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THEORETICAL ASPECTS AFFECTING THE SERVICE LIFE OF TEXTILE AND SEWING TECHNOLOGICAL MACHINES

Rakhimberdiyev Dilmurod Obidxon ugli
Impuls medical institute

Abstract: The article analyzes the main theoretical factors affecting the service life of textile and sewing technological machines. The reliability of machines, wear processes, friction and lubrication parameters, as well as the impact of dynamic loads on resource indicators have been studied. Based on the research results, recommendations for increasing the service life of machines have been developed.

Keywords: service life, reliability, wear, friction, dynamic loads, maintenance, textile and sewing machines.

Introduction

In modern light industry enterprises, the service life of textile and sewing technological machines is of great importance in ensuring production efficiency. The long-term and continuous operation of machines directly determines product quality and production volume. This article provides an in-depth analysis of the theoretical aspects affecting machine resources.

The research objective is to identify the main theoretical factors determining the service life of textile and sewing machines and to study their interaction. This issue is relevant from the perspective of our republic's light industry development strategy.

Research methodology

The following theoretical methods were used in the research process: mathematical modeling of tribological processes, laws of reliability theory, methods for analyzing dynamic systems, and statistical processing methods. Theoretical research was conducted based on the analysis of modern scientific literature.

Results and discussion

Fundamentals of reliability theory

The service life of textile and sewing machines is directly related to their reliability indicators. According to reliability theory, the probability of a machine operating over time without failure obeys the following exponential distribution law:

$$R(t) = e^{-\lambda t}$$

where $R(t)$ is the reliability function, λ is the failure intensity, t is the operating time.

The mean time to failure (service life) is determined as follows:

$$T_{mean} = 1/\lambda$$

In the mechanical systems of sewing machines, failures mainly occur as a result of wear processes. The Weibull distribution more accurately describes machine resources:

$$R(t) = \exp[-(t/\eta)^\beta]$$

where η is the scale parameter, β is the shape parameter (typically β = 2-3 range).

Tribological processes and wear mechanisms

The service life of machines largely depends on the wear rate of friction pairs. Archard's equation expresses the wear volume as follows:

$$V = K \times P \times L / H$$

where V is the wear volume, K is the wear coefficient, P is the load, L is the sliding distance, H is the surface hardness.

The following main types of wear are observed in textile and sewing machines: abrasive wear (in needles, crochet hooks, shuttle mechanisms), adhesive wear (in bearings, drive gears), fatigue wear (under high-frequency cyclic loads), and corrosion-mechanical wear (under environmental influence).

For the needle system of sewing machines, the wear rate obeys the following empirical equation:

$$I = A \times n^{\alpha} \times p^{\beta} \times t$$

where I is the wear intensity, n is the sewing speed, p is the force acting on the needle, t is the time, A, α, β are material-dependent coefficients.

Friction and lubrication theory

The friction coefficient determines the machine's energy consumption and wear rate. In the hydrodynamic lubrication regime, Reynolds' equation is applied, where the lubricant film thickness is a function of μ - dynamic viscosity, U - velocity, P - pressure.

The elastohydrodynamic (EHD) lubrication regime occurs at high loads and speeds. The minimum lubricant film thickness:

$$h_{min} = 2.65 \times \alpha^{0.54} \times (\mu_0 \times U)^{0.7} \times R^{0.43} / (W^{0.13} \times E'^{0.03})$$

where α is the pressure-viscosity coefficient, μ_0 is the initial viscosity, R is the radius of curvature, W is the load, E' is the reduced elastic modulus.

Proper selection of lubrication parameters in high-speed bearings of textile machines can increase service life by 2-3 times.

Effect of dynamic loads

Dynamic loads play an important role in the operation of textile and sewing machines. Considering the mechanical system of the machine as a single-degree-of-freedom oscillating system:

$$m \times \ddot{x} + c \times \dot{x} + k \times x = F(t)$$

where m is the mass, c is the damping coefficient, k is the stiffness, F(t) is the variable force.

In resonance conditions, the amplification coefficient is determined as follows:

$$\mu = 1 / (2\zeta)$$

where ζ is the damping coefficient (typically ζ = 0.05-0.15).

Dynamic loads can be 3-5 times higher than static loads, which sharply increases the wear rate. When operating at speeds of 3000-5000 stitches/min in sewing machines, inertial forces have a significant effect.

Fatigue failure theory

Under cyclic loads, materials undergo fatigue failure. The Wöhler curve expresses the relationship between the number of cycles N and stress amplitude σ:

$$\sigma^m \times N = C$$

where m and C are constants dependent on material properties (m ≈ 9-12 for steel).

According to the Palmgren-Miner hypothesis, accumulated damage:

$$D = \Sigma(n_i / N_i)$$

Failure occurs at D = 1. Fatigue failures in the crank-connecting rod mechanisms of textile machines limit service life.

Temperature effect

The thermal energy generated as a result of friction:

$$Q = \mu \times P \times V$$

where μ is the friction coefficient, P is the pressure, V is the velocity.

High temperature reduces lubricant viscosity and accelerates oxidation processes. In high-speed mechanisms of sewing machines, temperature can reach 80-100°C, which reduces material strength by 15-20%.

Resource prediction models

To predict the residual service life of a machine, the following model is applied:

$T_{res} = T_0 \times (1 - I_{actual} / I_{critical})^n$

where T_0 is the initial resource, I is the parameter value (wear, vibration), n is the model coefficient.

In the modern approach, accurate resource prediction is possible through continuous monitoring of diagnostic parameters.

Conclusions and recommendations

The research results allow us to draw the following conclusions:

The service life of textile and sewing machines is a multi-factorial parameter resulting from the complex interaction of tribological processes, dynamic loads, material properties, and operating conditions. Wear processes are the main factor determining service life and are directly dependent on loads, speed, lubrication quality, and material properties.

The following measures are recommended to increase machine service life: application of high-quality lubricating materials and optimization of lubrication regime; avoidance of resonance frequencies and ensuring dynamic balance; use of modern wear-resistant materials and coatings; timely preventive maintenance and implementation of diagnostic systems.

In the future, the development of resource prediction systems using artificial intelligence and machine learning algorithms is an urgent task.

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