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Research on Design of Heating System of Continuous Heat Transfer Machine

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***Abstract*—This equipment's temperature uniformity during continuous thermal transfer process has a critical influence on the transferred product. The bigger surface area of the roller, the poor temperature uniformity caused when heating starts. This study focuses on the thermal analysis of these electric tubes in hot rollers when heating. We use ansys steady-state heat conduction analysis to simulate the electric heating tube with the parameters of different electric power and different heating tube position, and to find the optimum temperature uniformity on the hot roller surface. For example, in the case of thermal transfer equipment, the allowable temperature range of the hot heat roller temperature is 4°C. According to the statistical normal distribution point, we know the larger probability and the smaller range gives the better temperature uniformity. So the temperature difference between the highest temperature and the lowest temperature of the measured temperature value must be within ±2 °C. This temperature difference range is also the effective temperature range in which the hot roller can be used.**

This paper discusses the related thermal theory of hot roller heating system, and uses the finite element analysis to simulate the numerical simulation ,and to know the roller, s thermal uniformity effect, then to get its refining method. When the temperature uniformity in the simulation meets the temperature accuracy specification, the heat roller implementation and temperature measurement are effective to reduce the development time and promote the quality of the equipment.

Keywords—continuous thermal transfer; hot roller; heat transfer

I. INTRODUCION

The continuous heat transfer production method is a high-efficiency process. It is widely used in many industry fields, such as printing, paper, textile or flexible circuit boards. continuous is its main feature, saving waiting and moving time.

In the traditional production way, it needs several work stations. Every work station have to input the raw material or semi-products and output simi-products. And the final work station outputs the products we need. Continuous process combines some processes to one. The more work stations combined, the more efficiency increases and the cost down greatly.

Thermal transfer process transfers the graphic on the functional intermediate carrier to the surface of the printed matter by means of heat and pressure [1]. It is a special printing technology which is based on the printing base for four major layouts and introduces the combination of several industrial technologies[2].

The thermal transfer process always use heating and pressing implementation to get good color appearance, from the simplest way only using heating and transferring to the complex way using advanced automatic equipment. Such implementations are so difficult for those conventional printing machines. Thermal transfer machines only need once heating and pressing. Meeting the decorative needs of various printed materials that cannot be printed in a normal manner is the reason why thermal transfer develops rapidly, with the development of thermal transfer materials.

The equipment's temperature uniformity during continuous thermal transfer process has a critical influence on the transferred product. The bigger surface area of the roller, the poor temperature uniformity caused when heating starts. For example, in the case of thermal transfer equipment, the allowable temperature range of the hot heat roller temperature is 4°C. That is the temperature difference between the highest temperature and the lowest temperature of the measured temperature value must be within ±2 °C. This temperature difference range is also the effective temperature range in which the hot roller can be used.

This study focuses on the thermal analysis of these electric tubes in hot rollers when heating. We use ANSYS steady-state heat conduction analysis to simulate the electric heating tube with the parameters of different electric power and different heating tube position[3], and to find the optimum temperature uniformity on the hot roller surface, then to get its refining method to reduce the development time and promote the quality of the equipment.

II. RESEARCH MOTIVATION AND PURPOSE

The most important factor for the color development in continuous heat transfer machine is the heat uniformity of the hot roller. The bigger surface area of the roller, the poor temperature uniformity caused when heating starts. Gradually increase the temperature uniformity since heat transfers from high temperature area to low temperature area[4].

At present, most arrangement of the heating tubes is determined by try and error due to personal experience or intuitive selection. Try the 1st set parameters, if not good, try another until getting the one we accept. It may waste much time

and resources. It is not a systematic approach.Even if we get the acceptable set of parameters, its experience values are so difficult to be passed to another [5].

We use ANSYS thermal steady state analysis module to simulate the hot roller temperature field in order to find the suitable parameters – position and kw required for the uniform design and optimum simulation of the continuous thermal transfer machines' heating system. Such more professional method may be recognized more easy.

III. Basis Theory

A. Heat Sublimation Transfer Printing Rollers

1) Heat transfer principle [6]

All heat transfer modes require temperature differences, since heat transfers from high to low temperature area.Conduction is effectively an energy transfer process from a matter particle with a higher energy to an adjacent matter particle with a lower energy, which rises the interaction between particles.

Fourier heat conduction equation:

$$q=\frac{Q_{cond}}{A}=-k\frac{dt}{dx} \tag{1}$$

$$q_1=\frac{Q_{cond}}{A}=-k\nabla T \tag{2}$$

In equations 1 and 2, q and q_1 are the heat values derived within a unit time period per unit area known as heat fluxes, *Qcond* is the thermal conductivity rate, *A* is the surface area, *k* is the coefficient of thermal conductivity for the material known as the thermal conductivity, a.

Mark description

q , q_1	heat values derived per unit time, unit area and known as heat fluxes.
Qcond	thermal conductivity rate
A	surface area
k	coefficient of thermal conductivity for the material known as thermal conductivity
dT/dx and ▽T	temperature increments per unit length along the heat transfer direction, known as the temperature gradient

IV. Experimental Method

We use ANSYS which is widely use in engineering analysis to study the thermal temperature uniformity on the heating system of the continuous heat transfer machine. We use it to understand the heat rollers' surface temperature distribution with different parameters - heat position and power consumption.

A. Elemental Form Setting

The model is established as a 3D solid model and is used for an analysis about transient heat transfer. The element of the mold is meshed with the heat transfer 3D hexahedral element Soild70, and the Mesh Size is 5 mm to produce a finite element model, see Figure 1 and Figure 2.

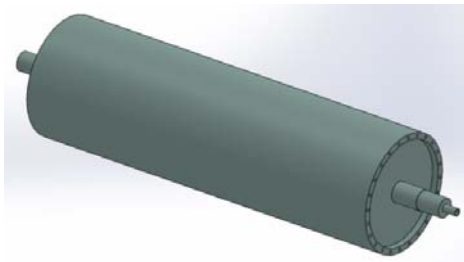

FIGURE I. HOT ROLLER WHEEL MODEL

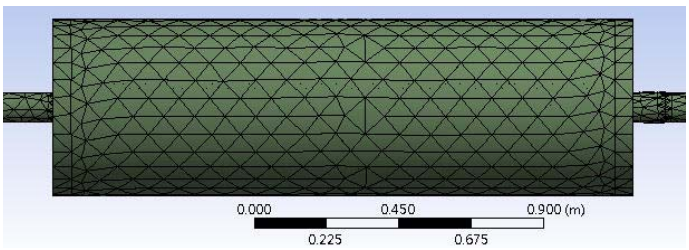

FIGURE II. HOT ROLL WHEEL SOLID MODEL MESHING

B. Material Properties

The hot roller material is SS400, its related properties are shown in Table 1.

TABLE I. HOT ROLLER MATERIAL PROPERTIES

Density,Borated	Conductivity	Specific Heat
7850 kg/m^3	48 W/m.k	0.12 kcal/kg°C

C. Modular Boundary Condition

The simulation is steady-state heat transfer analysis, and the boundary conditions are set as shown in Table 2.

TABLE II. HOT ROLLER BOUNDARY CONDITION SETTINGS

The initial temperature (°C)	25
Air heat transfer coefficient (W/m^2.K)	7

D. Hot Rollers' Electric Heating Tube and Power Configuration

We use electric heating tubes to generate heat. The power required, the heating tube position and their temperatures are shown in Figure 3 and Table 3 according to this paper' study.

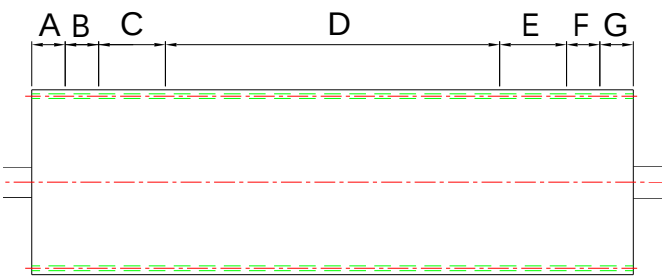

FIGURE III. DIAGRAM SHOWING THE POSITION OF HOT ROLLER'S ELECTRIC HEATING TUBE

TABLE III. ELECTRIC POWER FOR EACH HOT ROLLER ELECTRIC HEATING TUBE (UNIT: W)

Item	A	B	C	D	E	F	G	Total power
Origin	38	22	36	181	36	22	38	8.952
final	32	23	52	176	52	23	32	9.360

E. Heat Transfer Analysis about Continuous Thermal Transfer Machine's Heat Roller

This study's purpose is to know the temperature distribution on the hot roller surface. After all settings, including element characteristics, material properties and boundary conditions, we can start power supply until all tubes temperatures reach the required temperature. According to the post-processing data diagram, we can judge whether the heat transfer effect is good or not. We can adjust all parameters by these data. See Figure 4 and Table 3.

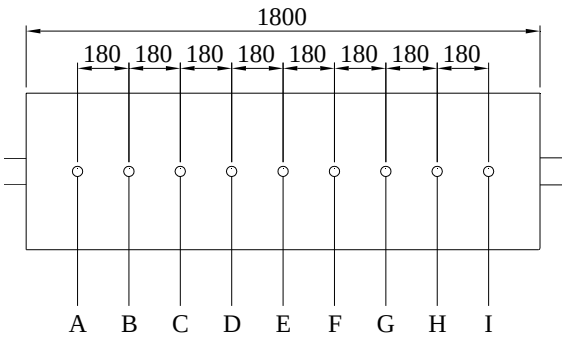

FIGURE IV. TEMPERATURE MEASURING POSITION ON THE HEAT ROLLER SURFACE

F. Evaluation Method for the Hot Roller Temperature Uniformity

We can use the statistical standard deviation with the concept of the normal distribution map [7], as shown in Figure 5 to know the temperature uniformity on the hot roller temperature.

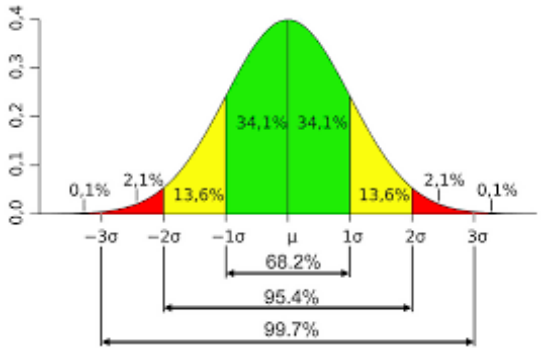

FIGURE V. NORMAL DISTRIBUTION MAP

V. RESULTS AND DISCUSSION

Figure 6 shows us the temperature on the middle portion is higher than others before adjustment. Figure 7 is the case after adjustment. It has better temperature uniformity. Temperature measuring position on the heat roller surface is shown in Figure 8.

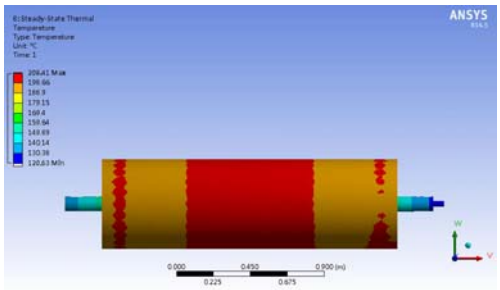

FIGURE VI. HEAT ROLLER HEATING TEMPERATURE

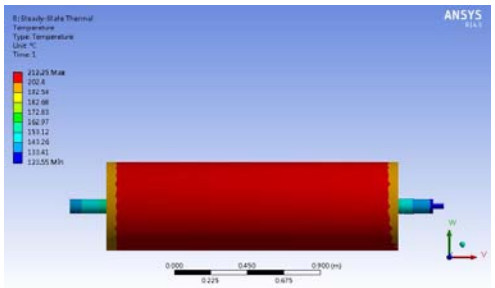

FIGURE VII. HEAT ROLLER HEATING TEMPERATURE DISTRIBUTION (BEFORE ADJUSTMENT) DISTRIBUTION (AFTER ADJUSTMENT)

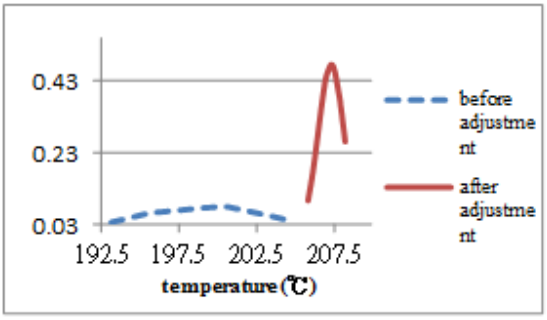

FIGURE VIII. NORMAL DISTRIBUTION OF SIMULATED HOT ROLLER HEATING

Figure 8 shows us different temperature data before (blue dash line) and after (red line) heat tubes' position. Compare Figure 6 ,Figure 7 we find the higher the probability with narrow temperature range, the better the temperature uniformity. And the final temperature difference is under 2.4 °C, it meets the accuracy specification.

VI. CONCLUSION

We know heat flows from high temperature area to low temperature area. How to determine the optimum parameters such as heat tube position, heat power required, number of heat tube is important for continuous heat transfer machine. Numeric data analysis is a good approach. It helps us to predict some situation and make proper adjustments. This study supports it. may it be good for those persons who engage in such fields .

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