OPTIMIZING CYCLE TIME OF DVD-R INJECTION MOULDING MACHINE

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Abstract:
This paper describes the cycle time reduction approach of injection moulding machine for DVD manufacturing. Optimizing the parameters of the injection moulding machine is critical to improve manufacturing processes. This research focuses on the optimization of injection moulding machine parameters. Suggestions for process improvements are made based on the results of a designed experiment. The objective of this experiment is to provide statistical evidence for optimizing parameters of an injection moulding machine. The machine parameters to be investigated include cooling time, holding time, and robot take out time limit. These parameters are evaluated against the problem of decreasing the cycle time for each part. Experimental data were collected following the designed experiment procedures, and a statistical analysis was performed to give a basis for process improvement recommendations. The results of the experiment showed a way to achieve the goal of optimizing the injection moulding machine in a sensible and cost efficient way.

Keywords: *Injection moulding machine, Cycle time reduction, DVD manufacturing***.**

I. Introduction

Cycle time reduction is inherently different from traditional cost cutting approaches to profit improvement. It enables rather than diminishes an organization’s ability to compete, by strengthening a company’s core capabilities and by developing the dimension of time as a new strategic weapon. Slashing cycle time is the fastest and most powerful approach to profitability improvement, especially for companies who have already realized most of their core manufacturing efficiency improvement opportunities. Cycle time reductions will directly impact almost every contributor to costs within your operations.

To provide the best quality DVD product at low cost is a big challenge in today’s competitive environment. DVD is produced with the combination of different sequential steps. Injection moulding machine is the initial and most important step of this process. Through moulding machine, a blank substrate is produced. This study was conducted to reduce the cycle time of moulding machine from 3.0sec to 2.7 sec. Injection moulding machine (IMM) is used to produce the blank substrate through the combination of different sequential steps. In this process molten polycarbonate is injected through cavity into mould. Injection moulding machine used is Sumitomo-35~40 ton.IMM cycle time-It is the time duration between the productions of two consecutive blank substrates. This time can be collected from the moulding control panel. Fig-1 shows the injection moulding process of DVD manufacturing.

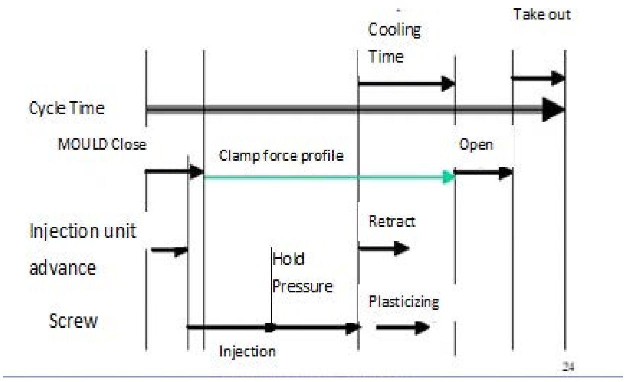

Fig. 1. Injection moulding process.

2. Material and Methods

This study was conducted in Moser Baer India Ltd. It is the one of the largest DVD manufacturing company in the world. Experimental procedure is as follows-
1. Optimization of mould open/close time.
2. Optimization of cooing time, hold time & robot take out time
3. Provide statistical evidence for optimizing parameters of an injection moulding machine.
4. A statistical analysis will be performed to give a basis for cycle time improvement recommendations.
Optimization of mould open/close time- In this phase, we had optimized the mould reference position and mould open/close speed. Mould reference position was reduced from 90mm to 80mm and mould open/close speed increased from 90% to 99%.After implementation moulding cycle time reduced from 3.0sec to 2.90sec and gain in the process is 0.1sec.

To reduce the moulding cycle further a brainstorming session was organised to find out the important key input process variables. Factors effecting injection moulding machine cycle time are-

- Injection time
- Injection speed
- Hold on time
- Hold on pressure
- Cooling time
- Eject time
- Robot take out time

Out of above factors 3 main factors were selected by cause & effect matrix. These are-

- Cooling time
- Hold time
- Robot take out time

2.1. ***Cooling time-***Time taken to solidify the molten polycarbonate from the end of holding time.

2.2. ***Hold time-***This is the extra time to hold the back flow of material injected & compensate the shrinkage after injection.

2.3. ***Robot takes out time-*** Time taken by the robot to pick the disc from mould & place it to the input handler of cooler.

3. Design of Experiment

DOE carried out for IMM C/T time. The levels of key process input variables were decided through brainstorming process. Table 1. shows the min/max level of key process input variables.

Table 1. Key process input variables.

KPIV	Min. Level	Max. Level
Cooling time	1.6	1.8
Hold time	0.2	0.29
Robot Take out time	0.24	0.29

The DOE was designed for 2 level & 3 factors with 1 centre point. Table 2 shows the different combinations of cooling time, hold time & robot take out time and their effects on cycle time. Microsoft excel and Minitab software were used for analysis.

Table 2. Design parameters & experimental data.

StdOrder	RunOrder	CenterPt	Blocks	Cooling time	Hold time	Robot Take out time	Cycle time
9	1	0	1	1.7	0.245	0.265	2.75
8	2	1	1	1.8	0.29	0.29	2.9
7	3	1	1	1.6	0.29	0.29	2.71
2	4	1	1	1.8	0.2	0.24	2.76
6	5	1	1	1.8	0.2	0.29	2.81
4	6	1	1	1.8	0.29	0.24	2.81
1	7	1	1	1.6	0.2	0.24	2.56
3	8	1	1	1.6	0.29	0.24	2.66
5	9	1	1	1.6	0.2	0.29	2.66

Fig. 2 shows the Pareto chart of effects of different factors and their combination on cycle time. Cooling time is the most important factor to reduce the cycle time.

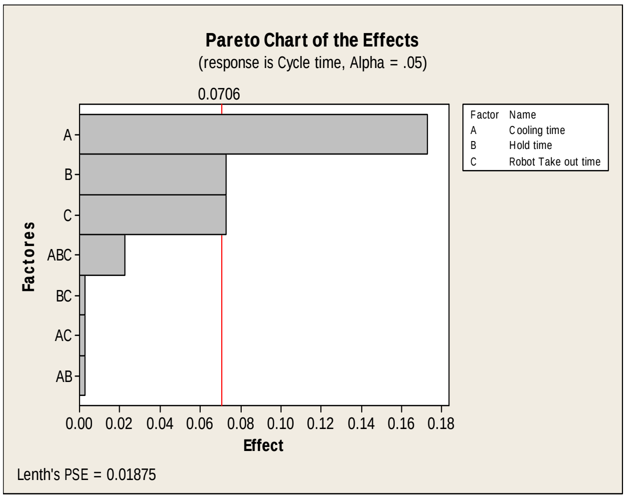

Fig. 2. Pareto chart of effects via Minitab.

Fig. 3 & 4 shows the main effects of different moulding parameters on cycle time and their interaction via Minitab.

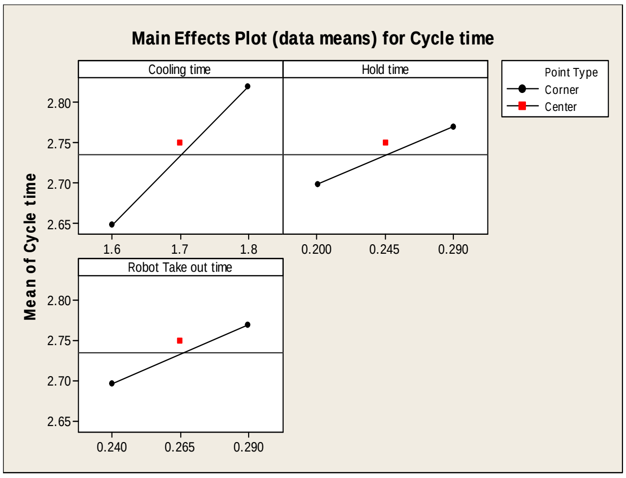

Fig. 3. Plot of main effects via Minitab.

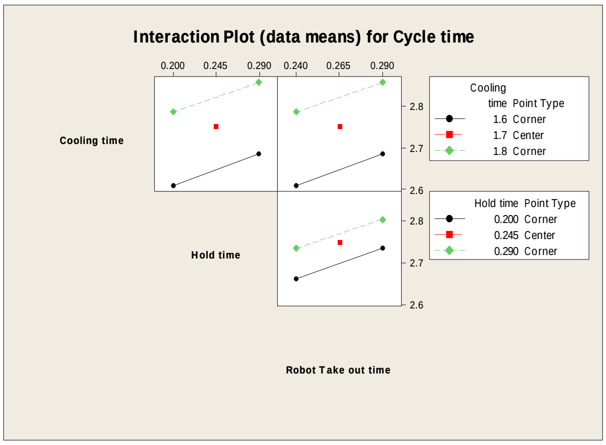

Fig. 4. Plot of interaction via Minitab.

Fig. 5 shows the optimized value of different parameters with the help of response optimizer via Minitab. It is observed that optimized value for cooling time is 1.65sec & for hold time is 0.24sec to achieve 2.70 moulding cycle time & for robot take out time it is 2.70sec.

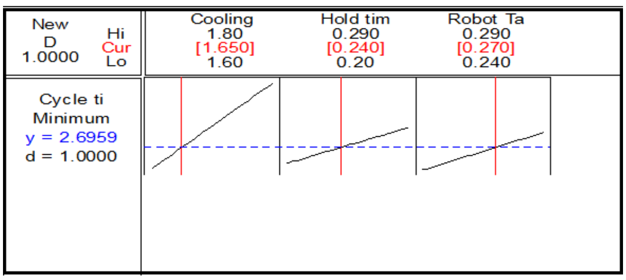

Fig. 5. Response optimizer via Minitab.

As per the response optimizer, optimized value of cooling time, Hold time and robot take out time were implemented and analysed the effect on cycle time. To compensate the effect of low cooling temperature on tilt, a new process window for clamping parameters was designed. Table 3. shows the process window at 3.0sec & Table 4. shows the process window for 2.70sec. To compensate the effect of low cooling time a Chiller Unit was provided for Cooling of Sprue. This Chiller unit reduces the Temp. of incoming water from Utility from 20 deg to 15 deg & send it to Mould. This will help in sprue cooling @ low Cycle time & minimize the Sprue breakage issue.

Table 3. Process window of moulding parameters for 3.0sec cycle time

3.0 sec		
	Active	Dummy
Back pressure 1	10	15
pressure 2	10	15
Plast. Revolution 1	240	210
CLAMP CONTROL		
Clamp Force		
2	35	35
3	11	10
4	12	8
5	35	34
CLAMP TIME		
3	0.32	0.28
Barrel Temp		
15A	285	310
15	320	320
4	380	355
3	385	355
2	355	350
1	290	280
MOULD TEMPERATURE		
Fixed Side	124	103
Moving Side	84	82
Sprue Temp	84	40
COOLING TIME	1.8	1.8

Table 4. Process window of moulding parameters for 2.70sec cycle time

2.70 sec		
	Active	Dummy
Back pressure 1	12.50	20
pressure 2	12.50	20
Plast. Revolution 1	265.00	280
CLAMP CONTROL		
Clamp Force		
2	35.00	35.00
3	12.50	10.00
4	12.50	15.00
5	30.00	30.00
CLAMP TIME		
3	0.55	0.70
Barrel Temp		
15A	287.50	305.00
15	310.00	320.00
4	387.50	357.50
3	387.50	357.50
2	350.00	330.00
1	280.00	280.00
MOULD TEMPERATURE		
Fixed Side	122	102.50
Moving Side	89	92.50
Sprue Temp	26	25.00
COOLING TIME	1.65	1.65

4. Result and Discussion

After implementation of optimized parameter, moulding cycle time was observed. All the data were analysed with the help of Minitab software Fig- 6 shows that all the four p-values are >0.01, thus data is independent. From fig. 7 it is observed that all the values are under upper & lower control limits, thus data is stable.

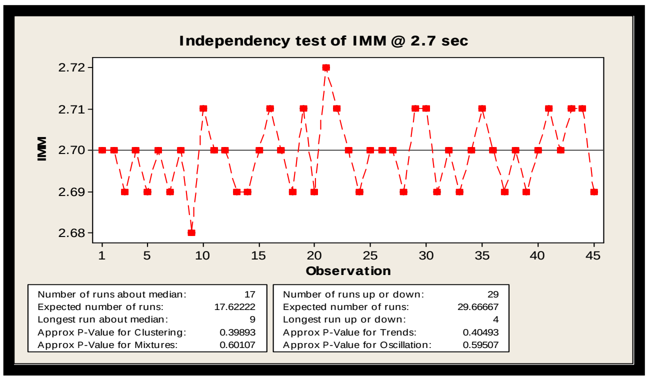

Fig. 6. Independency test of IMM at 2.70sec.

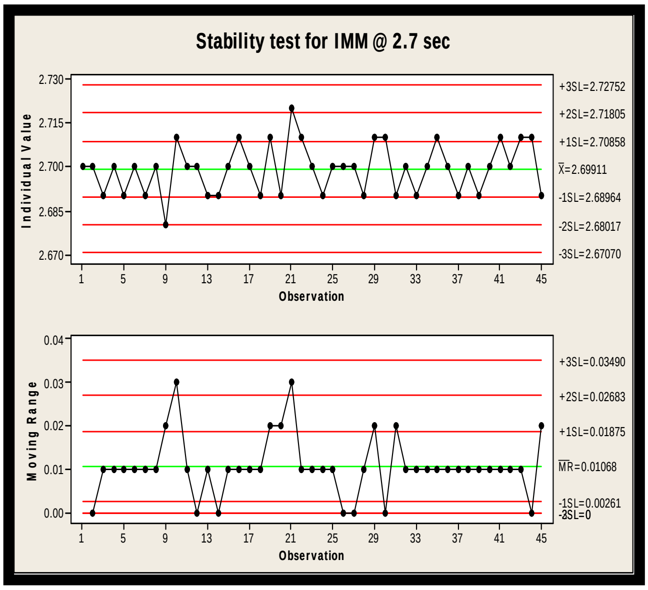

Fig. 7. Stability test of IMM at 2.70sec.

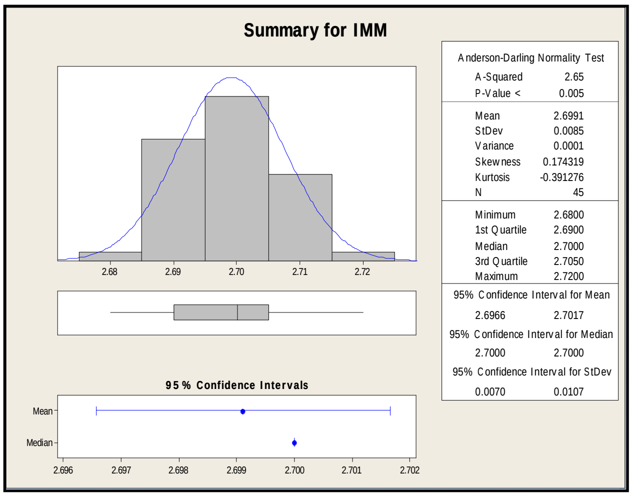

Fig. 8. Anderson-Darling Normality test.

It is to be observed from Fig. 8 That confidence interval for mean, median & standard deviation is 95%. Thus results are satisfactory. Fig. 9 & 10 shows the box plot comparisons & 2t-test of tangential Tilt at 3.0sec & 2.70sec.since the p-value is <0.05. So the effect of low cycle time on tangential tilt is significant. From the box plot it is clear that tangential tilt have been improved.

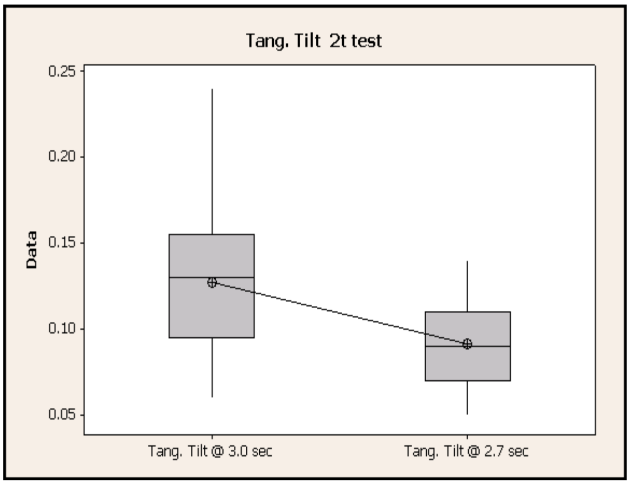

Fig. 9. Box plot comparison of Tangential Tilt.

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Two-sample T for Tang. Tilt @ 3.0 sec vs Tang. Tilt @ 2.7 sec

                N   Mean   StDev  SE Mean
Tang. Tilt @ 3.0  45  0.1271  0.0410   0.0061
Tang. Tilt @ 2.7  45  0.0913  0.0245   0.0036


Difference = mu (Tang. Tilt @ 3.0 sec) - mu (Tang. Tilt @ 2.7 sec)
Estimate for difference:  0.035778
95% CI for difference:  (0.021576, 0.049980)
T-Test of difference = 0 (vs not =): T-Value = 5.02  P-Value = 0.000  DF = 71
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Fig. 10. 2T-test of tangential Tilt at 3.0sec & 2.70sec.

Fig. 11 & 12 shows the box plot comparisons & 2t-test for Radial Tilt at 3.0sec & 2.70sec. Since the p-value is >0.05, So there is no significant effect of low cycle time on radial tilt.

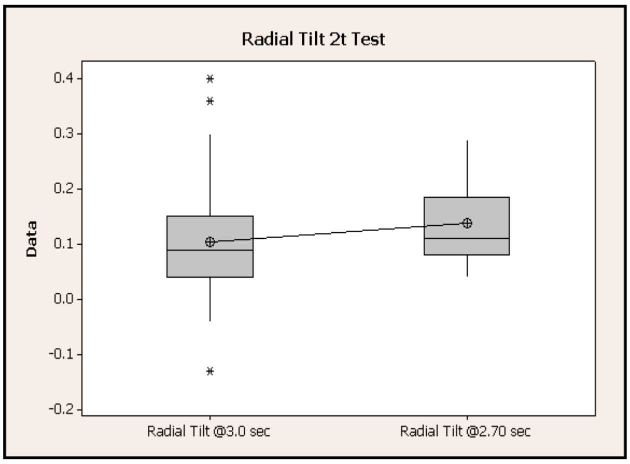

Fig. 11. Box plot comparison of Radial Tilt.

Two-sample T for Radial Tilt @3.0 sec vs Radial Tilt @2.70 sec

	N	Mean	StDev	SE Mean
Radial Tilt @3.0	45	0.105	0.108	0.016
Radial Tilt @2.7	45	0.1378	0.0763	0.011

Difference = mu (Radial Tilt @3.0 sec) - mu (Radial Tilt @2.70 sec)
Estimate for difference: -0.033111
95% CI for difference: (-0.072376, 0.006154)
T-Test of difference = 0 (vs not =): T-Value = -1.68 P-Value = 0.097 DF = 79

Fig. 12. 2T-test of Radial Tilt at 3.0sec & 2.70sec.

Fig. 13 shows that there is no significant change in write/read time at 2.70sec.

Writer Details							3.0 sec			2.70sec		
SN	AML No	Make	Model	Type	Fw	Drive Max Speed	Write Speed	Write Time	Read Time (mm:ss) Lg : GSA-H10N	Write Speed	Write Time	Read Time (mm:ss) Lg : GSA-H10N
1	287	BenQ	DW-1640	DVD ± R	BSRB	16x	16x	6:08	4:51	16x	6:07	4:51
2	426	Panasonic	SW-9587	DVD ± R	TP5G	16x	16x	6:01	4:51	16x	6:01	4:51
3	451	Lg	GSA-H42L	DVD ± R	SZ26	16x	16x	5:18	4:51	16x	5:17	4:51
4	485	Pioneer	DVR-212DBK	DVD ± R	1.24	18x	16x	6:08	4:51	16x	5:46	4:51
5	516	Sony Nec	AD-5170	DVD ± R	1.13	18x	16x	6:07	4:51	16x	6:08	4:51

Fig. 13. WRS test at different drives.

Fig. 14 and 15 shows the advanced media reports. That also suggests that there is no significant change was observed in critical to quality parameters at 2.70sec cycle time.

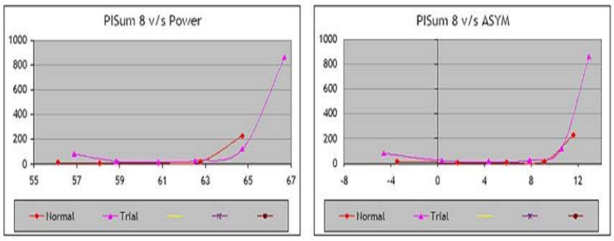

Fig. 14. pisum8 v/s power & asymmetry.

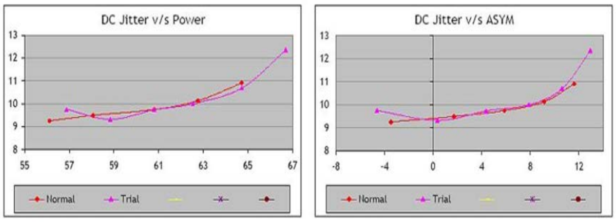

Fig. 15. jitter v/s power & asymmetry.

5. Conclusion

This paper represents that by optimizing the effective distance travel & speed of mould we can reduce the DVD moulding cycle time. Similarly, the cooling time, hold time & robot take out time are also the effective parameters to reduce the cycle time of DVD moulding machine up to 2.70sec. This research will improve the performance of DVD manufacturing machine thereby reducing the cost also.

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