Research Article
Experimental Analysis of Residual Stress and Bending Strength of Gear Tooth Surface after Shot Peening Treatment

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Received 14 January 2020; Revised 12 May 2020; Accepted 23 May 2020; Published 10 June 2020

Academic Editor: Sundararajan Natarajan

The fatigue strength of a gear tooth surface is affected by various factors, which subsequently impacts the transmission performance of gears. Usually, shot peening treatment is carried out during processing to improve the performance of gears. Most current studies focus on theoretical descriptions and simulation analyses of shot peening treatment. However, in this paper, the relationships among shot peening treatment, residual stress, and bending fatigue strength of a gear tooth surface are discussed, through experimental methods. Based on X-ray stress analysis, at select locations on the test samples, the residual stresses on gear tooth surfaces with and without shot peening treatment are determined and contrasted. The results show that shot peening treatment can effectively increase the residual stress on gear tooth surfaces. In addition, an electromagnetic resonance fatigue tester is used to analyze the bending fatigue strength of gear tooth surfaces. The test results indicate that the bending fatigue strength of the gear teeth with shot peening is higher than that of the gear teeth without shot peening. The obtained conclusions lay the foundation for further practical engineering applications of gears.

1. Introduction
Residual stresses in the parts are caused by various kinds of elastic and plastic deformation in the machining process [1]. The formation of residual stress is related to the material, shape, forming, and processing technology of a part, and residual stresses usually cannot be directly determined through formulas or empirical evidence. Residual stress greatly influences the fatigue strength, stress corrosion, and shape accuracy of the parts. In recent years, many scholars have used different principles and methods to conduct studies pertaining to residual stress, including the measurement and calculation of residual stress, analyses of residual stresses in key parts during service, and analyses of residual stresses in new materials and new technology [2–12].

Gear transmissions are an important part of the modern industry. Related research has gradually focused on producing high-speed, heavy-duty, long-life, and low-cost gear transmissions. Shot peening treatment is usually used in gear processing to provide improved fatigue strength. At present, there are in-depth studies on shot peening strengthening that review the development of traditional shot peening machines and discuss new shot peening methods, such as laser impact technology and ultrasonic impact technology [13–17]. Scholars have found that shot peening treatment can improve material performance because of the residual compressive stress distributed on the part surface. However, the relationship between shot peening and residual stress and the relationship between residual stress and gear performance have gradually become the research focus in recent years.

Due to the limitations in experimental conditions, most studies on the relationship between shot peening and residual stress have been made based on finite element
simulation analysis or residual stress measurement with mechanical methods. For studies on gear strength, summarized conclusions have been obtained, but there is little specific experimental data to analyze.

In this paper, gears are subjected to shot peening treatments, wherein the shot peening variables are controlled during processing; other gears from the same batch are not subjected to shot peening and are used as a comparison. Furthermore, experimental studies based on an X-ray stress analyzer and an electromagnetic resonance fatigue tester is proposed. The results from these studies are utilized to determine the relationships among shot peening strengthening, residual stress, and bending strength of gears.

2. Residual Stress Comparison Test

2.1. Experimental Scheme. The gear material used in this experiment was 20CrMnMo, which has good comprehensive mechanical properties. The basic design parameters of the gears are shown in Table 1.

Fifty gears from the same batch were randomly selected and divided into groups A and B. For group A, shot peening treatment was performed on the tooth root after processing, whereas group B was not subjected to a shot peening treatment. Table 2 shows the parameters and the standard used in the shot peening process.

After performing the shot peening procedure, measurements were carried out using a Proto-iXRD type X-ray stress analyzer. Three gears were randomly selected from group A and group B. Locations T1, T2, and T3 were also determined along the outer circle of the gear, wherein these locations are separated by 120°. Moreover, two test points were selected for each position. The stress analysis site is shown in Figure 1.

2.2. Residual Stress Test. The detected residual stresses on the gear surface for group A and group B are displayed in Table 3.

The absolute value of the maximum stress difference between test point 1 and test point 2 was 41 MPa. Obviously, the residual stress was higher on the shot peened gear surface with shot peening treatment than on the gear surface without shot peening treatment. The increases in residual stress varied because of the randomness of the residual stress distribution. To evaluate the overall improvement level, we used the average residual stress as a comparison. The average stresses of group A and group B were −585.833 MPa and −513.278 MPa, respectively. Compared with group B, group A had 14% higher residual strength. Thus, shot peening treatment can effectively increase the residual stress in gear teeth.

3. Analysis of the Bending Strength of Shot Peened Gear Teeth

Usually, a gear tooth can be simplified as a cantilever beam under the working condition. Given the normal load on gear teeth, bending stresses will occur on the root of the teeth; as a result, cracks often appear due to the serious stress concentrations. With continuous crack propagation, whole teeth or parts of teeth may fracture [18].

In this section, an analysis of shot peening treatment on the bending strength of gear teeth is discussed by means of experimental comparisons.

3.1. Experimental Scheme. This experiment adopted a high-frequency pulsation gear test, wherein the tested gear is always in a state of rest within the testing apparatus. Moreover, the pressure head applied a pulsating cyclic load on the tested gear teeth to allow the gear teeth to break off. The test equipment used for this test was a Zwick/Amsler 250 HFP 5100 electromagnetic resonance fatigue testing machine (Germany), as shown in Figure 2. The testing machine possessed a high loading precision: the static-dynamic loading was ±0.5%, the static loading range was ±150 kN, and the dynamic unidirectional pulsation was ±125 kN. The loading frequency range was 35–300 Hz.

According to GB/T 14230-1993 [19], the following can be determined through calculations and simulations with the tested gear parameters while the gear was clamped. The test was performed on five teeth of the tested gears. The distance between the high point of action and the low point of action was 68.523788 mm, which was the same as the length of the common normal line spanning 5 teeth. The dimensional error during installation was controlled within ±0.1 mm.
This test adopted group and staircase methods. The test load can also be divided into four load levels. The group method was used to determine the diagonal part of the P–S–N curve, and the staircase method was used to determine the straight line in the curve.

The test load was set in accordance with GB/T14230-1993. The number of bending stress cycles of each test point at the highest stress level was ≥ 0.5 × 10^5. Random sampling in all products can reflect the general features. The test aimed to fully utilize each gear tooth and minimize the mutual effect of loading gear teeth. Two gear teeth separated every two tested gear teeth, and each loaded gear tooth was numbered accordingly. The tested gears can be divided into two categories under three kinds of numbering, which adhered to the following principles:

1. In this test, a gear with shot peening treatment was an A series and a gear without shot peening treatment was defined as a B series.
2. According to the test order of the same gear series, the tested gear teeth were numbered as 1, 2, 3, etc.
3. The test load level was labeled.

| Gear number | Gear location | Test point 1 (N) | Test point 2 (N) | Absolute value of difference [Δ] (N) |
|-------------|---------------|-----------------|-----------------|-------------------------------------|
| B1          | T1            | 498             | 518             | 20                                  |
| B1          | T2            | −531            | −521            | 10                                  |
| B1          | T3            | −540            | −535            | 5                                   |
| A1          | T1            | −621            | −612            | 9                                   |
| A1          | T2            | −572            | −551            | 21                                  |
| A1          | T3            | −621            | −611            | 10                                  |
| B2          | T1            | −511            | −491            | 20                                  |
| B2          | T2            | −507            | −488            | 19                                  |
| B2          | T3            | −538            | −562            | 24                                  |
| A2          | T1            | −565            | −553            | 12                                  |
| A2          | T2            | −516            | −529            | 13                                  |
| A2          | T3            | −586            | −577            | 9                                   |
| B3          | T1            | −501            | −486            | 15                                  |
| B3          | T2            | −499            | −504            | 5                                   |
| B3          | T3            | −511            | −498            | 13                                  |
| A3          | T1            | −637            | −596            | 41                                  |
| A3          | T2            | −557            | −565            | 8                                   |
| A3          | T3            | −639            | −637            | 2                                   |

**Table 3: Detected residual stresses.**

**Table 4: Calculation parameters of tooth root stress.**

| Symbol | Value |
|--------|-------|
| B      | 50 mm |
| m      | 5 mm  |
| Y_{SA} | 1.836 |
| Y_{FA} | 2.482 |
| Y_{ST} | 2     |
| Y_{RdT}| 1     |
| Y_{RoT}| 1.12  |

(1) In this test, a gear with shot peening treatment was an A series and a gear without shot peening treatment was defined as a B series.

(2) According to the test order of the same gear series, the tested gear teeth were numbered as 1, 2, 3, etc.

(3) The test load level was labeled.
For example, B1-1-78kN means testing the first tooth of the No. 1 gear without shot peening treatment with a load of 78 kN.

The tested gear teeth were in a certain order of test. The high working teeth were numbered 1, 2, 3, and 4, whereas the corresponding low working teeth were numbered 1', 2', 3', and 4'.

### Table 5: Bending fatigue test load of the gear.

| Stress level                  | I     | II    | III   | IV    |
|-------------------------------|-------|-------|-------|-------|
| Load value (kN)               | 78    | 75    | 73    | 72    |
| Calculated tooth root stress (MPa) | 579.15 | 556.88 | 542.03 | 534.60 |
| Pulsating tooth root stress (MPa) | 560.80 | 538.84 | 524.21 | 516.90 |
| Mean test load (kN)           | 40.950| 39.375| 38.325| 37.800|
| Test dynamic load (kN)        | 37.050| 35.625| 34.625| 34.200|
| $F_{\text{min}}$ (kN)         | 3.90  | 3.75  | 3.65  | 3.60  |
| $F_{\text{max}}$ (kN)         | 78    | 75    | 73    | 72    |

### Table 6: Data processing of the bending fatigue test of the gear.

| Ordinal number | Fatigue life at different stress levels |
|----------------|----------------------------------------|
| Lifetime       | No. | Lifetime | No. | Lifetime | No. | Lifetime | No. |
| 1              | 52001 | B2-4-78  | 80295 | B16-2-75 | 189195 | B19-1-73 | 803965 | B1-3-72 |
| 2              | 54434 | B13-4-78 | 150568 | B6-2-75  | 532257 | B18-2-73 | 925469 | B5-2-72 |
| 3              | 66220 | B13-1-78 | 164084 | B18-1-75 | 879460 | B15-4-73 | 1346204 | B4-3-72 |
| 4              | 81369 | B1-1-78  | 224971 | B9-2-75  | 1057880 | B2-2-73  | 2181065 | B4-2-72 |
| 5              | 91155 | B11-4-78 | 695260 | B11-2-75 | 1515670 | B15-1-73 | 2395745 | B5-4-72 |
| 6              | 154634 | B9-1-78 | 712435 | B5-1-75  | 1721448 | B17-2-73 | 2857876 | B11-3-72 |
| 7              | 170261 | B16-3-78 | 1020368 | B8-4-75  | 1811442 | B7-4-73  | 3000000 | B19-2-72 |

### Table 7: Distribution test results.

| Lifetime distribution | Lifetime correlation coefficients ($R$) at different stress levels |
|-----------------------|---------------------------------------------------------------|
|                       | 560.80       | 538.84       | 524.21       | 516.90       |
| Lognormal distribution | 0.9615     | 0.9634     | 0.9296     | 0.9667     |
| Three-parameter weibull distribution | 0.9886 | 0.9758 | 0.9725 | 0.9765 |

### Table 8: Fitting parameters.

| Stress level | Shape parameter ($M$) | Scale parameter ($\eta$) | Location parameter ($r$) |
|--------------|-----------------------|--------------------------|--------------------------|
| 560.80       | 0.6154                | 43533                    | 50889                    |
| 538.84       | 0.7019                | 37900                    | 66318                    |
| 524.21       | 1.2976                | 1316760                  | 0                        |
| 516.90       | 0.7735                | 1149989                  | 728240                   |

### Table 9: Bending fatigue test load of the gear.

| Stress level                  | I     | II    | III   | IV    |
|-------------------------------|-------|-------|-------|-------|
| Load value (kN)               | 74    | 72    | 70    | 68    |
| Calculated tooth root stress (MPa) | 549.45 | 534.60 | 519.75 | 504.90 |
| Pulsating tooth root stress (MPa) | 531.52 | 516.90 | 502.30 | 487.70 |
| Mean test load (kN)           | 38.85 | 37.80 | 36.75 | 35.70 |
| Test dynamic load (kN)        | 35.15 | 34.20 | 33.25 | 32.30 |
| $F_{\text{min}}$ (kN)         | 3.7   | 3.6   | 3.5   | 3.4   |
| $F_{\text{max}}$ (kN)         | 74    | 72    | 70    | 68    |
The gear teeth labeling is shown in Figure 3.

The criteria for stopping the bending fatigue test are as follows.

During the test, if one of the following conditions occurs, then the bending is terminated:

1. Fatigue cracks observed in the tooth root.
2. The load or frequency dropped by 5%–10%.
3. The tooth broke along the root. If the gear does not fail within the $3 \times 10^6$ stress cycle, then the test will also be stopped.

3.2. Tooth Root Stress Calculation. According to the load capacity calculation method for an involute cylindrical gear [20], the equation for tooth root stress calculation is shown as follows:

$$\sigma_F' = \frac{F_t \cdot Y_{FA} \cdot Y_{SA}}{b \cdot m \cdot Y_{ST} \cdot Y_{relT} \cdot Y_{relT} \cdot Y_x} \quad (1)$$

where $F_t$ is the nominal tangential force of the pitch circle in the end face (N), $b$ is the tooth width, $m$ is the tooth modulus, $Y_{FA}$ is the tooth profile coefficient of the action point of the gear teeth under load, $Y_{SA}$ is the stress correction coefficient of the action point of the gear teeth under load, $Y_{ST}$ is the stress correction coefficient of the test gear, $Y_{relT}$ is the relative sensitivity coefficient of the root fillet, $Y_{relT}$ is the relative condition coefficient of the root surface, and $Y_x$ is the bending strength calculation dimension coefficient.

Table 4 shows the parameters settings for the calculation of the root stress in this test.

Substituting the parameter values into the equation above indicated that the relationship of root stress and load is as follows:

$$\sigma_F = \frac{F_t \cdot Y_{FA} \cdot Y_{SA}}{b \cdot m \cdot Y_{ST} \cdot Y_{relT} \cdot Y_{relT} \cdot Y_x} = 0.007425 F_t \quad (2)$$

Due to the limitations in the test equipment, the loading pressure head created instability in the clamp and the test piece. Therefore, to avoid this instability effect, a certain minimum load, which is the cyclic performance coefficient $R = F_{min}/F_{max}$, is maintained in the test. The actual root stress should be converted to the pulsating cycle root stress $\sigma_F$ when $R = 0$. The conversion equation is as follows:

$$\sigma_F = \frac{(1 - R)\sigma_F'}{1 - R(\sigma_b/(\sigma_b + 350))}, \quad (3)$$

where $\sigma_b$ is the tensile strength (N/mm²).

3.3. Bending Fatigue Strength Test of the Gear without Shot Peening Treatment

3.3.1. Test with Group Method and Data Processing. Through the gear root stress calculations and the preliminary experiments, the experimental load with the group method was determined, as shown in Table 5.

The results of the test with the group method are shown in Table 6.

Lognormal distribution and three-parameter Weibull distribution tests were performed on the fatigue life at the load levels above.
Weibull distribution is derived from the weakest link model. It can be simply described that a chain is formed by many chain links in series. When both ends are under tension, any one of the links breaks and the chain fails. Obviously, the chain fracture occurs in the weakest link. The life of components, parts, devices, and equipment stopping whole running due to a certain local failure can be regarded as following the Weibull distribution, while the fatigue strength, fatigue life, and wear life in machinery mostly follow the Weibull distribution. The probability density function and distribution function of three-parameter Weibull distribution are defined as

\[
\begin{align*}
    f(x) &= \frac{\beta}{\eta} \left( \frac{x - \gamma}{\eta} \right)^{\beta - 1} \exp \left( -\left( \frac{x - \gamma}{\eta} \right)^{\beta} \right), \\
    F(x) &= 1 - \exp \left( -\left( \frac{x - \gamma}{\eta} \right)^{\beta} \right),
\end{align*}
\]

where \( \eta \) is the scale parameter, \( \beta \) is the shape parameter, and \( \gamma \) is the location parameter.
where $\beta$, $\gamma$, and $\eta$ are three parameters for describing Weibull distribution, $\beta$ is a shape parameter, which determines the shape of the distribution curve, $\gamma$ is a position parameter and it determines the starting position of the distribution curve, and $\eta$ is a scale parameter, which reflects the dispersion of the life data.

The correlation coefficients ($R$) were calculated, and the results are shown in Table 7.

The three-parameter Weibull distribution exhibited the best fitting effect on the bending fatigue life of the gear. Thus, the three-parameter Weibull distribution calculation in each stress level is shown in Table 8.

The position parameter $r$ showed that the lifetime of the gear without shot peening treatment followed the three-parameter Weibull distribution at stress levels I, II, and IV. This gear also followed the two-parameter Weibull distribution at stress level III.

### Table 13: Data processing of the gear bending fatigue life.

| Ordinal number | Fatigue life at different stress levels |
|----------------|-----------------------------------------|
|                | I No. | II No. | III No. | IV No. |
| 1              | 50892 A8-4-81 | 141594 A10-3-78 | 190347 A1-2-76 | 543860 A17-3-75 |
| 2              | 79582 A7-2-81 | 156529 A6-1-78 | 194017 A2-2-76 | 726517 A19-2-75 |
| 3              | 111899 A7-3-81 | 251908 A2-1-78 | 241713 A8-1-76 | 1227752 A6-2-75 |
| 4              | 112428 A3-4-81 | 269224 A17-2-78 | 278029 A1-1-76 | 1324990 A10-3-75 |
| 5              | 124084 A10-2-81 | 342719 A7-4-78 | 811387 A4-1-76 | 1748937 A4-2-75 |
| 6              | 156865 A11-1-81 | 376832 A11-2-78 | 1125686 A1-3-76 | 1939033 A15-2-75 |
| 7              | — — — — | — — — — | 1401843 A2-4-76 | 2057398 A17-4-75 |

### Table 14: Distribution test results.

| Lifetime distribution | Lifetime correlation coefficients ($R$) at different stress levels |
|-----------------------|--------------------------------------------------------------|
| Lognormal distribution | 582.81 560.80 546.16 538.84 |
| Three-parameter Weibull distribution | 0.9524 0.9644 0.9323 0.9734 |
| Three-parameter Weibull distribution | 0.9767 0.9676 0.9816 0.9707 |

### Table 15: Fitting parameters.

| Stress level | Three-parameter Weibull distribution parameters |
|--------------|-----------------------------------------------|
|              | Shape parameter ($M$) | Scale parameter ($\eta$) | Location parameter ($r$) |
| 582.81       | 2.5720 | 123053 | 0 |
| 560.80       | 2.5528 | 292756 | 0 |
| 546.16       | 0.3518 | 279014 | 189939 |
| 538.84       | 2.0620 | 1585335 | 0 |

### Table 16: Bending fatigue test load of the gear.

| Stress level | Load value (kN) | Calculated tooth root stress (MPa) | Pulsating tooth root stress (MPa) | Mean test load (kN) | Test dynamic load (kN) | $F_{\text{min}}$ (kN) | $F_{\text{max}}$ (kN) |
|--------------|-----------------|------------------------------------|-----------------------------------|---------------------|-----------------------|----------------------|----------------------|
|              | 75              | 556.88                             | 538.84                            | 38.85               | 35.15                 | 3.7                  | 75                   |
|              | 74              | 549.45                             | 531.52                            | 37.80               | 34.20                 | 3.6                  | 74                   |
|              | 73              | 542.03                             | 524.21                            | 36.75               | 33.25                 | 3.5                  | 73                   |
|              | 72              | 534.60                             | 516.90                            | 35.70               | 32.30                 | 3.4                  | 72                   |

3.3.2. Test with Staircase Method and Data Processing. The test loads with the staircase method are shown in Table 9.

The test data with the staircase method are shown in Table 10.

Table 10 shows that the test from the 6th testing point through the 18th testing point satisfies the following stability error condition:

$$\sigma_n \leq 0.5\%.$$ (5)
The up-and-down test results obtained with the staircase method are shown in Figure 4. The total number of samples was 18, of which 9 broke.

The median load of this gear can be obtained as $F = 70.5 \text{kN}$ through calculation with the staircase method. The median fatigue strength of the gear is shown as follows:

$$\sigma_{A50} = 505.95 \text{ MPa}.$$ (6)

The $P-S-N$ curve of the bending fatigue strength of the gear without shot peening treatment is displayed in Figure 5. According to the results in the figure above, the ultimate bending strength of the gear without shot peening treatment under different degrees of reliability is shown in Table 11.

3.4. Bending Fatigue Strength Test for the Shot Peened Gear

3.4.1. Test with Group Method and Data Processing. The test loads were determined, as shown in Table 12. The results of the test with group method are displayed in Table 13.

Lognormal distribution and three-parameter Weibull distribution tests were also performed on the fatigue life at the load levels above. The $R$ values are shown in Table 14.

The three-parameter Weibull distribution exhibited the best fitting effect on the bending fatigue life of the gear. Thus, the three-parameter Weibull distribution calculation at each stress level is depicted in Table 15.

The location parameter showed that the bending fatigue life of the shot peened gear followed the two-parameter Weibull distribution at stress levels I, II, and IV and followed the three-parameter Weibull distribution at stress level III.

3.4.2. Test with Staircase Method and Data Processing. Through preliminary tests with the test data collected from the group method, the test loads with the staircase method were obtained, as shown in Table 16. The results of the test with the staircase method are also shown in Table 17.

Table 17 shows that the staircase test from the 3rd testing point through the 16th testing point satisfies the stability error $\sigma_n \leq 0.5\%$.

Table 17: Stability test data.

| No. | Sample no. | Load value $F_N$ (kN) | Lifetime $(N \times 10^5)$ | $F_N = \left(1/n\right) \sum_{i=1}^{n} F_i$ | $\sigma_n = \left|\left[F_n - F_{n-1}\right]/F_n\right|$ |
|-----|------------|-----------------------|---------------------------|------------------------------------------|------------------------------------------|
| 1   | A13-2-75   | 75                    | 3.83                      | 75.00000                                 | 0.06710                                  |
| 2   | A13-1-74   | 74                    | 30.00                     | 74.50000                                 | 0.002232                                 |
| 3   | A12-1-75   | 75                    | 3.49                      | 74.66667                                 | 0.002240                                 |
| 4   | A13-3-74   | 74                    | 30.00                     | 74.50000                                 | 0.002240                                 |
| 5   | A12-2-75   | 75                    | 3.54                      | 74.60000                                 | 0.001340                                 |
| 6   | A16-1-74   | 74                    | 6.09                      | 74.50000                                 | 0.001340                                 |
| 7   | A6-3-73    | 73                    | 30.00                     | 74.28571                                 | 0.002880                                 |
| 8   | A14-2-74   | 74                    | 3.57                      | 74.25000                                 | 0.000480                                 |
| 9   | A20-1-73   | 73                    | 30.00                     | 74.11111                                 | 0.001870                                 |
| 10  | A20-2-74   | 74                    | 30.00                     | 74.10000                                 | 0.001500                                 |
| 11  | A20-3-75   | 75                    | 1.65                      | 74.18182                                 | 0.001103                                 |
| 12  | A14-1-74   | 74                    | 6.25                      | 74.16667                                 | 0.000200                                 |
| 13  | A6-4-73    | 73                    | 7.89                      | 74.07692                                 | 0.001210                                 |
| 14  | A4-4-72    | 72                    | 30.00                     | 73.92857                                 | 0.002010                                 |
| 15  | A12-4-73   | 73                    | 30.00                     | 73.86667                                 | 0.000840                                 |
| 16  | A20-2-74   | 74                    | 30.00                     | 73.87500                                 | 0.000113                                 |

![Figure 6: Test results with the staircase method.](image)

The up-and-down test results with the staircase method are shown in Figure 6. The total number of samples was 16, of which 8 broke.

The median load of this type of gear can be obtained as $F = 73.875 \text{kN}$ through calculation with the staircase method. The median fatigue strength of the gear is shown as follows:

$$\sigma_{A50} = 530.61 \text{ MPa}.$$ (7)

The $P-S-N$ curve of the gear with shot peening treatment is displayed in Figure 7. Table 18 shows the ultimate bending strength of the gear with shot peening treatment under different degrees of reliability, according to Figure 7.

3.5. Results and Discussion. In accordance with reliability theory, the $P-S-N$ curves of the gears with and without shot peening treatment and the bending fatigue strength of these gears under different reliability degrees can be obtained. The results are summarized in Table 19.

The shot peening treatment increased the bending fatigue strength by $14.35\%$ at a reliability degree of $99\%$. The residual stress test indicated that the residual compressive stress in the shot peened gear roots (group A) was $14\%$ higher than that of gear roots without shot peening (group B). The mean values of the gear residual compressive stress with and without shot peening were $-585.5 \text{ MPa}$ and $-530.61 \text{ MPa}$, respectively.
The relationships among shot peening treatment, residual stress, and bending fatigue strength of the gear tooth surface were discussed based on the experimental study in this paper. Based on X-ray stress analysis, the residual stresses on gear tooth surfaces with and without shot peening treatment were determined and contrasted. The average residual stress in group A (shot peening treatment) and group B (without shot peening treatment) were \(-585.833\) MPa and \(-513.278\) MPa, respectively, illustrating that shot peening produced a 14% increase in residual stress. Thus, shot peening treatment can effectively improve the residual stress of gear teeth. The bending fatigue strength of the gear tooth surfaces was also analyzed with an electromagnetic resonance fatigue tester. The test results indicated that the bending fatigue strength of the gear teeth with shot peening was higher than that of gear teeth without shot peening; the shot peening treatment increased the bending fatigue strength of the gears by 14.35% at a reliability degree of 99%. Therefore, the data showed that the residual compressive stress layer distributed at the root of the gear teeth after shot peening treatment can effectively increase the gear tooth bending fatigue strength.
peening treatment can effectively increase the gear tooth bending fatigue strength.

**Data Availability**

All data generated or analyzed during this study are included within this article.

**Conflicts of Interest**

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Acknowledgments**

The research was supported by the National Natural Science Foundation of China (Grant no. 51975078), Fundamental Research and Frontier Exploration Program of Chongqing City (Grant no. cstc2018jcyjAX0029), and Science and Technology Research Program of Chongqing Municipal Education Commission (Grant nos. KJQN201902502 and KJQN201900736). The financial support is gratefully acknowledged.

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