The Mechanical and Microstructure Study of Knitting Needle Materials

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Abstract

In order to improve the quality of the local knitting needles, the microstructure and chemical composition of all experimental needles were analyzed under SEM, EDS, and XRD. By comparing the service life and composition of the imported and domestic knitting needle, it was concluded that the service life of the domestic knitting needles was much shorter than the imported ones, along with a lower hardness. The result showed that all needles exhibited martensite matrix and sphere carbides. However, the morphology and amount of sphere carbides differs. As the more the carbides were spheroid, the higher the hardness reached, and the longer time the needles serviced. This paper also suggested by the results that a suitable content of Cr and Ni could improve the mechanical properties of the needle significantly.

Keywords

Knitting needle, material, chemical composition, hardness.

1. Introduction

Compared to others parts of the knitting machine, needles run the most frequently, correspondingly, the shortest life, and most likely to fail and damage. In the actual servicing process, the main failure forms of needle are mainly loosening of needle tongue, wear of needle tongue, pin, and body, and deformation and rupture of needle body. Due to the parts that the needle failed at, the failure formed could be categorized in root fracture, tongue rupture, tongue loose, tongue wear, hook abrasion, needle body wear broken, and deformation. Since the needle possess sharp, thin, small, light characteristics and other features, its production process requires more high dimensional accuracy; therefore, the needles of high flexibility, high wear resistance, high durability and service life are knitting needles quality problems [1]. Therefore, in order to improve the mechanical properties of the needle, the chemical composition and the optimum microstructure of the needles should be studied [2]. However, such research has barely been carried on. Therefore, this paper laid emphasis on the comparison of knitting needles, especially on their microstructure, chemical composition, and the mechanical properties. Final, chemical compositions were given for local companies to produce high quality needles.

2. Results

2.1 Investigation of serving time of the needles

Knitting needle material composed of two main elements iron and carbon [4].Through the survey of Germany, Japan and China, it was found that the needles were prone to have an early failure as shown in Table 1. By statistical analysis, the result showed that among all the failure models, the wear failure played a big role. The failure forms of needles produced in China had three types: (1) The needle tongue was early loosening. (2) There were grinding marks inside of the hook. (3) Pin became narrow due to milling.

The most logical reasons for these three failure form were wear. Wear was caused by the cutting and grinding of the abrasive grains, which were generated from the friction of contact surfaces when the relative movement took place. The wear was severe at the place where the needle groove wall and the tongue, the tongue and the tongue pin, hook and surface interactions yarn, pins and triangle caused relative movements. Those grains produced cutting action to the needle [5]. Therefore, to improve the wear resistance of the knitting needle, needle hook and pin was the main problem faced by needle factories.

Table 1. Life and Failure form of the Needle

Region	Service Life (month)			Failure Form
	Color polyester	Polyester	cotton	
Germany GROZ	2-3	12	10-12	Normal wear on every area of needle
Japan FUKUHARA	2	10	6-9	Normal wear on every area of needle
China	1	6-7	3-6	(1)Early loosening of the needle tongue (2) Grinding marks inside of the hook (3) Pin milled narrow

2.2 The hardness of the needles.

D Needle hardness determined the wear resistances of the needle in some degree. In order to further resolve why the hook parts were prone to fail, the hardness values of different positions of the needles were examined. The Rockwell hardness values of the table were converted from the Vickers hardness values, only as qualitative comparisons. Elasticity value was measured by STC measuring instrument. During this measurement, pressure upon the needle was to produce a constant bending deformation. The elasticity, shown in Table 2, was characterized by the residual deformation, large residual deformation indexing poor flexibility. The results illustrated that the higher the hardness, the longer the needle served.

Table 2. Performance of Needles After Heat Treatment

Region	Hardness (HRC)			Elasticity(Residual Deformation)
	Pinhook	Needle latch	needle groove	
Germany GROZ	61	60	59	0.02mm
Japan FUKUHARA	58	58	56	0.03mm
China	57	50	51	0.06mm

2.3 Microstructure analysis of knitting needles

SEM and EDS were used to investigate the microscope morphologies and distribution of the elements among the various phases in the needle products [5]. The microstructures of the needle were observed under both optical microscope and scanning electron microscope. The results were shown in Figure 1. It showed the optical microscope image of the needle, and the secondary electron image.

Figure 1. Microstructure analysis of German needles (a) Optical microscope, (b) SE (secondary electron), and (c) the X-ray energy spectrum

It is clear that microstructure was composed of martensite matrix with sphere carbides as shown in Figure 1. The amount of sphere carbides was huge, and they diffused and distribute uniformly among the matrix. The sphere carbides were analyzed by spot scanning. The scanning position was stamped as Figure 1(b). The corresponding weight of the elements of the spot was individually shown in Table 3. The X-ray diffraction experiment was carried out. Two sets of diffraction peaks were appeared, as shown in Figure 1(c). Therefore, it could be conclude that the microstructure was composed of ferrite phase and cementite phase, while the retained austenite content was below 2% that X-ray diffraction could not detects.

Table 3 illustrated the composition of the carbides. It was shown that the carbon content was around 1.0%. It was known that with the increase of carbon content, the amount of dissolved carbon in martensite would increase, so did the hardness. However, if the carbon content was too high, eutectic cementite components would increase, which would result in reducing the toughness, ductility and cold formability. It exhibited high content of carbon as much as 11.84wt%, which ensured the high hardness and excellent wears resistance. Chromium in Table 3 reached 0.81 wt%. Chromium can significantly improve the steel hardenability. The quench rate could reduce 100 Kelvin per second, if 0.4 wt% of chromium was added to 1.0 wt% carbon steel. That was to say, needle quenching performance could be sufficiently improved. Manganese could reduce driving force of martensitic transformation. It played more important part in stabilizing austenite than nickel. 2.06 wt% of manganese could significantly increase martensite strength and strain hardening rate in the experimental steel.

Table 3. Chemical composition of the sphere carbides (%)

Element	Weight%	Atomic%
C	11.84	38.42
Cr	0.81	0.61
Mn	2.06	1.46
Fe	85.28	59.51
Total	100.00	100.00

2.4 coating surface knitting needles

Under the scanning electron microscope, we found that the surface plated chromium layer was approximately 10um thick in the coating surface of the needle. Coating morphology and EDS analysis results were shown in Figure 2 and Table 4. Figure 2 showed the thickness of needle coating surface. The weight and atomic contents of the elements in the coating surface were listed in Table 4. It was found that the chromium content in coating surface was more than that in the matrix. In order to increase the needles rust resistance and improve the wear resistance of the needles, chromium was about 88.05 wt% and 64 atomic%.

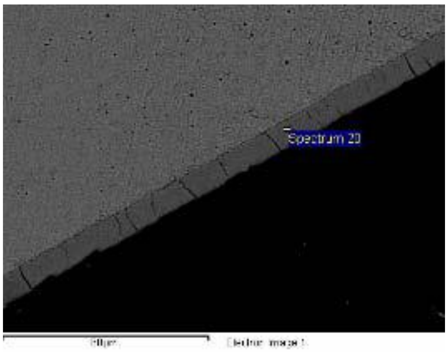

Figure 2 Chemical analysis of needle coating

Table 4. Analysis of coating surface of Germany needle

Element	Weight%	Atomic%
C	11.13	35.17
Cr	88.05	64.27
Fe	0.82	0.56
Totals	100.00	100.00

3. Conclusion

The following conclusions can be drawn from the analysis results above:

(1) The higher the hardness, the longer the needle serves.

(2) The microstructure of needle material is composed of martensite matrix and large amount of sphere carbides, which together ensure the high hardness and excellent wears resistance.

(3) According to the testing results of all experimental needles, and considering all revolving factors, it is suggested that the optimum chemical composition is: carbon content in 0.75 ~ 0.90, Si content in 0.17 ~ 0.22, Mn content in 0.40 to 0.45, and P, S content under strict control.

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