15mm. The material used is mild steel. The length of each rocket motor is 3m. Following are the weights of different rocket motors:

1. For 200mm diameter Rocket motor:

W200 = ρ*V*g
Where,
ρ = Density of the material
V = Volume of the rocket motor
g = Acceleration due to gravity

Thus,
W200 = (7850*Π*(0.22-0.172)*3*9.81) / 4
W200 = 2014.06 N
Similarly,
W300 = 3102.74 N
W400 = 4191.42 N
W500 = 5280.1 N

C. Height

The height of the axis of rotation of rocket motor should be in the range of 925mm to 975mm so that the boom with the spray gun attached gets properly preceded and there is no contact between the rocket motor inner wall and spray gun.

IV. MECHANISMS

A. Wheel-Slider-Spring Rotary Mechanism

This mechanism consists of spring and sliders. Whenever the rocket motor rests on the two rollers, the links actuate depending on the weight of the motor casing. The two rollers move outwards and the spring at the center gets elongated. This elongation of the spring does not allow the rollers to move towards the extreme ends. The central axis of rotation of the rocket motor casing is to be maintained. Hence the elongated spring keeps the central axis of rotation fixed.
During this movement of the rollers and the springs the links connecting the rollers and the sliders also move. The movement of the links is such that the sliders tend to move outwards linearly. To stop the further movement of the sliders and to support the weight of the motor while rotation these sliders have to be clamped to the rails or the guides on which these are sliding.

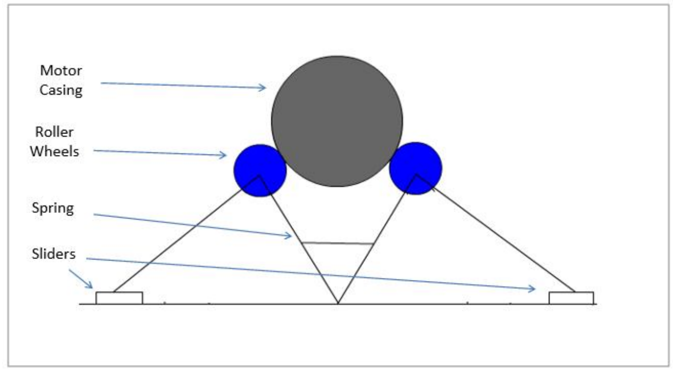

Figure 3: Wheel-Slider-Spring Rotary Mechanism

B. Inclined Rollers-Slider-Spring Mechanism

Instead of just rotating, a linear motion can be given to the motor. The mechanism consists of two long rollers on each side of the motor. These rollers are inclined at an angle in the horizontal direction with respect to the position of the motor. The power is given to either of the two rollers or both of them.Since the rollers are inclined at an angle to the motor, the forces acting on the motor are in such a way that, once the rollers start to rotate the motor also starts rotating and traverses in the forward direction hence a rolling motion is achieved.

Figure 4: Inclined Rollers-Slider-Spring Mechanism

The motor can be retracted by changing the direction of rotation of the rollers. Using this type of motion the nozzle, spraying the material in the motor does not have to travel a long distance. The distance that the motor travels can be constrained using proximity sensors. The centre of the motor can be adjusted using slider mechanism.

C. Lead Screw-Slider -Spring Mechanism

An advancement in the rolling type motion is using a lead screw. One of the lead screws will be power driven out of the two and the rocket motor would be placed on the top them. Due to the threads on both the screws, it will give a linear motion to the motor up to a certain distance in one direction. If the motor has to be retracted then the screw could be rotated in the opposite direction. The lead screws need not be kept at angle. The threads give a forward motion to the cylinder, so the lead screws and the motor have to be parallel to each other. The distance, the motor would travel can be constrained using sensors, which would stop the motion of the lead screws once the motor has traversed the proximity sensors. The centre of rotation can be maintained using sliders.

Figure 5: Lead Screw-Slider-Spring Mechanism

V. WHEEL MATERIAL SELECTION

The coefficient of friction of the material which is to be coated on the two roller wheels should be above 0.38 to transmit the motion effectively and below 0.55 to restrict it from wearing the casing material. Also, the speed range in which the machine will get operated is 20-50 RPM (0.20 m/s – 1.30 m/s). Hence, the material should be selected which will satisfy all the above parameters.

The comparison between different friction materials is discussed in this chapter. The friction materials are distinguished depending on different composition of phenolic resin base. We have selected material FM125 because it optimizes all the material as discussed in the section below.

A. Variation of Friction Coefficient (μ) of Composites with Load

It can be observed from the graph shown in figure (4) as in [14], that the material FM1350 consistently shows a higher coefficient of friction at all loads, which is in the required range for our application. FM125 also meets the requirement, showing slightly lower coefficient of friction than FM1350.

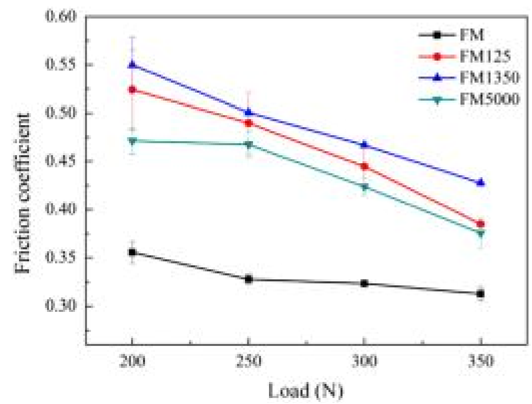

Figure 6: Variation of coefficient of friction of composites with load

B. Variation of Friction Coefficient (μ) of Composites with speed

It can be observed from the graph shown in figure (5) as in [14], material FM125 has higher μ initially but as the speed increases, material FM1350 takes the lead and maintains throughout. But, the coefficient of friction (μ) between the speed range (0.2 m/s – 1.3 m/s) satisfies our requirement which is between 0.38 and 0.55. Hence, material FM125 is suitable material in this case.

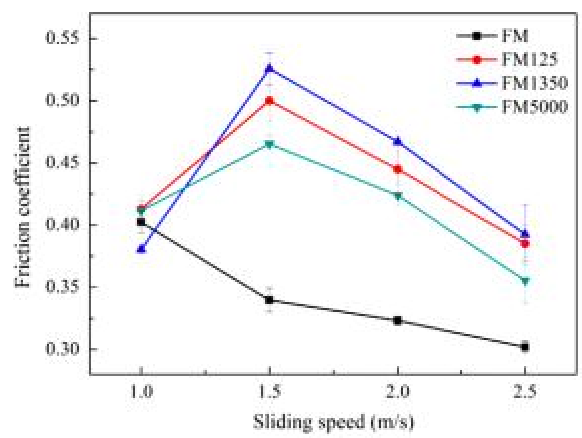

Figure 7: Variation of coefficient of friction of composites with speed

C. Variation of Specific Wear Rate of Composite with Load

It can be observed from the graph shown in figure (6) as in [14], specific wear rate of material FM1350 increased rapidly with load, which is undesirable for our application. Material FM125 shows a very low wear rate even at a higher load. Hence considering the high μ requirement and low wear rate requirement; FM125 is suitable for our application.

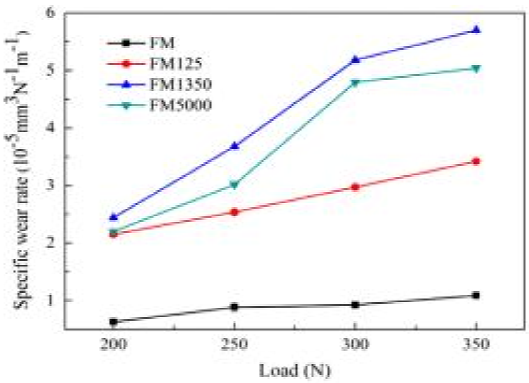

Figure 8: Variation of wear rate composites with load

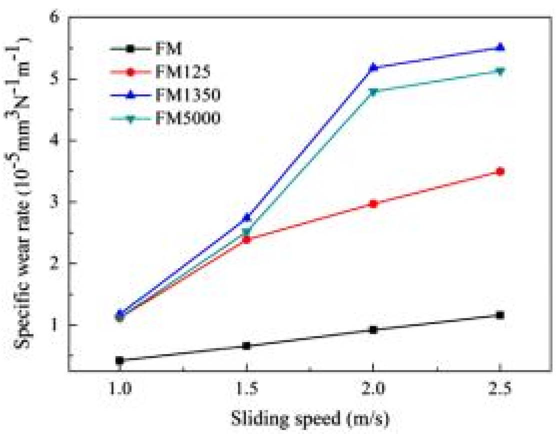

Figure 9: Variation of wear rate of composites with speed

D. Variation of Specific Wear Rate of Composites with speed

It can be observed from the graph shown in figure (7) as in [14], initially all the friction materials excluding FM increases rapidly; but material FM125 stables out as the speed increases. The range of coefficient of friction at the particular speed required in our case is getting satisfied by the material FM 125.

VI. CONCLUSION

It can be concluded that friction material FM125 can be used as a coating material for the roller wheels as it shows optimum values of the friction coefficient and low specific wear rate, each with respect to both varying load and sliding speeds. As per calculations the distance between the contact points of the rolling wheels with the motor casing should range between optimum values for motor casing diameters ranging from 200 mm to 500 mm respectively. This distance should be maintained in order to allow transmissibility of maximum torque. After analyzing the mechanisms, we found that the lead-screw mechanism, irrespective of its advantages, had a fair share of drawbacks such as being heavy and bulky, also it cannot be disassembled that makes shifting the machine a problem. Inclined Rollers- Sliders- Spring mechanism increases productivity as spraying gun and mechanism are advancing towards each other; but the whole gyratory mechanism is needed to move which makes it heavy and becomes impossible the site. The slider-spring rotary mechanism is flexible, self-adjusting, light in weight and easy to dismantle which satisfies our objectives.

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