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EXPERIMENTAL INVESTIGATION AND DYNAMIC SIMULATION FOR SINGULARISING UNIT IN PART FEEDERS

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Abstract

In the automotive sector, the act of feeding and orienting the asymmetric components in desired orientation was considered as major problem. Brake pad was considered in this work and a singularising unit (hopper) was developed for separating them. The objective of this work was to identify the suitable parameters for feeding the irregular part one by one in the specified orientations. Experiments were conducted for various frequency levels at various levels of inclination of the hopper using base plates. The experimental outcome provides the suitable parameters of base plate thickness and frequency of vibration. The hopper model was developed and the vibration analysis was carried out using dynamic simulation software. The results of the physical experiments and simulated design experiment were compared. The comparison shows an appreciable relationship to each other.

Keywords: Singularising unit, Markov model, Dynamic simulation, Brake pad and real time experiments.

1. Introduction

Linear Part Feeding System was used to handle the irregular parts without expensive robots and vision systems during the part assembly process. The part feeder receives the randomly oriented parts at its input and delivers them in a specified orientation. A vibratory feeder is an instrument that uses vibration to feed the part to a process or machine. The vibration ensures that the parts keep moving towards the exit of the feeder without congested. The art of feeder design is a trial and error process with respect to the tangible nature of the part for which the feeding system has to be developed. The parts which are regular in shape yields more flexibility to feed and to assemble them. Being an irregular part, brake pad is having more than a stable form. It possesses the function of feeding in the specified orientation is complex. This demands to develop a singularising unit by considering the shape and the possible orientations of the part for feeding and orienting them in an appropriate orientation.

Initially, the backing plate of the brake pad is stamped. After the stamping process, the surface of backing plate is roughened to increase adhesion to avoid material breaking away from the backing plate. Then adhesive is applied to the backing plate and the plate is prepared to bond with the friction materials. Raw materials are formulated for highest quality for better performance and long life. Materials are blended to obtain the best formulations so that the performance of the brake pad is improved. Then the unique formulations are moulded under extreme temperatures and pressure into the shape of the bricks. After the molding process, the friction materials are bonded to the backing plate under immense heat and pressure. Then the pads are heated again in the heating processor for 8 to 10 hours to attain everlasting attachment. Painting embellishes the appearance of the brake pads and protects them from rust and corrosion. After the molding process the brake pads are oriented and stored manually, which consumes more labour time. So a part feeding system is introduced in-between the molding and bonding process. Because of the part feeding system, productivity can be increased by reducing the labour time. The asymmetric part like brake pad has more number of orientations as shown in Fig. 1. This makes the process of feeding, orienting and storing a tedious task. Hence, a specialised feeding system has to be designed.

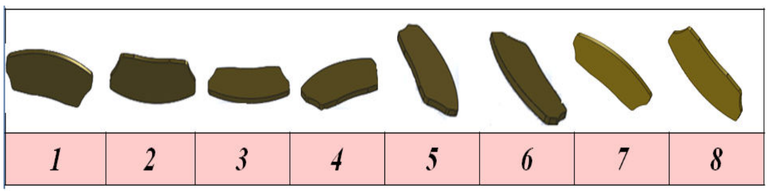

Fig. 1. Possible Orientations of Brake Pad.

2. Literature Review

Suresh et al. [1] found the favorable orientation of a brake pad using drop test and theoretical methods. Berkowitz and Canny [2] performed multiple feeder design experiment and developed a tool based on dynamic simulation to design the part feeders. Berkowitz and Canny [3] described the use of dynamic simulation for part feeder design and stated that the results of dynamic simulation and physical experiment show strong similarities. Gary et al. [4] developed a mathematical model and explained that from the model, a computer simulation can predict the part feed rate. Vilan et al. [5] described a model for predicting the behavior of the part in vibratory bowl feeder. To highlight the reliability of the obtained numerical results, the behavior of a part was simulated, using the visual Nastran program. Sheng et al. [6] conducted experiments and simulation study to investigate the drop impact of portable electronic devices. The drop impact responses examined are compared with the modeling simulation results. Reznik et al. [7] presented a qualitative examination of the motion of the micro actuated array based on dynamic simulation. Moll and Erdmann [8] used dynamic simulation for determining the pose distribution for an object. The experimental results show that simulation is a useful tool for determining the initial condition for uncertainty reduction.

3. Hopper Design and Testing

3.1. Markov analysis

The singularising unit was designed by Markov Analysis, a mathematical system that undergoes transitions of part from one state to another, between a finite or countable number of possible states. The part has eight possible orientations which were identified through drop test [1]. Singularising unit is a mechanism which is used to transfer or move an object from one specific location to another within a specific duration of time period, the "Hopper feeder or singularising unit" used to transfer the brake pads from the drop point to the end of the feeder, during this process it has a dual role of not only delivering the object but also singularising the brake pads and letting them to pass out in a specific number (here one at a time). The specialised hopper system designed is shown in Fig. 2.

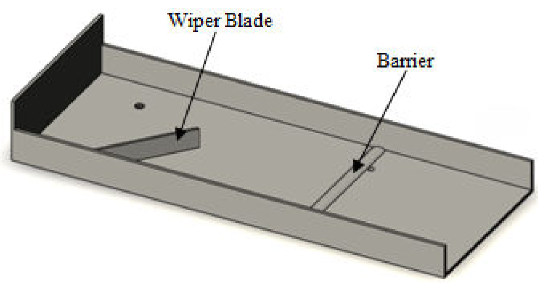

Fig. 2. Hopper.

The hopper feeder should be designed to get the orientation 5 and 6 as the output. In stage I, the wiper blade (Gate I) introduced at the entry of the hopper to change orientation 1, 2, 3, 4, 7 and 8 to orientation 5 and 6 respectively.

In stage II, barrier (Gate II) is introduced to send the parts one by one to next stage. Because of the geometry and shape of the part, these orientation changes occur. The obtained Markov model for each gates were chained together to get a model of the final hopper feeder. Final hopper unit was designed by combining the stages I and II as shown in Fig. 3.

3.2. Experimental testing

The hopper is placed over the vibrator. To increase the performance of the feeding system, base plates of various thicknesses are placed between the hopper and the vibrator. Base plate is shown in Fig. 4. By varying the parameters of base plate thickness and frequency the experiments were conducted. The obtained results were noted.

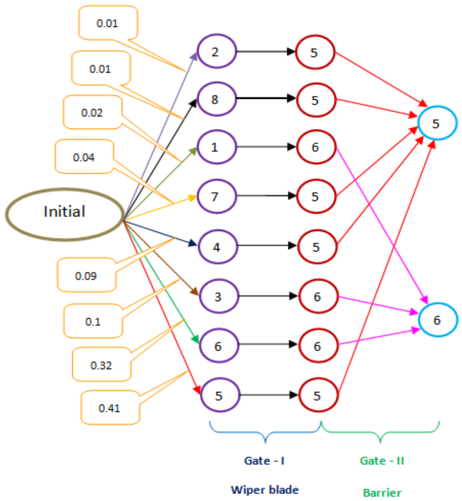

Fig. 3. Markov Model for Wiper Blade and Barrier.

Fig. 4. Base Plate.

An accelerometer is connected to the bottom of the hopper system, the accelerometer output is connected to a DAQ Card, and the system is also connected through a display system. The acceleration response was obtained for all the part motion using lab VIEW software. The time taken for the passing of the brake pad was recorded using a stop watch. The experimental setup is shown in Fig. 5.

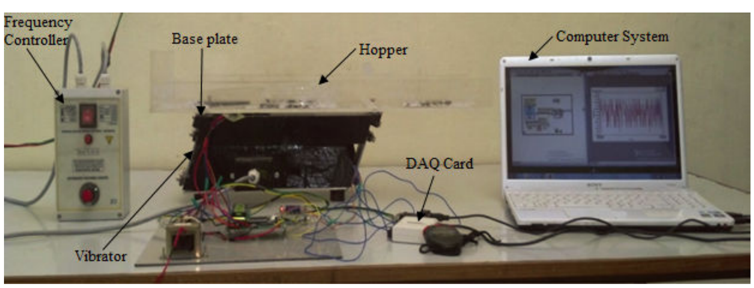

Fig. 5. Experimental Set-Up.

Because of the applied vibration the possible orientations are converted into the favorable orientations. Thus the experiments were conducted by varying the heights of the hopper and changing the frequency of vibration by using vibration controller.

3.3. ADAMS vibration analysis

A functional virtual prototype of the singularising unit is efficiently built using ADAMS/View to take the system to different operating points to analyse the vibration behaviour using ADAMS/Vibration as shown in Fig. 6.

Input channels and output channels are created to vibrate the system and measure the response respectively. A vibration actuator applies force input or a displacement, velocity, or acceleration to vibrate the system. The model was tested and evaluated by running vibration analysis for different input ranges. Animation and frequency response helps to improve the system performance.

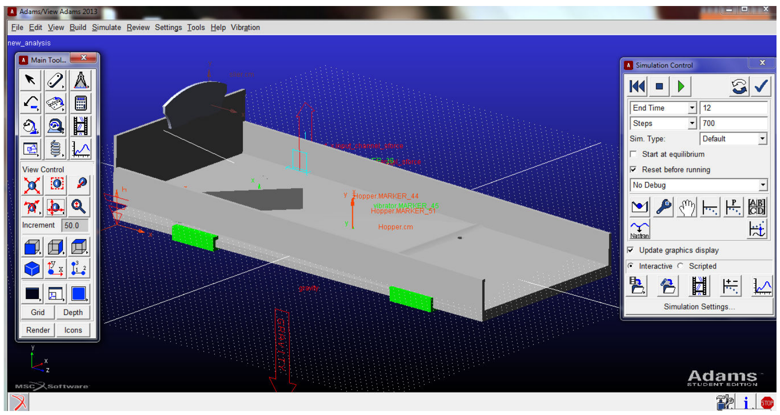

Fig. 6. Feeder Design using ADAMS Software.

4. Results and Discussions

The outcome of the experimental results and simulation results are discussed in this section.

4.1. Experimental results

Experiments were conducted for the frequency levels of 40 Hz to 85 Hz for various base plate thicknesses of 2 mm to 22 mm. Tables 1-3 shows the acceleration and time values obtained for the base plate thickness of 4 mm, 8 mm and 12 mm respectively.

Figure 7 shows the plots of Frequency value and time value. The graph shows that the time taken for the brake pad to travel on the singularising unit was minimum for the frequency levels of 65 Hz to 75 Hz for the base plate thicknesses of 10 mm, 12 mm and 14 mm.

Table 1. Result Tabulation for Base Plate of 4 mm Thickness.

S. No.	Base plate thickness (mm)	Frequency (Hz)	Time (sec)	Acceleration (mm/sec^2)
1	4	40	72.63	1.766
2	4	45	72.56	1.952
3	4	50	72.42	2.163
4	4	55	72.19	1.824
5	4	60	72.24	1.748
6	4	65	72.12	2.047
7	4	70	72.08	2.109
8	4	75	71.02	2.730
9	4	80	71.00	1.964
10	4	85	72.69	1.920

Table 2. Result Tabulation for Base Plate of 8 mm Thickness.

S. No.	Base plate thickness (mm)	Frequency (Hz)	Time (sec)	Acceleration (mm/sec^2)
1	8	40	67.12	7.414
2	8	45	66.92	8.291
3	8	50	65.00	9.394
4	8	55	64.61	9.842
5	8	60	62.48	10.196
6	8	65	60.12	10.546
7	8	70	59.31	11.231
8	8	75	59.13	10.636
9	8	80	63.72	10.352
10	8	85	66.92	9.794

Table 3. Result Tabulation for Base Plate of 12 mm Thickness.

S. No.	Base plate thickness (mm)	Frequency (Hz)	Time (sec)	Acceleration (mm/sec^2)
1	12	40	62.34	10.436
2	12	45	61.76	10.563
3	12	50	58.41	10.741
4	12	55	55.28	10.825
5	12	60	53.32	10.972
6	12	65	49.91	11.127
7	12	70	46.13	11.373
8	12	75	45.17	11.427
9	12	80	51.27	10.359
10	12	85	54.12	9.728

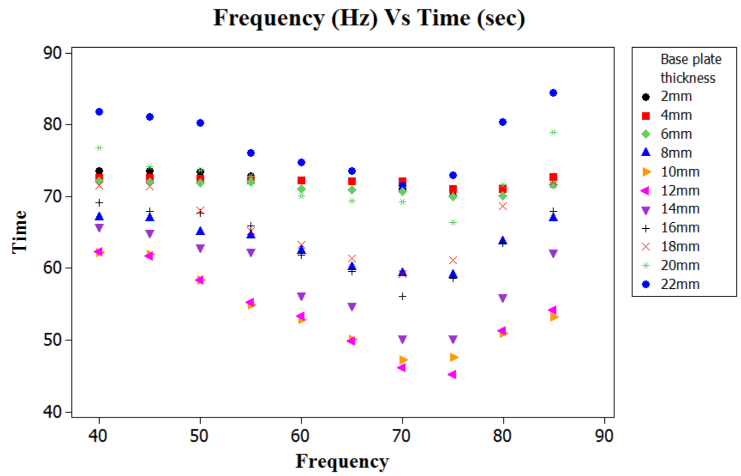

Fig. 7. Frequency vs. Time Plots.

Figure 8 shows the plots of the frequency value and the acceleration value. The graph shows that the acceleration of the brake pad is high for the frequency levels of 65 Hz to 75 Hz for the base plate thickness of 10 mm, 12 mm and 14 mm.

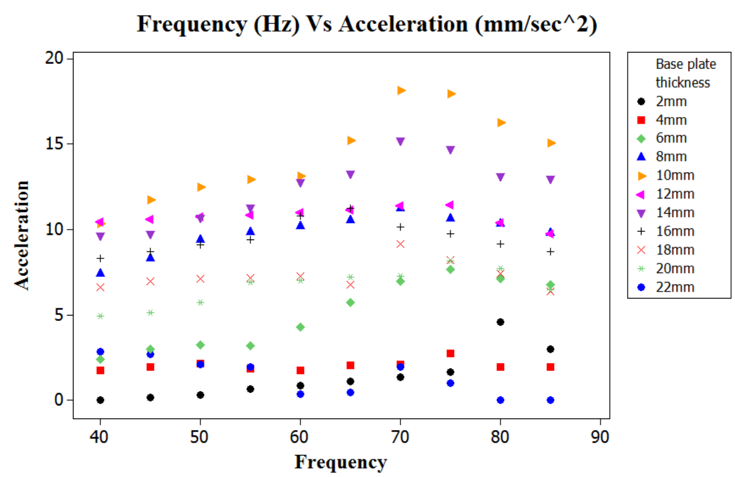

Fig. 8. Frequency vs. Acceleration Plots.

From the graphs the suitable parameters were identified, i.e., the frequency level of 65 Hz to 75 Hz and the base plate thickness of 10 mm to 14 mm.

4.2. Outcome of ADAMS analysis

Forced Vibration analysis was conducted on the virtual prototype by setting up the appropriate input and output channels. The input channels provides the ports into the system that was used to drives the system using vibration actuators. The output channels are output ports at which the frequency response of the system is examined. The frequency response of the model was evaluated by providing the input frequency at various levels and the effective simulation result was obtained for the frequency of 75 Hz.

The vibration study of the system using frequency domain analysis predicts the behaviour of the parts accurately. ADAMS/Postprocessor evaluates the frequency response functions for magnitude characteristics in plotted format by studying the data from the performed vibration analysis. This plot helps to understand that how the vibration affects the part motion on the system.

From the frequency response it was identified that the magnitude of vibration is low for the frequency of 75 Hz for base plate thickness of 12 mm. It is evident from the simulation results, which the part motion is effective and the appropriate function of the system is accomplished for the frequency of 75 Hz. From the analysis the optimum frequency level of the system was obtained as 75 Hz for base plate thickness of 12 mm. The frequency response obtained from the simulation was shown in the Fig. 9.

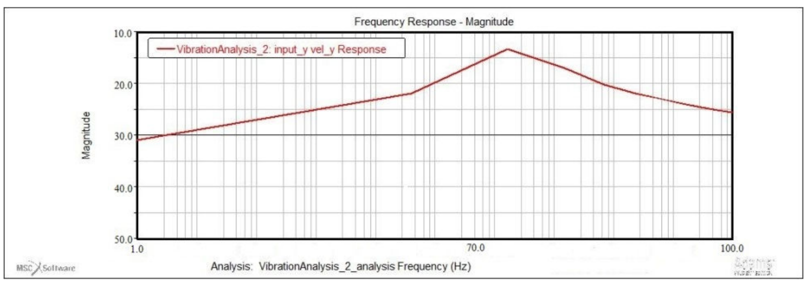

Fig. 9. Outcome of ADAMS Simulation.

From the experimental results the frequency levels of 65 Hz to 75 Hz and the base plate thickness of 10 mm to 14 mm was obtained as the suitable parameters for feeding the part on the singularising unit. As well as the frequency of 75 Hz for base plate thickness of 12 mm was obtained as the optimum value by conducting series of virtual test on the virtual prototype model using ADAMS software. By comparing the results of real time experiments and dynamic simulation, the frequency of 75 Hz and base plate thickness of 12 mm was obtained as the optimum value.

5. Conclusions

A singularising unit is designed in this work to improve the productivity of the brake pad manufacturing process. The importance of the singularising unit is to send the parts one by one to next unit. The hopper feeder is designed using the Markov model and the outcome is very encouraging. Experiments were also conducted using the innovative hopper feeder and the time for conveying the parts is also reported. Vibration analysis were conducted on the singularising unit using Lab VIEW, it provides the optimum frequency levels and base plate thickness. Further motion analysis is performed using ADAMS software and the predicted value correlates with the experimental results. Hence the effective part motion is obtained for the frequency of 75 Hz and for the base plate thickness of 12 mm.

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