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Design and Development of Hank Dyeing Machine and in-house field trials for Khadi Cluster

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Abstract: ***In India Textile product processing industry is the only way which can help to boost the rural economy and the development of rural sector in India. Today's customers are seeking for reduced prices, high quality product and the excellent durability of textiles. As increasing population directly increases the demand of textile in market. To meet that demand there is a necessity to replace the manual operation method by machine operation.***
Nowadays there are many automatic hank dyeing machines are available in the market but they are too costly and most of the rural based khadi industries or NGOs are unable to afford and maintain that machine. On the request of KVIC, MGIRI WARDHA has designed and developed the hank dyeing machine which is user friendly and cheap in cost as well as in less maintenance and also operated by unskilled operator.
The developed hank dyeing machine can dye 7 kg of dry hanks in 30 minutes. This machine dyes single batch in just 30 minutes. This is cost effective, energy efficient, electric driven machine suitable for rural based small scale textile industry.
Keywords: Hank: Dyeing: Coloring: Machine: Textile.

I. INTRODUCTION

In India, after agriculture textile industry is the only industry that has created the huge employment. Textile industry is considered as the second largest employment generating industry in India. India is at second position for production of cotton in the world. India's 60% textile industry is based on cotton. Reeling, the process of converting yarn into a commercially transportable form, produces hanks. It is customarily done after twisting or winding to carefully wrap yarn for processing in hank form and afterwards unwinding [1].

A skein is called a hank if it includes exactly 840 yards of cotton or 560 yards of worsted, or if it contains multiples of these lengths, such as double hanks, which have 1680 yards of cotton or 1120 yards of worsted. In contrast to cone yarn, which is utilized in mill manufacturing, hank yarn is primarily used in handloom production. Hank Yarn is used in making of sarees, kurtas, clothing materials, dhotis, sherwanis, lungies, bedsheets, and many other traditional Indian handloom items. The range of handloom products reflects the cultural significance of Indian capabilities, and the viability of this endeavor is fully dependent on the output and availability of hank yarn, as well as the necessary skills of weavers [2].

The color of the clothes or textiles is very important from aesthetic and fashion point of view. The different color gives birth to different looks of the textile or clothes. Specifically, in Khadi (100% pure cotton) the coloring of clothes or apparels gives boost up to the production of khadi clothes due to increase in demand of cotton clothes. The coloring of textiles gives vital commercial success to the product. In the language of textile designing, the coloring is called as dyeing. The coloring of textile gives impressive visual effects in aesthetic. About 1000 meter of yarn makes one hank [3].

The coloring (dyeing) of hank is done by old method in which hank is dipped in container which contains color. But in this method the inner threads of hanks not get colored. For coloring those portions, they use to dip those hanks again in that container and kept it there for some time. This is very time consuming and hectic process and also need more man-power as compared to machine dyeing process. Therefore, there is a need of optimization in design and development of new machine for hank dyeing.

So, the aim is to completely color the each and every thread of hank thoroughly. Hence, there is a need to design a principle which should be responsible and gives result in the complete dyeing of hank.

Khadi Village Industries Commission (KVIC) has requested Mahatma Gandhi Institute for Rural Industrialization (MGIRI) located at Wardha for the design and development of hank dyeing machine for khadi cluster. MGIRI is a national level institute comes under Ministry of Micro, Small and Medium Enterprises, Government of India [4].

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II. REVIEW ON AVAILABLE DYEING MACHINES

Many hank dyeing machines are available in India as well as in overseas for coloring of yarn/hanks on industrial scale. Following are the dyeing machines available in the market.

1) Beaker Dyeing Machine
2) Textile Dyeing Machine
3) Multi Nozzle Soft Flow Economical Dyeing Machine
4) U Type Fabric Dyeing Machine
5) Winch Machine
6) Arm Dyeing Machine

In the past, winch dyeing machines were the only coloring machines used for dyeing of yarn in textile industries [5]. Beaker dyeing machine is used for dyeing of yarn at the temperature of 98 ^{O}C. The Beaker machine is fabricated with stainless steel material of grade SS 304 to avoid the corrosion occurred due to use of dyeing chemicals.
Textile dyeing machine is well developed and structured specifically designed for large scale textile industries. This machine is used for dyeing of woven and knits fabrics of silk, cotton and wool [6].
Package dyeing process includes wound of yarn to be dyed on compressible dye spring, tubes or cones. This type of dyeing is carried out under high pressure mounted on hollow spindles.

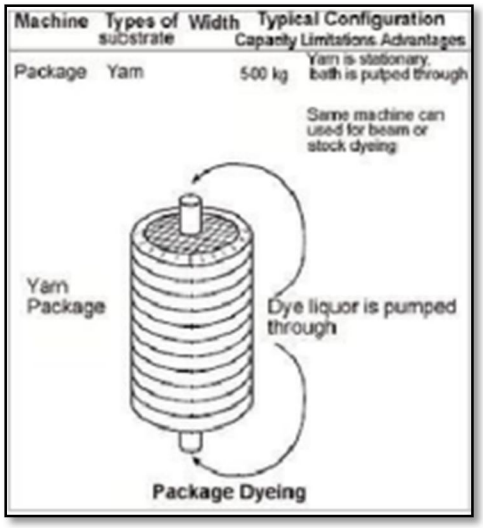


Figure 1: Package Dyeing Process

Figure 1 describe the details of package dyeing process of yarn in textile industries.

These spindles are fixed on dyeing carriers and inserted into the vessels after closing of lid of the machine. Then dyeing liquor is poured into the vessels and process is completed when dye is fully exhausted. The dyed yarn is dried with the help of an infrared drying oven [7].

III. PROBLEM IDENTIFICATION

In the old traditional method of hank dyeing, the dyeing of hank was performed by dipping the hank small container full of liquid color. In this method, there was a problem of improper dipping of color in hank, the liquid color is not get inserted properly inside the hank. The inner threads of hank remain uncolored. This method takes longer time for hank dyeing. There is also need of human intervention while dipping the hank in container. This is one kind of manual dyeing. The hank dyeing rate of this method is less as compared to machine dyeing and the dyeing is also not uniform. The external threads of hank get colored properly and the inner one remains uncolored.

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IV. OBJECTIVES

1) To increase the dyeing rate of hank obtained from small spinning unit (8 Spindle charkha).
2) To achieve the uniform dyeing of hank to make clothes more attractive.
3) Reduce the dyeing time as a comparison with manual dyeing.
4) To reduce the human drudgery like in manual dyeing of hanks.
5) Increasing the quality of liquid mass transfer into hank.

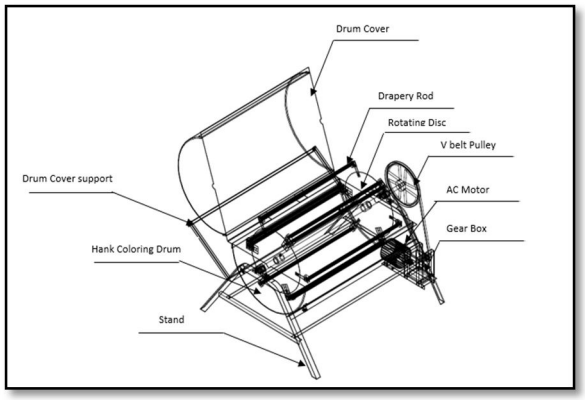


Figure 2: Isometric View of Hank Dyeing Machine (Source: drawn by Creo Software by Author)

V. NEWLY DESIGNED HANK DYEING MACHINE

When it comes to the most common equipment, a hank dyeing machine unit consists of a circular mild steel drum into which the hank is loaded circumferentially over the drapery rod, which are mounted on the two-rotating disc. These two rotating discs are mounted on shaft and that shaft is mounted on frame with the help of two pedestal bearing. The half semicircle of the drum will act like a cover and the remaining half semicircle of the drum will act as a storage reservoir for color liquid which we are going to apply to hank mounted on drapery rod.

On one side of shaft V-belt pulley is mounted and that v-belt has been driven by AC Induction motor. The gearbox is provided for variation in speed.

The capacity of this machine is of 7 kg dry hank. That hank is tied on the drapery rod alternate to one other and like the one end of hank is on one draper rod and the other end is on the other draper rod. The discs are having small plates for the mounting of draper rod. To have the best contact between yarn and liquid, which allows uniform coloring, the entire package of hanks must have a uniform volumetric distribution. One batch nearly took 30 min to completely dyeing the hank. The main aim of designing and fabricating a hank dyeing machine is to replace the old traditional method of hank dyeing by hand to hank dyeing by machine. This increases the production rate of hank dyeing.

In old traditional method, the hank is allowed to put in a container full of liquid color in which the hank get soaked and kept there for some time. But in this old method the penetration of dye (color) to the inner thread of hank is not get accomplished properly which means the inner thread of hank remain uncolored. The old method creates fatigue in operator or labor. In this new machine as hank is continuously in rotation due to that the color or dye penetrates properly up to inner thread of hanks.

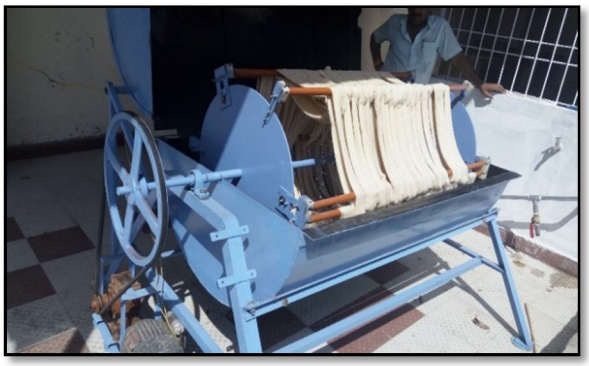


Figure 3: Mercerization of Hanks in Hank Dyeing machine (Source- Author)

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VI. MATHEMATICAL DESIGN

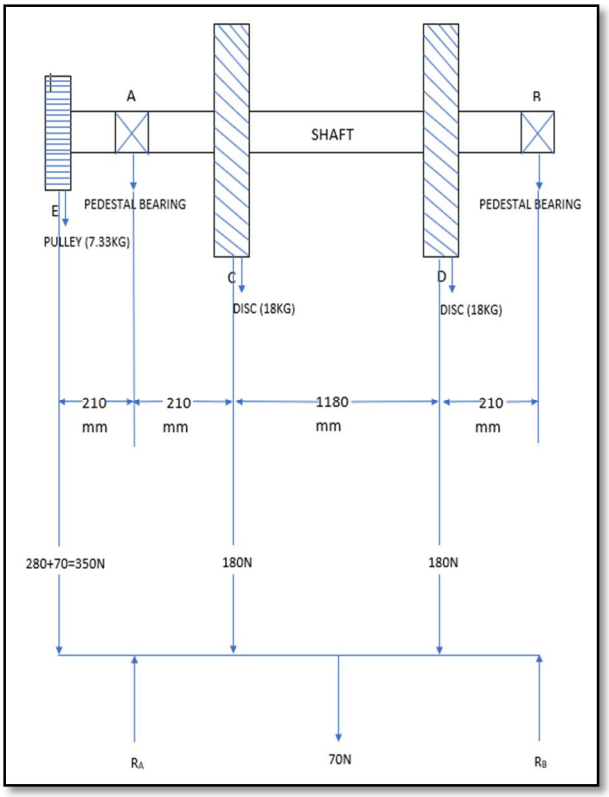


Figure 4: Free Body Diagram of Hank Dyeing Machine (Source: Calculated by Author)

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Figure *4* is the free body diagram (FBD) of the newly designed hank dyeing machine. This FBD shows us the magnitude of forces acting on the shaft acting through pulley, rotating disc and pedestal bearing [4].

For proper dyeing of each and every hank in machine we need to rotate drum at optimize RPM.

Therefore, Taking RPM (N) = 6 RPM

As the shaft is of mild steel material, so we will take,

σ_{allow} = allowable tensile stress = 200 MPA

τ_{allow} = allowable shear stress = 115 MPA

We can calculate, the torque transmitted by the shaft is,

$T = \frac{P\ X\ 60}{2\pi N} = \frac{400\ X\ 60}{2X3.14X6}$ = 636.61 X 10^3 N-mm

Since, the torque acting at disc C and D and on pulley E is same as that of the shaft. Therefore, the tension in cable on pulley is,

$F_{tE} = \frac{T}{Re} = \frac{636.61\ X\ 10^3}{228.6}$ = 2784.82 N

And total load acting on pulley E is,

= $F_{TE} + W_E$ = 2784.82 + 70

But, tension in pulley will be act on both side of pulley,

Therefore, F_{TE} = 2784.82 X 2 = 5569.64 N

Therefore, Total load acting on pulley E is,

F_{TE} = 5569.64 + 70 = 5639.64 N

Now, assuming the shaft as a simply supported beam as shown in FBD, the maximum bending moment may be obtained as discussed below,
Let, R_A and R_B = Reactions at A and B respectively.

$R_A + R_B$ = Total load acting downwards at C, D and E

$R_A + R_B$ = 5639.64 + 180 + 70 + 180 = 6069.64 N

Now, taking moment about A,

5639.64 X 120 = 180 X 210 + 70 X 800 + 180 X 1390 – R_B X 1600

Therefore, R_B = -525.20 N

Therefore, $R_A = (R_A + R_B) – R_B$ = 6069.64 – (-525.20) = 6594.84 N

Now, the maximum bending moment on shaft is,

M = R_B X 120 = -525.20 X 210 = -110292 N-mm (Max^m bending moment transmitted by shaft)

We know that, the twisting moment,

T = Input Torque – Load on shaft disc.

T = 636.61 X 10^3 – (7 X 9.81 X 292.4) = 616530.89 N-mm

Again, we know that equivalent bending moment,

$M_{eq} = \frac{\Pi}{32} X \sigma X d^3$

But, $M_{eq} = \frac{1}{2}(M + \sqrt{M^2 + T^2})$

$M_{eq} = \frac{1}{2}(-112092 + \sqrt{-112092^2 + 616530.89^2}$ = 248146.74 N-mm

Therefore, 248146.74 = $\frac{\Pi}{32} X\ 200\ X\ d^3$ = 23.29 mm.

Now, we will calculate equivalent twisting moment,

$T_{eq} = \sqrt{M^2 + T^2} = \sqrt{-112292^2 + 616530.89^2}$ = 606585.53 N-mm

We know that,

$T_{eq} = \frac{\Pi}{16} X \tau X d^3$

606585.53 = $\frac{\Pi}{32} X 115 X d^3$

d = 29.94 mm

Consider the larger of the two values, we have [5].

d = 29.94 ≈ 30 mm

But, 30 mm diameter size of MS shaft is not easily available in market, while 32 mm diameter size is easily available in market. Therefore, we took 32 mm shaft with outer diameter in size for hank dyeing machine.

VII. WORKING

Firstly, we have to load the 7 kg of dry hanks on the drapery rod alternately and tied them properly on the drapery rod. Before starting the dyeing, we have to bleached and mercerized the hank so that the dirt gets removed and hank gets cleaned and to impart strength of the hank. For that we have to introduce clean and soft water in the drum and then close the drum upper cover and allow steam inside the drum through the steam inlet valve so that the water get heated and hot water will properly remove the dirt from the hank. Some chemical agents for bleaching and mercerization are added into that water. Then for fifteen minutes rotate the drum at six rpm.

After the fifteen minutes drain the hot water inside the drum and introduce in proper proportion the fresh water with the color liquid which we want to apply on the hanks. Then introduce the steam inside the drum so that the liquid color gets heated and properly get applied on hank. Then again rotate the drum for minimum fifteen minutes at six rpm.

As the drum rotates the centrifugal force is get applied on the hank and due to that the liquid color, which we want to apply on the hank is get properly applied and the liquid color get properly penetrated inside the hank up to its inner thread. As the hank are tied circumferentially the hanks get strengthen. As the drum is continuously in rolling condition the liquid color get properly streamed down inside the hank. After the fifteen minutes open the drum cover observe the colored hank and then drain the hot water from the drum and remove the colored hank from the drapery rod and then keep it for drying in sunlight. In this way by using the rotary drum mechanism this hank dyeing machine is useful to color the hank in just thirty minutes.

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Figure 5: Coloring in Hank Dyeing Machine (Source: Author)

Innovative design of a hank dyeing machine is very simple and it is useful for micro industries. New hank dyeing machine is so sophisticated and easily operated; even an unskilled individual can operate it. New hank dyeing machine can be operated by hand or motor and it can be driven in a solar mode of energy also. Energy consumption is very low Complicated hank attaching problem has been solved in this design.

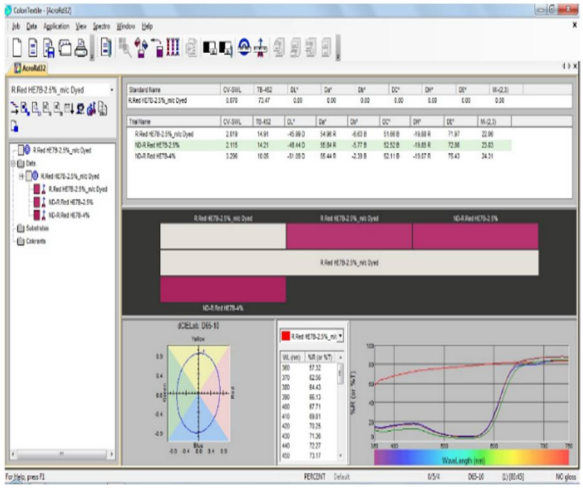


Figure 6: Actual Coloring Result plotted by Spectrophotometer for hank colored in hank dyeing machine

VIII. DATA COLLECTED & IT'S ANALYSIS:

The machine developed is suitable for dyeing khadi yarn in hank form to get uniform shades. When the final model hank dyeing machine was developed, the first lot of hanks were dyed in the machine using Reactive dyes. In dyeing the hanks, two things are very important. One is uniform colouration and second the fastness of the colour applied.

Cotton hanks were taken and dyed with 2.5% shade of Reactive Red HE 7B. One lot is dyed in hank dyeing machine and the other by exhaust method by hand. After dyeing is completed, both samples were analysed for uniform colouration, i,e. K/S value and fastness to wash and rubbing.

K/S values of dyed cotton khadi hanks were determined by measuring surface reflectance of the dyed samples using X-rite (Gretag Macbeth) portable spectrophotometer.

Colour fastness to washing (BIS/ISI Handbook of Textile Testing, 1982) of the dyed hank samples was determined as per the IS: 764-1984 method following IS -3 (equivalent to ISO-III) wash fastness method using Megatech Overseas India Launder-O-Meter and relevant grey scale.

Colour fastness to rubbing (dry and wet) was assessed as per the IS: 766-1984 method (BIS / ISI Handbook of Textile Testing, 1982) using an electronic crock meter and relevant grey scale.

Surface colour strength values as analysed in spectrophotometer and respective values are mentioned as below.

IX. FIELD TRIALS CONDUCTED:

Total 50 numbers of participants were called from North (06), South (02), East (09), West (05) and North-East (03) zones for conducting trials of the developed hank dyeing machine at MGIRI, Wardha. Workshop on field trials for developed hank dyeing machine was organized during the period from 02/01/2018 03/01/2018 in khadi and textile division of MGIRI. Invited participants were expertize in dyeing of yarn and working in reputed khadi institutions of India.

Cotton khadi yarn in hank form dyed with Reactive Dye.	K/S at λmax	ΔE	ΔL	Δa	Δb	ΔC	ΔH	MI	CDI
Reactive Red HE-7B – 2.5% Dyed in machine	2.019	71.97	-45.99 D	54.96	-6.63 B	51.66 B	-19.88 R	22.06	1.255
Reactive Red HE-7B – 2.5% Dyed by hand	2.115	72.86	-46.44 D	55.94	-5.77 B	52.52 B	-19.85 R	23.03	1.195

Figure 7 showing that the participants were observing actual working procedure of hank dyeing machine.



Figure 7: Participants observing the working of hank dyeing machine

As per feedback received from all participants, the dyed hank from the machine is of uniform type as compared to the manual hank dyeing process. Two days workshop on hank dyeing machine was ended with the concluding session on 02/01/2018.

X. CONCLUSION

The developed hank dyeing machine suitable for small scale khadi industries in India. This hank dyeing machine help to eradicate the practices for manual dyeing of hanks and reduce the human drudgery. In-house field trials have been conducted in Khadi and Textile division of MGIRI and found satisfactorily as per the dyeing expert from the division. Workshop may be organized at MGIRI regarding awareness and live demonstration for colouring of hanks to the representatives of khadi cluster in India. There are a great number of small businesses in the country that produce woven and knitted related fabrics. The aim of design and development of hank dyeing machine is to reduce the time for the hank dyeing. Dyeing of single hank by manual method is very time consuming. The time required for manual dyeing varies from worker to worker. As a result of this work, a hank dyeing machine was developed. As a result of this the hank dyeing procedure will be more convenient for woven fabric production. The hank dyeing machine will be manufactured and distributed to small-scale woven fabric makers in the different section of the country.

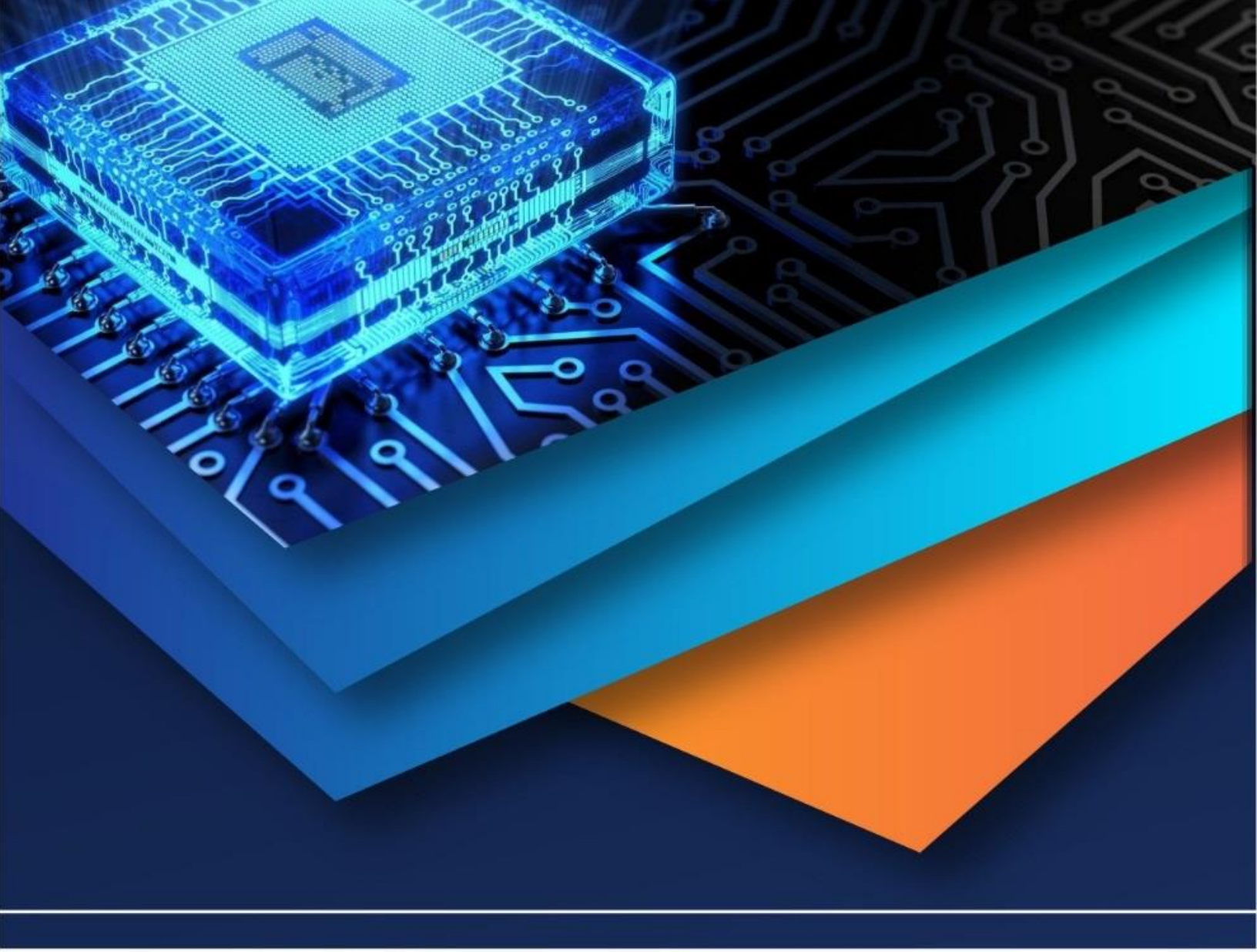
Table 1: Surface Colour strength values as per Spectrophotometer

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