CALCULATED DETERMINATION OF OPTIMUM PEENING CONDITIONS IN TERMS OF COLLISION ENERGY ON COIL SPRING BY SHOT PEENING

2005063

A. Amano, T. Sakakibara and M. Wakita

Chuo Spring Co., Ltd., JAPAN

ABSTRACT

This subject focuses on the simulated shot peening analysis of the collision energy and simulated collision energy distribution on coil spring. The authors studied hit condition by changing peening angle. There have been no reports that describe an analysis on the simulated shot peening effect on the helical-shaped whereas reports on flat material exist (Watanabe, 1995) (Fathallah, 1998). In this paper, shot size, peening angle, and spring wire overlapping are considered. The optimum peening angle is computed in case where a coil spring does not move (but self-rotates along its center axis only), and the collision energy distribution is also calculated in case where the spring moves about. The effectiveness of this analysis is verified in comparison with the previous test result where light was used to check the shadow of shot shower.

SUBJECT INDEX

Peening condition, Collision energy, Coil spring

INTRODUCTION

In regards to compression coil springs such as engine valve springs in automobiles, the stress from load applied to the springs is higher on the inner-surface of the coils than on the outer-surface, and the starting-point of crack is often initiated from the inside of the coil. Therefore, when conducting shot peening, it is important to aim the shot so it hits the inside of the coil. In an effort to discover the optimum peening angle which would allow a collision to evenly impact the inside the coil spring, the variation of collision energy on the inside of the coil according to different angles of projection was calculated. Peening conditions (peening angle of shot, shot size), the size of the coil spring (wire diameter, coil diameter, pitch angle), and the effect of spring-wire overlap were all monitored and evaluated.

The peening angle becomes random in case where the spring moves about. Computations on the collision energy distribution identified the areas on the spring surface that were less shot peened in such a case.

A report from Hirose et al. (Hirose, 1983) discusses collision energy during shot peening. Photodiodes were placed on the inside and outside of a coil spring-shaped model. The ratio of light energy absorption (the ratio of energy on the inside and outside of the coil) was sought by measuring the light energy absorbed on the inside and outside of the coil. Validation of the effectiveness of our simulation method was achieved through a comparison of our results with those obtained by Hirose et al.

CALCULATION METHOD

Shot Diameter Effect (Mitsubayashi, 1995)
Differences in shot diameter sizes may result in a misalignment between the shot path and the collision area. Considering the shot to be the material point, we conducted our calculations supposing that there was a hypothetical spring external diameter in the location where the spring wire diameter was widened only for the shot diameter. (Fig.1)

Wire Overlap Effect
It is difficult to aim the shot so that it strikes the inside of a coil spring. Fig.2 shows the spring from the perspective of the nozzle. One can see that there are areas where interference from other part of same spring prevents the shot from striking the inside of the spring. The effect of wire overlap on shot obstruction was studied.

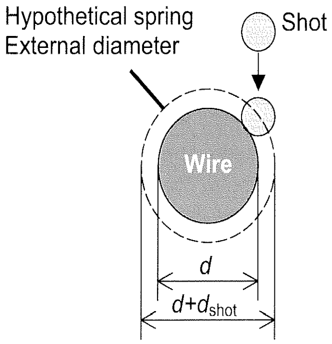


Fig.1 Sectional view

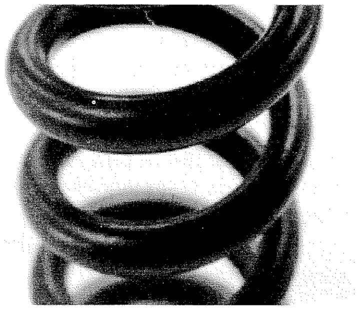


Fig.2 Spring wire overlap

Judgment of wire overlap (Fig.3)
It is considered that the form of a spring is the trajectory of sphere K. K's diameter is spring wire diameter plus shot diameter.

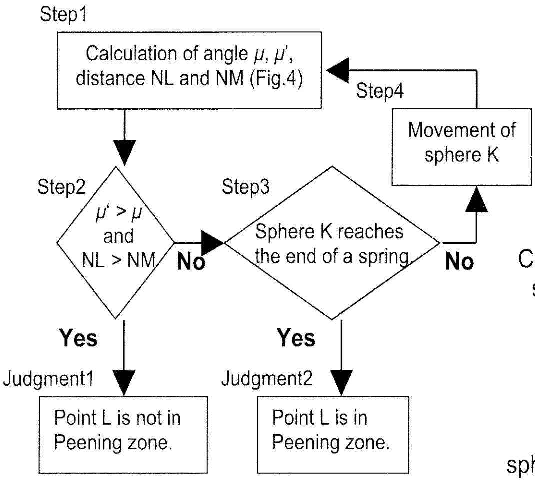


Fig.3 Flow of judgment of wire overlap

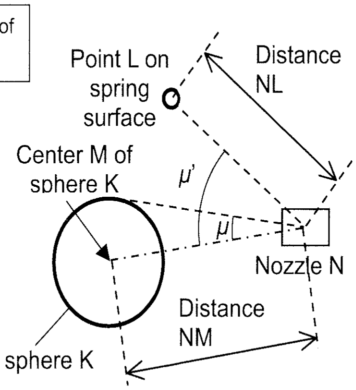


Fig.4 Angle μ, μ', distance NL and NM

COLLISION ENERGY

Collision Energy Per Shot

Collision energy given to the spring surface is the difference of the movement energy of a shot before the collision, and after the collision (Fig. 5). Thus collision energy per shot is

$$E = \frac{mV^2}{2} - \frac{m\left((V\sin\psi)^2 + (kV\cos\psi)^2\right)}{2} \qquad (1)$$
$$= \frac{m\,(1-k^2)\,V^2\cos^2\psi}{2},$$

where k is coefficient of restitution.

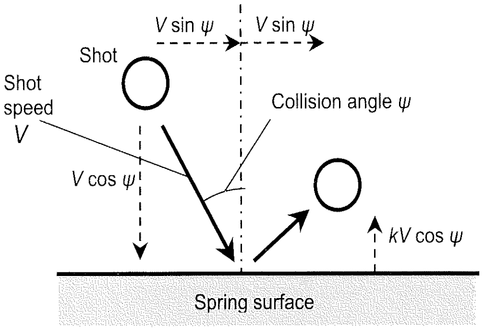


Fig. 5 Collision energy

Collision Energy

Since Collision energy is proportional to collision frequency and collision energy per shot, Collision energy is proportional to $V^2\cos^3\psi / r^2$.

OPTIMUM PEENING ANGLE

The difficulty of striking the inside of the coil spring with a shot peening varies according to the peening angle. A calculation of the peening angle allowing the shot to most easily strike the inside of coil was conducted.

Optimum Peening Angle

The calculation of a peening angle optimum for reducing variation in collision on the inside of the coil was performed. Emax represents the maximum collision energy inside the coil after adjustment of the peening angle, and Emin represents the minimum collision energy inside the coil after adjustment of the peening angle. Coil energy variation is defined as (Emax – Emin)/(Emax + Emin) x 100[%]. The formula is defined so that the collision energy is considered to be 0 (the shot misses) when the collision energy variation is 100%.

Only the inside ($\theta = 180°$) of the coil has been considered up to this point. The inside surface of the coil is defined as a range in which θ lies between 120° to 240° (Fig. 6), and a peening angle that minimized the variation of collision energy within that range was sought.

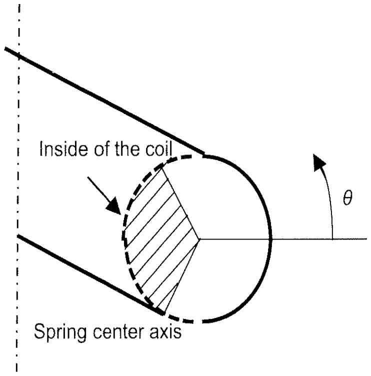


Fig. 6 Inside of coil

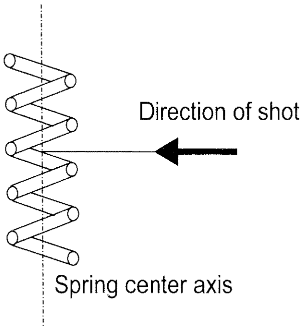


Fig. 7 Optimum peening angle for 1 nozzle

Use of 1 nozzle

The distribution of collision energy on the inside of the coil when one nozzle is used ceases to be symmetrical when the peening angle moves away from 0°. A peening angle of 0° (Fig. 7), has minimal collision energy variation. Additionally, at a peening angle of 0°, there is also minimal spring wire overlap.

Use of 2 nozzles

From the perspective of the symmetry in collision energy distribution, the absolute values of the two peening angles are the same. It is necessary to give them opposite notation (Fig. 8). Absolute values are employed to indicate the peening angle, since only the notation used for the two nozzles differs. Calculations of each pitch angle according to our definition of the optimum peening angle, which is the angle of minimum collision energy variation, are shown in Fig. 9. The optimum peening angle varies according to the pitch, but if pitch is considered to range from 0~20°, the optimum peening angle is about 35°.

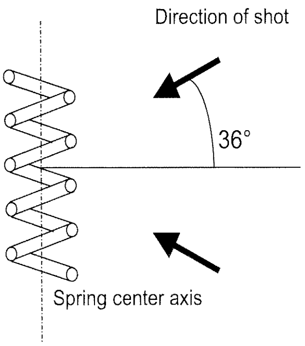


Fig. 8 Optimum peening angle for 2 nozzles

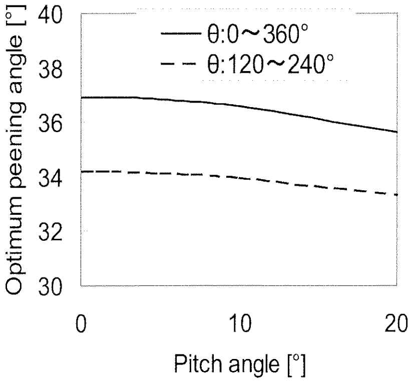


Fig. 9 Relationship between optimum peening angle and pitch angle for 2 nozzles

EXPERIMENTAL FORMULA AND VALIDATION

Hirose et al. measured the light energy absorbed on the inside spot and outside spot of the coil spring when light is shone on the coil spring surface (Fig. 10). They constructed the ratio of energy on the inside of the coil and energy on the outside of the coil by using the following experiment formula, which shows good agreement with the actual measurements (inferred from arc height)[3].

$$R_0 = 1 - \exp\left\{-0.818\left(\frac{P}{d} - 1\right)\right\} \tag{2}$$

R_0 :Ratio of energy inside/outside the coil
(coil spring inner surface/coil spring outer surface)
P :Pitch
D :Wire diameter

The effectiveness of our simulation was confirmed by calculating the ratio of energy on the inside and outside surfaces of the coil. A formula similar to that used by Hirose et al. was employed, and the calculations were conducted under the same experimental conditions as those used by Hirose et al (Fig. 11).

Coil shape
  Average coil diameter :104mm
  Wire diameter :13mm
Shot conditions
  Projection distance :300mm
  Nozzle angle :30°
  Coil revolution speed :60rpm
  Coil movement speed :10mm/min

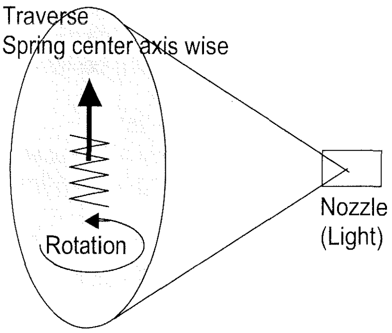


Fig. 10 Test method

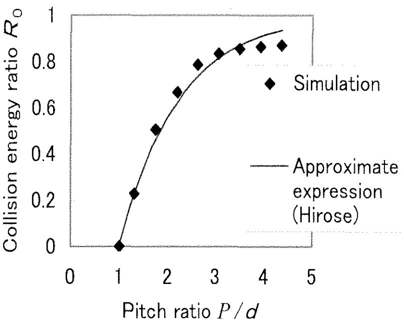
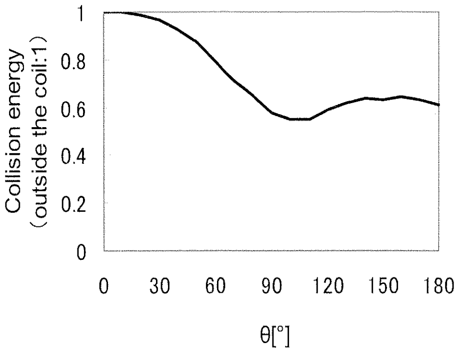


Fig. 11 Relationship between pitch ratio and collision energy ratio

RANDOM MOVEMENT AND COLLISION ENERGY DISTRIBUTION

In a tumbler-type shot peening machine, since a sprig moves around inside the machine, the peening angle cannot be appointed. Here, the collision energy distribution on the spring surface was calculated with assumptions that the peening direction of shots to a spring was random and uniform. The result is shown in Fig. 12, which tells that the lateral area of a spring enjoys less shot impacts.



0°:outside the coil
180°:inside the coil

Fig. 12 Collision energy

Coil shape
  Average coil diameter :21.2mm
  Wire diameter :3.2mm
  Pitch angle :9.47°

distribution

CONCLUSION

A consideration of the effects of peening conditions (shot peening angle, shot size), coil spring shape (wire diameter, coil diameter, pitch angle), and coil wire overlap, revealed the following items pertinent to the relationship of collision energy variation and peening angle.

1. It is possible to predict collision energy distribution from projection conditions and coil shape.
2. There is an optimum peening angle inside the coil at which shots will uniformly hit. When employing one nozzle, the optimum peening angle is 0° (spring center axis and vertical direction)
   When employing two nozzles, the optimum peening angle is about 35°.
3. We confirmed the validity of the results of our simulation of the ratio of the energy inside the coil to the energy outside the coil by demonstrating a significant agreement with the experiment formula of Hirose, et al.
4. In a tumbler-type shot peening machine, the lateral area of a spring enjoys less shot peening.

REFERENCE

Fathallah,R., Inglebert,G., Castex,L., Material Science and Technology (1998), 631
Hirose M., TsuTsumi A., Bane Gijutsu Kenkyu-Kai 1983 Shuki Kouen-Kai Maezuri-Shu (1983), 61
Mitsubayashi M., Aihara H., Ogino M. et al., Nihon Kikai-Gakkai Ronbun-Shu A-Hen (1995), 214
Watanabe, Y., Thesis, Gifu University (1995)