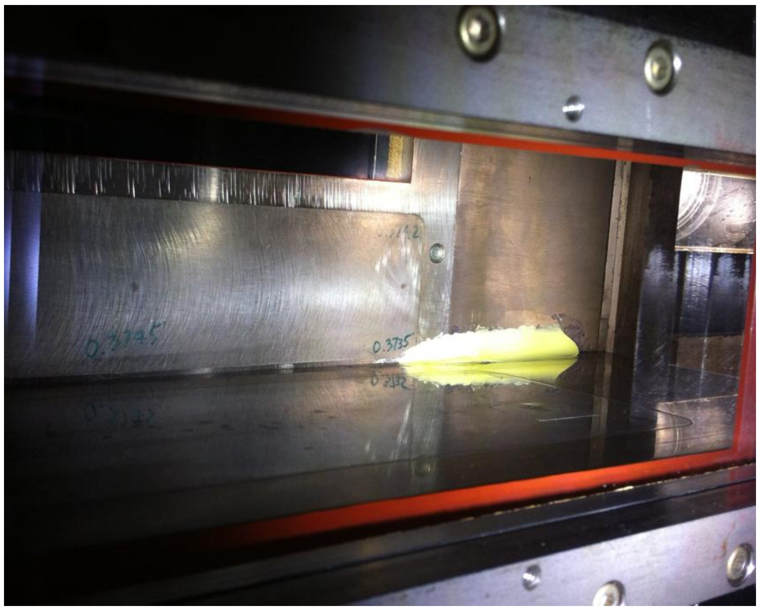
Investigation of Materials for Boundary Layer Control in a Supersonic Wind Tunnel



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May 16, 2013

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- Background
  - Supersonic inlet research
- Trade study
  - Objective
  - Testing
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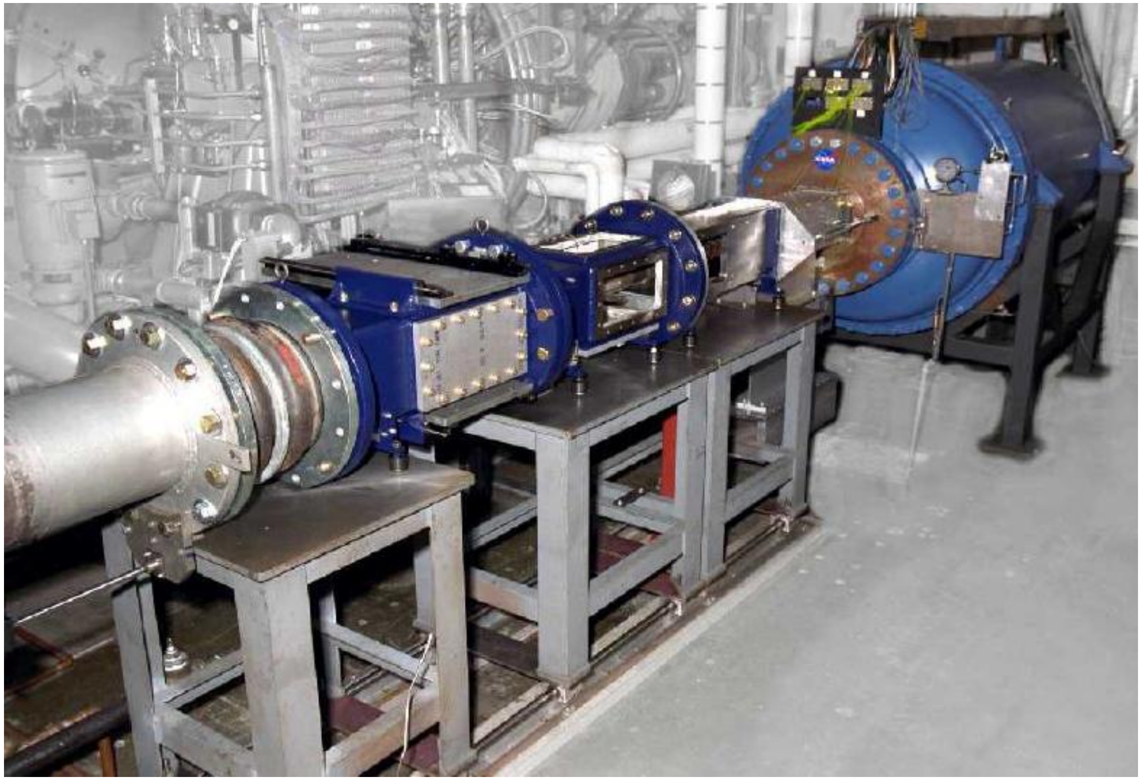
- Summary and Conclusions



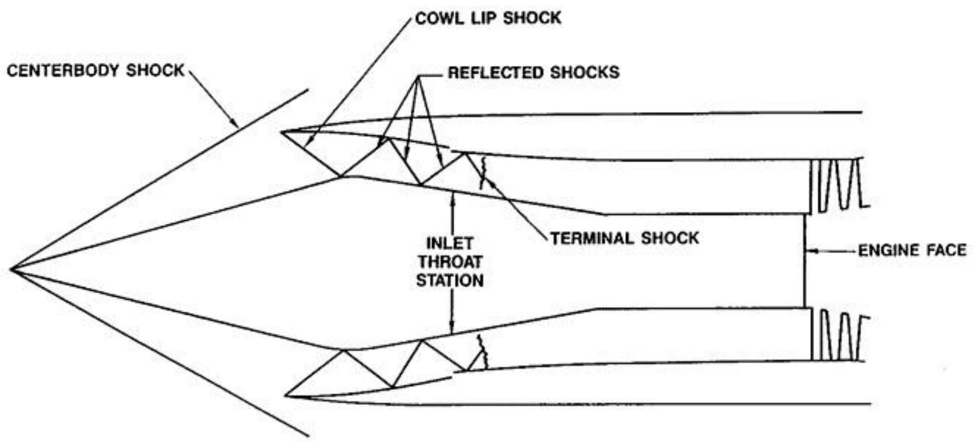
- 15 cm by 15 cm Supersonic Wind Tunnel at NASA GRC

Objective

- Determine low-cost, readily available materials acceptable for use in a supersonic wind tunnel
  - Prevent any damage to wind tunnel
  - Consistent, repeatable experiments
  - Good aerodynamic qualities
  - Ease of use

Background

- Supersonic Inlets
  - Compress and slow incoming air
  - Mixed compression using external/internal oblique and normal shockwaves



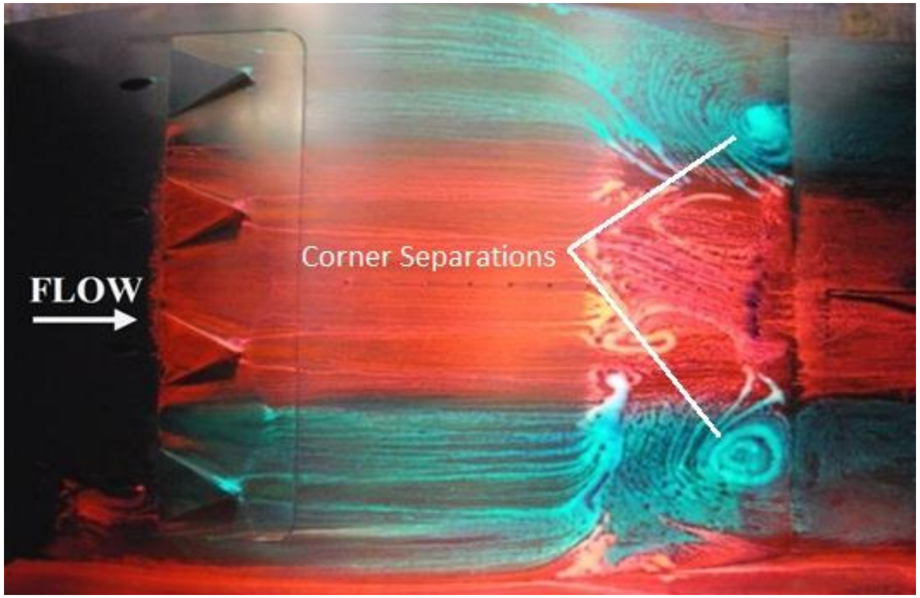
http://www.456fis.org/YF-12A_SR-71_ENGINE.htm

Shockwave Boundary Layer Interactions (SBLI)

- Boundary Layer
  - Regions near solid surfaces were friction is important
- Entrance to the compressor
  - Uniformity of flow at compressor is important
- SBLI
  - Thicken boundary layer
  - Possible separation

Flow Control

- Boundary Layer Bleed
  - Traditionally used
- Research into other types of flow control
  - Main focus is on vortex generators



Experiments at NASA GRC

- Planned experiments to test corner fillets
  - 15 cm by 15 cm Supersonic Wind Tunnel
  - Determine the effects of:
    - Radius of curvature
    - Total length
    - Taper length
  - Traditional supersonic wind tunnel inserts
- Proposed approach using polymer/adhesive materials

Trade Study

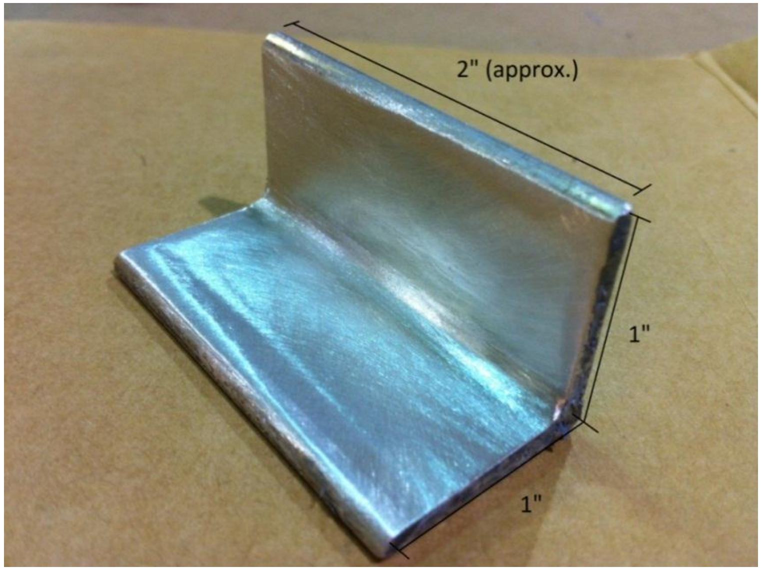
- Select best option from readily available materials
  - Sealants
  - Adhesives
  - Dental impression material
- Criteria for selection and comparison
  - Non-damaging
  - Adhesion
  - Surface roughness
  - Formability
  - Precision
  - Application/Removal Ease

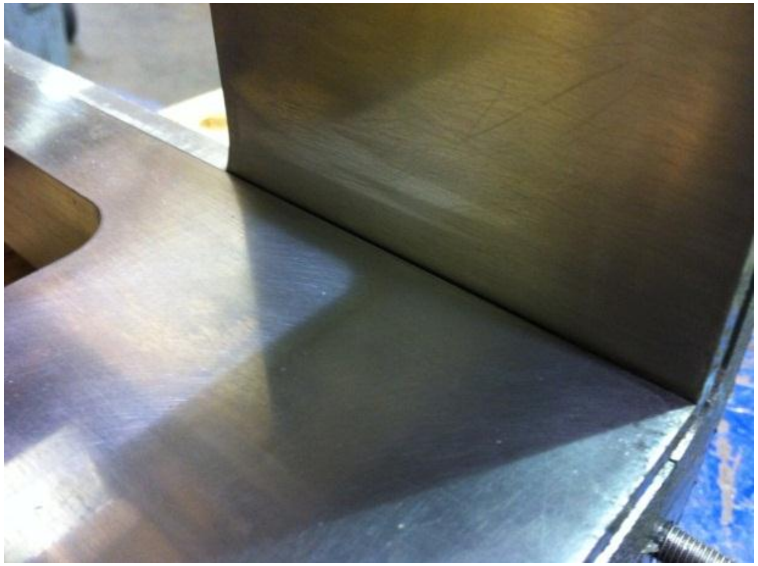
Materials

Material Type
Polyurethane Sealant
Vinyl Polysiloxane Dental Impression Material 1
Vinyl Polysiloxane Dental Impression Material 2
Polyester Filler Paste
Silicate Cement
Resin/Solvent Based Sealant
Silicone Adhesive Sealant
Vinyl Adhesive Caulk
Spackling Paste
Basic Sculpting Epoxy

Stages

- Aluminum angle iron tests
- In-tunnel tests





Figures of Merit

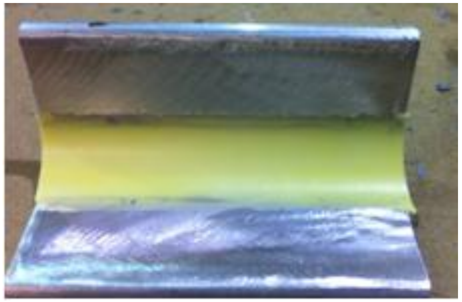
- Quantitative
  - Surface Roughness
  - Eccentricity
  - Repeatability
  - Cure Time
- Qualitative
  - Ease of Removal
  - Flow during application
  - Formability
  - Shrinkage
  - Adhesion to surface

- Scanning White Light Interferometer (SWLI)

- Observations during tests

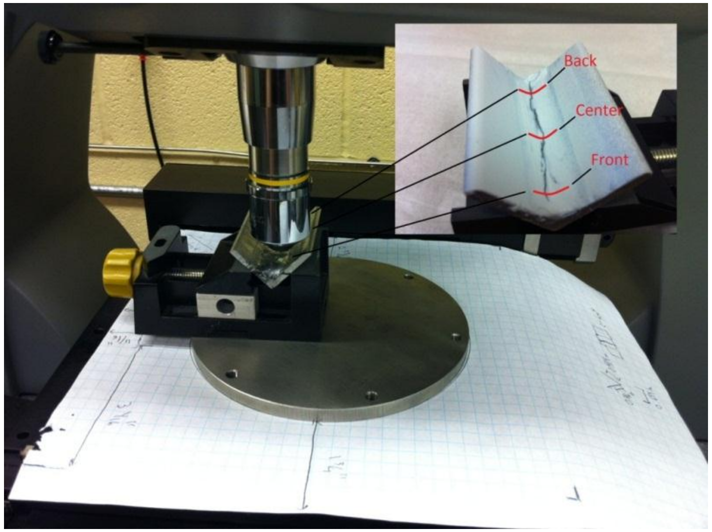
Angle Iron Tests

- Application and removal processes
  - Each material
  - Each radii of curvature
- Measurements of surface using SWLI
  - Each material
  - Eccentricity
  - Average surface roughness
  - Repeatability of eccentricity

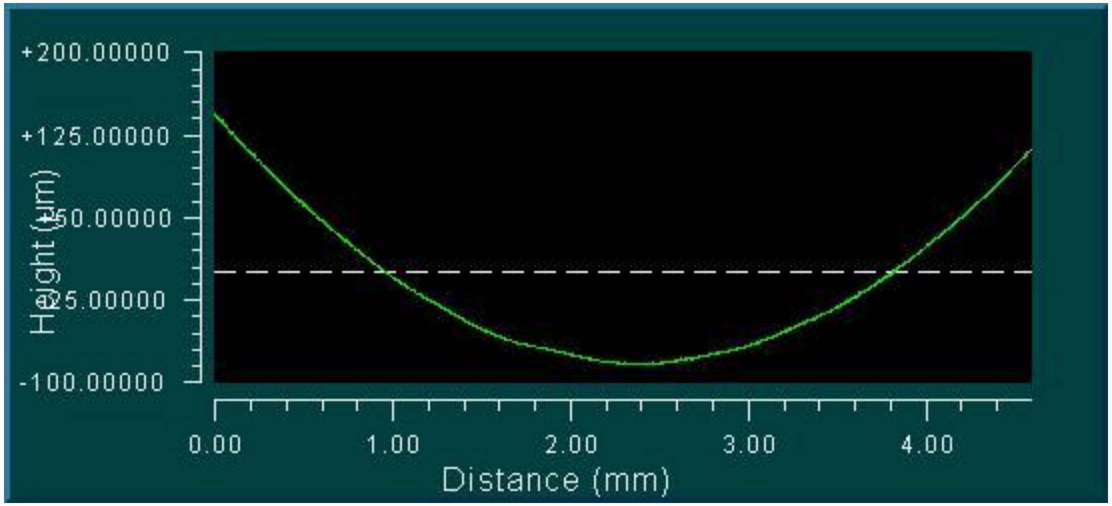


Repeatability Tests

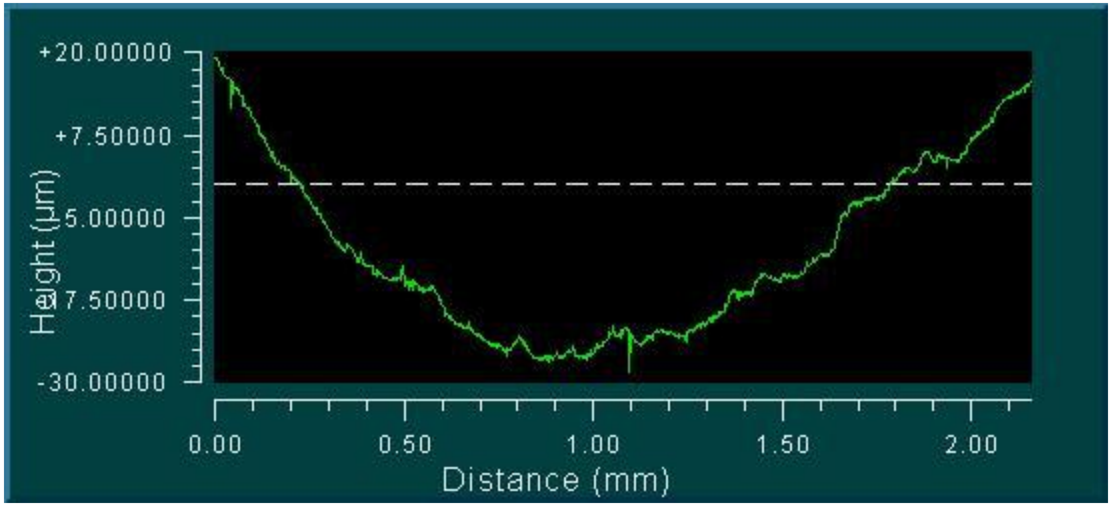
- After initial angle iron tests
- Additional 6 measurements on 5 samples
  – Heavy body dental impression material
  – Polyurethane sealant



- Residual error
  - Minimized by eccentricity
  - Mean
  - Standard deviation



• Regular type dental impression material profile output from SWLI



• Polyurethane sealant profile output from SWLI

Qualitative Results

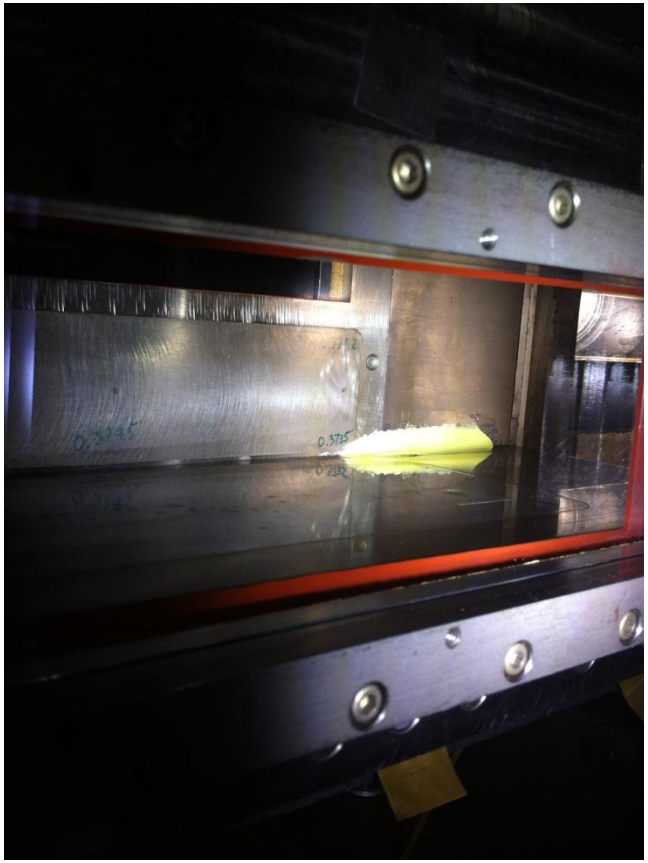
Material Type	Shrinkage	Flow During Application	Formability	Ease of Removal	Adhesion to Surface
Dental Impression (Plastic Rod)	5	5	5	5	3
Heavy Body Dental Impression	5	5	5	5	3
Regular Type Dental Impression	5	5	5	5	3
Basic Epoxy (Plastic Film)	5	4	4	3	4
Polyurethane Sealant	5	4	2	3	5
Silicone Adhesive Sealant	5	2	2	2	5
Resin/Solvent Based Sealant	3	4	2	5	2
Spackling Paste	1	3	2	5	5
Silicate Cement	1	4	2	4	5
Vinyl Adhesive Caulk	1	1	2	2	4
Polyester Filler Paste	5	3	2	1	5

Quantitative Results

Material Type	Roughness	Cure Time	Eccentricity	Repeatability
Heavy Body Dental Impression (Plastic Rod)	0.2781	5 min	0.1942	0.02627
Regular Type Dental Impression (Plastic Rod)	0.8790	5 min	0.0582	-
Heavy Body Dental Impression	1.1533	5 min	0.2668	-
Regular Type Dental Impression	1.3310	5 min	0.2212	-
Basic Epoxy (Plastic Film)	1.9873	5-24 hrs	0.3710	-
Polyurethane Sealant	1.9473	3-48 hrs	0.6471	0.1354
Silicone Adhesive Sealant	3.1523	24 hrs	0.2605	-
Resin/Solvent Based Sealant	1.8353	3-24 hrs	0.8652	-
Spackling Paste	7.0660	1-5 hrs	0.8087	-
Silicate Cement	6.9183	3-4 hrs	0.7917	-
Vinyl Adhesive Caulk	10.9183	12-48 hrs	0.7349	-
Polyester Filler Paste	6.7817	25 min	0.9587	-

Test in the Wind Tunnel

- Best material tested in wind tunnel
  – Heavy body dental impression material
- Conditions
  – Mach 2
  – Reynolds number of 13-26 million per meter



Heavy Body Dental Impression Material

Overall Results

- Materials sorted by choice for use in the wind tunnel

Choice	Material
1	Dental Impression (Plastic Rod)
2	Heavy Body Dental Impression
3	Regular Type Dental Impression
4	Basic Epoxy
5	Polyurethane Sealant
6	Resin/Solvent Based Sealant
7	Silicone Adhesive Sealant
8	Spackling Paste
9	Vinyl Adhesive Caulk
10	Silicate Cement
11	Polyester Filler Paste

Summary

- Need for method to create radii of curvature in supersonic wind tunnel corners
- Use of low-cost polymer/adhesive material for radius formation proposed
- Selection of best material from 10 candidate materials

Material Selected

- Heavy body dental impression material
  - Non-damaging to wind tunnel
  - Repeatable
  - Similarity to wind tunnel surface

Use in Research

- Repeatable method for creating desired precise shapes in wind tunnel corner still needed
- Other applications for testing in supersonic wind tunnels

Acknowledgements

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- NASA Glenn: Robert Clark, Stefanie Hirt, Cleve Horn, John Lucero, and Marty Velez.

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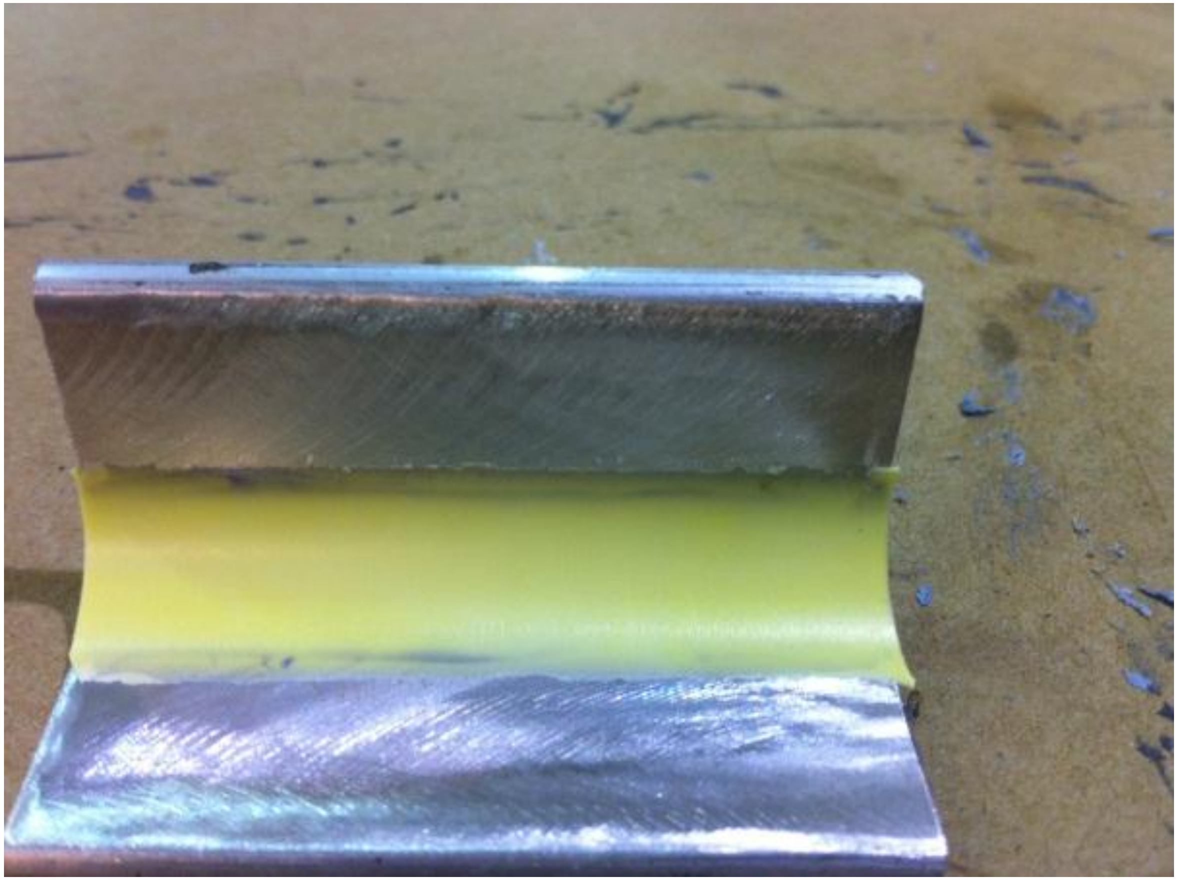
Supplementary Slides

Surface Roughness

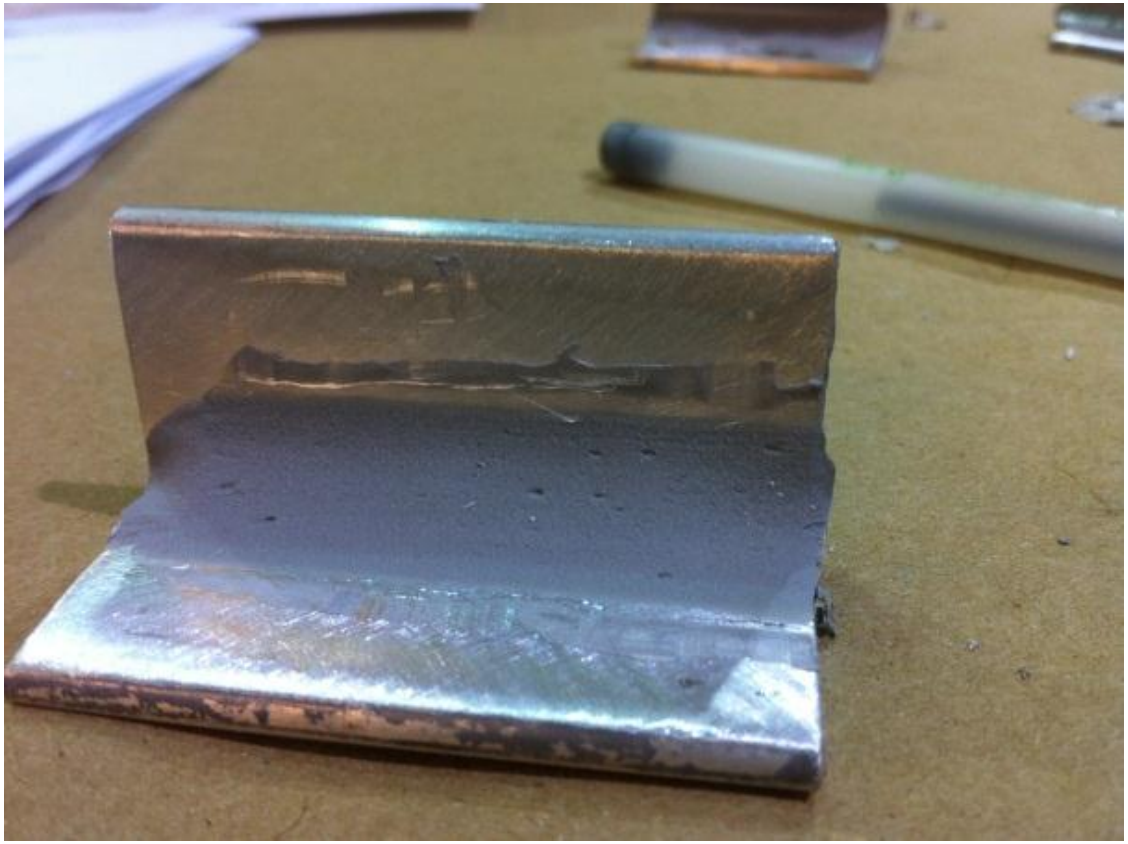
Rank	Material	Rouhgness (μm) +/- 0.020 μm
1	Heavy Body Dental Impression (Plastic Rod)	0.2781
2	Regular Type Dental Impression (Plastic Rod)	0.8790
3	Heavy Body Dental Impression	1.1533
4	Regular Type Dental Impression	1.3310
5	Resin/Solvent Based Sealant	1.8353
6	Polyurethane Sealant	1.9473
7	Basic Epoxy	1.9873
8	Silicone Adhesive	3.1523
9	Polyester Filler Paste	6.7817
10	Silicate Cement	6.9183
11	Spackling Paste	7.0660
12	Vinyl Adhesive Caulk	10.9183

Eccentricity

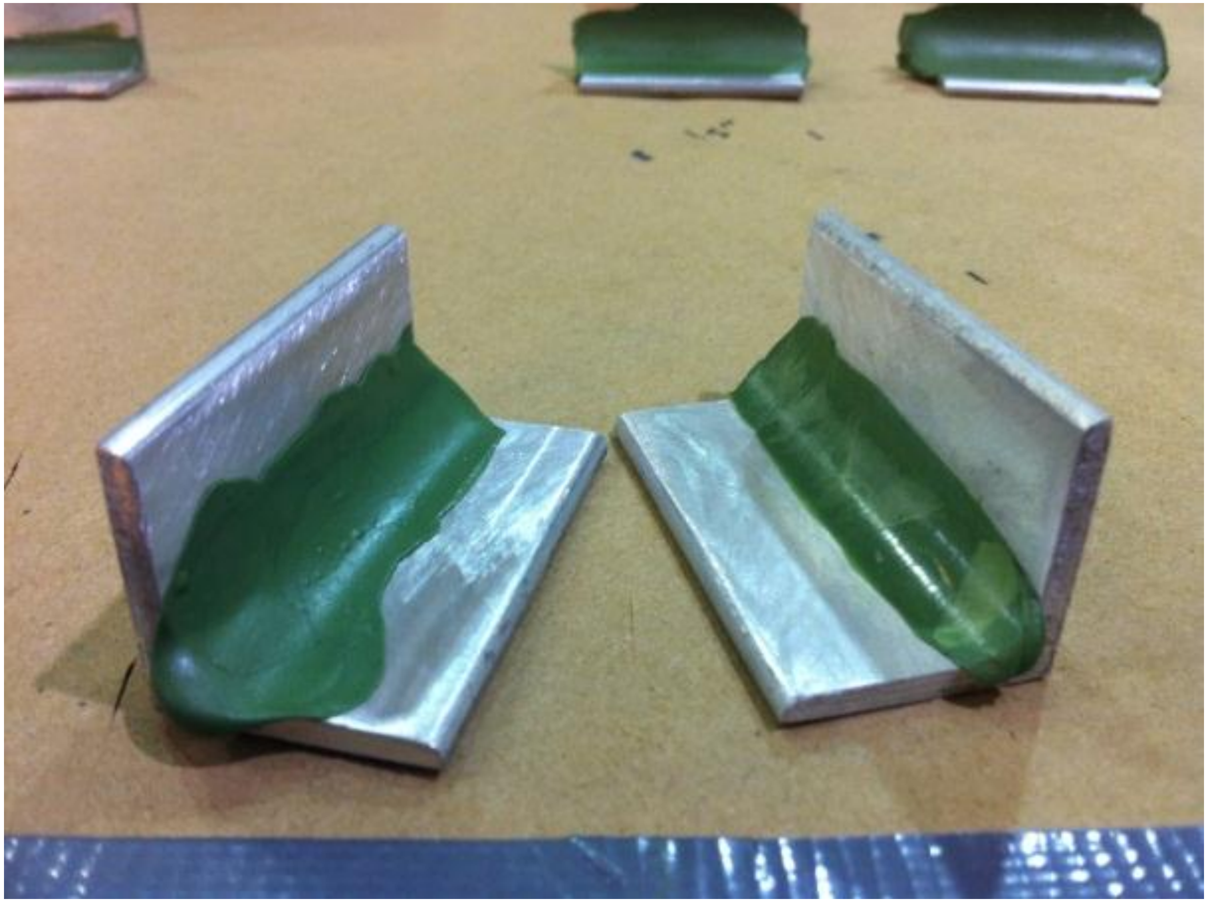
Rank	Material	Average Eccentricity
1	Regular Type Dental Impression (Plastic Rod)	0.0582
2	Heavy Body Dental Impression (Plastic Rod)	0.1942
3	Regular Type Dental Impression	0.2212
4	Basic Epoxy	0.3710
5	Silicone Adhesive Sealant	0.2605
6	Heavy Body Dental Impression	0.2668
7	Polyurethane Sealant	0.6471
8	Vinyl Adhesive Caulk	0.7349
9	Silicate Cement	0.7917
10	Spackling Paste	0.8087
11	Resin/Solvent Based Sealant	0.8652
12	Polyester Filler Paste	0.9587



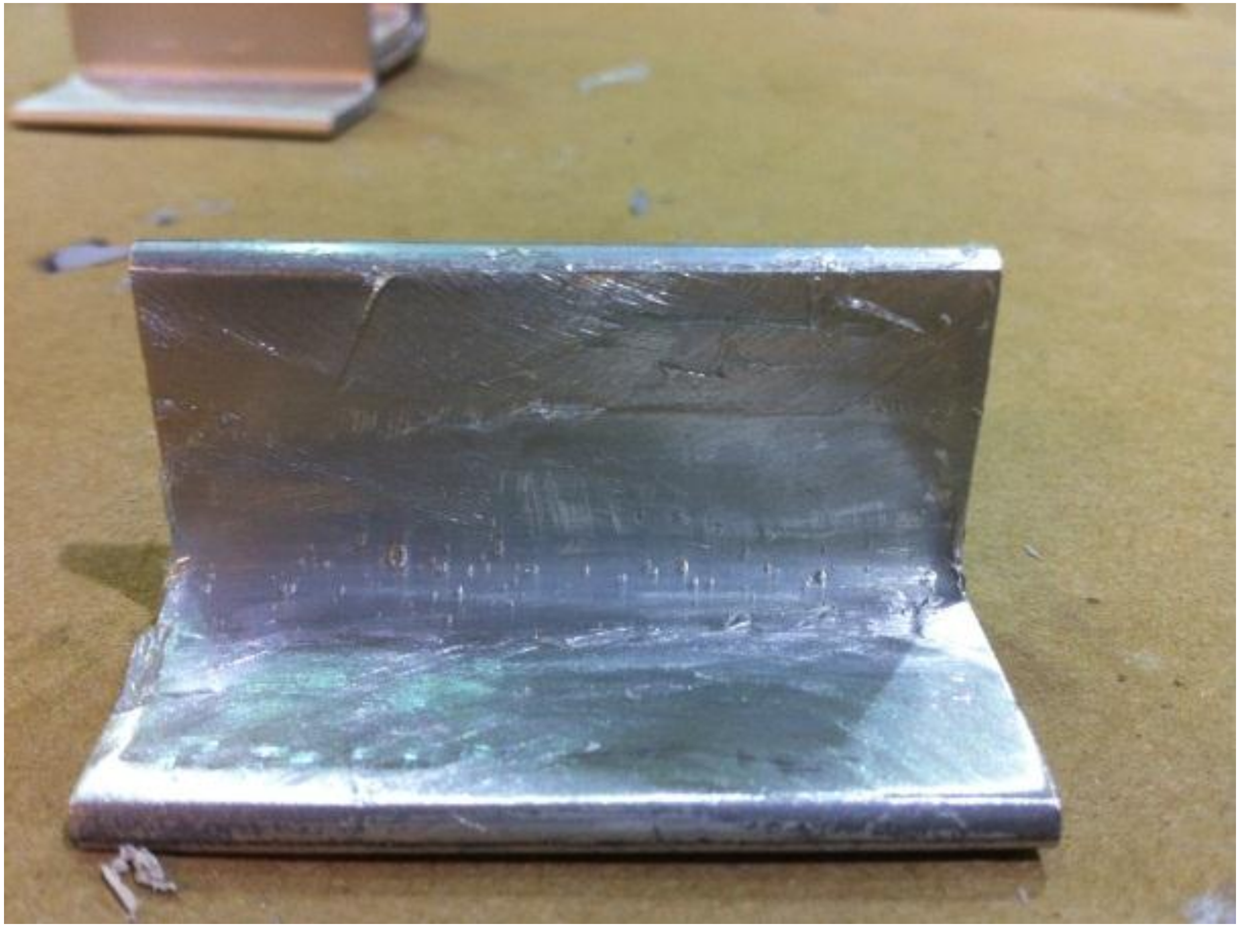
- Heavy Body Dental Impression Material



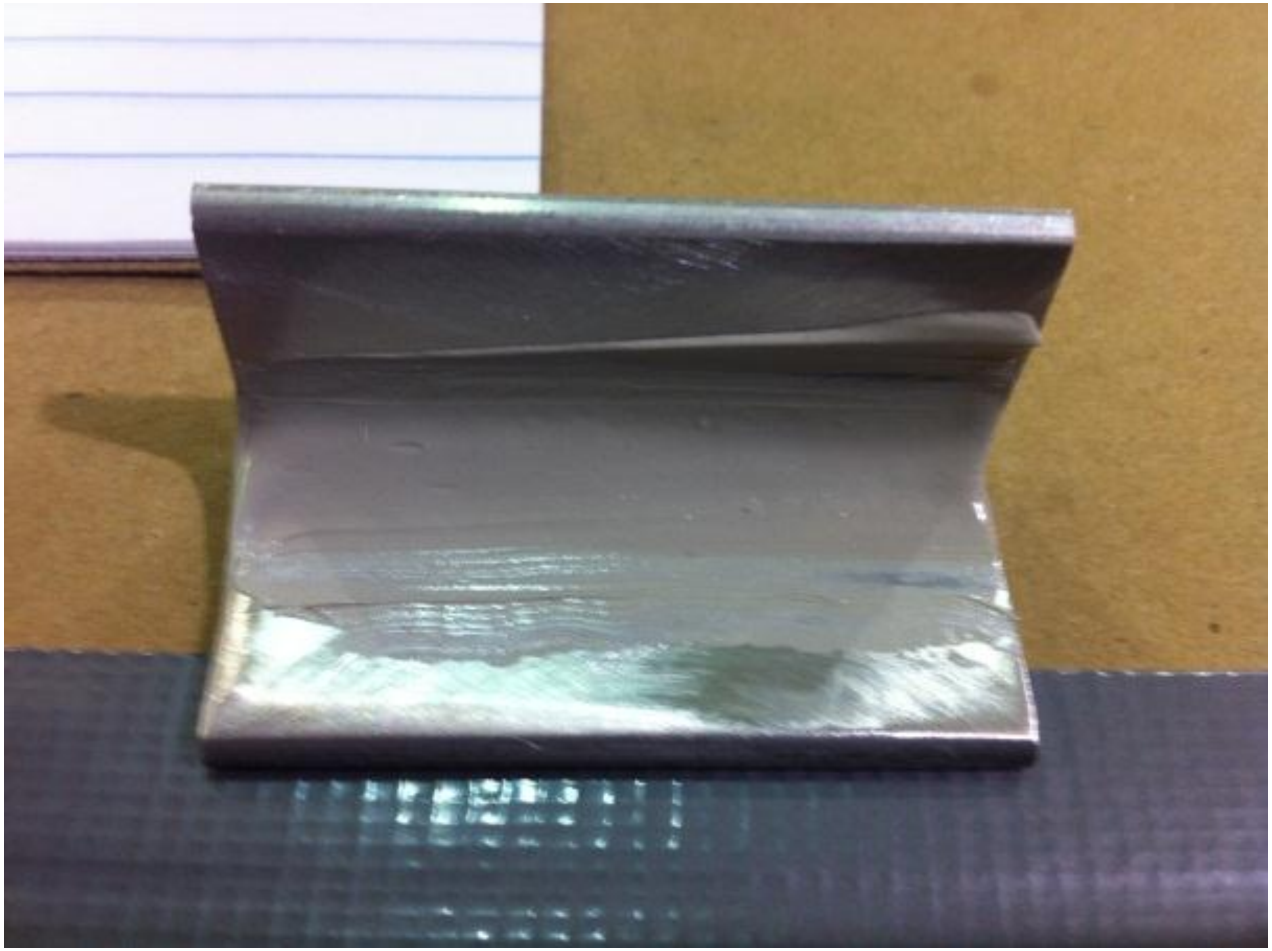
• Polyester Filler Paste



- Sculpting Epoxy

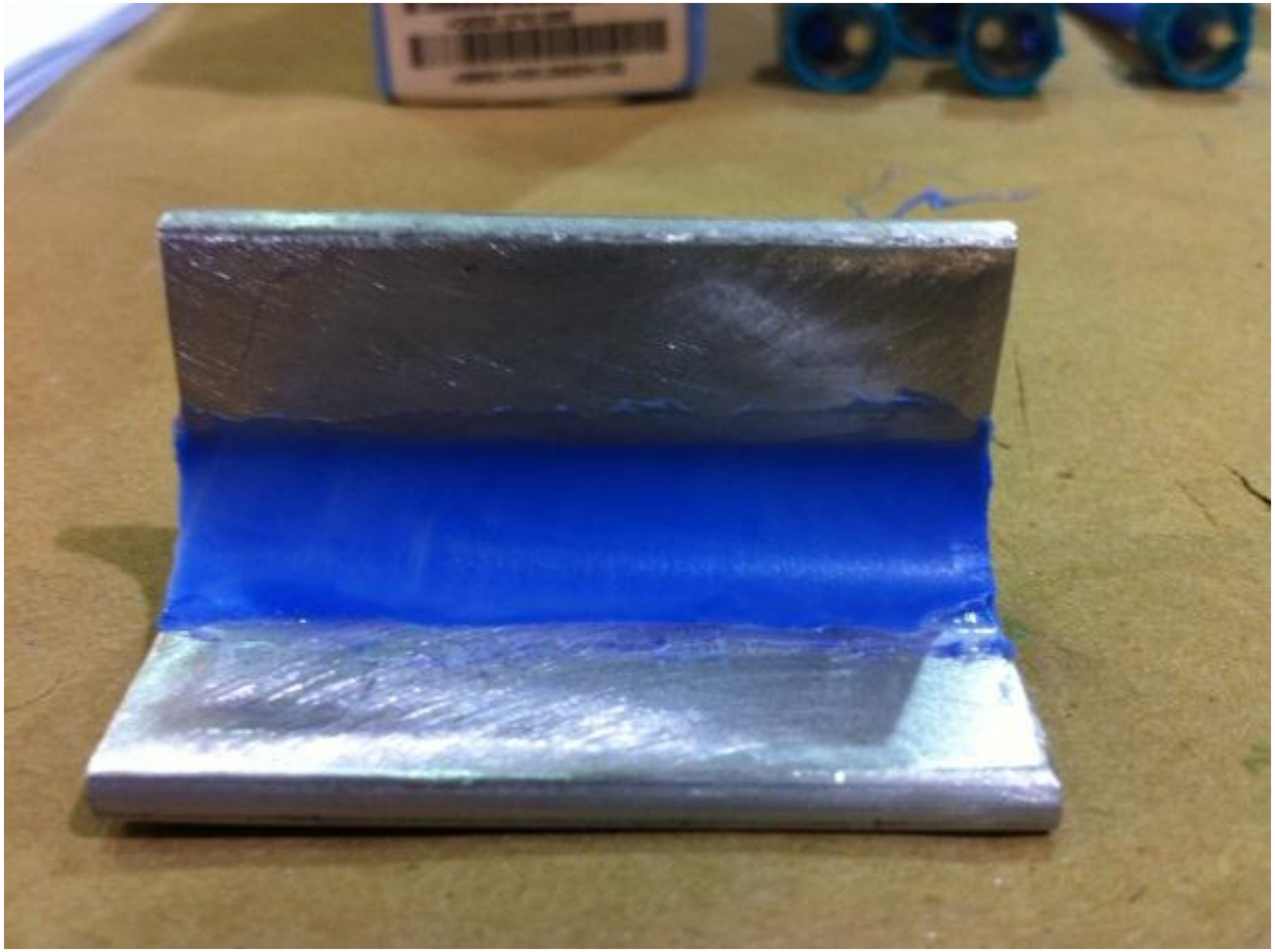


- Resin/Solvent Based Sealant



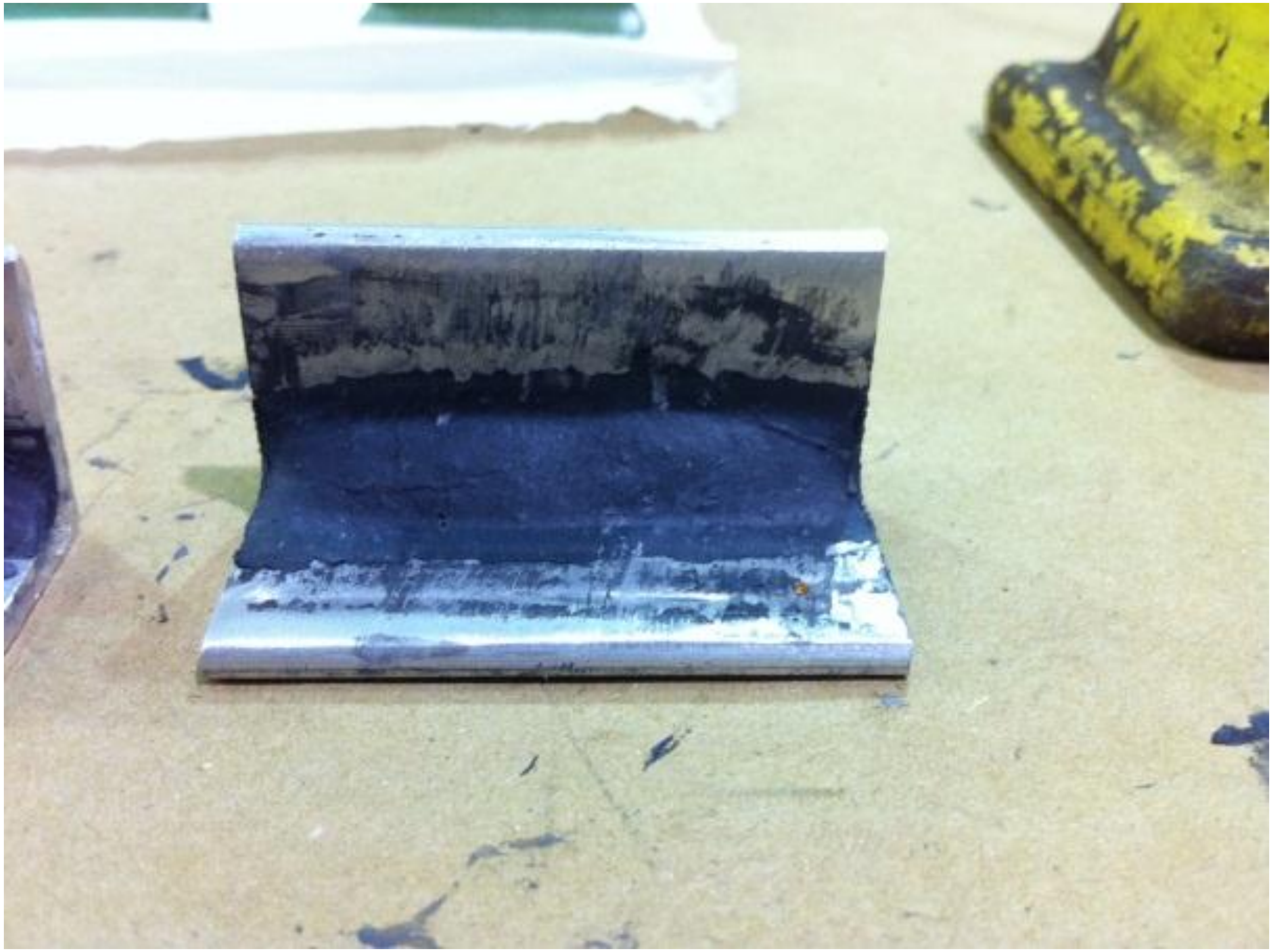
- Polyurethane Sealant

- Silicone Adhesive



- Regular Type Dental Impression Material

• Spackling Paste



- Silicate Cement

- Vinyl Adhesive

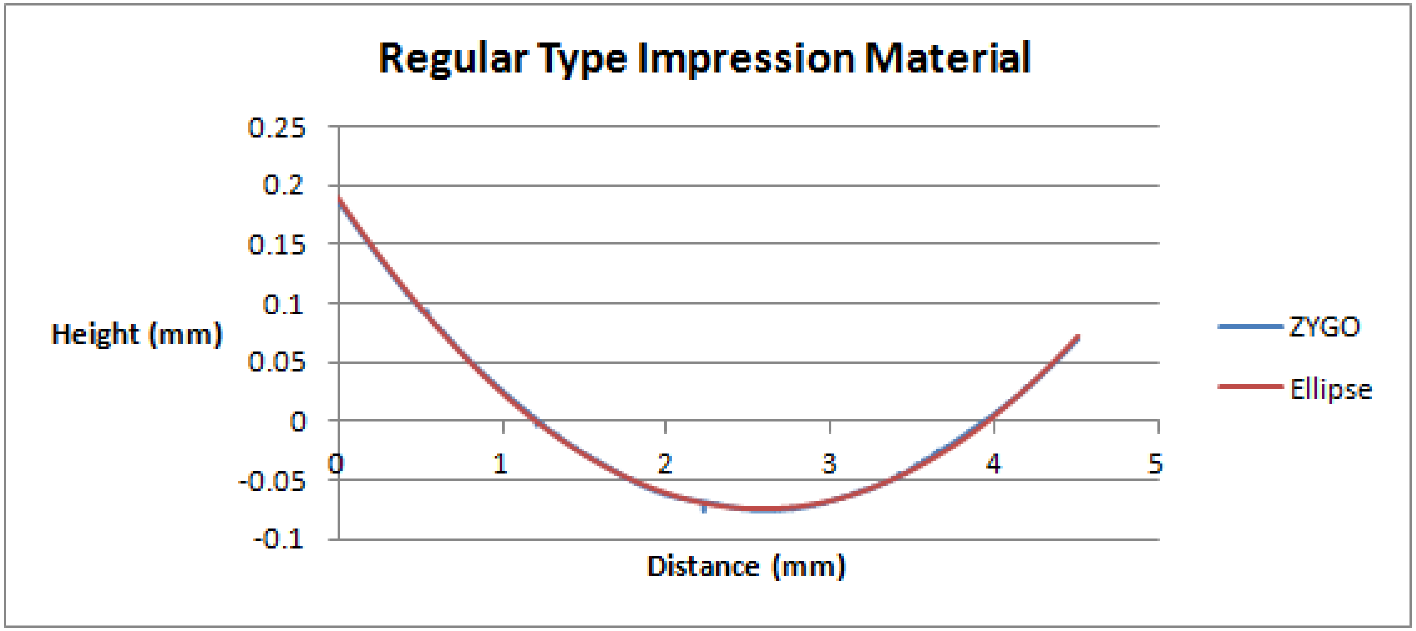


Figure 11: Curve Fit of an Ellipse to the Profile Data Obtained from the SWLI for the Regular Type Impression Material Applied with the Plastic Rod.

Test Matrix

Sample Number's	Material Type	Plastic Film	Teflon/Plastic Rod	Form Fillet by Scraping Excess Away	Spray Paint	Zygo (mm)
#1-4	Spackling Paste		T	X	X	9.525
#5-8	Silicone Adhesive Sealant		T	X	X	9.525
#9-12	Vinyl Adhesive Caulk		T		X	9.525
#13-16	Silicate Cement		T		X	9.525
#17-20	Basic Epoxy	X	T			9.525
#21-24	Regular Type Dental Impression		T			9.525
#25-28	Heavy Body Dental Impression		T			9.525
#29-32	Polyurethane Sealant		T	X		9.525
#33-36	Resin/Solvent Based Sealant		T	X	X	9.525
#37-40	Polyester Filler Paste		T	X	X	9.525
#41	Regular Type Dental Impression		P			12.7
#42-46	Heavy Body Dental Impression		P			12.7
#47-51	Polyurethane Sealant		P	X	X	12.7