I&ME 454
Advanced Data Analysis

Rubber Band Strength

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Table of Contents

Management Summary

The rubber band strength experiment studied the impact of various chemical and physical treatments on the strength of a rubber band. The four factors tested were:

- Heat Treatment
- Ammonia Submersion
- Gasoline Submersion
- Hole Diameter

The rubber band strength was measured by holding one end of the rubber band stationary and stretching the rubber band until it snapped. Stronger rubber bands stretched further and weaker rubber bands snapped with less stretching.

Pilot Study

All four factors were tested in the pilot study. Please see Table 1 for a list of the levels, factors, and significance in the pilot study. To obtain required accuracy, two replications of the pilot study were performed.

Factor	Low Level	High Level	Significant
Gasoline Submersion	0 minutes	30 minutes	Yes
Ammonia Submersion	0 minutes	30 minutes	Yes
Hole Diameter	None	1/8" Diameter	Yes
Temperature	65℉	200℉	No

Table 1: Levels, Factors, and Significance in the Pilot Study

Full Blown Experiment

Several levels of each of the significant factors were tested in the full blown experiment. To ensure an accurate conclusion, four replications of the experiment were performed. Please see Table 2 for a list of the factors and levels.

Factor	Level 1	Level 2	Level 3	Level 4
Gasoline Submersion	0 minutes	30 minutes		
Ammonia Submersion	0 minutes	45 minutes	90 minutes	
Hole Diameter	0"	3/32"	5/32"	3/16"

Table 2: Factors and Levels Tested in Full Blown Study

Conclusion

Both the individual effects of gasoline and the size of the hole had significantly reduced the strength of the rubber band. In addition, the interaction of gasoline and hole size reduced the strength even more than the independent effects of those two factors. Ammonia and heat treatment had no effect on the strength of the rubber band.

Final Report

Introduction

The strength of rubber is important to the design of components and products. Like most products, the strength decreases over time and can lead to product failure. Certain factors that may cause rubber deterioration include chemical and heat exposure, physical damage, vibration wear, and plastic deformation. By taking into account the factors leading the rubber decay, a design engineer can develop rubber products that provide years of service without failure.

Four factors that may lead to rubber deterioration commonly found in industry include ammonia and petroleum chemical treatments, heat treatments, and physical damage. Specific questions regarding the factors include which factors cause rubber deterioration, if some factors help reduce the impact of other factors, and if the reduction in strength is dependent on the level of the factor.

Solution Alternatives

General Options

Several options were available to answer the questions presented above. Some possibilities included studying the number of rubber replacement parts sold for the machines exposed to the various factors, performing strength tests in a laboratory setting, and studying the chemical interactions of the rubber with the various factors academically.

Comparing the number of replacement parts sold would have introduced many variables beyond the four factors selected, including dirt, ultraviolet radiation, other chemical treatments, and operator judgment of when a part catastrophically fails. Because of these additional variables, an analysis of replacement parts would have had limited application.

Studying the chemical interactions academically would also have had limited application. The academic study would have been only pertinent to new rubber and pure chemicals. Additional factors that may have been present – oxidization, mineral deposits, and grease bubbles – would not have been included in the academic study and thus limited the use of the results. In addition, an academic study would have been outsourced to a third party and would have been cost prohibitive.

Performing a strength test of rubber samples in a laboratory setting was the best option. Because real rubber samples were tested, the results are applicable to real applications provided the experiment was properly designed. Because the experiment took place in a laboratory setting, the factors impacting the experiment were carefully controlled and confounding was avoided. The cost of the experiment was minimal because the rubber samples were readily available and the experiment was performed with just a few hours of time.

Specific Details

Because the abundance of numerical data strength testing provides, statistical analysis worked well to condense the data into a brief and concise summary. Several types of analyses were available, including hypothesis testing with multiple means, factorial design experimentation, and Latin square analysis of variance. Hypothesis testing is generally not practical for multiple means because the level of significance decreases greatly when several means are tested. Analysis of variance using a Latin or Graeco-Latin square design also was impractical because it would have required a balanced number of levels and factors and would have reduced the degree to which the experiment was designed. Factorial design experimentation was the best choice because it allowed for a wide range of levels and factors but did not reduce the level of significance.

The four factors mentioned above were chosen because they were commonly encountered in the application of the rubber products. The specific levels of each factor were also chosen by studying the operating environment for the rubber products. Please see Table 3 for the factors and levels used in the pilot study and Table 4 for the full blown study.

Factor	Low Level	High Level
Gasoline Submersion	0 minutes	30 minutes
Ammonia Submersion	0 minutes	30 minutes
Hole Diameter	None	1/8”
Temperature	65°F	200°F

Table 3: Factors and Levels Tested in the Pilot Study

Factor	Level 1	Level 2	Level 3	Level 4
Gasoline Submersion	0 minutes	30 minutes		
Ammonia Submersion	0 minutes	45 minutes	90 minutes	
Hole Diameter	0”	3/32”	5/32”	3/16”

Table 4: Factors and Levels Tested in the Full Blown Study

Methods

General

Rubber bands were selected to simulate the rubber products. Ninety-six rubber bands were selected at random from a batch of 200 uniform bands. For safety, leather gloves and safety glasses were worn to provide protection from the flying rubber bands.

Treatment

Treating rubber bands was accomplished using standard household equipment and chemicals. Ammonia, diluted to 5% concentration, and gasoline provided the chemical treatment, a leather punch provided the physical treatment, and a toaster oven provided the heat treatment.

Each rubber band was submerged in a small container containing the chemical for the desired length of time. The chemical was swirled during treatment to ensure consistent results. After each chemical treatment, the rubber bands were dried using a paper towel.

To provide the heat treatment, the rubber bands were placed in a toaster oven and heated to 200°F for 30 minutes. After the time elapsed, the rubber bands were allowed to cool to room temperature before testing.

The physical treatment was accomplished using a leather punch. The punch was capable of creating several sizes of holes and diameters of 3/32”, 5/32”, and 3/16” were chosen for this project. Each hole was punched in the middle of the rubber band and the hole was kept in the same position when the rubber band was tested.

Strength Test

One end of the rubber band was fixed using a steel vice and the other end was stretched to the breaking point using a wooden dowel. The maximum intact length was measured using a yardstick and recorded.

To reduce error, four replications of the experiment were conducted and analyzed. While the number of replications was much greater than required, the cost of additional replications was very low and the response variability was very high.

Results

As shown in Table 5, both gasoline and the presence of holes significantly decreased the strength of the rubber samples. The difference in hole diameter also had a significant impact on the strength of the rubber band, as shown in Table 6. Finally, the interaction effect of gasoline and presence of holes significantly decreased the strength beyond the effect of either individual factor.

Factor	Significant
Gasoline	Yes
Ammonia	No
Heat	No
Hole Diameter	Yes

Table 5: Significance of Tested Factors

Hole Diameter	Significant
0" – 3/32"	Yes
3/32" – 5/32"	Yes
5/32" – 3/16"	No

Table 6: Significance of Hole Sizes

Conclusions

Rubber products should be kept well away from gasoline to prevent deterioration and product failure. Also, rubber should not be used where sharp objects may penetrate the rubber. Rubber will deteriorate even faster when exposed to both holes and gasoline and the useable product life will be almost nil.

Ammonia had no significant effect on the strength of rubber products. Therefore, it should be safe to use the rubber in refrigerators and in chemical plants where ammonia exposure may be experienced.

Heat treatment also had no effect on the strength of rubber. Leaving the rubber products in warm places, including the trunk of a car or in a greenhouse, should not be an issue provided the rubber cools to room temperature before being used. Since this experiment tested one heat cycle, further study would be required to conclude if multiple heat cycles is detrimental to the strength of rubber.

None of the four factors tested increased the strength of rubber. If the strength of untreated rubber is too low, it will be necessary to use a different material for the product.

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Appendices

Appendix A: Pilot Study Raw Data

Appendix B: Pilot Study Calculations

Appendix C: Pilot Study Results

Appendix D: Full Blown Study Data

Appendix E: Full Blown Study Calculations

Appendix F: Full Blown Study Results

Appendix G: Duncan Multiple Range Test Calculations

Appendix H: Duncan Multiple Range Test Results