Coating on Viscose - Poor Wet Strength of Viscose can be Improved by the Application of Chemical Finishes like Water Repellent and Soil Release Finishes.

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***Abstract*— Cotton as a dominating natural fibre imparts a major contribution in the whole textile market including natural and artificial fibres. The demand of this cellulosic fibre is increasing rapidly day by day, on the other hand supply cannot fulfill its demand, and as a result price goes higher in world market. Viscose as cellulosic origin, the cheapest of all cellulosic fibres could be the best alternative. Viscose fibre exhibits some similar properties compared to cotton except its poor wet strength. In this research work different chemical finishes were applied to improve the wet strength of viscose fabric. For this purpose water repellent and soil release finishes were applied. Both water repellent and soil release finishes helped in reducing the molecular barrier around the individual fibres that lowered the surface tension of the fibre. It reduces the absorbency of viscose fibre hence leads to higher wet strength. Water repellent finish was applied alone as well as in combination with soil release finish. It was seen that viscose fibre exhibited better wet strength after applying water repellent and soil release finishes on it. This improved property of viscose could replace the cotton fibre in certain applications like bed linen.**

***Index Term* — Cotton, cellulose, viscose, wet strength, water repellent, soil release.**

1. INTRODUCTION

According to Hearle (2001), among all the textile fibres, cellulose have the wide range of structures and properties. Even apart from the variety of natural cellulose fibres, with their highly crystalline fibrillar structures in various helical forms of lay-down, the less highly ordered regenerated cellulose fibres have many different structures, which lead to different properties and applications. Cellulose is mainly obtained from wood pulp and cotton.

Viscose is an important cellulosic fibre mostly used in textile. Today there is a renaissance for viscose made from cellulose, a constituent of all land growing plant life. A variety of dissolving grade wood pulps is used as cellulose source to produce viscose rayon. Johnson (2001) suggests that being cellulose based, viscose is supposed to give an answer to the steadily increasing problems of:

1) Higher world market cotton prices
2) Higher demand for fibers, including a chase for new fiber material sources and
3) A need for a broadening of the market for wood and pulp industry.

Viscose fibres with improved wet tenacity and improved elastic recovery called High wet modulas viscose fibres (HMW). The brand names of these viscose fibres are High Wet Modulas fibres, Modal fibres. The properties of these fibres are same as the regular viscose fibre (however lower water absorption), in addition to high wet strength. These fibres are often mixed with cotton fibres. They stand most cotton finishing processes as for example mercerization. HMW fibre fabric performs like cotton and can be machine washed without any severe shrinkage. (Woodings, 2001)

A more recent and environmentally friendly rayon derivative is lyocell. Lyocell is a regenerated cellulose fibre made from dissolving pulp (bleached wood pulp). Lyocell process is complicated compare to viscose and very expensive. Lyocell fibres are the strongest cellulose fibres, almost twice as cotton fibres (especially for tear strength). These are as strong as cotton even in wet stage. The fabrics made from these fibres have very soft hand and good drapability properties**.** The reason for better properties of lyocell and modal than regular viscose is due to their higher DP, higher degree of orientation and higher crystalinity. (Woodings, 2001)

Comparison of properties among different cellulosic fibres is focused on table I.

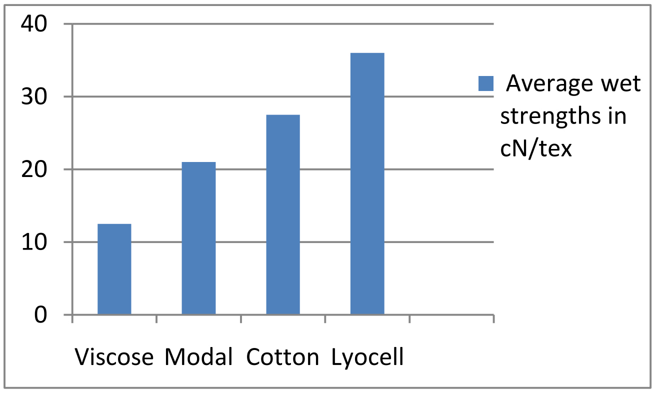


Fig. 1. Comparison on wet strengths in cN/ Tex (Woodings, 2001)

Viscose has lower wet strength as compared to modal, cotton and lyocell seen in the fig 1.

Viscose has the tendency to absorb higher moisture. The applied hydrophobic soil release was used to improve water repellency that was responsible for the improving the wet strength of viscose fabric. Water and soil resistant treatment helped in reducing the molecular barrier around the individual fibres that lowered down the critical surface tension of the fibres. This reduced surface tension of viscose fabric helped in improving its wet strength. (Shalini, 2011)

Table I
Comparison of various cellulosic fibres properties (Woodings, 2001)

Fibre type	**Cotton**	**Viscose**	**Modal**	**Lyocell**
Titre dtex	1.8	1-100	1.0-3.3	0.9-3.3
Tear strength cond. cN/tex	24-28	20-24	34-36	40-44
Elongation cond. %	7-9	20-25	13-15	34-38
Wet tear strength cN/ tex	25-30	10-15	19-21	34-38
Rel.wet strength %	105	55	57	85
Elongation wet %	12-14	25-30	13-15	16-18
Degree of polymerization	2000-3000	250-350	300-600	550-600
Fabrilation tendency	2	1	1	4-6
Water retentivity %	45-55	90-100	75-85	65-70
Crystalinity %	77-80	25	25	40

The mechanism of repellent finishes is to reduce the free energy at fibre surface. If the adhesive forces between a fibre and a liquid drop are greater than internal cohesive forces in between the liquids, the drop will spread. However, if the adhesive forces between a fibre and liquid drop are less than internal cohesive forces in between the liquids, the drop will not spread. Surfaces that have low interaction with liquids are referred to as low surface energy. And their critical surface tension should be less than the surface tension of liquids that is to be repelled. Therefore, oil repellency with fluorocarbon always achieves water repellency but it is difficult to achieve with fluorine free products like silicone based products. The surfaces with low energy surface tension also provide a measure of dry soil repellency by preventing soil particles by adhering to the fibre surfaces. Due to these low interaction forces, the soil particles to be easily dislodged and removed by mechanical action. (Hauser & Schindler, 2004)

2. PRACTICAL WORKS

2.1 *Materials:*

Fabric Specifications: Cotton: 100 % mercerized cotton with plain weave. 0.74 g/m$^{2;}$ Count: 32 threads per cm in warp direction and 32 threads in weft direction

Viscose: 100% spun rayon, scoured plain weave. 1.35 g/m^{2,} Count: 38 threads per cm in warp direction and 38 threads in weft direction.

Both type of fabrics were commercially prepared: mercerized cotton and scoured viscose from Whaley (Bradford) LTD, U.K.

2.1.1 *Coating material:*

Water repellent finish (Ruco dry DHN), soil repellent finish (C_6 based fluorocarbon-Ruco guard AFB), and acetic acid (24 % conc.). Practical works have been done by four different recipes that are given below.

2.1.2 *Ruco dry- DHN:*

Ruco-dry DHN is wax-based dendrimer. It has specific properties including cationic, ecological water repellent with dendrimer, better abrasion resistance, environmentally friendly, APEO-free, solvent-free and flurochemicals-free.

2.1.3 *Ruco-guard AFB$_6$ Conc.:*

Ruco-guard AFB6 is an ecological optimized agent, oil and soil-repellent finish, gives very good resistance to washing and dry cleaning. It is also free of Perfluorooctanoic acid (PFOA) and Alkyl phenol ethoxylates (APEO). [Rudolf Chemical]

W (water repellent) g/l	25, 50, 100
W (soil resistant-AFB-6) g/l	40
Acetic acid g/l	1
W liquor pick up (%)	100
Drying Temperature, T_{drying} (^{0} C)	130
Drying time, t_{dry} (min)	4
Cross linking temperature, T_{cross} (^{0} C)	160
Cross linking time, t_{cross} (min)	1.5

For further discussion some abbreviations are used like Ruco-dry DHN= DHN and Ruco guard AFB$_6$ conc. = AFB$_6$

Table II
Recipes for coating in impregnation bath.

Batch	Chemicals	Amount(g/l)
1	DHN	25
	Acetic acid	1
2	DHN	50
	Acetic acid	1
3	DHN	100
	Acetic acid	1
4	DHN	50
	AFB_6	40
	Acetic acid	1

Each batch was prepared based on one liter (1L) solution in total.

2.2 *Machine*

Pad mangle: Brand name: ERNST BENZ, Textile machine
Type: LQ 350/ 2, R 2227.65.15
Country- Switzerland
Dryer: Brand name: ERNST BENZ, Textile machine
Type: MT-D

Table III
The contents of the finishing bath and the conditions of the finishing with soil release and fluorocarbon (Chemicals manufactured by Rudo Chemi)

AATCC standard rating	Note:
100 ISO 5	100: No sticking or wetting of upper surface.
90 ISO 4	90: Slight random sticking or wetting of upper surface
80 ISO 3	80: Wetting of upper surface at spray points.
70 ISO 2	70: Partial wetting of whole of upper surface.
50 ISO 1	50: Complete wetting of whole surface.
	0: Complete wetting of whole upper and lower surface.

Country –Switzerland

2.3 *Method*

Samples were coated following the procedure of dip coating. This included impregnation, drying and curing. The contents of the finishing bath and the condition of drying and curing are shown in table 1. All the samples were cut according to 35 cm in length and 28 cm in width size. The above four recipes were applied to both cotton and viscose fabrics.

After coating the samples were conditioned for 24 hours at room temperature. All the samples were tested after proper conditioning.

2.4 *Tensile test*

Measurement of maximum force and elongation were carried out using the stripe method in a standard atmosphere ($T=20^0$ C and RH= 65%) using tensile tester.

Specification of tensile tester:
Brand name: Tinius Olsen
Model: THE-5000 N
Capacity: 5000N
Serial number: 180496

All samples were taken 15 cm in length and 2.5 cm in width. It was measured 5 samples for each test. All the samples were measured in both warp and weft directions. As the count of viscose in both directions was equal, so the same values for warp and weft directions were observed. That was also seen for cotton fabric. For measuring the wet strength the samples were soaked for one min.

2.5 *Spray test*

The standard test method for the water repellency measurement of woven textile fabrics was used (SIST EN 24920). Table 4: AATCC standard rating for spray test.

2.5.1 *Method*

In this method, coated fabric was adjusted on the fabric clipper and the clipper was put on spray stand at 45 degree angles. 250 ml distilled water was taken in a volumetric flask at temperature 20^0 C. The water poured in spinneret keaf from it water is showered on stretch fabric. After doing the showering we have matched it with rating chart by visual assessment. We measured 3 samples for each test of cotton and viscose.

2.6 *Wear and abrasion resistance*

The purpose of this method is to check the fabric durability and colour change by applying different load on the round test sample that are going to be abraded against viscose and cotton. After abrasion we checked the thread breakage of abraded sample on microscope. By microscopic observation we counted the thread breakage value that should be stand as Martindale value for that fabric.

Machine specification: Martindale wear and Abrasion tester by James H-Heal and Co.Ltd.Halifax. England, Serial no. 103/1173, Weight of each bar is 12 kg.

Round fabrics were taken according to holder, 4 cm for small holder and 16cm for large holder. The same fabric was used against abraded sample and same load was applied for each test. The tests were performed at different cycles to check the weight loss of fabrics. After that threaded breakage of abraded samples were observed on electronic microscope and recorded all the values.

2.7 *Dimensional stability*

The objective of this test method (SS EN ISO 3759) is to measure fabric shrinkage/ stretch after washing and drying. For both directions (warp and weft) dimensional change in viscose and cotton are calculated and reported as percentage (%) values.
Viscose rayon fabrics tend to shrink more than cotton fabrics of similar construction. Spun viscose rayon fabrics shrink more with repeated laundering than fabrics made of the filament yarns.
Washing condition: Temperature 60 ^{o}C, Time 40 mins.
All the samples were taken according to 35 cm in length and 28 cm in width. We scaled the length and width of coated fabric before washing for all recipes, both cotton and viscose fabrics. Then washed the samples and dried at room temperature. After washing and drying the samples were again scaled and recorded the shrinkage in both directions for viscose and cotton. All the samples were measured in three distances for each direction.

3. RESULT WITH DISCUSSION

3.1 *Determination of mechanical Properties*

By tensile tester, we measured the dry and wet strength of cotton and viscose.

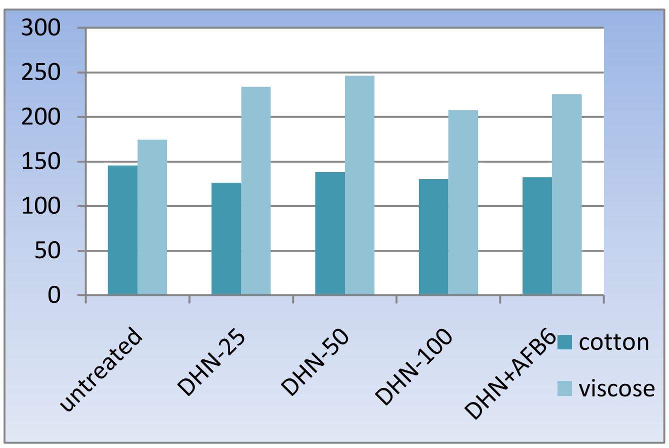


Fig. 2. Maximum force (N) of cotton and viscose (dry condition)

As shown in the bar chart 2, there is a difference between dry strength of untreated cotton and viscose. Initially, untreated cotton and viscose had dry strengths 145.6N and 174.4N respectively. After applying water repellent finish the strength of Viscose was gradually increased (233.8N and 246.4N at DHN-25 and DHN-50g/l respectively). Further addition of DHN followed downward result (207.4N for DHN-100) and combination of DHN and AFB_6 showed better result (225.6N) for viscose. Cotton has a very low effect over DHN and AFB_6 at dry condition. For combination recipe it is seen that viscose has better dry strength than cotton.

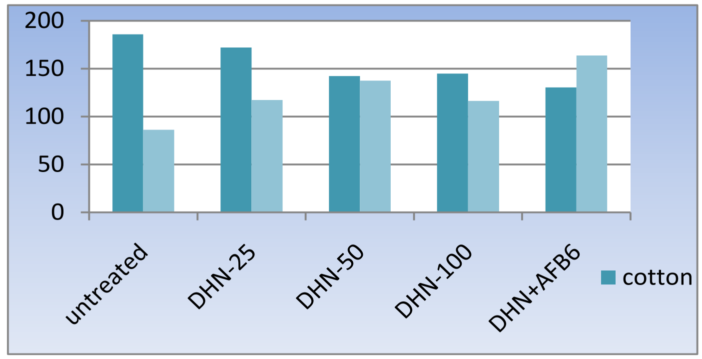


Fig. 3. Maximum force (N) of cotton and viscose (wet condition)

As illustrated in figure 3, untreated viscose has poor wet strength compared to untreated cotton (86.2N and 186N respectively). By applying water repellent finish wet strength of viscose was increased dramatically (117.4N and 137.6 for DHN-25 and DHN-50) and with the addition of fluorocarbon achieved highest value (163.8N) that can be compared to the wet strength of untreated cotton. On the other hand, the wet strength of cotton is gradually decreased after coating. Finally, for combination recipe viscose showed higher wet strength than cotton and it is comparable to wet strength of untreated cotton.
Viscose has higher moisture regain properties compare to other cellulosic fibres. When it is wetted it absorbs much water and swollen that makes it weaker. After applying the water repellent finishes the surface tension of the fabric becomes lower. Thus it absorbs less water and improves wet strength.
Water and soil resistant, (fluorocarbon) treatment helps in reducing the molecular barrier around the individual fibres that lowered down the critical surface tension of the fibres. This reduced surface tension of viscose fabric helped in improving its wet strength.

Table V
Weight loss of viscose and cotton for different cycles

Chemicals	Viscose-Wt. Loss (100 cycles)	Viscose-wt.Loss (500 cycles)	Cotton-Wt.Loss (100 cycles)	Cotton-Wt.Loss (500 cycles)
Untreated	No Loss	1,15%	No Loss	No Loss
25g/l DHN	No Loss	1,0%	No Loss	No Loss
50 g/l DHN	No Loss	1,0%	No Loss	No Loss
100g/l DHN	No Loss	0,5%	No Loss	No Loss
50g/l DHN+40 g/l AFB_6	No Loss	No Loss	No Loss	No Loss

3.2 *Water repellency*

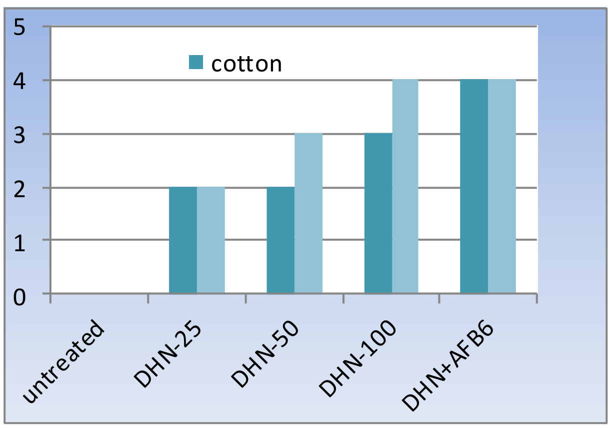


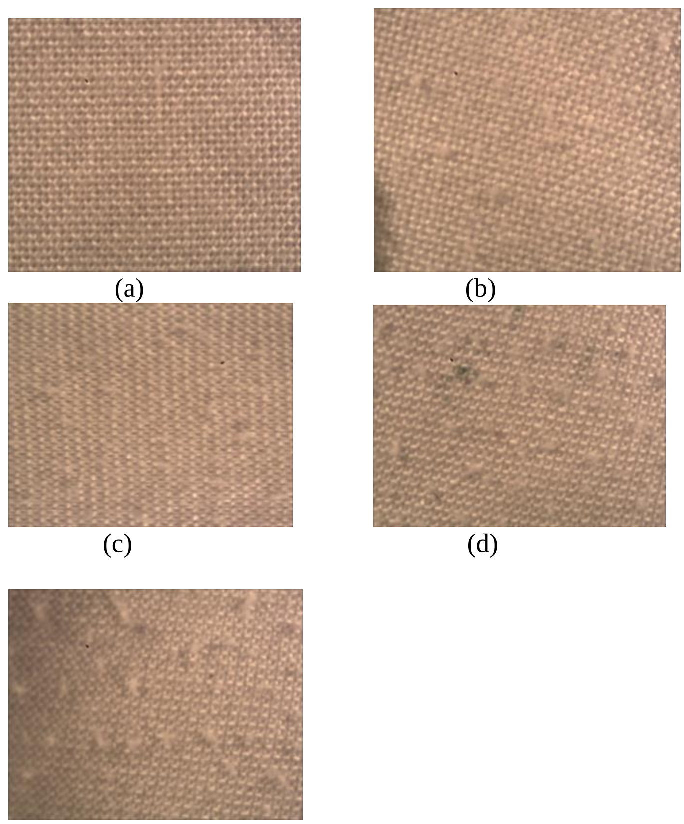
Fig 4: spray rating of cotton and viscose

As it is seen from the above figure 4, untreated Cotton and viscose was totally wetted in upper and lower surface when water sprayed on it, spray rating for untreated cotton and viscose was zero (o rating). After applying coating both cotton and viscose exhibited improved spray rating (2 for both cotton and viscose at DHN-25). Viscose performed higher water repellency than cotton at DHN-50 and DHN-100(3&4 for viscose and 2&3 for cotton). For combination recipe both viscose and cotton had the optimum value and same spray rating (4 for both).

Water repellent finishes increase the hydrophobicity of the cellulosic fabric; fluorocarbon also increases the water repellency of cotton and viscose and therefore decreases the absorbency of the fabric.

3.3 *Durability*

As stated on the above table 6, untreated viscose and cotton has no weight loss at 100 cycles. But untreated viscose showed 1.15% weight loss for 500 cycles where as untreated cotton has no weight loss after abrasion. After applying coating the weight loss of viscose was reduced (1.0 % at DHN-50 and 0.5% at DHN-100). In combination recipe viscose enjoyed no weight loss after abrasion. Throughout the entire recipe cotton exhibited no weight loss after abrasion at 100 cycles and 500 cycles.



(a) (b) (c) (d) (e)

Fig. 5. Untreated viscose (a) and (b), (c), (d), (e) for four batches consecutively after abrasion (500 cycles).

So from the above result it was clear that the durability of viscose was improved after applying water repellent and soil release finishes.

From the above fig 5(a, b, c, d, e), microscopic structures of different viscose samples can be observed.

3.4 *Dimensional stability*

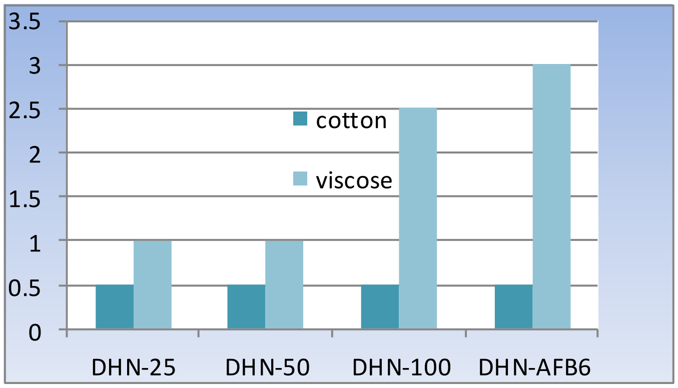


Fig. 6. Shrinkage percentage for both cotton and viscose in warp direction

As observed from the figure 12, coated viscose (at DHN-25g/l) has higher shrinkage percentage compare to cotton after washing (1% for viscose and 0.5 % for cotton). The shrinkage remained same at DHN-50 for viscose and cotton. Further addition of water repellent finish increased the shrinkage of viscose. In combination recipe viscose showed optimum shrinkage after washing. Cotton has no shrinkage percentage after washing throughout the entire recipes.

Viscose rayon fabrics tend to shrink more than cotton fabrics of similar construction. Spun viscose rayon fabrics shrink more with repeated laundering than fabrics made of the filament yarns.

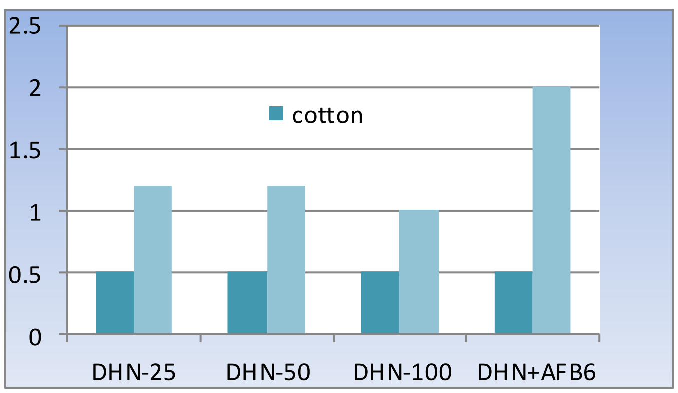


Fig. 7. Shrinkage percentage for both cotton and viscose in weft direction

As similar to warp direction, viscose exhibited higher shrinkage percentage compare to cotton in weft direction. In combination recipe viscose showed maximum shrinkage percentage in weft direction after washing where as cotton remained unchanged.

4. ENVIRONMENTAL ASPECTS

The chemical finishes traditionally used to make textiles water and soil release involved long chain fluorocarbons (FCs) that is suspected to harm humans as well as environment. The conventional fluorocarbon (C_8- based fluorocarbons) means that polymer consists of 8 carbons and 17 fluorine atoms. These are (C_8- based fluorocarbons) are suspected to release bio-persistent and toxic component Perfluorooctanoic acid (PFOA) and Perflurooctane sulfonate (PFOS). They affect the human reproduction, hormone system and cell processes.

Modern research and development in water, oil and soil resistant treatment has been done to find the alternative of conventional C_8 technology. After immense research and development chemists succeeded to replace C_8 chemistry with C_6 by using short 6 carbon-fluoro chains. They excluded the possibility of fluorocarbon products broke down into PFOA. The compound Perfluorohexanoic acid (PFHA) obtained from C_6 technology has 40 times less bioaccumulative effects than PFOA.

5. CONCLUSION

The results lead to the following conclusion:

Viscose has poor wet strength due to higher moisture regain. The most desired property of viscose for this project was wet strength and it was improved to a large scale applying water repellent and soil release finishes. Elongation (dry and wet) of viscose was improved after applying the soil repellent and water repellent finishes. Cotton was more durable than viscose over the water repellent finishes. Durability of viscose was also improved. Viscose tends to shrink more than cotton and dimensional stability of viscose was improved after the application of water repellent and soil release finishes.

So, it is seen that viscose had a potential to replace cotton as an alternative by applying water repellent and soil release finishes.

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