CONSTRUCTION AND PERFORMANCE OF QUALITY COMERCIAL VIOLIN STRINGS

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INTRODUCTION

Sets of high quality commercial violin strings have been investigated to discern their construction and their vibrational performance. Strings made by Pirastro in the Olive, Green (Eudoxa), Gold and Black labels have been examined. This report is a continuation of investigations into the design of strings for musical instruments (1,2).

The construction of the strings was obtained from photographs from a Scanning Electron Microscope which, having a calibrated magnification, has the facility of showing on each photograph a marker line of stated length in the object plane under investigation. Dimensions of gut core, nylon underwrap and wrapping wire can thus be obtained from the photgraphs and ckecked by measuring with micrometer. Linear density of strings was obtained by accurately weighing a known length.

The dynamic vibrational behaviour of the violin strings were obtained from measurements on a massive sonometer when the strings were at playing pitch. The frequencies of the harmonics of strings to the ninth or tenth were obtained, and after each measurement of a harmonic the fundamental frequency of the string was checked in case there had been a drift in fundamental pitch during the measurment process, and corrections were made should this have occurred. In this way the inharmonicity of the harmonics of the strings were measured. Four new G strings from each label were measured.

The lowest string with the largest core diameter was investigated in these studies because inharmonicity should be greatest for violin strings as predicted from the expression for inharmonicity f_n/nf_1 of the nth harmonic f_n (2,3)

$$\frac{f_n}{nf_1} = (1+Bn^2)/(1+B)$$

where $$B = 8\pi^3 E d_c^4 / Tl^2$$

d_c is the diameter of the core, E Young's modulus of the core material, T the tension in the string, and l the length of the string.

CONSTRUCTION

The constructions of some of the violin strings investigated are shown in Figure 1. These have been selected from the total obtained to show the main features which are present. Strings are made of three parts:

(1) the core is of gut in Pirastro Olive, Green, Gold and Black Label (G,D,A);

(2) there is an intermediate wrapping of nylon or similar very thin mono- filament material which is applied in three different ways - as a floss over-wrapped around the core, as a set of strands overwrapped around the core, or as a braiding knitted around the core;

(3) the outer wrapping of the string is of silver or aluminium, or both together, and the wire which is generally used is circular. In the Olive and Green A the wrap is of rectangular section.

The intermediate winding, or braiding of the gut core is an important part in making overwrapping strings for it enables a better fix to be obtained to the core.

Label	String	OD mm	ϕ gut + wrap mm	ϕ core mm	Pitch of gut mm	Circular floss (18µm)	Braiding No. of fibres (18µm)	ϕ wrap mm	No of wrap	Material of wrap
Pirastro				gut						
Olive	G	.81	.61	.55	6		10/16	.12	3	Ag
Green	G	.81	.63	.56	5		10/16	.12	2	Ag
Gold	G	.82	.64	.61	5.5	10		.12	2	Ag
Black	G	.85	.63	.61	5.1	10		.12	2	Ag
				gut						
Olive	D	.85	.67	.61	6		7 x 12	.11	3	Al, Ag, Al
Gold	D	.87	.63	.63	5	10		.15	2	Al
Black	D	.86	.63	.60	5	10		.14	2	Al
				gut						
Olive	A	.62	.54	.54	6.5		NIL	.07	1 x Rect	Al
Green	A	.66	.56	.49	6.5	10		.07	1 x Rect	Al
Gold	A	.69	.54	.54	6.5		NIL	.09	2 x O	Al
Black	A	.69	.53	.53	6.5		NIL	.09	2 x O	Al
				steel						
Flexocor	A	.48		.24(=.07x7)	2.4		7x12 lengthwise	.06	1 Rect	Al
				gut						
Perfection	G	.81	.65	.6				.12	2 x O	Ag
	D	.86	.65	.6				.15	2 x O	Ag
	A	.67		.55				.08	2 x O	Al
Pirastro Wonderton	D	.86	.61	.61				.15	2 x O	Al June

TABLE 1

The difficulty of making overwrapped gut strings has been noted from the earliest times (4), and to obtain a good adhesion between winding and core, which, because of its low Young's modulus, stretches considerably when tuned to pitch, is an important aspect of manufacture.

Table 1 gives data for the construction of the strings, and Figure 2 shows this data plotted for the strings and gives the tension (T) and the tensile stress ($T_s = 4T/\pi d^2$), for a violin at pitch, with Pirastro wire E added.

SEM photographs of strings (Fig.1) show that braiding for the intermediate wrap is used in Olive and Green Label strings, whereas simple floss overwrapping is used in Gold and Black. The surface finish of the metal wrapping, produced in all cases by longitudinal working, is better polished in the Olive and Green than in the Gold and Black. In Olive and Green polishing has been carried out longer to obtain a nearly smooth surface and there is considerable cold working of the metal wrapping to fill the gaps between adjacent windings. In Gold and Black there are depressions between windings because of incomplete polishing.

INHARMONICITY

Inharmonicity, defined above, has been calculated from measurements on G strings for the Pirastro Olive, Green, Gold and Black Label and the results are shown in Figure 3. Inharmonicity arranged over four strings is plotted in Figure 3 in cents and standard deviation for each harmonic is indicated. Figure 3 indicates that strings are ordered from high to low inharmonicity as Green, Olive, Gold and Black, and the standard deviation of measurments increases in the order Olive, Green, Gold and Black. It would appear, therefore, that the simple construction of Black where a nylon floss is used for the intermediate wrapping gives a lower inharmonicity than the more complicated braid knitted around the core in other labels. Nevertheless, the superior finish of the Olive, and Green strings leads to a smaller standard deviation in measurements, which could be ascribed to a better quality control during manufacture. This is reflected also in the price of the strings which are ordered from high to low price as Olive, Green, Gold and Black.

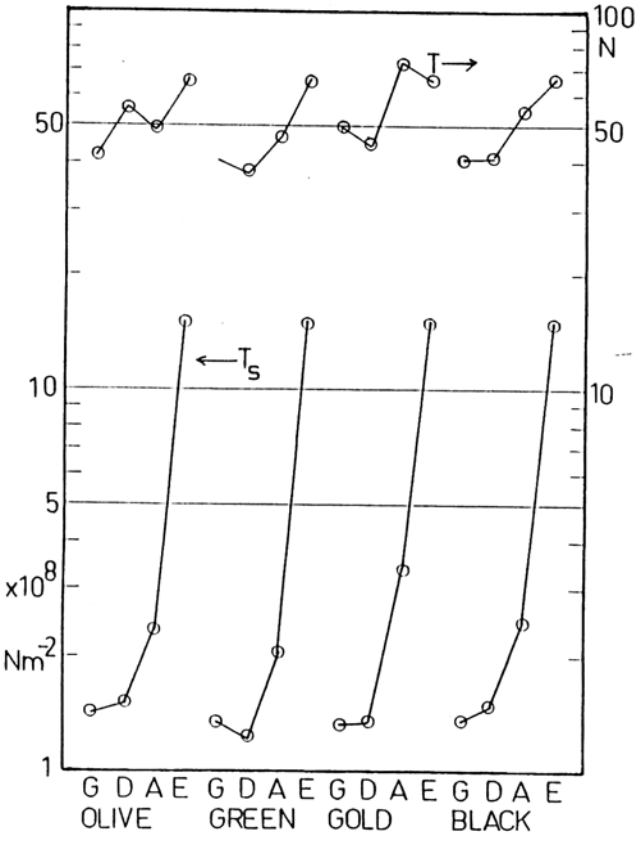

FIGURE 2. Calculated tension and tensile stress for Olive, Green, Gold and Black Pirastro Violin Strings tabulated in Table 1.

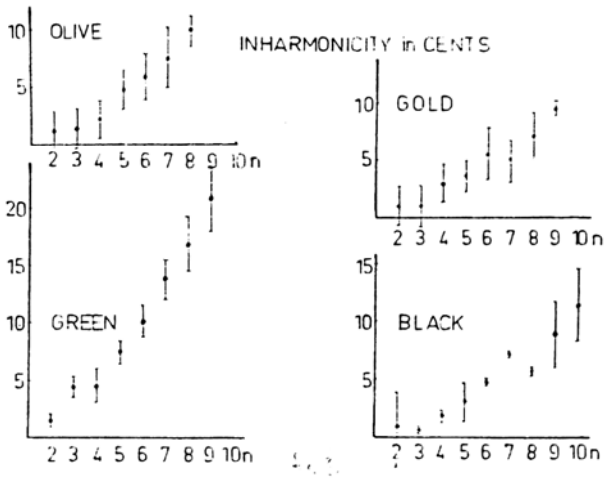

Figure 3. Measured inharmonicity for Olive, Green, Gold and Black Pirastro violin G strings plotted in cents versus the harmonic number, n of the partials of the strings.

It is apparently the case that there is a preference by players ordered Olive, Green, Gold and Black which is clearly not dictated by market price. This is the reverse order to inharmonicity, but is that of finish both from the final surface of the string for the bow and the complexity of manufacture. Preference must be due to the playablility of the string from the mechanical and practical standpoint: good surface, firm and lasting adhesion of the windings on the gut core. It is clear that a good playing regime among the harmonics can be established in the Olive and Gold, although their inharmonicity is higher than the others, and it would be interesting to establish if the Quality Factors of the harmonics of these strings, which were not measured in this study, are lower than Gold and Black due to the different intermediate wrapping in the string.

ACKNOWLEDGEMENTS

The SEM photography was undertaken at the Scottish Universities SEM Facility at the University of Edinburgh and it is a pleasure to thank Mr Jim Goodall for his pleasant and patient assistance. Measurements of inharmonicity were made by Miss Amanda Gallacher, and calculations leading to Figure 2 were undertaken by Miss Clare Sykes who are both thanked for their meticulous work. The support of Salvi Harps in this project is gratefully acknowledged.

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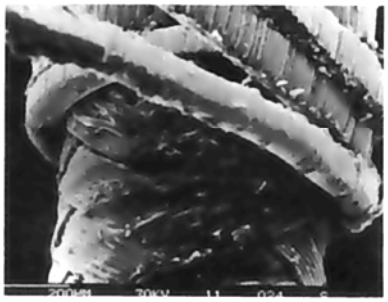
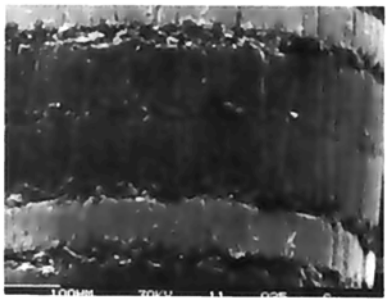
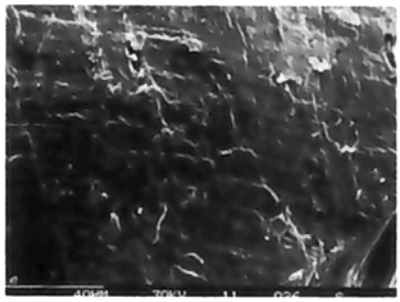
1. Ian Firth, Overwrapped Strings:Design Guide Incorporating Acoustical Limitations, J Catgut Acoust Soc 45, 7 (1986)
2. Ian Firth, Equation for the Design of Strings, Catgut Acoust Soc (accepted for publication).
3. H. Fletcher, Normal Vibrations Frequencies of a Stiff String, JASA 36, 203 (1964).
4. Albert Cohen, A Cache of 18th-century Strings, Galpin Soc J 36, 37 (1983).



(a) Showing three circular wrappings (Al,Ag,Al) over a brading of 7 x 20 µm nylon. Indentations of the wires are seen in the brading.

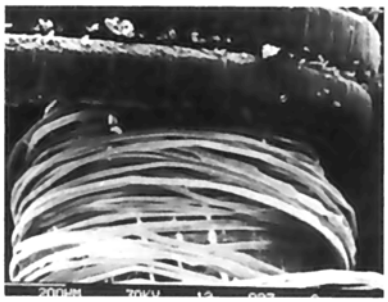


(b) Surface of the overwrap wires, from the top Ag 94µm, Al 105µm, Al 105µm, Ag 94µm. Surface polishing is longitudinal with surface scratches to 5µm, and the indentations between windings nearly filled with cold worked material.

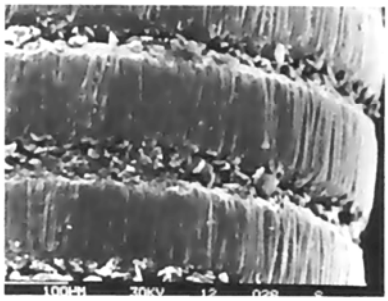


(c) Surface of the gut core of the string which is under the braid in (a). Surface has been profiled by centerless grinding to about 1-2 m. Right hand bottom shows the cut made in exposing the string.

PRIASTRO VIOLIN OLIVE D

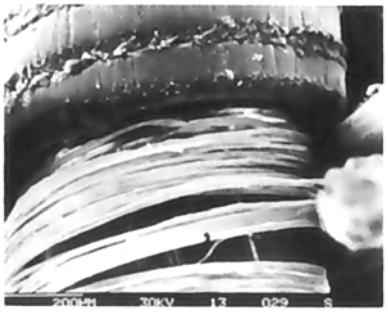


(a) Wire wrap in this string is two strands of Al 140 m wrapped into a nylon floss wound circumferentially around the gut core.

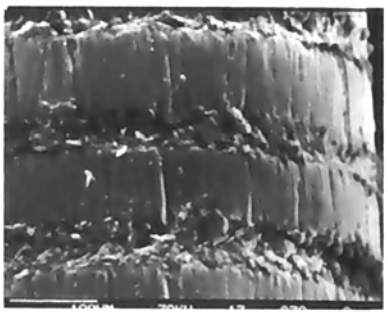


(b) Surface polishing of the Al wrap is longitudinal, but the spaces between the windings are incompletely filled.

PIRASTRO VIOLIN GOLD D



(a) Wrapping is two wires of Al onto a circularly wound floss of nylon over the gut core.



(b) Surface polishing of the Al wrap showing that the spaces between winding are nearly filled.

PIRASTRO VIOLIN BLACK D

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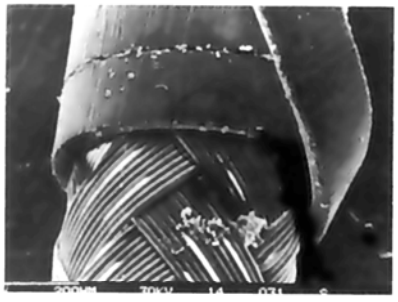
Ian Firth, Professor of Physics at St. Andrews University, Scotland, longtime active member and contributor to our JOURNAL, has engendered great interest in the harp, both its historical and acoustical aspects. His work was recently written up in the St. Andrews "Courier".

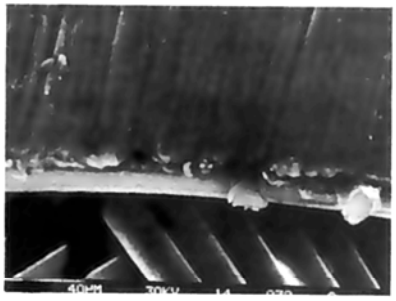
PIRASTRO VIOLIN OLIVE A

(a) Rectangular Al wire is wound directly onto the gut core. The flat winding is polished longitudinally, here with slight helical marks.

PIRASTRO VIOLIN GREEN A

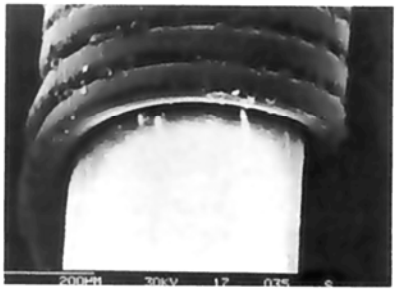


(a) Rectangular Al wire is wrapped onto a smooth brading of nylon overwrapped onto the gut core.



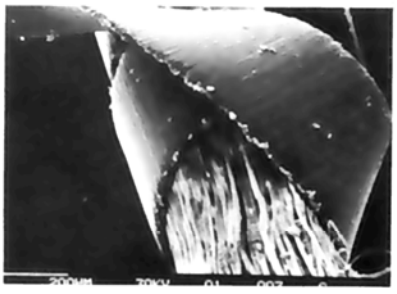
(b) Surface finish of the Al flat wire showing longitudinal polishing to about 5um, some cold working of the material to fill the spaces between winding, and the undistorted nylon brading underneath.

PIRASTRO VIOLIN BLACK A

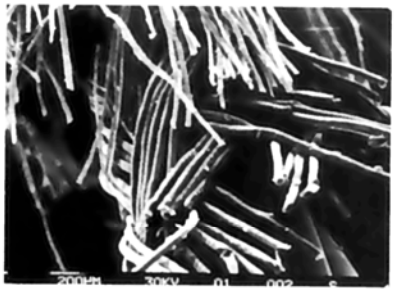


(a) Circular Al wrappings onto gut core with imperfect polishing of the outer surfact so that the spaces between windings are incomplerely filled.

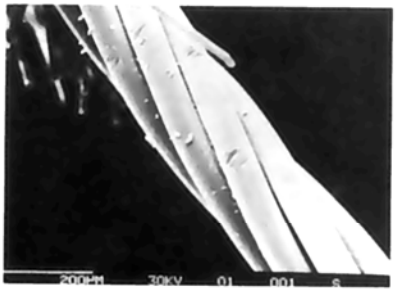
PIRASTRO VIOLIN FLEXOCORE A



(a) General view of the rectangular Al wire wound over a longitudinal nylon floss. Surface of the Al flat winding is along the length of the string.



(b) View of the end cut of the longitudinal floss exposing underneath a brading of nylon woven onto the wire rope core.



(c) Wire rope of steel strands as the core of this string in order to produce a string of great transverse flexibility, and hence small inharmonicity.