The Effect of Change of Temperature in Twisting or Untwisting Wires which have suffered Permanent Torsion

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Again, since

$$\Delta = \frac{C+D}{C}\{B(C+D)+G(B+C)\},$$

$$q = x_1 \frac{BCDK_2 - B^2DK_1 + L_1\frac{C^2}{D} - L_2\frac{BC}{D} - L_3C + L_4B}{B(C+D)+G(B+C)}$$

$$= x_1 \frac{K_2BC - K_1B^2 + L_1\frac{C^2}{D^2} - L_2\frac{BC}{D^2} - L_3\frac{C}{D} + L_4\frac{B}{D}}{\frac{BC}{D} + B + \frac{G(B+C)}{D}}.$$

If A and D are now made infinite,

$$q = x_1(K_2C - K_1B);$$

the same result that we obtain if there is no self-induction in the branches B and C.

XI. *The Effect of Change of Temperature in Twisting or Untwisting Wires which have suffered Permanent Torsion.* By HERBERT TOMLINSON, *B.A.**

In a paper recently communicated to the Physical Society†, Mr. R. H. M. Bosanquet has drawn attention to the remarkable behaviour of a very fine hard-drawn platinum wire, which twisted or untwisted very appreciably when subjected to small variations of temperature. As some experiments made by myself nearly eight years ago, but of which the results have not been as yet published, seem to bear on the interesting phenomenon in question, I now venture to bring them forward. I had previously been investigating the effects of permanent extension and compression on the longitudinal elasticity of wires in the following manner:—A wire of from 60 to 90 centimetres in length and 1 millimetre in diameter was suspended vertically, with its upper extremity clamped to a rigid support, and its lower one attached to a little brass block provided with a hook at the bottom, to which weights could be attached. Permanent torsion was imparted to the wire, which was afterwards subjected to various

* Read June 25, 1887.

† *Ante*, p. 50.

amounts of longitudinal stress. The permanent twisting of the wire in the direction of a right-handed screw causes the portion A B C D (fig. 1) to be permanently extended along the diagonal A C and compressed along the diagonal B D (fig. 2).

Fig. 1.

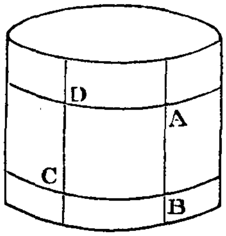
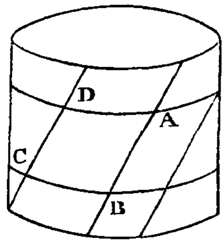


Fig. 2.



If now the wire be loaded, the stress will produce temporary twist or untwist according as the elasticity is greater or less in the direction B D than in the direction A C. A full account of these experiments will be found in the 'Philosophical Transactions,'* so that it will suffice to state here that all the wires examined showed temporary twist or untwist to be the result of loading. The amount of twist or untwist produced by loading was comparatively small, and was measured by the usual mirror lamp-and-scale arrangement, the mirror being attached to the brass block at the end of the wire.

It then occurred to me that a similar arrangement might be used for testing the effect of permanent extension and compression on the thermal expansibility of a metal. A wire was suspended in the axis of an air-chamber, consisting of two concentric brass cylinders enclosing an annular space between them 6 millim. thick. The length of the air-chamber was 120 centim. and its outer diameter 10 centim. When the required amount of permanent torsion had been imparted to the wire, steam from a boiler was admitted into the annular space through a tube soldered into it near its lower extremity, and passed out through a similar tube near the top, where it was condensed in a vessel of cold water. After a period ranging from $\frac{1}{2}$ hour to 2 hours, when the *permanent* untwisting which invariably accompanied the heating had ceased

* Part I. 1883: "The Influence of Stress and Strain on the Physical Properties of Matter."

to become sensibly greater, the position of the light on the scale was noted and the action of the steam stopped. The annular space was now filled with cold water, and in about ten minutes afterwards the position of the light on the scale was again noted. The difference between the two readings was a measure of the amount of temporary twist or untwist produced by the change of temperature, the last being, on the average, 85° C. In several cases the heating and cooling were repeated with little or no variation in the amount of temporary twist or untwist. The length of each wire was nearly 120 centimetres and the diameter 1 millimetre.

The results of the experiments will be found in the following Table, in which are given the amount of temporary twist or untwist in scale-divisions, the amount of permanent untwist, and the load hanging on the wire during the experiment. The wires were all well annealed before being permanently twisted.

Metal ...	Copper.		Iron.		Aluminium		Silver.		Platinum.	
Load on the wire, in kilos.	1		1		$\frac{1}{2}$		1		1	
Number of complete turns of permanent torsion.	Permanent untwist produced by heating. P.	Temporary effect of heating. + signifies temporary twist, T.	P.	T.	P.	T.	P.	T.	P.	T.
10	......	.. ...	24	3·5−	800	74−	298	2·5−	...	4+
20	......	31+	...	......	...	71−				
30	......	......	...	6·0−						
40	......	......	...	......	...	......	...	3·0−		
50	555	36+	...	......	...	74−	...	......	63	10+
100	690	41+	...	5·0−	...	......	...	3·0−	138	
150	......	......	...	......	...	78−	...	......	273	12·5+
200	861	......	58	......	...	......	...	......	...	13·0+

We may gather from the Table the following particulars:—

(1) Rise of temperature from 15° C. to 100° C. produces in permanently twisted iron, aluminium, and silver temporary

untwist, showing for these metals less thermal expansibility in the direction of permanent extension than in the direction of permanent compression. With copper and platinum, on the contrary, rise of temperature produces temporary twist.

(2) The amount of temporary twist or untwist is in all cases small compared with the amount of permanent untwist produced by rise of temperature. It is also absolutely very small*.

(3) A few turns of permanent torsion suffice to produce the maximum alteration of thermal expansibility which can be effected by this means.

Small variations of the load hanging on the wire produced no sensible effect on the temporary twist or untwist following on rise of temperature. The case, however, was different when large loads were employed. With platinum, for example, by increasing the load from 1 to 7 kilos. the temporary twist produced by rise of temperature was increased threefold. With copper also there was a similar effect produced by largely increasing the load. On the contrary, it would seem that with these metals, in which untwist is produced by rise of temperature, increase of load diminishes the untwist; and if the load be sufficiently large, the wire begins to be twisted temporarily by rise of temperature. This was found to be the case with annealed iron. The wire was twisted permanently with gradually increasing amounts of load on it, and after each twisting was slightly heated by running a burner up and down it. As before, with moderate loads there was temporary untwist on heating; when the load reached 10 kilos. there was neither temporary twist nor untwist; and finally, when the load was 16 kilos., there was very appreciable temporary twist.

Annealed piano-steel behaved like annealed iron; but with unannealed piano-steel rise of temperature caused a very appreciable temporary *twist*, instead of untwist, even with small loads on.

A remarkable feature about all these experiments was the great difference with different metals in the facility with which the effect of permanent torsion in one direction could be reversed by permanent torsion in the opposite direction. With copper, for example, one complete revolution in the opposite

* 100 scale-divisions only represent torsion through an angle of 2° 20′.

direction was sufficient to reverse the effect of 200 complete turns of permanent torsion, whilst with iron the difficulty of reversing the effect of previous torsion was considerable.

I am inclined to believe that the phenomenon observed by Mr. Bosanquet is to be, at any rate partly, attributed to unequal expansion in different directions. I have always found in wires which have been hard-drawn a certain amount, and sometimes a considerable amount of permanent torsion: this, we have seen, will cause temporary twist or untwist to be produced by rise of temperature. The amount of twist or untwist in any case, however, observed by myself was very much less than that observed by Mr. Bosanquet; and it would be of interest to ascertain how far the comparatively very large variation of torsion with small rise of temperature which occurred with the platinum wire used by him, is to be attributed to the comparatively great longitudinal stress on the wire*.

XII. *Remarkable Effect on raising Iron when under Temporary Stress or Permanent Strain to a Bright-red Heat.* By HERBERT TOMLINSON, *B.A.*†

IT has been shown in the preceding paper that an annealed iron wire which has been permanently twisted is temporarily untwisted when the temperature is raised to 100° C., provided there is not too great a load on the end of the wire; but that if the load on the end of the wire is sufficiently great, a temporary twist follows on the rise of temperature. Fresh experiments were therefore entered on with the view of ascertaining whether, with a small load on the end of the wire, the temporary untwist produced by rise of temperature would be changed to twist when the temperature exceeded a certain limit. A few preliminary trials were made by merely heating a portion of the permanently twisted wire with a burner; and it was found that when the wire reached a bright red heat a most remarkable and sudden change occurred, the wire sharply *twisting* in the same direction as that in which it had previously suffered permanent torsion. When the burner was

* See above, the effect of increasing the load on the wire.

† Read June 25, 1887.