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Resin optimization in the ophthalmic lens production process

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Abstract:
The present project shows the analysis carried out in an ophthalmological lens manufacturer in order to reduce the cost of resin consumption in the manufacturing process, without affecting the lens with respect to its properties and the specifications established in the quality department. The study was carried out in the Coating Area, where machines are used to coat ophthalmic lenses with 1193 A1 resin, making them more resistant to bumps and scratches. This project was developed through the application of six sigma based on the DMAIC methodology which was used to identify the opportunity area that would allow saving in the percentage of resin consumption by 50% and generating annually savings of up to $ 90,000 USD.Based on the results obtained in the scratch tests (Bayer), adherence (Craze) and % solids, it is possible to modify the resin filler to 7% for the cover of ophthalmic lenses.

Key Word*: Six sigma, optimization, continuous improvement, DMAIC, resin*

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I. Introduction

In all organizational activity it is necessary to measure its performance, without distinguishing what type of activity it is dedicated to. A business organization as an organizational system needs to know how each of its organizational subsystems is working in a highly competitive and aggressive environment (Manuel García P., Luis Ráez G., 2003). In this project carried out in a Lens production company, located in Tijuana, Baja California, which has twenty-nine years supporting the work of this plant, successfully directed by Mexican talent and positioned as the laboratory and manufacturing site largest Ophthalmic in Latin America, an area of opportunity has been detected that allows entering the dynamics of continuous improvement and this time it is presented in the Coating Area of Line 54, building 2.1 CR39.

In the manufacturing process of the ophthalmic lens, within its stages, resin must be replaced by 14%, this has caused concern about the opportunity to reduce costs through the decrease in the replenishment of fresh resin. During a week, with 14% replacement, 6,150 kg of resin are consumed. If the resin replenishment is reduced to 7%, the consumption will be 4,575 kg, so an average of 1,575 kg per week can be saved for each 1193A1 resin utilization coating machine. Considering the above data, it is convenient to apply the analysis methods and continuous improvement tools that are adapted in the most appropriate way to achieve the objectives set.

II. Material And Methods

Since the beginning of the introduction of the 1193 resin to the progressive lens process, SV72 and SV76 of CZVM1 in individual containers of 3 kg, the regeneration of the resin was related to fresh replacement daily from the second day to the tenth day (10 days is the lifetime of the resin) by 14%. Using the Six Sigma methodology, lenses coated with a 7% resin coating will be analyzed, the values of the boiling test (Craze) and the values of the scratch test (Bayer) will be tested to know if the specifications of minimum quality requirements of the control system are fulfilled. The standard specification for Bayer is ≥ 4 and it is an important metric for this project.

Another important metric is the resin adhesion test which involves placing 2 spin coater coated lens samples in boiling water at a temperature of 97 - 99 ºC for 3 hours. As part of the Quality Control (QC) test, every hour the lens samples are removed from the hot water to cool for approximately 5 minutes and then the QC inspector performs the adhesion test and checks for resin delamination. If resin delamination occurs during the test period and is determined to be out of specification, then the product is rejected and reworked.

Bayer's test consists of a process to rub a lens with sand in an oscillating machine, to measure the resistance of the resin layer that was applied in the coating machine and the test is carried out as follows: 3

coated lens samples are taken by each coating machine and one control lens, the 4 lenses are measured before the friction process starts in a machine called a spectrophotometer and the result value is called haze. After rubbing 2 lenses, one sample, and control at 600 cycles of the oscillating machine, the haze value if the control lens should be between 17 and 19 haze value. Upon reaching this turbidity value with the control lens, the other 2 lenses are placed in the machine and the 3 lenses are measured again and an arithmetic formula (1) is applied:

$$\text{Turbidity} = \text{Hf Lc} - \text{Hi Lc} / \text{Hf Lm} - \text{Hi Lm} \quad (1)$$

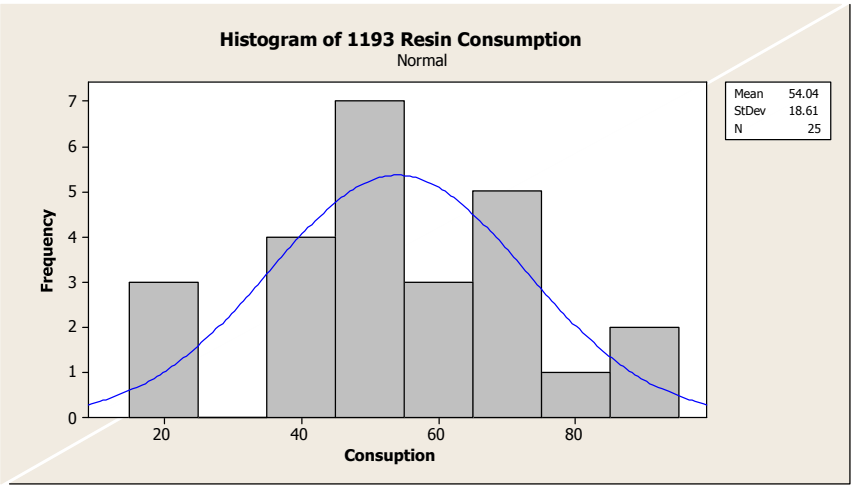
Where:
Hi Lc = Initial haze on control lens
Hf Lc = Final haze on control lens
Hi Lm = Initial haze on sample lens
Hf Lm = Final haze on sample lens

Troubleshooting six sigma strategy (Define, Measure, Analyze, Improve, and Control-DMAIC) to determine if key process input variables that change the % Resin Replenishment could cause any issues related to the process metric. After the conclusion of this project, the Opportunity will be monitored over the course of 30 days to assess the effectiveness of the action plan.

Define

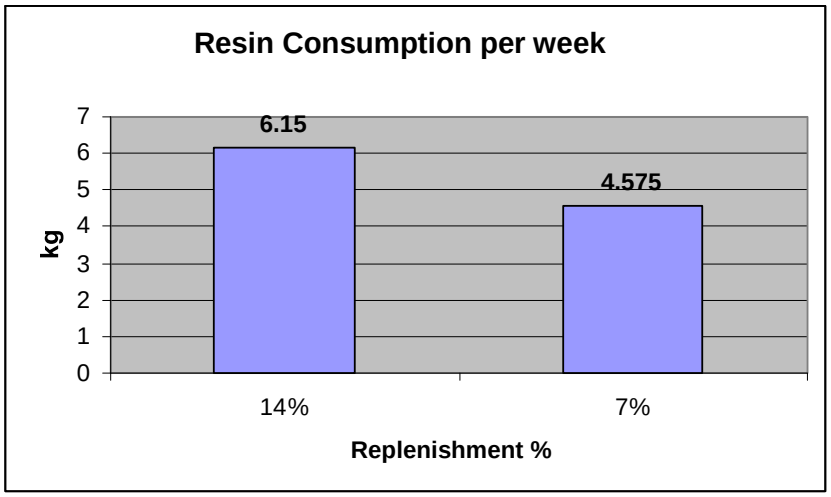
As graph 1 show, the actual replenishment of the resin is 14%, which is equivalent to an average consumption of 54.04 kg for all machines per week.

Hence the concern to investigate the possibility of reducing current performance levels in the average consumption of resin per machine, which is 6.15 kg with 14% replenishment, which represents a cost of $13,530.00 USD with an average of 10 machines, being anannual total cost of $351,780.00 USD.



Graph 1. Average consumption of resin

Tests were carried out on the replenishment, reducing it to 7% in the average consumption of resin per machine, as shown in graph 2, which gives us an average consumption of 4,575 Kg. against 6.15 kg at 14%, which would give us savings of 1,575 kg of resin, representing significant savings in its consumption, the question is whether with the 50% replenishment reduction it retains the same quality characteristics and resistance specifications at 14%.



Graph 2. Average resin consumption 14% vs 7%

Measure

- **Data collection**

Once the proposal to reduce the replenishment of the proposal has been defined, how to carry out the project by answering the questions of;
Who?: The Project Leader and the Process Owner will supervise and verify that each member of the team will participate in the data collection.
What?: The team leader will measure a particular Line.
Where?: Data collection will take place at Manufacturing Line 54 CR-39. Data analysis will be in the process engineering department.
Scope: Sampling plan (Number of observations): 72;
Base product 600;
Days: 12;
Data collection was performed every day from 6:30 a.m. to 7:30 a.m.
4 process metrics were needed to be tested and analyzed which are Scratch Test - Bayer, Adhesion Test - Craze, Coating Thickness and Solids Percentage

- **Target performance levels**

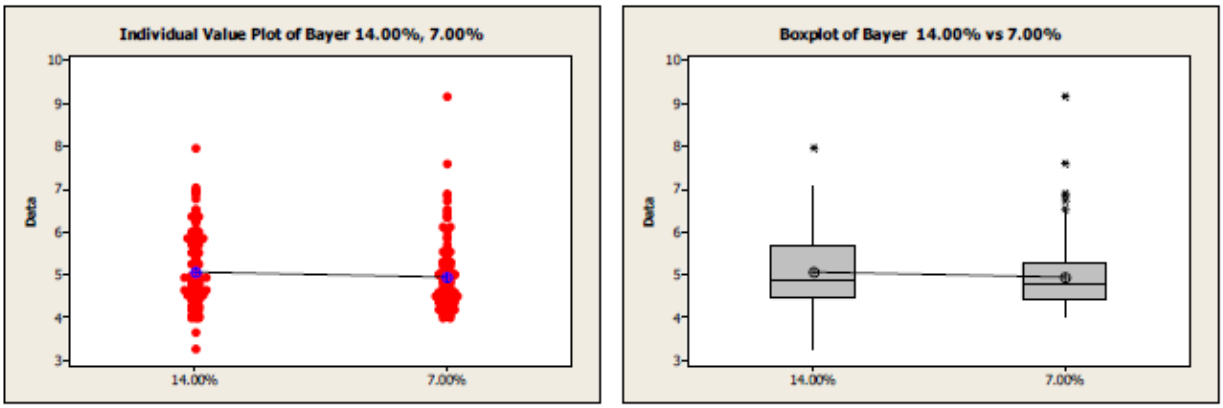
Reduce from 14% to 7% the replenishment of Resin 1193 coating, testing if the critical process input variables can cause a quality problem according to the specifications, as well as implementing the control method to maintain the recommended replenishment

Analyze

Bayer percentage tests (scratches): This test were performed in the change of the resin replacement from 14% to 7% as shown in table 1, the data was captured in minitab and the results as shown in graph 3 for the Bayer test, the mean and standard deviation of the two samples at 14% and 7% are not significantly different. It shows a p-value> 0.05, which confirms that there is no solid evidence to conclude that there is a significant impact on Bayer in the replacement of the resin.

Table no.1: Hypothesis test in scratch analysis, at 14% and 7%.

Practical approach	Does the reduction of the resin make-up have an impact on the Bayer test?
Factor	Bayer test: Replacement at 14% vs 7%
Null Hypothesis	H0: µ1 replacement 7% = µ2 replacement 14%
Alternative Hypothesis	H1: µ1 replacement 7% <µ2 replacement 14%
Sample size	134
Statistical tool	Two samples T-Test



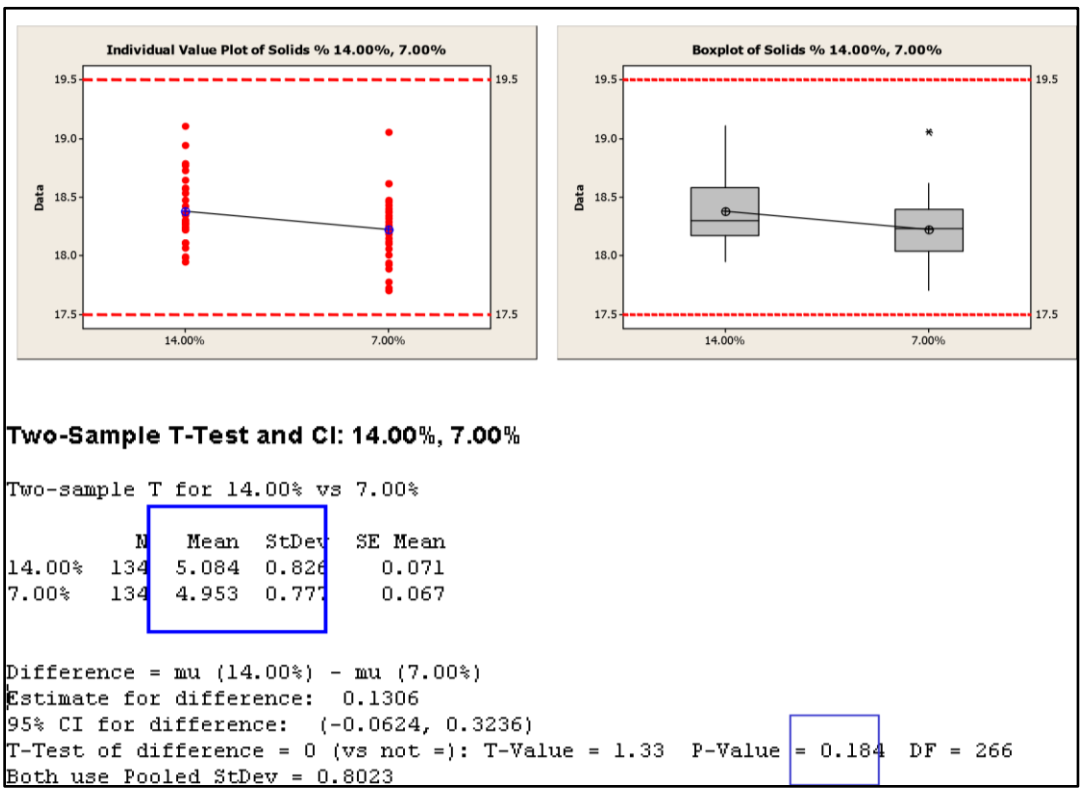
Graph 3. Bayer test results for 14% and 7%

From the PValue (>0.05) it can be concluded that there is no evidence to reject Ho, so it is assumed that µ1 replacement 7% = µ2 replacement 14% for Bayer test.

Solids percent tests: were performed in the change of the resin replacement from 14% to 7% as shown in table 2, the data was captured in minitab and the results as shown in graph 4 for thetest.

Table no.2: Hypothesis test in solids percent analysis, at 14% and 7%.

Practical approach	Does the reduction of the resin make-up have an impact on the solids % test?
Factor	Solids % test: Replacement at 14% vs 7%
Null Hypothesis	H0: µ1 replacement 7% = µ2 replacement 14%
Alternative Hypothesis	H1: µ1 replacement 7% <µ2 replacement 14%
Sample size	29
Statistical tool	Two samples T-Test



Graph 4. Solids % test results for 14% and 7%

From P Value (>0.05) it can be concluded that there is no evidence to reject Ho, so it is assumed that µ1 replacement 7% = µ2 replacement 14% for Solids % test.
The mean and standard deviation of the two samples at 14% and 7% are not significantly different. It shows a p-value> 0.05, which confirms that there is no solid evidence to conclude that there is a significant impact on Solids percent in the replacement of the resin.

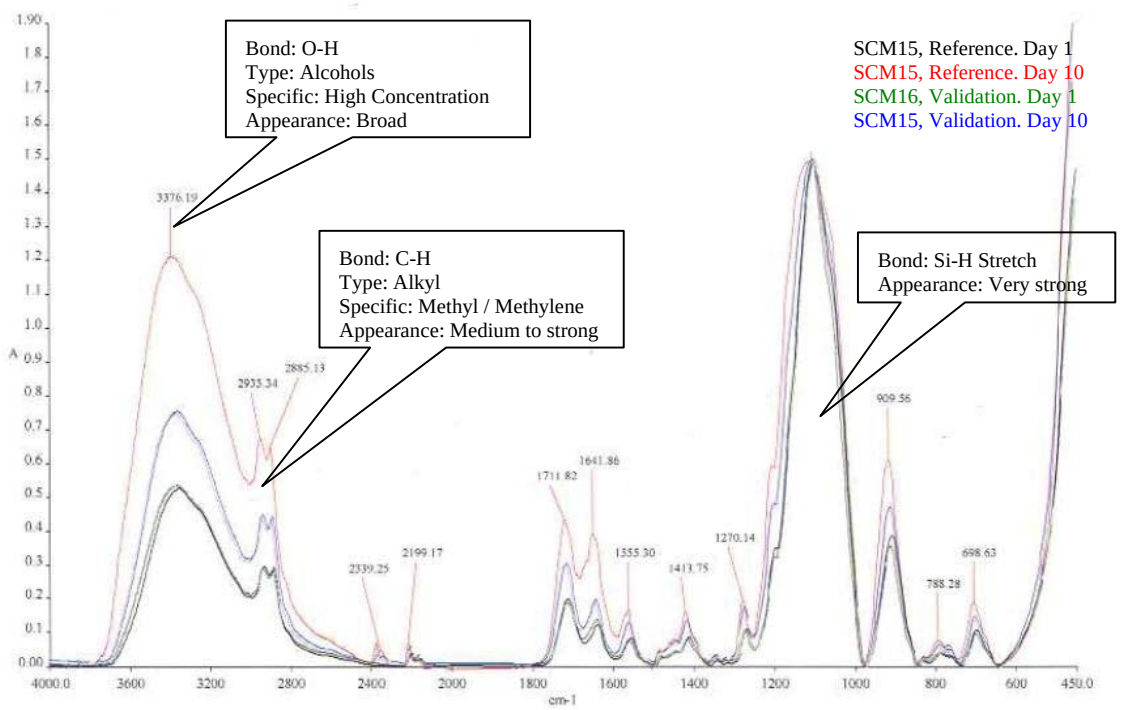
Boling test: The boiling test was carried out to measure the delamination and adhesion of the 7% resin in different machines, the results shown in table 3 indicate that the quality standards required for this control test were met.

Table 3. Boiling test data

		BATCHES																								
MACHINE	HOUR	8515	9022	9023	9024	9025	9026	9032	9033	9034	9035	9036	9042	9043	9044	9045	9046	9052	9053	9054	9055	9056	9057	9062	9064	9065
MACHINE 15 L54 14 %	1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	3	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	4	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	5	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
MACHINE 15 L55 14 %	1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	3	OK	OK	OK	OK	OK	OK	OK	2	OK	OK	1	OK	1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	4	OK	OK	OK	OK	OK	OK	OK	3	OK	2	1	OK	4	OK	OK	OK	OK	OK	OK	OK	1	OK	OK	2	OK
	5	OK	OK	OK	OK	OK	OK	OK	4	OK	4	2	OK	4	1	OK	OK	OK	OK	OK	OK	3	OK	OK	4	OK
MACHINE 16 L54 7 %	1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	3	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	4	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	1	OK
	5	OK	OK	OK	OK	OK	OK	OK	OK	OK	3	1	OK	OK	OK	3	OK	OK	OK	OK	OK	OK	OK	OK	2	OK
MACHINE 16 L55 7%	1	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	2	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	3	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	4	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	1	1	2	2	OK	1	OK	OK	OK	OK	OK	OK	OK	OK	OK
	5	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	1	1	4	4	OK	1	1	OK	OK	OK	OK	OK	OK	OK	OK

After the boiling, tack and % solids tests, an additional coating solution aging analysis test is performed to see the differences between 14% resin replenishment and 7%.

Aging test: Coating solution samples from spin coating machines (SCM) number 15 and 16, each with a replenishment rate of 7% (validation) and 14% (control) MP-1193A1 resin fresh respectively, were collected every day for 2 weeks of evaluation. Samples from the first day (MP-1193A1 100% fresh) and samples from the tenth day were analyzed by Fourier Transform Infrared Spectroscopy (FTIR).

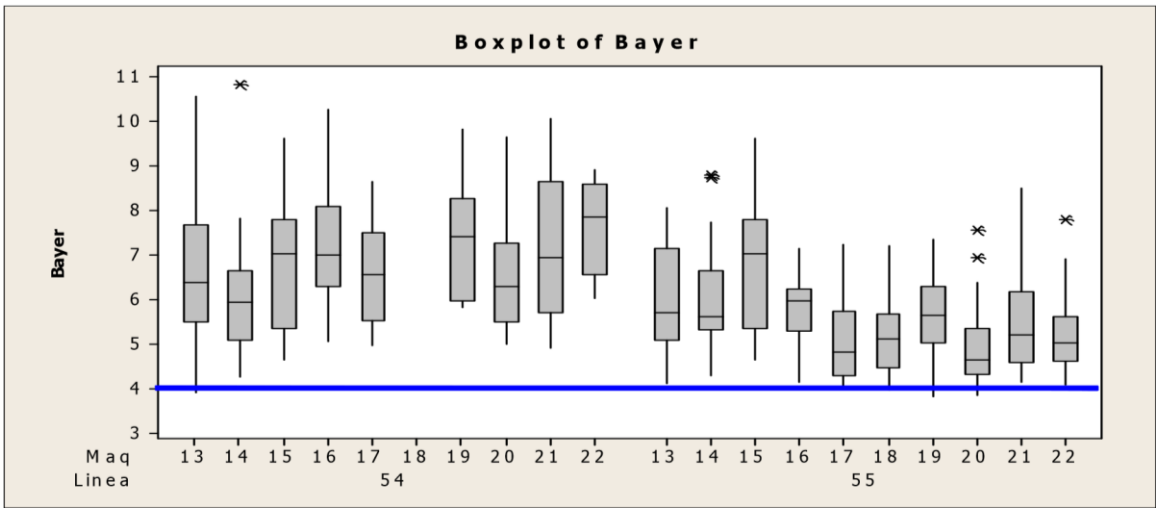


Graph 5.FTIR analysis

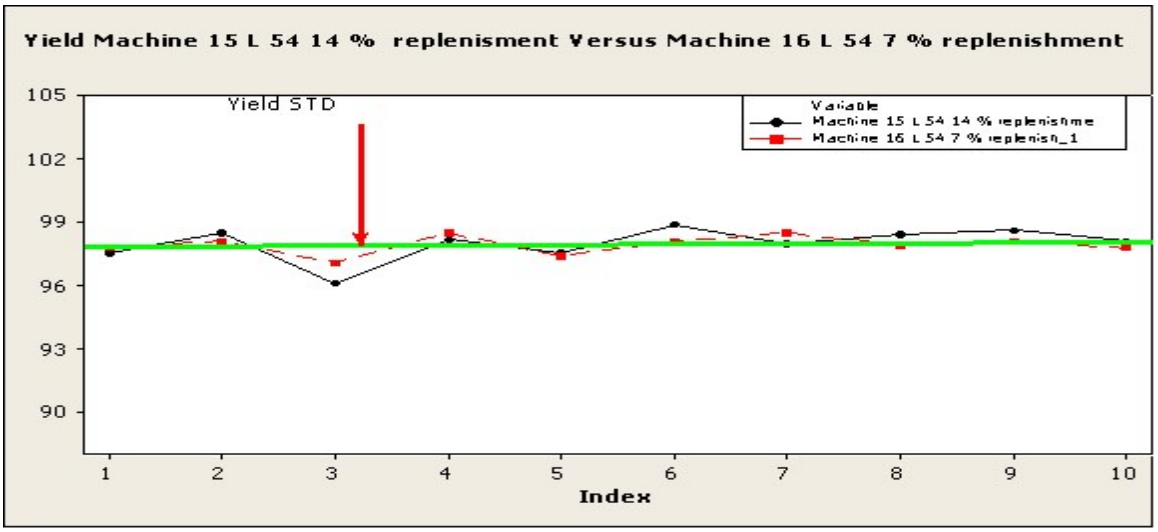
The representative peak for the main material of interest, the polysiloxane Si-H bond, remains at the same absorbance level regardless of replenishment regimens and time elapsed indicating no significant material degradation occurred.

Improve

Based on the results obtained from the critical Bayer metric – scratches (Graph 6), the production yield (Graph 7) and the savings it represents for MXMA CR 39 BU, using MP 1193 A1 resin, 7% replacement is recommended instead of 14% daily.



Graph 6. Bayer Results



Graph 7. Production performance: replacement 14%, replacement 7% vs Yield STD

Control

To ensure the successful completion of the project, the following plan must be achieved:

Scratches: RPM according to CZVM1-MNT-MNT-PO-002, % solids, viscosity, resin temperature, heater temperature, KOH temperature and E.G according to CZVM1-CR-RES-AV-002. Control Charts are developed for trend tracking and scratch control.

Adherence: % solids, viscosity, resin temperature, heater temperature, post-curing temperature, KOH temperature and E.G according to CZVM1-CR-RES-AV-002. Control Charts are developed for trend following and adherence control.

Coating thickness: RPM, % solids, according to CZVM1-MNT-MNT-PO-002

% Solids: F-CZVM1-029

III. Result and discussion

After 12 days of sampling and data collection, with its subsequent analysis, the results obtained are beneficial for the project and the company.

The tests showed that when managing a reduction to 7% of resin replacement, the quality parameters required for ophthalmic lenses are met:

- Bayer test (scratch): Ho is not rejected, μ1 replacement 7% = μ2 replacement 14%
- Percent solids test: Ho is not rejected, μ1 replacement 7% = μ2 replacement 14%
- Boiling test: Meets standards
- Aging test: no significant material degradation occurred

Considering the results obtained, the modification of a 14% replacement to a 7% replacement of 1193 A1 resin is proposed, thereby achieving significant annual savings of $351,780.00 USD.

To achieve the expected results, it is important to follow the procedures and operating standards stipulated in the operating documents, under these standards the tests were carried out for the 50% reduction in resin replenishment, remaining at a recommended resin 7% replacement.

IV. Conclusion

Based on the results obtained from the scratch test, adhesion, coating thickness, performance and aging analysis of the coating solution, we can conclude that 7% MP1193 A1 resin can be implemented instead of the actual 14% in production. massive, reducing the cost of with the reduction of the % of use of resin.

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