Why are Copper Plated Zinc Cents Resistant to Lamination?

By **Pete Apple**

I am a curious person who enjoys research. I have researched my family's ancestry into early 17th century Germany (studying Old German Script in the process), and have published papers in La Tierra the Journal of the Southern Texas Archaeological Association. My interest in Numismatics began as a kid in the late 1940s and has continued off and on since, gravitating to Variety and Errors in the last 6 years.

Since I have found numerous copper cents with laminations but no zinc cents with laminations, I began to wonder why that was.

1915-S 1959-D

Lamination Examples

So I began a study to explore why lamination errors occur on copper base cents, but not on copper plated zinc base. Laminations may occur as a result of a defect in the strip during processing for the production of planchets. These defects may also arise because of impurities or internal stresses in the alloy which causes metal to separate along horizontal planes of weakness. Lamination flaws may also occur as the result of an inadequately mixed alloy.[1] Copper alloy cents are 95% copper and 5% tin and zinc (until 1962 when the cent's tin content, which was quite small, was removed). Thus the amount of the alloying metal was sufficient to create separation along horizontal planes if the alloy was not mixed properly.

Copper plated Zinc Cents are composed of Zinc Alloy 190 electroplated with 8 microns of copper. Zinc Alloy 190 contains 0.005% max Lead; 0.010% max Iron; 0.005% max Cadmium; 0.7% to 0.9% Copper; and 99.08% Zinc. At less than 1%, the amount of alloying in this composition is insufficient to be reflected as an inadequate alloy mix capable of producing a lamination.

Another major difference between copper and zinc alloys is their work hardening (strain hardening).[2] Work hardening is a metal's response to plastic (i.e., permanent) deformation. This deformation results in the metal becoming harder. Christopher Pilliod[3] has found, during previous testing on five Traditional Coining Alloys for US Coins using off center strikes, that there was evidence of strain (work) hardening on all five. In the manufacturing of a coin, the striking introduces approximately 10% strain to the planchet. This is considered a mild to moderate amount of strain. He executed a Rockwell Hardness Test on four off center CPZ (copper plated zinc) cents. The most surprising result of this testing on off center CPZ cents is that the CPZ cents show a negative strain hardening rate! *This is a very atypical characteristic of metals.*

Off center cents were used so that there would be no question that hardness before and after striking was being measured on the same planchet. The Rockwell Hardness results for the CPZ cents = Ave 68.3 Rt-15 on the blank area and Ave 57.3 RT-15 on the struck area – a decrease of 16% = a negative strain hardening rate! This is believed to be a major reason for the resistance of CPZ cents to lamination. (See table of values in Appendix A)

There are other more minor differences between copper alloy and CPZ cents which undoubtedly contribute to the CPZ cents' resistance to lamination:

- The Interfacial Free Energy for Zinc is significantly less than for Copper.[4]

A CPZ Cent after testing
Rockwell 15T

- Zinc strip - as it is being processed for rolling into coils – has lubrication applied to it which leads to improved surface finish, as well as distributing a corrosion-protective barrier on the strip.[5] This lubrication giving added protection serves to further prevent corrosion induced laminations from developing.
- The Metallic Crystalline Structure of Copper is more conducive to lamination than it is in Zinc.[6]
- With earlier gas or coal/coke fired furnaces the metal had to be stirred to mix the metals. This could lead to incomplete mixing, and/or introduction of contaminants into the melt. The problem of incomplete mixing is absent in contemporary Induction furnaces which are self-stirring.[7]
- With today's modern sensors it is possible to take the melt to a specific temperature and hold it there allowing contaminates and gas bubbles time to rise to the surface where they can be skimmed with the dross and without vaporization. The result is a solid more uniform ingot.[7]
- The lower the Tensile Strength of a metal or metal alloy, the less likely a metal (alloy) is to produce laminations. The Tensile Strength of the zinc alloy is significantly lower than the copper alloy.[8]

Footnotes:

(1) http://www.error-ref.com/lamination -loss-after-strike/

(2) ALTERNATIVE METALS STUDY Contract Number: TM-HQ-11-C-0049 FINAL REPORT August 31, 2012 by Concurrent Technologies Corporation, Submitted to: United States Mint, Page 6, Page 42.

(3) Christopher Pilliod is Sr. Metallurgist—Process Technology Group for Carpenter Technology and has participated in the Alternative Metals Study for the US Mint (referenced in these notes). He earned a B.S. in Metallurgy from Case Western Reserve University in 1979. I am indebted to him for his editorial guidance for this paper.

(4) Surface Science 411 (1998) 186–202: The surface energy of metals by L. Vitos, A.V. Ruban, H.L. Skriver, J. Kolla´r---Center for Atomic-scale Materials Physics and Department of Physics, Technical University of Denmark, DK-2800 Lyngby, Denmark, Research Institute for Solid State Physics, H-1525 Budapest, P.O. Box 49, Hungary Received 3 November 1997; accepted for publication 2 May 1998 http://ronald-wagner.de/diss/html/lit/share/surfsci411(98)186.pdf

(5) Jarden Zinc - Technical Brief: Lubrication of Solid Zinc Strip

(6) "Primary Metallic Crystalline Structures - Similarities and Difference Between the FCC and HCP Structure" https://www.nde-ed.org/EducationResources/CommunityCollege/Materials/Structure/fcc_hcp.htm

(7) http://goccf.com/t/337498#2885808

(8) "Residual tensile strength monitoring of drilled composite materials by acoustic emission" by Navid Zarif Karimi, Hossein Heidary, Mehdi Ahmadi Non-destructive Testing Lab., Department of Mechanical Engineering, Amirkabir University of Technology, 424 Hafez Ave.,15914 Tehran, Iran Journal of Materials and Design 40 (2012) 229-236. https://www.researchgate.net/publication/257085891_Residual_tensile_strength_monitoring_of_drilled_composite_materials_by_acoustic_emission

Appendix A

"Hardness testing is designed to be performed on samples which are flat and have parallel smooth surfaces. So it works fine on coin blanks or the off center regions, but gets a little sketchy on struck regions where there are curves and the coin is thinner.

When the metal sample gets too thin unreliable readings are more prone. So the further off center the strike the thinner the struck region is. So this shows up in the data. I think we still can get a clue by throwing out the flyers. I took more readings on the struck portions."[3]

Unreliable readings (usually because the opposing surfaces of the indentations were not parallel) are in brackets {} in the tables below:

	1984 40%	**OFF CENTER**			**198? 25%**	**OFF CENTER**	
	BLANK	**AS STRUCK**			**BLANK**	**AS STRUCK**	
	hardness, 15T	hardness, 15T	location		hardness 15T	hardness 15T	location
	65.9	42.4	field		69.9	69.8	field
	66.9	{32.6}	field		70	68.9	field
	65.6	41.5	field		70	68.2	field
	67.3	53.3	field		70.1	69.7	field
	67.4	39.6	Bust		70.6	72.9	Bust
	67.6	{25.6}	Bust		70.3	71.1	Bust
	68.1	40.3	Bust			68.3	Bust
		44.9	Bust			69.9	Bust
		{17}	Bust				
		{31.3}	Bust				
		48.6	Bust				
		{34.4}	Bust				
AVERAGE	67.0	44.4		AVERAGE	70.2	69.9	

	Undated 50%	**OFF CENTER**			**Undated 30%**	**OFF CENTER**	
	BLANK	**AS STRUCK**			**BLANK**	**AS STRUCK**	
	hardness 15T	hardness 15T	location		hardness 15T	hardness 15T	location
	67.6	47.6	field		65.5	63	field
	67.9	46.9	field		68.2	59.8	field
	67.8	{42.1}	field		68.8	60.7	field
	69.7	{66.1}	field		66.5	62.9	field
	67	54.9	field		69.3	60.9	field
	69.6	{41.7}	Bust		68.3	67.5	Bust
		51.2	Bust			{54.8}	Bust
		57.8	Bust			{54.7}	Bust
		52.4	Bust			65.2	Bust
		50.1	Bust			66.3	Bust
		{42.1}	Bust			66	Bust
		{39.9}	Bust			{51.7}	Bust
		{39.5}	Bust			61.8	Bust
		{39.0}	Bust				
AVERAGE	68.3	51.6		AVERAGE	67.8	63.41	
	AVERAGE	**TOTAL**					
	BLANK	**68.3**			**STRUCK**	**57.3**	