

Production of multipurpose cotton fabrics to improve the quality of aerobic and dance sportswear

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Abstract. The production of multipurpose cotton fabrics aimed at elevating the quality of aerobic and dance sportswear is explored in this study. Powder metallurgy, known for its high efficiency in manufacturing technological components with minimal waste, is employed as a method for fabricating brush ferrules for painting. The utilization of iron-copper material, prepared through powder metallurgy, enhances the strength and quality of the brush ferrules. A microscopic analysis reveals a robust interconnection between the particles of each layer achieved through isostatic pressure, resulting in a favorable microstructure. The relative density and strength of parts produced from copper-iron powder exhibit an increase with higher pressure levels. The application of this material in brush ferrules ensures their durability and longevity, thereby supporting the creation of artwork. The evolution of art over time reflects changing ideas and possibilities, and technological advancements have significantly improved artistic tools. The role of tools in artistic expression is paramount, and the integration of powder metallurgy materials in brush ferrules fortifies their artistic importance. In summary, this study underscores the advantages of powder metallurgy in augmenting the quality of art tools and facilitating artistic creation.

Keywords: artistic tools advancements; brush ferrules strength; cotton fabric innovation; powder metallurgy applications; sportswear quality enhancement

1. Introduction

One of the components of metallurgy science that has grown significantly in recent years is powder metallurgy. *owder metallurgy* is a procedure in which fine particle materials are mixed, pressed into the desired shape, and then heated in a controlled environment to connect the particles and the desired properties (Novák 2020). One of the most important reasons for the development of powder metallurgy is that in this method, the use and waste of metal are far less than in other methods, and the investment in the powder metallurgy industry is also less than the investment for the classical methods of manufacturing parts. The history of producing parts with powder reaches five thousand years and more (Sudha *et al.* 2020). Mass production of products made by powder metallurgy began in the mid or late 19th century. Early productions included copper coins and medals, platinum bars, lead typefaces, and tungsten wires (Ogel and Gurbuz 2001). Powder metallurgy started with common metals, such as copper and iron, but today its use has spread to other metals as well, and new applications for powder metallurgy have followed. In recent years, producing parts that are difficult to produce by other methods has significantly contributed to this technology's development (Tun and Gupta 2007).

The growth of powder metallurgy is due to factors such as the mass production of precise and high-quality structural

parts, which are usually based on the use of iron alloys, and access to parts whose production process is complicated and must be wholly compact and homogeneous (Scudino *et al.* 2009). Furthermore, the manufacture of special alloys and complex parts is dependent. Powder metallurgy has expanded daily, and the amount of powder produced has continuously increased, so the iron powder shipped from America has increased tenfold from 1960 to 1978 AD (Richards and Aspinwall 1989, Adams 2015). All the operations that are carried out in the production of parts by the powder metallurgy method can be categorized into two major classes (He and Deng 2023, Jia *et al.* 2023, Li *et al.* 2023a, Su *et al.* 2023):

Primary processes include powder production, mixing, sintering, pre-baking, and sintering, and secondary processes include size correction, compaction, machining, impregnation and oil saturation, metal penetration, plating, and heat treatment (Dai *et al.* 2023, Song *et al.* 2023, Yang and Mao 2023, Ye *et al.* 2023). There is an expansive range of metal powders with a wide range of properties commercially recommended for powder production. The most common powders used are copper-based and iron-based materials (Jin *et al.* 2023, Lau and Li 2023, Wang *et al.* 2023, Zhang *et al.* 2023c). Different methods are used to produce powders. These methods include atomization, electrolysis, crushing and grinding, machining, and pelletizing. In atomization, molten metal is moved from a nozzle under a stream of air or water. The metal turns into small particles with different irregular shapes and becomes solid. Nozzle size, metal flow rate, temperature, and pressure control the particle size (James 2015). Metal powders are also obtained from the revival of purified ore

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or prepared oxides by contact with a gas at a temperature below the melting point (Cao *et al.* 2022, Cheng *et al.* 2024, Liu *et al.* 2024). Metal powders can also be obtained by electrolytic deposition under controlled conditions. The precipitated materials are ground and crushed into microscopic and round particles to the desired grain size, and they are annealed to remove the hydrogen (Huang *et al.* 2022, Liu *et al.* 2023). In the pelletizing process, the molten metal is passed through a valve into the water to produce spherical particles available for mixing (Mantell 1959). The process involves precisely mixing the alloy components, both dry and complete. Mixing moisture reduces dust and minimizes the risk of explosion. Lubricants are added during mixing to reduce friction during spraying and ease some parts' removal (Manyanin *et al.* 2021). In brick making and compaction, converting free powder particles into raw clay with its exact shape and size is a process that is carried out in steel mandrels and molds. Both mechanical and hydraulic presses are used for making bricks (Cheng *et al.* 2023, Fu *et al.* 2023, Li *et al.* 2023c, Zhang and Huang 2023). Mechanical presses are suitable for low pressures and high production, and hydraulic presses are used for higher pressures. They also make it easy and possible to produce high-density parts (Cristofolini *et al.* 2010).

Sintering means heating the powder at a temperature lower than the sintering temperature to increase strength and remove lubricants and lubricants added during the mixing stage. Sintering is done in large continuous furnaces with a controlled atmosphere to protect against oxidation and other chemical reactions. The parts are kept at the right temperature for a particular time so that their particles stick together very tightly by atomic forces, the strength of the parts is increased to the required amount, and the required hardness is achieved (Dewidar *et al.* 2006). Many products are used with power after the stage and in cases with accurate tolerance and a better level (Ryan *et al.* 2008). Copper-iron material is a heterogeneous combination of two metals with different properties in that its composition and structure change in a graded manner. Iron, with the chemical symbol Fe, is the name of a chemical element with the atomic number 26. Iron is a metal that is in the first period of intermediate metals. Iron is the largest building block of the earth from the point of view of the mass. Iron is the main component of the outer and inner core of the earth and the fourth most common element in the crust (Rajpurohit *et al.* 2019). Copper is the name of an element of the periodic table with the chemical symbol Cu, its atomic number is 29, and it is a metallic element with malleability and high thermal and electrical conductivity. It has the highest electrical conductivity after silver. Pure, soft, and malleable copper is part of it. It is located against the open air and is red-orange (Ma *et al.* 2021). This material, properties of iron such as high Young's modulus and special magnetic properties with the unique characteristics of copper such as thermal conductivity and excellent malleability combined Copper-iron material is used in many cases (Li 2023, Li *et al.* 2023d, Zhang *et al.* 2023a, b). These Applications include cooling channels due to high thermal conductivity and resistance, good corrosion, nuclear reactor components, electronic components, components are magnetic, and so on. The relatively small

difference between the melting points of copper and iron creates a good overlap for determining the annealing temperature range (Narasimhan 2001). The powders must have sufficient fluidity so that when pressed with presses Automatically fill the holes of the mold quickly, have good strength, and have high compressibility. The strength of pressed parts made of pure iron powder is limited. Mixing the iron powder with alloy element powders, especially copper powder, increases the strength of the parts (Wong-Ángel *et al.* 2014). Copper is also used as an alloying element in iron powder components to increase mechanical properties and control dimensional changes during firing, which is added by mixing or permeation (Gilman and Benjamin 1983). In addition to the above uses for copper powder, a large amount of copper powder and copper alloy is used in the form of flakes, as a powder whose thickness is small compared to its other dimensions. Such powders are used, for example, in antifouling paints, decorative and protective coatings, and printing inks. These powders are also used in non-structural applications such as soldering, cold soldering, mechanical plating for medals, decorative metal and plastic products, and various chemical and medical uses (Furuya *et al.* 2022).

Art is a collection of human-made works or processes that are created to affect human emotions and intelligence or to convey a concept. Art is not associated with beauty but has always been associated with human creativity. It can also be said that art is the skill of creating beauty. Visual arts (painting, drawing, sculpture, photography, calligraphy, and printing) are among the most critical art fields (Barbaros *et al.* 2022). This principle is a reminder of the direct relationship of examples, it has its historical period and is the basis of thinking about art with texture. Every art and its essentials, including work tools and materials, provides art (Guan 2023, Li *et al.* 2023b, Ma *et al.* 2023). Based on this principle, artists in Each period of art history had a tool for their artistic work - i.e., Religious or non-religious - were looking for a suitable medium to express the type of histology and their inner state in the format be the creation of a work of art. This was related to the truth in every age, and changing this relationship to another aspect of the world's hidden secrets gave man the means of a new civilization (Xie *et al.* 2022). A civilization that shows this transformation in all its manifestations. Art, the embodiment of civilization, is the best and brightest mirror, the truth of every period of human history and civilization, in which manifestations of the secrets of truth and creation are revealed. Each of the art schools in historical periods is undoubtedly continuous. They are dependent on each other. Because of the particular type of thinking in Any period, art schools are suitable for that particular type of attitude Artists have appeared in the world (Brandoff 2022).

A comment on the tools and materials used in modern art shows how art supplies are used. It is possible to consider the principle of the historicity of art and artistic tools. He recognized and understood the theoretical foundations of making various tools in the art of human history and How the choice or method of making artistic tools is a function of the ontology of historic artists (Benjamin and Jennings 2010). Painting is among the most popular and attractive art fields for many enthusiasts. One

of the tools used a lot in painting is the painting brush. A painting brush is a tool with a long wooden handle, a metal closure, and a hairy tip, which painters use to draw paint lines and paint. Each type of painting uses its brush (Lee 1997). The is the part that keeps the handle and the hair together and gives them shape. This part is usually made of metal, although not all brushes are made of metal. For example, bristle brushes can have plastic and wire ferrules. A quality ferrule will not rust or loosen. The tip of the brush forms the end of the hair, while the heel part is the part where the strands go from the end of the handle into the ferrule. As the name implies, the belly part of the brush is the thickest. This part is more visible in round brushes than in flat brushes. Ferrules can also be made of different types of metals, but the most suitable of them is steel. Also, in the central portion of the most elevated area of the hair, which is inside the metal strip, a blade is placed, which, by creating a hole between the hairs, plays the role of a paint reservoir in the brush known as the spacer branch. The material of this blade can be metal (Wu *et al.* 2021). Kawasaki and Watanabe (1997) investigated the powder metallurgy method of Making targeted materials and its success rate. They fabricated the target material of zinc sulfate phosphate and 304 stainless steel and investigated the effect of fabrication parameters such as pressure and temperature on its properties. Ogel and Gurbuz (2001) produced a targeted material of aluminum, copper, and silicon carbide utilizing a single-step hot pressure method and the process of changing the elastic modulus. Investigate the tensile strength and yield strength by changing the percentage of silicon carbide and observed that the mechanical properties of the resulting composite with the increasing percentage Aluminum improves (Zhang *et al.* 2022, Xue *et al.* 2023, Zhao *et al.* 2024). Cavdar *et al.* (2014) made a combination of copper and iron using powder metallurgy, and by changing the composition of the layers, they investigated its bending strength. Xiong *et al.* (2014) made the combination of copper and steel a purposeful tool in six layers. They prepared microscopic images of the resulting composition. These researchers investigated the resulting material's thermal properties to improve channel heat transfer (Hou *et al.* 2021, Huang *et al.* 2021, Xu *et al.* 2021, Wang *et al.* 2022).

Despite the comprehensive exploration of the production of multipurpose cotton fabrics and the use of powder metallurgy in brush ferrules for painting, certain shortcomings merit consideration in the current study. The abstract does not explicitly address potential challenges or limitations encountered during the fabrication process. Identifying and discussing such challenges could provide a more holistic understanding of the feasibility and practicality of implementing these innovations in the production of sportswear and artistic tools. Additionally, the abstract lacks information on the scalability of the proposed methods, leaving uncertainty regarding the applicability of these advancements on a larger industrial scale. To bridge these gaps, future research could delve into a detailed analysis of the challenges faced in implementing powder metallurgy techniques for specific applications, such as in the mass production of cotton fabrics for sportswear or the



Fig. 1 Arrangement of copper-iron layers

manufacturing of brush ferrules. Furthermore, exploring potential solutions or optimizations to overcome these challenges would contribute valuable insights to the field. Addressing scalability concerns through a systematic examination of the proposed methods in larger production settings would enhance the practical relevance of the study's findings. The novelty of the current study lies in its intersection of powder metallurgy, cotton fabric production, and the enhancement of sportswear and artistic tools. By incorporating iron-copper material prepared through powder metallurgy, the study introduces an innovative approach to improve the strength and quality of brush ferrules. The microscopic analysis revealing a strong interconnection between particles adds a unique dimension to the understanding of microstructures in materials produced through isostatic pressure. Additionally, the emphasis on the application of these materials in artistic tools and sportswear contributes to the novel integration of powder metallurgy advancements in diverse practical domains, showcasing the versatility and broad impact of this technology.

2. Experimental part

2.1 Materials

Table 1 lists the materials required for the fabrication of iron-copper material through the powder metallurgy method, intended for utilization in artistic brush tools. The powders utilized in this process necessitate a sufficient level of fluidity to promptly occupy mold cavities, ensuring optimal strength and minimal alterations in dimensions. The powder materials specified in the aforementioned table exhibit a particle size of 50 microns and boast a purity level of 99%. The augmentation of mechanical properties and regulation of dimensional changes in iron powder components are achieved by the application of copper powder, followed by the implementation of powder metallurgy (Azimi *et al.* 2016, Ghadiri *et al.* 2016a, b, Shafiei *et al.* 2016, 2017). In order to get to know more about iron and copper, their physical properties are shown in Table 2.

The equipment employed in this study includes a digital scale with a precision of 0.001 grams, utilized for

Table 1 the variations of non-dimensional buckling temperature ($\overline{\Delta T}_{cr}$) of a square ($a = b$) composite plate

No.	Name of the material
1	Iron (Fe) powder
2	Copper (Cu) powder

Table 2 Physical properties of Iron and Copper

	Iron	Copper
Molar mass (g/mol)	55.845	63.546
Melting point (°C)	1,538	1,085
Density (g/cm ³)	7.874	8.96
Coefficient of thermal expansion (10 ⁶ /°C)	11.8	16.8

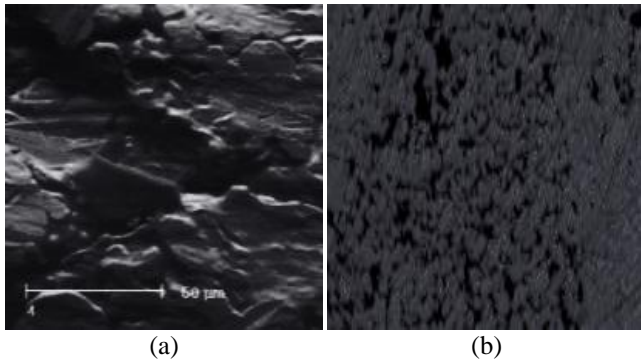


Fig. 2 (a) Microstructure of pure iron powder after compression, (b) Microstructure of copper and iron layers pressed by a uniaxial



Fig. 3 Cu-Fe optical microscope image

measuring the weight of powders in each layer. To facilitate the mixing of iron and copper powders, a magnetic stirrer was employed. The metal powder pressing stage involved the use of a press machine. Additionally, a furnace was utilized for the sintering of the samples (Omidi *et al.* 2013, Ghadiri *et al.* 2016c, Mousavi *et al.* 2017).

2.2 Test steps

In this study, the material is produced through the powder metallurgy process, achieved via powder accumulation. The composition of these powders undergoes a stepwise transition, progressing from a pure copper layer to an iron net layer. The layout of these layers is illustrated in Fig. 1. The weight percentage of metal powder in each layer is specified. Initially, the layer consists of 100%

copper, followed by the second layer where iron constitutes 25% of the composition. In the subsequent layer, the shares of iron and copper are each reduced by half, leading to the final layer composed entirely of pure iron (100%).

Two distinct types of presses find application in the compaction of metal powders—namely, the uniaxial press and the cold isostatic press. Discussed in this section are the notable differences between these two press variants. The uniaxial press generates axial pressure, concurrently elevating the sample temperature to approximately 230°C. To achieve this, copper and iron powder layers are coated within an 85 mm diameter cylindrical steel mold. Following the application of powders, the mold undergoes pressing, subject to an axial pressure of 2300 bar at a temperature of 230°C over a duration of 4 hours. Conversely, the cold isostatic press involves placing copper and iron powders within a silicone mold, subsequently immersed directly into the pressure chamber. Here, isostatic pressure of 4700 bar is uniformly applied in all directions on the outer surface of the mold, shaping the powder into the desired form. A key distinction between the cold isostatic press and the uniaxial press lies in the former's capability to exert pressure from all directions, offering a distinct advantage in the pressing process (Ehyaei *et al.* 2017, Ghadiri *et al.* 2017a, b, Shivanian *et al.* 2017).

2.3 Sintering

Following the pressing of powders to form the primary raw parts, these samples undergo placement in the sintering furnace. During this phase, the powder is heated to a temperature below the metal's melting point, allowing the metal powders to bond. In the initial stage, within a regenerating environment that inhibits oxidation, the raw material is heated, causing the evaporation of glue or lubricant and resulting in a porous material. The sintering step plays a pivotal role in defining part characteristics, marked by condensation and grain growth. While the pore structure smoothens in the intermediate stage, they remain connected until the final phase. To mitigate undesirable dimensional changes, shaping is executed under high pressure, coupled with reduced time and temperature during sintering, especially in cases where condensation reduction is sought. Conversely, for refractory metals, greater emphasis is placed on condensation in the second sintering stage, necessitating a multifaceted consideration (Ebrahimi *et al.* 2017, Ghadiri *et al.* 2017c, Shahabinejad *et al.* 2018, Shafiei *et al.* 2020).

In the second stage, the temperature is once again elevated (occasionally up to 90% of the mixture's melting point) for effective material fusion. Subsequently, the temperature is maintained for a duration, fixing the structural position of the complex. The extended sintering time is crucial for achieving desired characteristics and solidification of the piece. The final sintering stage is a gradual process where individual spherical pores contract from each other through volume diffusion. Pore coarsening increases their average size while decreasing their number, with larger pores growing at the expense of unstable smaller ones. Sintering in the solid state at a temperature 1000°C lower than Copper's melting temperature forms a surface

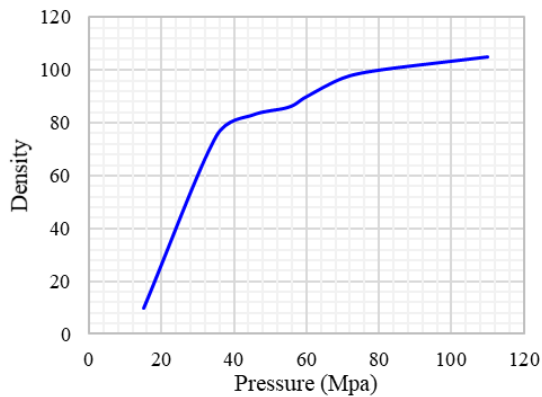


Fig. 4 Variations of relative density versus compaction pressure

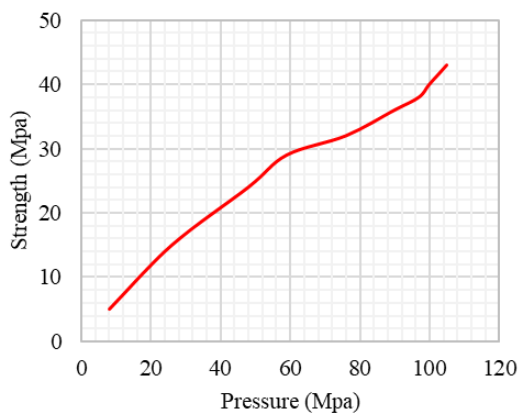


Fig. 5 Variations of relative strength versus compaction pressure

bond between adjacent particles. After evaporating zinc stearate used in mold lubrication for 40 minutes, the temperature is increased until reaching 1000°C. Sintering occurs at this temperature for 70 minutes, followed by gradual cooling in the furnace. In this study, the strength of dense parts was assessed using the diagonal pressure test. Employing a 250-STM device, the sample is positioned laterally between lower fixed and upper movable parts. Initiated at a loading speed of 2 mm/s, the upper jaw moves downward, exerting diagonal pressure on the sample. The compressive force of the upper jaw progressively increases until the part fails, marked by the creation of a crack. At the point of cracking and part failure, the force decreases, and the maximum force recorded by the device is considered the breaking force of the part.

3. Results

3.1 Examining the microstructure of the sample

Fig. 2.A shows the microstructure of pure iron powder after compression. As seen in the figure, an example of it has a completely uniform structure and few empty spaces. It is observed between the powder particles. The bonding method between the powder particles is due to the locking phenomenon. Which also occurs mechanically. Also, the

connection between the powder particles at the grain boundary is well done. Fig. 2.B shows the microstructure of copper and iron layers pressed by a uniaxial press. The high amount of empty spaces in the targeted material pressed by the press Uniaxial is observed. It is clear from the microstructure images that a fine microstructure has not been established in Purposeful material pressed by a uniaxial press with a high cavity volume.

Nevertheless, by isostatic pressing, as seen in Fig. 3, a good connection between the particles of each layer has been established. There are a few holes in the layers. Generally, picture Light microscopy shows that between the particles of copper and iron, an interfacial connection is Good during stable construction, and an acceptable microstructure is established.

3.2 Density and strength

Figs. 4 and 5 show changes in relative density and strength of parts produced from copper-iron powder in terms of pressure and density. As can be seen in these two figures, the density and strength of the parts increase with increasing pressure. In the case of relative density, the slope increases first, then decreases, and finally increases. In the first step, we see a significant increase in density and strength values due to the placement of powder particles in the empty spaces between each other and the establishment of molecular forces between adjacent particles. In the second stage, since there is no space left for movement and collision between powder particles, pressure Condensation causes increased friction, and local heat on the surface of the particles has been This does not have much effect on the increase in density, but because it causes Creating a connection between the powder particles, its effect on increasing the strength is significant. In the third stage, the hardening in the powder particles causes the continuation of the process of changing the shape of the particles at a higher compression pressure. The surface of the parts made by this method is so perfect and flawless that it does not need any other work on other items.

4. Discussion

Powder metallurgy is one of the most common methods of producing parts. Among the unique features of this method, we can mention the excellent use of raw materials, the ability of automation and high speed in the production of parts with a large number, and the ability to control physical properties. Including the porosity in the production parts, the ability to produce composite parts, and finally, the need for machines with low cost and high safety has expanded its use in various fields. The powder metallurgy method includes placing powder particles in one shape and density in different ways, such as one-sided pressing, Double-sided, or hot and cold hydrostatic press. As a result of heating the parts in Furnace, weak mechanical bonds between powder particles, to bonds The strength of the converted metal and physical properties such as density and mechanical properties such as strength increase a lot. Sintering can be defined as a process in which powders are

closely packed and heated to a peak temperature where the diffusion of atoms becomes meaningful. Sintering is considered a heat treatment for compact to improve its properties in the sense of “Green” compact. Powder metallurgy is proper when small parts are needed on a large scale. Therefore, the use of powder metallurgy to prepare iron-copper material for use in the metal part of the brush, which is a piece of small dimensions, can be beneficial and widely used.

5. Conclusions

In light of the escalating demand for heightened production efficiency and the concomitant constraints on energy consumption, alternative methods tailored to require less energy for shaping materials with elevated melting points, such as metals and ceramics, have been under consideration. Notably, powder metallurgy has emerged as a viable option. The imperative adoption of the sintering method has stemmed from its intrinsic advantages, notably improved quality and reduced energy consumption.

This research delved into the utilization of the powder metallurgy method for crafting 5-layer copper-iron materials with bridging functionality, aligning with the overarching goal of enhancing the production of multipurpose cotton fabrics to elevate the quality of aerobic and dance sportswear. In comparison to alternative methods, this construction approach offered heightened reliability, ease of use, and increased accessibility in terms of construction facilities. Employing this technology facilitated the production of copper-iron materials with elevated density. The ability to exercise precise control enabled the creation of fine microstructures, laying the groundwork for fabricating targeted materials characterized by high quality and desirable properties.

Several pivotal factors influenced the successful production of these targeted substances, encompassing the purity of the utilized powders, the type and magnitude of pressure applied during the press stage, the sintering heat treatment cycle, and the atmosphere used in the furnace. Distinctive properties were observed between targeted parts manufactured using uniaxial and isostatic presses, stemming from variations in factors such as the direction and magnitude of applied pressure, as well as temperature conditions during pressure application. These variations manifested in differences in microstructure quality, density, and, ultimately, the mechanical properties of the two types of targeted materials.

In the context of fabricating friction parts, the alloying of copper metal powder with tin, zinc, nickel, and other metals was undertaken. Additionally, copper powder served as an alloying element for iron powder, enhancing the strength of the resulting material and augmenting its durability during the baking process, leveraging its favorable mechanical properties. This multifaceted approach aligns with the broader theme of advancing the production of multipurpose cotton fabrics, thereby contributing to the improvement of the quality of aerobic and dance sportswear.

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