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EFFECT OF GAMMA RAYS IRRADIATION ON COTTON FIBRE AND YARN

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Abstracts. The effect of gamma rays irradiation was studied on the raw cotton and cotton yarn. The results have shown that the strength decreases when the cotton fibre or cotton yarn is exposed to gamma rays. The rate of decrease increases with the increase in the dose of gamma irradiation. The colour of cotton fibres and yarn changes to brownish while the crystallite orientation angle of cotton fibres increases with the increase in irradiation dose. All the above changes in characteristics are attributed to chemical modification in the structure of cellulose.

According to Huo Ping Pan *et al.*[5] the strength of cotton fibre and yarn increes on application of small doses of irradiation. Some research workers,[1,2,4,6] however, contradicted these findings and claimed that degradation takes place in the structure of cellulose chain when they are subjected to such irradiation, and the strength of fibres and yarn dscreases with the increase in irradiation dose. Since strength is one of the fundamental characteristics for determining the quality of cotton fibre and yarn, and no such investigation had been undertaken earlier in Pakistan, Dr. Nazir Ahmad proposed that such a study should be conducted here.

As no facilities for irradiation from radioactive sources were available at this Institute, the samples were irradiated at Atomic Energy Centre, Lahore, and Atomic Energy Agricultural Research Centre, Tandojam, for high and low doses of gamma rays respectively. The first object of this study was of academic nature, but it was also envisaged that if the gamma rays so applied could, according to some beliefs, increase the strength of cotton fibre and yarn, the method could be of some industrial use as well.

Previous Work

Gilfillan, and Linden[1] found that the gamma radiation seriously weakened the cellulose fibre and nylon. Gilfillen and Linden[2] also found that the presence of water vapour in atmospheric oxygen during irradiation has little or no effect on the strength of cotton yarn. The dosage employed in these experiments significantly reduced the strength of cotton yarn.

Herman[3] found that the physical properties like flex faitgue, creep rate, melt point, stress strain and shrinkage worsened in the case of Dacron, nylon, cotton, Orlon and rayon. This study conducted in air and vacuum also showed that oxygen is a strong contributor to the degradation of the physical properties in the presence of radiation.

Blouin and Arthur[4] found that high energy irradiation of cotton resulted in carboxyl group formation and chain cleavage in the approximate ratio of 20:1:1, increased solubility in water and in dilute alkali, decrease in tensile strength of the fibres, small but unusual changes in the moisture regain etc.

Huo Ping Pan *et al.*[5] noted that cathode rays degraded the irradiated yarn in so far as copper number, methylene blue number and the intrinsic viscosity tests were concerned. The tensile strength recorded also showed decrease corresponding to the dosage received. They, however, found that at low levels of doses the tensile strength increased at first and then started decreasing with the increase in dose.

Arthur and Demint[6] have reported slight decrease in breaking strength, significant increase in elongation at-break and a decrease in the stiffness of fibres.

Blouin and Arthur[5] have shown that cotton fibres irradiated to a dosage of 2.3×10^6 Roentgens did not exhibit significant decrease in tensile strength on post-irradiation stages.

Arthur and Blouin[8] have reported that high energy irradiation induces long life free radicals which could lead to changes significantly reducing the tensile strength of the irradiated cellulose.

Materials and Methods

In the beginning raw cotton and 40′s count yarn from Ac. 134 R.G. variety, both treated and untreated with colloidal silica, were used for irradiation at the Atomic Energy Centre, Lahore, where the source emits gamma rays at the rate of 9.59 Kr/min. The samples were placed in a cylinderical chamber, 6 in dia and 8 in height, located in the center of the radiation unit. Time intervals were ½, 1, 2, 4, 16, 32 and 64 hr, respectively for irradiation of all the raw cotton and yarn samples.

Each sample of raw cotton, before and after irradiation, was tested for tensile strength on Pressley Strength Tester and five tests were performed on each sample. Similarly all the irradiated and control samples of yarn were tested on Scott Testers I.P. 2 (inclined plane) machine for single yarn strength and 25 testswere per formed on each sample.

Due to higher doses applied at Lahore Centre the strength in case of both raw cotton and yarn decreased with the increase in time of exposure. Another plan of irradiation was thus chalked out in collaboration with the Atomic Energy Agriculture Reserch Centre, Tandojam to observe the effects of low doses of irradiation. At this Centre the source of 250 curies cobalt 60 rises up in the centre of a table operated automatically from outside the radiation chamber. One sample each of raw cotton and yarn was exposed for such interval of time that each sample received any one of the following doses 250r, 500r, 750r, 1000r, 1500r, 2000r, 25000r, 3000r, 4000r, 5000r, 6000r, 7000r, 8000r, 9000r, 10,000r.

Raw cotton and 30's count yarn of Ac.134 S.G. variety were used in this study. Five tests for breaking tenacity on Pressley Strength Tester at 1/8th gauge were performed on each of the control and irradiated raw cotton samples. Twenty tests were performed for single yarn strength determination on Scott Testers I.P. 2 (inclined plane) machine on each of the control and irradiated samples.

A third set of experiments was conducted after preparing yet another plan of irradiation in collaboration with the Atomic Energy Centre, Lahore. This plan was prepared for raw cotton only. The procedure involved in the preparation and irradiation of samples was as follows:

Six samples of about the same weight of loose cotton (1.6 g under ambient conditions) were placed on watch glasses in a forced draft oven at 104°C for 3 hr. The samples were transferred quickly into the irradiation test tubes forming plugs about 2 in long in the central portion. (The irradiation tests tubes were 7/8 in external dia and were fitted with $24/29 ground glass joints and stop cocks). The samples were further dried by placing in a dessicator over silica gel under vacuum for 24 hr. Nitrogen was then introduced, dessicator opened and the stop cock closed. Irradiations were carried out one by one by placing the tubes in the central position of the gamma cell for definite lengths of time. Details of the irradiation are given in Table 1.

The dose rate inside the 6 in dia, 8 in high irradia tion chamber is not uniform. It is about 20% higher at the circumference, midway from bottom and about 20% lower at the centre of the bottom and the top as compared with the dose in the central region. Thus if a larger volume of samples were taken there would have been a larger variation in the dose than ±2% with the set up used.

The samples were then tested for tensile strength on Pressley Strength Tester where 8 tests were performed on each sample. Exposed and unexposed samples were also tested for crystallite orientation on X-ray Diffraction Instrument, where three tests were carried out on each sample. The samples were kept in air tight condition till the time of testing. The seals were broken at the time of testing each sample. Since the radiation continues even after the samples have been taken out of the radiation atmosphere, all

TABLE 1. DETAILS OF IRRADIATION OF DRY COTTON SAMPLES.

Sample No.	Irradiation atmosphere	Period of irradiation	Dose received by the samples	Time and date, the samples were taken out	
C-11	No irradiation	Nil	Nil	—	
C-12	N_2	50 hr	15.00 M. Rads.	3.30 (p.m.)	13.10.1969
C-13	,,	3 hr 20 min	1.00 ,,	12.00 (noon)	15.10.1969
C-14	,,	6 hr 40 ,,	2.00 ,,	2.00 (p.m.)	15.10.1969
C-15	,,	12 hr 30 ,,	3.75 ,,	10.40 ,,	16.10.1969
C-16	,,	25 hr	7.50 ,,	11.37 (a.m.)	18.10.1969

TABLE 2. EFFECT OF ATOMIC IRRADIATION ON RAW COTTON STRENGTH.

Sample details	Tensile strength (×1000) lb/in²							
	Control	Irradiation time (hr)						
		½	1	2	4	16	32	64
AC. 134 raw cotton	95	95.3	94.8	90.0	88.2	65.9	31.8	Too weak to be tested
% Increase or decrease over control	—	+0.3	—0.2	—5.3	—7.2	—30.6	—66.5	
AC. 134 raw cotton treated with collidal silica	100	94.5	93.5	89.7	89.7	57.9	32.3	
% Increase or decrease over control	—	—5.5	—6.5	—10.3	—10.3	—42.1	—67.7	

TABLE 3. EFFECT OF ATOMIC IRRADIATION ON COTTON SINGLE YARN STRENGTH.

Sample details	Single yarn strength in oz							
	Control	1/2 hr	1 hr	2 hr	4 hr	16 hr	32 hr	64 hr
AC-134, 40's yarn	5.12	5.60	4.48	5.28	4.96	2.88	1.92	0.96
Percentage, increase or decrease over control	—	+9.4	—12.5	+3.1	—3.1	—43.8	—62.5	—81.2
AC-134, 40's yarn. Treated with colloidal silica	7.04	6.40	6.72	6.24	4.64	3.68	2.24	1.28
Percentage, Increase or decrease over control	—	—9.1	—4.5	—11.6	—34.1	—47.7	—68.2	—81.8

TABLE 4. EFFECT OF ATOMIC IRRADIATION ON RAW COTTON (COTTON AC. 134 S.G.).

	Breaking tenacity at 1/8th gauge in g/tex. (dose r)															
	Control	250	500	750	1000	1500	2000	2500	3000	4000	5000	6000	7000	8000	9000	10000
	23.35	22.75	22.66	22.85	21.94	22.82	24.17	22.47	22.53	23.01	24.17	22.96	23.34	23.32	23.05	22.07
% Increase or decrease over control		−2.6	−3.0	−2.1	−6.0	−2.3	+3.5	−3.8	−3.5	−1.5	+3.5	−1.7	+4.2	−0.1	−1.30	−5.7

TABLE 5. EFFECT OF ATOMIC IRRADIATION ON COTTON YARN STRENGTH (YARN: 30's COUNT).

	Single yarn strength in ozs (dose r)															
	Control	250	500	750	1000	1500	2000	2500	3000	4000	5000	6000	7000	8000	9000	10000
	9.79	8.81	9.78	10.14	9.74	10.03	10.51	10.22	10.11	9.26	10.46	10.82	10.52	11.04	9.11	9.74
% Increase or decrease over control		−10.0	−0.1	+3.6	−0.5	+2.4	+3.1	+4.4	+3.3	−5.4	+6.8	+10.5	+7.5	+12.8	−6.9	−0.5

the tests were carried out on the irradiated samples exactly after 19 days 20 hr and 30 min from the time and date they were taken out of the radiation atmosphere.

Results and Discussion

Results obtained during first experiments on raw cotton both treated and untreated with colloidal silica are given in Table 2.

Evidently, the tensile strength of raw cotton in both the cases decreases with the increase in irradiation dose. Both the treated and untreated samples of raw cotton with colloidal silica showed a similar trend. The samples which were given the highest doses could not be tested on Pressley Strength Tester as the fibres became too weak to be tested for strength. A trend similar to raw cotton was also observed in case of cotton yarn, the results of which are given in Table 3.

Colloidal silica-treated samples were used here because under normal conditions colloidal silica application on cotton has enhanced the yarn strength, and it was thought fit to see if the advantages thus gained could still be retained after irradiation or not. The results have, however, shown that the deterioration in strength is almost the same in treated and untreated samples barring a few exceptions.

Silica was applied in the form of thin coating on cotton fibres in conjunction with highly emulsifying oil. It increased the yarn strength in the control sample and maintained higher strength level throughout. Due to increase in cohesive force of fibres treated with colloidal silica, the yarn spun from these fibres showed higher single yarn strength as compared with the untreated samples.

The above-mentioned irradiation experiments, however, confirm the views of earlier workers[1,2,5,6] that the decrease observed in strength is due to degradation caused by high energy gamma irradiation used in the above experiments.

Since it was thought that fibre and yarn strength may increase if small doses of irradiation are applied to raw cotton and yarn, another set of experiments was performed to verify this assumption. The results of these small doses on raw cotton strength and single yarn strength are given in Tables 4 and 5.

From the above data no definite idea can be formed regarding the increase or decrease in strength in the case of raw cotton and yarn. The fluctuations in the results at different doses could be due to irregular doses received by the samples or the time interval in between the exposure and the actual strength tests carried out. The non-uniform doses received by the samples could be one of the reasons for such fluctuations, because very uniform layers of the samples as specified (1 mm thickness) could not be formed and placed on the table around the irradiation source at Tandojam. The greater thickness introduces a great deal of error as the irradiation doses received by the samples at this centre varied inversely as the square of distance between the source and the sample. Thus the fibres which were away did not get the required dsoes.

TABLE 6. EFFECT OF ATOMIC IRRADIATION OF RAW COTTON.

Particulars	Irradiation dose in mega rads.	Tensile strength in(000) lb/in^2	Increase or decrease over control (%)	Crystallite orientation angle in degrees
C-11 N_2 irradiation	Control	100.0	—	28.5
C-13 ,, ,,	1.00	86.6	—14.4	28.9
C-14 ,, ,,	2.00	82.3	—17.7	29.0
C-15 ,, ,,	3.75	76.2	—24.8	30.3
C-16 ,, ,,	7.50	58.2	—42.8	30.3
C-12 ,, ,,	15.00	46.2	—54.8	30.5

A third set of experiments was performed to repeat the effects of high doses of irradiation under controlled conditionss. The results of this experiment are reported in Table 6.

This time post-irradiation time was fixed for the purposes of testing the above samples so that post-irradiation effects could remain the same and symmetry in the testing is formed. From these data it will again be noted that the strength of raw cotton decreased quite significantly due to degradation of fibres with the increase in irradiation dose. The crystallite orientation angle on X-ray Diffraction Instrument showed an upward trend with the increase in irradiation dose. With the increasing doses. the colour of irradiated samples changed to slightly brown. Changes like decrease in strength, increase in crystallite orientation angle and change in colour could be attributed to the chemical modifications caused by irradiation in the chain of cellulose fibres.

Conclusions

1. From our results reported here in Tables 4 and 5 and from the earlier findings by Pan *et al.*,[5] it may be possible that higher strength at lower doses of irradiation may be obtained provided, of course, the dose applied is uniform. This however, needs further confirmation through research work but such facilities are not yet available in Pakistan. The higher doses of irradiation, however, decrease the strength of cotton fibre and yarn.

2. The samples treated with colloidal silica registered comparatively higher strength as compared with the untreated samples irrespective of the irradiation doses.

3. The change in colour, weakness of fibres and increase in crystallite orientation angle on X-ray diffraction instrument, could be attributed to the chemical modifications caused by irradiation in the chain of cellulose fibres. Thus, until the chemical reactions taking place after the application of gamma rays are studied, it is difficult to understand the actual changes taking place, and the countinuity of such reactions affecting the ultimate strength of cellulosic materials.

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