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Original Research Paper

Forensic Science

FORENSIC EXAMINATION OF DIFFERENT FIBRES USED IN LIFE THREATENING MANJA (KITE STRING) BY SIMULTANEOUS THERMAL ANALYSIS

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ABSTRACT Science for justice is the principle of forensic science. Physical and biological evidences from crime scene are sent to forensic science laboratories for analysis and the reports generated through analysis are important in judiciary system. As social peace is important for society, likewise, it is also necessary to care for the environment. The Environmental Protection Act 1986 of India covers such activities that are harmful for environment. Use of synthetic kite string (manja) is one of these activities as it is harmful for human, animal and avian life. There has been a surge in the number of cases in which both humans and birds have received fatal Manja injuries. In India, therefore Central Pollution Control Board (CPCB) has directed all the state governments to prohibit the manufacturing, sale, storage, purchase and use of all synthetic threads for flying kites. Due to all these reasons, kite string/manja is seized under Section 188, 336 of Indian penal Code and 5,15 Environment Protection Act and submitted to the forensic science laboratories for chemical examination. The objective of this paper is to compare the properties of different types of fibres/thread using Simultaneous Thermal Analysis (STA) and thus to ascertain the nature of fibre /thread used in Manja.

KEYWORDS : Manja, Thermal analysis, Environment, Forensic examination, Kite Strings, polymer

INTRODUCTION

India is rich in various religions. Different festivals are celebrated in India. Many games/ activities are the manifestation of happiness in festival celebration. Kite flying is one of these activities, especially enjoyed on the occasion of Makar Sankranti. Kite flying gives pleasure to all, from young to old. In this game, the kite is flown high in the sky with the help of a string called Manja. People enjoy bringing down opponent's kite by cutting the string. For cutting opponents' kite the edge of the kite is made sharper. Traditional making of sharp Manja was based on fine pure cotton thread, coated with a mixture of rice glue, tree gums or similar natural ingredients and finely powdered glass as abrasive. In recent years polymer thread is used as Manja. This non-biodegradable synthetic polymer thread is harder to break and makes the string more dangerous.

The joyous moments during kite flying sometimes lead to serious accidents. The accidents include the falling of individuals from height, accidents on roads while trying to catch cut kites and electrocution while taking kites away from electric poles or wires. Similarly, polymer kite string causes other injuries such as injury to the neck/ throat, eyes, face, and hands due to the sharpened edge of Manja sometimes resulting in fatal cases. In the past, there has been an increase in the number of cases in which both humans and birds have received fatal Manja injuries. Various authors [1-9] have studied the fatal injuries caused by polymer-based manja string.

Considering all the threats caused by synthetic manja to humans as well as birds, National Green Tribunal (NGT) in India, asked the Central Pollution control Board (CPCB) to submit complete analysis report on the composition of kite string (manja) and its harmful effects on health and environment and directed all state governments to prohibit the manufacture, sale, storage, purchase and use of synthetic manja for flying kites. Due to all these reasons, kite string/manja is submitted to forensic science laboratories for chemical examination.

Fibres /threads are one of the important physical evidence in forensic investigation and fibre comparison has its own importance in various crime cases. In forensic science laboratory, fibre detection and comparison are done in various contexts such as cloth comparison; rope comparison to link the evidence with the crime scene and thus helps in confirming the circumstantial evidence. Fibre and thread comparison is performed by using many conventional techniques mainly based on various physical and chemical methods. Modern analytical techniques for cloth, fibre analysis involve scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR) etc [10,11,12].

In the recent years, Simultaneous Thermal Analysis (STA) constituting both Thermogravimetry (TG) and Differential Scanning Calorimetry (DSC) has shown vast application in pharmaceutical industry, polymer industry, automobile industries and textile industry[13,14,15]. Thermal analysis has also proved a very important instrumental analytical technique for fibre and polymer comparison in forensic science. Comparison of cardboard and tire rubber by thermal analysis in a murder case [14,15], comparison of vehicle fibre materials in a hit and run case [16], comparison of cable wires in cheating cases [17], etc. are few examples where STA technique is successfully used. Most of the Forensic examination involves the comparison of samples, but sometimes it becomes essential to detect or identify the nature of the exhibit or sample to reach a conclusion. Thus for such analysis, thermal detection is one of the best analytical techniques.

Literature on manja is restricted mainly to the injuries caused by it [1-9]. Present forensic investigation of chemical analysis of Manja is focused on thermal analysis of fibres used in kite string/manja. Applications of classical techniques along with modern techniques help in successful and full-proof forensic examination and support the judicial system.

Comparative study of different fibres on the basis of thermal behavior using instrumental analysis gives a clear idea about the nature of fibre used in manja preparation. Though various physical and chemical methods have been reported by different authors for the determination of thread or fibre in forensic analysis, STA also plays an important role in the confirmation of the nature of the fibre. Instrumental analysis provides clear and reliable results in addition to classical chemical methods.

MATERIALS AND METHODS:

Fibres from different materials such as coconut coir, jute rope, cotton, wool, silk, reference polyester, nylon fibres and samples from received exhibits were finely cut into pieces and used for analysis. Chemicals used in the present study were AR grade.

Preliminary Analysis: Preliminary analysis of fibre include feel of fibre, burning behaviour and chemical test such as action of strong sulphuric acid.

STA Analysis: The STA was performed using NETZSCH STA 449. About 3-5 mg sample was taken in aluminum crucible with pierced lid. Sample used in this study was heated in the range of 50°-600° at the rate of 20K/min. in nitrogen atmosphere as purged gas at a flow rate of 40 ml/min and 60 ml/min. Data was analyzed using NETZSCH STA 449 Protease software.

RESULTS

In spite of the legal ban, nylon/ polyester manja is sold by shopkeepers and this manja is seized by police authority and sent to forensic science laboratories to ascertain the thread nature of manja. Cases received in our forensic science laboratory in last few years are given in Fig 1. The numbers in the chart show physical seizer of manja from shopkeepers but now a days manja is purchased online and hence actual picture is different than the cases received in laboratory as given in Figure 1.

Fig. 1- Yearwise manja articles received in Nagpur region

Preliminary Analysis

Results on preliminary analysis of different types of fibres are summarised in table 1. Concentrated sulphuric acid dissolves cellulose fibres while synthetic fibre shows a dark brownish viscous solution. Polyester degrades by H_2SO_4 at high temperatures

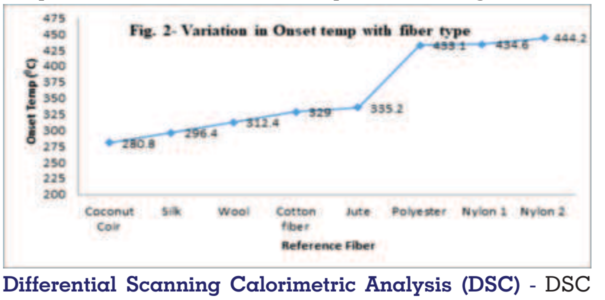
Table 1. Results On Preliminary Analysis Of Different Fibres

Sr. No.	Type of Fibre	Heating Effect	Effect of H_2SO_4
1	Cotton fibre	Burns instantaneously with yellow edge, extinguishes when removed from flame but continue to glow and then produce smooth ash.	Charred
2	Coconut coir	Burns instantaneously with yellow edge, extinguishes when removed from flame but continue to glow and then produce black fibrous ash.	Charred
3	Jute	Burns instantaneously, with yellow orange edge, extinguishes when removed from flame but continue to glow and then produce fibrous greyish ash.	Charred
4	Wool	Fibre burns continuously fast with yellow flame and gives black rough ash.	Charred.
5	Silk	Burns instantaneously, shrink and gives beads like appearance and produce gritty ash.	Charred
6	Polyester	Slight burning produces fine fibre on stretching and when heated strongly fibres burn vigorously producing black smoke. On cooling give beads like appearance and when crushed gives rough black ash.	Resistant to sulphuric acid and after sometime turns into dark brownish viscous liquid.
6	Nylon	Fibre burn with yellow flame with blue edge, melt completely, drip and self extinguished.	Resistant to sulphuric acid and after sometime turns into dark brownish viscous liquid.

Thermal Analysis: Thermal behaviour of standard natural fibres (such as cotton, coconut coir, jute fibre, wool, silk) and synthetic fibres along with samples received in laboratory were studied and compared.

Tg Onset Temperature: The thermogravimetric analysis of plant origin fibres such as cellulose based fibres, insect/animal origin fibres and synthetic fibres were studied and presented in **Table 2** and **figure 3-10**. Coconut coir show onset at about 280°C, raw cotton fibre show onset at 329°C while jute fibre show onset at 335°C. Animal/insect-based fibre show onset temperature at 296.4°C and 312°C for silk and wool fibres respectively. Synthetic fibres such as polyester show TG onset at 434.6°C and for nylon about 444°C. Variation in onset temperature for different fibres are presented in **Fig 2.**

Fig. 2- Variation in Onset temp with fiber type



Differential Scanning Calorimetric Analysis (DSC) - DSC measures constant pressure heat capacity as a function of temperature. DSC gives melting and decomposition temperatures. The Melting temperature and decomposition temperature of different reference fibres are presented in **table 2** and **fig. 3-10.** Melting peak for cellulose based cotton fibre show broad endothermic peak in the range of 95-110°C. Wool shows a single sharp exothermic peak at 317.1°C. Synthetic fibres such as polyester show endothermic peak at 249°C and nylon fibre show 221.5°C and 158.8°C respectively. Decomposition peak for cellulose based fibres such as jute, coconut coir, cotton is observed at about 360°C. Synthetic fibre show decomposition peak at 455.8°C for polyester and at 464°C-468°C for nylon fibres.

STA Analysis Of Exhibits From Questioned Fibres:

Out of received articles/samples in forensic science laboratory in Nagpur region, results of STA analysis of 3 representative samples are presented in **Table 3**.

Sample 1 as shown in **fig. 11** shows TG onset value at 328 ^{0}C and DSC value temperature are 107^{0}C and 353^{0}C. Sample 3 show TG onset value in the range of 430-435 ^{0}C. DSC melting temperature value for sample 3 show melting temperature in the range of 245-255^{0}C followed by decomposition temperature 450-458^{0}C as given in **fig. 12**. Sample 3 show TG onset value in the range of 433-435 ^{0}C and DSC melting temperature value 221^{0}C followed by decomposition temperature about 460-466^{0}C. as per **fig 13**.

In forensic examination of the manja fibres it was found that about 80-85 % are polyester fibres while only 10-15% samples are of nylon fibres and 1-5 % are cotton fibres. Thermal analysis clearly shows distinguishing results for cotton and synthetic fibres. During manja making, different colures or additive may be applied to the fibres to make it stiffer. Similarly different companies may use their own procedure during processing of fibre in manja preparation. Thus, effect of such treatment may lead to variation in thermal analysis. Hence in the present paper results of fatal synthetic fibres obtained in questioned samples were compared with reference nylon and polyester fibres. Out of received samples in forensic science laboratory in Nagpur region, results of STA analysis of 5 representative samples of polyster and nylon fibres are presented in **Table 4.**

Table 2: Comparison of different fibres by thermal analysis

Sr. No	Fibre type	TG onset (°C)	DSC(°C)	
			1	2
	Reference Natural Fibres			
1	Coconut Coir	280.8	-	371
2	Silk	296.4	51.4	302.2
3	Wool	312.4	-	317.1
4	Cotton fibre	335.7	102.1	365.7
5	Jute	335.2	95.1	369.9
	Reference Synthetic Fibres			
1	Polyester	433.1	249.2	455.8
2	Nylon Thread 1	434.6	221.5	464.7
3	Nylon Thread 2	444.2	158.8	468.1

Table 3 : STA analysis of representative questioned fibres received in FSL Nagpur

Sr. No	Fibre type	TG onset (°C)	DSC(°C)	
			1	2
	Exhibits from questioned fibres			
1	Sample 1	328	107.2	353.9
2	Sample 2	435.9	221.5	459.7
3	Sample 3	433.0	249.9	455.1

Table 4 : STA analysis of representative questioned synthetic fibres received in FSL Nagpur

	Polyester fibres				Nylon fibres			
	Melting Temp. (^{0}C)	**Decomp. Temp (^{0}C)**	**Onset Temp (^{0}C)**	**Mass change (%)**	**Melting Temp. (0C)**	**Decomp. Temp (^{0}C)**	**Onset Temp (^{0}C)**	**Mass change (%)**
1	249.1	454.1	434.1	66.34	221.5	459.7	435	83.1
2	245.8	453.3	432.7	70.86	220.2	464.7	443.8	88.83
3	249	456	440.3	67.67	223.9	466.6	440.8	83
4	246.7	455.5	432.2	66.96	223.1	468.4	441.8	82.36
5	252.8	454.6	440	67.34	222.9	463.8	437.3	80.2
Average	**248.68**	**454.7**	**435.86**	**67.834**	**222.32**	**464.64**	**439.74**	**83.498**
Range	245-252	453-455	434-440	65-70	**220-224**	**458-465**	**435-440**	**80-90**

DISCUSSION:

Preliminary analysis for detection /identification and comparison of fibres include microscopic tests, but it has the disadvantage that many synthetic fibres are similar in appearance and hence not distinguishable using microscope. Plant fibres show smooth ash on heating and easily dissolved in concentrated sulphuric acid. Synthetic fibres show different heating pattern and somewhat resistance to concentrated sulphuric acid.

Definitive results were obtained regarding nature of fibre in the study when STA was used adapting similar thermal conditions. Thermal onset on TG curve of plant and animal-based fibres are found to be at lower temperatures than synthetic fibres. The results of DSC also show remarkable differences in melting and decomposition temperature of plant, animal-based fibres and synthetic fibres. Nylon is available in different forms and they show differences in their thermal behavior. Thus, DSC results can easily distinguish polyester or nylon manja.

STA analysis results of exhibits from questioned fibres as shown in **table 3** and as presented in **fig 11, 12 and 13** when compared with reference fibres clearly indicate that sample 1 is made up of cotton fibre, sample 2 is made up of polyester fibre while sample 3 is made up of nylon fibres.

As discussed in section 3.3 in the present paper results of five fatal synthetic fibres obtained in questioned samples were compared with themselves based on the results given in table 4 polyester and nylon fibres show onset temperature in the range of 430-440^{0}C and mass change of polyester in the range of 65-70% while nylon fibres show mass change in the range of 80-90%. Similarly differential scanning calorimetry (DSC) results showed remarkable difference in melting temperature of polyester fibres and nylon fibres while decomposition temperature of polyester fibres is about 10^{0} C lower than the nylon fibres.

Thus, Thrmogravimetry results on the basis of onset temperature could not reveal the nature of fibres successfully however mass change of nylon fibre is higher as compared to polyester fibres.

Polyester based synthetic manja is most commonly found in Nagpur region as compared to synthetic nylon origin manja and cotton based manja. The results obtained by STA are reliable and sufficient to conclude the nature of fibre in manja thread/fibre.

CONCLUSION

In this study along with preliminary thermal and classical tests, different types of fibres are analyzed on STA and thermal properties were found out. The STA results obtained for reference fibres and samples are compared to know the nature of thread in manja. Present study of different fibres successfully gives clear idea whether polymer or cotton based thread has been used in making manja.

Thus role of forensic science in environmental issues to certain extent cannot be denied. The present study will also help in solving many cases related to fibre identification received in forensic laboratories.

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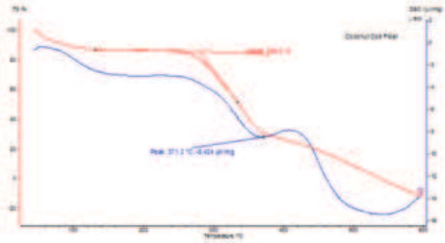

Figure 3.: Simultaneous thermal analysis (TG and DSC) of coconut coir Fibres

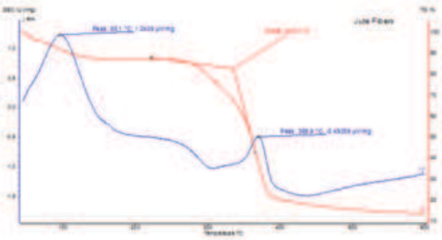

Figure 4. : Simultaneous thermal analysis (TG and DSC) of jute fibres

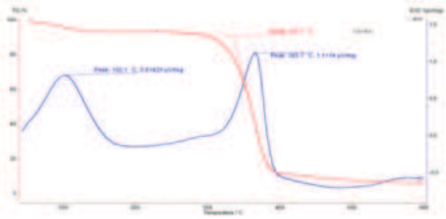

Figure 5. : Simultaneous thermal analysis (TG and DSC) of cotton fibres

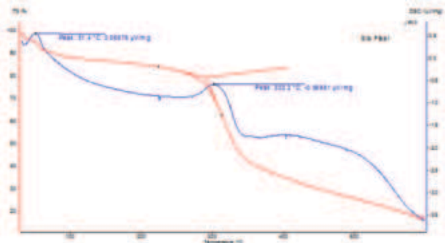

Figure 6. : Simultaneous thermal analysis (TG and DSC) of Silk fibres

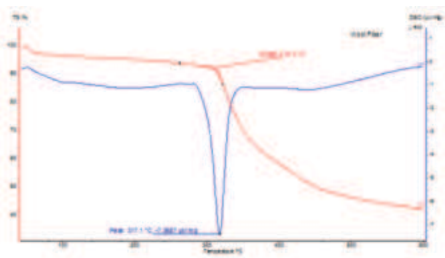

Figure 7. : Simultaneous thermal analysis (TG and DSC) of wool fibres

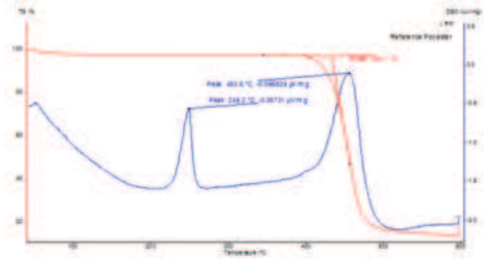

Figure 8. : Simultaneous thermal analysis (TG and DSC) of polyester fibres

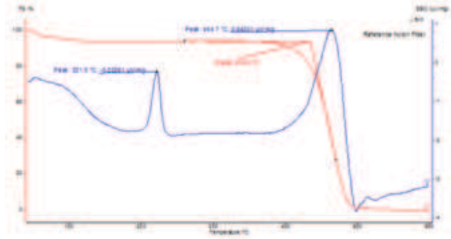

Figure 9 : Simultaneous thermal analysis (TG and DSC) of Nylon 6,6 fibres

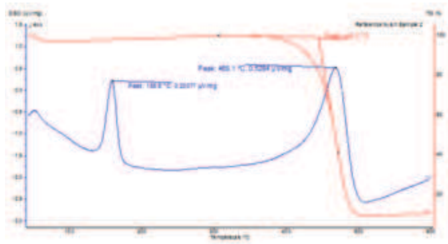

Figure 10. : Simultaneous thermal analysis (TG and DSC) of Nylon (Sample -2) fibres

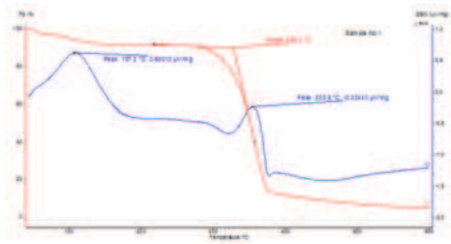

Figure 11 : Simultaneous thermal analysis (TG and DSC) of questioned fibres 1

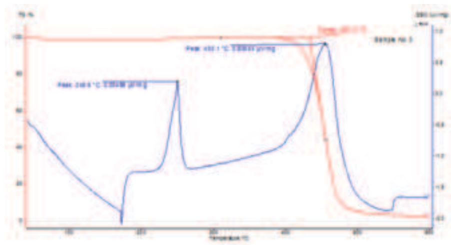

Figure 12. : Simultaneous thermal analysis (TG and DSC) of questioned fibres 2.

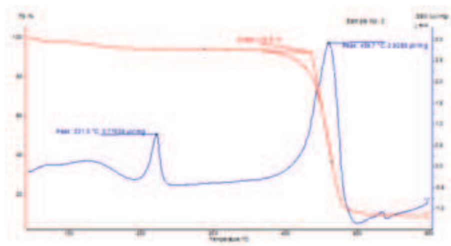

Figure 13. : Simultaneous thermal analysis (TG and DSC) of questioned fibres

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