Research on Methods of Weft Insertion by Air Gun

Part 2 : Practical Analysis and Experiment.

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Abstract

An experiment was made to make the experimental weft-inserting equipment referred to in Part 1 serviceable. The experiment was aimed at continuous running of this equipment and weaving by it—and was conducted by attaching it to a conventional loom run at high speed.

The results of the experiment raised a question. How are the flying orbit of the carrier and the carrier speed influenced by weft tension, air resistance and acceleration of gravity? An equation on the carrier speed was deduced theoretically to analyse the influencing factors.

1. Introduction

Continuous running of the weft-inserting equipment needed a device to collect carriers into the shooting place, another to bring the weft thread lying in the shooting barrel back to the nozzle after each pick, and a third to pool the weft thread until the carrier was shot by compressed air. We made these devices, combined them to form complete weft-inserting equipment and attached this equipment to a conventional loom.

It occurred to us that this method would subject the flying orbit of the carrier and the carrier speed to the influence of weft tension and of air resistance to the carrier, because the carrier was small in size and light in weight. We then deduced an equation on the carrier speed to analyse these influencing factors.

2. Carrier Speed and Flying Orbit of Carrier

2-1 Deducing Equation on Carrier Speed

The speed of a carrier which inserts a weft thread into a shed is reduced by air resistance and weft

tension. This must be taken into consideration in deducing an equation on the carrier speed.

Generally, air resistance consists of frictional resistance and profile drag. The frictional resistance may be ignored in this method, because the Reynolds number (Re) is in the range of 2×10^5 to 3×10^5 .

Air-resistance D (g) acting on a columnar carrier when the carrier flies parallel to the cloth fell through a shed, is obtained thus :

$$D = C_D (\pi d^2 / 4) (\rho v^2 / 2) \quad \dots\dots(1)$$

where C_D : drag coefficient
 d : Carrier diameter (m)
 ρ : Air density (g sec²/m⁴)
 v : Carrier speed (m/sec)

C_D is influenced by Re and l/d , but these values are almost constant in this method.

Assuming $K = C_D (\pi d^2 / 4) (\rho / 2)$, eq. (1) transforms into :

$$D = K v^2 \quad \dots\dots(2)$$

showing that air resistance D is proportional to the square of the carrier speed.

2-1-1 Speed of Carrier Carrying no Thread

If a carrier is shot from a shooting barrel at initial speed v_0 (m/sec), carrier speed v (m/sec) at time t (sec) is :

$$m \frac{dv}{dt} = -K v^2, \quad -\frac{1}{v} = -\frac{K}{m} t + c$$

An initial condition with $t=0$ being $v=v_0$,

$$c = -\frac{1}{v_0}$$

$$\therefore \frac{1}{v} = \frac{K}{m}t + \frac{1}{v_0} \quad \dots\dots\dots(3)$$

where,

- m : Mass of carrier ($\text{g sec}^2/\text{m}$)
- t : Time passing after shooting (sec)
- K : Proportional constant of resistance

2-1-2 Equation on Speed of Carrier Carrying Weft Thread

The speed of a carrier carrying a weft thread is reduced more by the resistance of the weft-tension than if it carries none. If acceleration α (m/sec^2) of weft-tension resistance is constant during the flight of the carrier, the equation on the speed of the carrier with a thread on it is :

$$m \frac{dv}{dt} = -m\alpha - Kv^2$$

Assume $\sqrt{\frac{K}{m\alpha}} = a$ and integrate it. Then we obtain :

$$\frac{1}{a} \tan^{-1} (av) = -\alpha t + c$$

An initial condition with $t=0$ being $v=v_0$,

$$c = \frac{1}{a} \tan^{-1} (av_0)$$

$$\therefore \frac{1}{a} \{ \tan^{-1} (av) - \tan^{-1} (av_0) \} = -\alpha t \quad \dots\dots\dots(4)$$

Eq. (4) is the equation on speed of the carrier with a weft thread on it.

2-1-3 Examining Equation on Carrier-speed

The equations on the speed of the carrier with and without a thread on it have been deduced in eqs. (3) and (4). They cannot be used for practical purposes, however, because K and α in each are unknown.

We, therefore, measured the initial speed of the carrier and the carrier speed at $t=4.0 \times 10^{-2}$ sec, and from them, obtained the values of K and α :

$$K = 5.48 \times 10^{-2} \text{ g sec}^2/\text{m}^2, \alpha = 48.4 \text{ m/sec}^2$$

Putting these values into eqs. (3) and (4) gives us :

$$V = \frac{1}{1.31 \times 10^{-1} t + 3.32 \times 10^{-2}} \quad \dots\dots\dots(5)$$

$$V = \tan (1 - 2.53 t) / 5.23 \times 10^{-2} \quad \dots\dots\dots(6)$$

The theoretical curves calculated from eqs. (5) and (6) and the values actually measured are shown in Fig. 1 and almost agree with each other. We believe, therefore, that eqs. (3) and (4) can be used in this method without chances of a major mistake.

2-2 Examining Flying Orbit of Carrier

The flying orbit of the carrier during its flight through the shed is presumably influenced by gravity and weft tension. This means the lowering of

Fig. 1 Carrier-Speed

the carrier by gravity and the shifting of the carrier toward the cloth fell by weft tension because the pooling device for the weft yarn is fixed apart from the muzzle of the shooting pipe and close the cloth fell line.

2-2-1 Influence of Gravity

Assuming acceleration g (cm/sec^2) of gravity and flying time t (sec) of the carrier, then :

$$z = \frac{1}{2} g t^2 \quad \dots\dots\dots(7)$$

Assuming $g = 980 \text{ cm/sec}^2$, $t = 4.0 \times 10^{-2}$ sec, we obtain $z = 0.8 \text{ cm}$

Accordingly, the influence exerted by the acceleration of gravity on the flying orbit of the carrier may be ignored.

2-2-2 Influence of Weft Thread Tension

When the carrier flies through the shed while squeezing the weft thread, the carrier orbit is bent toward the cloth fell by weft tension.

Fig. 2 Diagram of Resistance by Weft Tension

See Fig. 2, think of the carrier as a point, and assume that tension T on weft AO is equal to tension on weft CO ; that $\angle AOB = \theta_1$, $\angle BOC = \theta_2$; and that

the mean force of resistance to the carrier generated by weft tension is F (g). Then we obtain :

$$F = T \left\{ \int_a^b \cos \theta_1 d\theta_1 / (b-a) + \int_c^d \cos \theta_2 d\theta_2 / (d-c) \right\} \quad \dots\dots\dots(8)$$

where,

a : The value of θ_1 when the carrier is at the muzzle of the shooting pipe.

b : The value of θ_1 when the carrier passes through the whole weaving width.

c : The value of θ_2 when the carrier is at the muzzle of the shooting pipe.

d : The value of θ_2 when the carrier passes through the whole weaving width.

Here assume $a=0$, $c=\pi/2$. Eq. (8), then, transforms thus :

$$F = T \{ \sin b/b + (\sin d - 1)/(d - \pi/2) \} \quad \dots\dots\dots(9)$$

If b is thought of as a small value, then

$$\sin b/b \div 1$$

We measured T with a tension measurer which used a strain gauge, and obtained $T=12.35$ g.

Here we have

$$F = 12.35 \{ 1 + (\sin d - 1)/(d - \pi/2) \} \quad \dots\dots\dots(10)$$

The resistance of the weft thread being $m\alpha$, we obtain

$$m\alpha = 9.8 \times 12.35 \{ 1 + (\sin d - 1)/(d - \pi/2) \} \quad \dots\dots\dots(11)$$

where, $m = 4.18 \times 10^{-1}$ (g sec²/m)

$$\alpha = 48.4 \text{ (m/sec}^2\text{)}$$

$$\therefore d = 8.21 \times 10^{-4} \text{ (rad)}$$

Accordingly, the carrier, while passing through whole weaving width (47 inches), is shifted 0.92 cm from the shooting pipe line toward the cloth fell by weft tension. Therefore, the influence generated by weft tension on the flying orbit of the carrier may be ignored.

3. Efficiency of Weft-Inserting Equipment for Continuous Running

3-1 Experiment on Efficiency of Weft-Inserting Equipment

After completing the weft-inserting device, we measured its efficiency for continuous running at high speed.

3-1-1 Experimental Conditions

The experiment was made under the following conditions, and our equipment could be run at up to 360 p.p.m. :

Carrier weight	: 3.1 g
Carrier diameter	: 12.4 mm
Carrier length	: 28.0 mm
Inside diameter of carrier	: 3.0 mm
Length of shooting pipe	: 25 cm

Pressure of compressed air	: 2.5 kg/cm ²
Weft thread	: Cotton 60/2s
Warp thread	: None
Insertion length of weft thread	: 80 cm

The carrier being made of Nylon 66, both ends of the penetrating hole were damaged in the shape of a groove by the weft thread. The groove would break the weft thread. We prevented it by plugging the hole of the carrier with a brass pipe. This, however, increased the weight of the carrier and reduced its speed.

3-1-2 Upping Efficiency for Continuous Running

Something had to be done to restore the carrier, even with its increased weight, to its original speed. There were three methods, reported in Part 1: (1) Increase the pressure of the compressed air; (2) Increase the area of the carrier section; or (3) Increase the length of the shooting pipe. Method 1 is uneconomical. Method 2 is also undesirable because it increases the carrier weight. We used method 3—increasing the length of the shooting pipe. Assume pressure P (kg/cm²) of compressed air, area A (cm²) of the carrier section, length L (cm) of the shooting pipe, weight W (kg) of the carrier and acceleration g (cm/sec²) of gravity. The initial speed V_0 (cm/sec) of the carrier is, then, obtainable thus :

$$V_0 = \sqrt{2PALg/W} \quad \dots\dots\dots(12)$$

Assuming $K = V_0^2/2PAg$, then

$$L = KW \quad \dots\dots\dots(13)$$

If $W = 3.1$ g, then $L = 25$ cm. If $W = 4.1$ g, then $L = 33.1$ cm.

The shooting pipe was made 35 cm long to increase the carrier speed slightly. Although the carrier was rebuilt for more strength and the shooting pipe was increased in length to 35 cm, we were still able to run the weft-inserting equipment continuously at 360 p.p.m.

3-2 Experimental Weaving

We did high-speed test weaving with our equipment which was attached to a conventional loom, type SO-C.

3-2-1 Experimental Conditions

Loom speed	: 180~270 r.p.m.
Carrier weight	: 4.1 g
Carrier diameter	: 12.4 mm
Carrier length	: 28.0 mm
Inside diameter of carrier	: 3.0 mm
Length of shooting pipe	: 35 cm
Pressure of compressed air	: 2.5 kg/cm ²
Weft	: Cotton 60/2 s, 68 picks/in
Warp	: Blended yarn (30 % Nylon, 70 %

Rayon) 40/2 s, 60 ends/in by bad pooling state of the weft.

Insertion length of weft thread : 115 cm

3-2-2 Results of Test

It was possible to weave continuously at up to 250 r.p.m., but it was difficult to weave continuously at more than over 250[r.p.m., because the warp broke often and the weft snarled often near the selvage opposite the shooting pipe.

3-2-3 Discussion

Weaving at a speed above 250 r.p.m. is not possible because of frequent warp breakage and frequent snarls of the weft. The warp is broken by the carrier touching it. However, as shown in Fig. 1, the carrier speed does not decrease by as much as the value of the carrier's touching of the warp of the clean shed. Nor is the flying orbit of the carrier changed by as much as the value of the carrier's touching of the warp (see 2-2).

Presumably, then, warp breakage and weft snarls are to be blamed on the heavy weft tension generated

4. Conclusions

On equation on the speed of the carrier with a thread unposed on it has been deduced. The equation makes it clear that the influence of weft tension and of gravity on the flying orbit of the carrier is slight. It has also been made clear that our weft-inserting equipment can be run a tup to 360 p.p.m. and that weaving on a conventional loom at up to 250 p.p.m. is possible by attaching our equipment to the loom. Our initial aim was a loom with a speed of more than 400 r.p.m. for a 132-cm reed space, but this needs a much more efficient pooling device.

Reference

- [1] T. Sakamoto, N. Inui, T. Suzuki, M. Kurata and M. Inagawa; *J. Text. Mach. Soc. Japan*, 19, 124 (1966)