HISTORY OF SHOT PEENING

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ABSTRACT

A brief historical summary of the root sources of shot peening (mechanical prestressing), with reference to development of the technology from needs of the military, the scientific, and the industrial community. Chronology of the development shows that the earliest investigations were probably inspired by military requirements, closely paralleled by correlation of tests for hardness and metallurgical response, culminating in the present industrial technology to improve properties of metals.

KEYWORDS

Shot peening; mechanical prestressing; cold working; history of shot peening; dynamic loading; hardness testing; impulsive impact; ballistic testing; rolling; plastic deformation.

INTRODUCTION

The purpose of this paper is to present the chronological development of interest in the mechanism of cold working of metals, and the cross-pollination of the three disciplines (1) the military, (2) the scientific, and (3) the industrial, which combined to produce the very useful process that is now known as shot peening, or mechanical prestressing.

Improvements in fatigue strength thru use of present shot peening practices can result in 10 to 100 percent improvement in fatigue strength (100 to 1200 percent in fatigue life), yet it's full economic potential is still not realized. Measurement of the depth and character of the shot peening effect on production parts is not possible without destructuctive examination, thus quality depends upon conscientious control of the process. Researching past work in this field might inspire creation of non-destructive inspection methods.

No really exhaustive bibliography of source material exists, probably because the subject cuts across such a broad expanse of investigation. The items referred to at the end of this paper contain a multitude of references in the three disciplines which should make a good beginning for research.

Shot peening is a term that evolved from shot blast cleaning when it was recognized that blasting with steel shot would produce substantial improvements in the strength of metals if the process is carefully controlled. The process of shot peening now is identified by the broader term "mechanical prestressing", to include metal-working such as rolling, coining, stress peening, and other mechanical stressing under close control.

CHRONOLOGICAL HISTORY

A few published works include citation of most of the earliest references to mechanical prestressing, i.e., Bush (1962)*, Rinehart (1954)*, S.A.E. (1952 thru 1981)*, Gensamer (1949)*, Wheelabrator (1962)*, Hayes (1938)*, and Petrenko (1936)*. Examination of references in these sources will reveal most of the writing on the subject, however this author regrets that he is unable to present here a more complete bibliography containing the many other valuable publications, on mechanical prestressing world-wide, which certainly exist.

Early History

Bush* (1962) points out that the earliest record of mechanical prestressing probably predates 2700 B.C., when hammered gold helmets were found in Ur. during the Crusades, (1100 -1400 A.D.), knights cold-worked armor to final shape and hardness. Damascus and Toledo blades were cold-worked to provide flexibility with strength. Hayes* (1938) reports the first use of cannon in 1350, which used round shot from a few inches to 25 inches in diameter, made of stone. The shot was expected to impact a target of course, with some penetrating effect.

In 1553, according to Bush*, the first rolling of iron was practiced, which was followed in 1700 by construction of a four high mill in Sweden by Polherm, to replace "tilting" of sheet metal with a hammer to flatten it.

Small* (1960) explaines how hardness of materials was tested in 1722 by crossing sharp-edged bars, one above the other, and striking them with a hammer to see which one indented first. P. Musschenbroeck, in 1729 - 1759, used a knife struck with a particular ivory ball to measure hardness. The number of blows divided by the specific gravity of the metal being tested yielded a hardness number.

Bush* finds that Henry Court, in 1738, took out patents in England on grooved rolls for rolling metal, while in 1789 Acton, of London, hammered the outer surface of gun barrels to give them special strength.

The Nineteenth Century

According to Williams*(1942) Mohs developed his scratch-hardness test in 1822 - 1884, probably the earliest controlled test for hardness.

About 1861, according to Hayes*(1938) round shot for cannon was abandoned in favor of shaped projectiles.

Bush* shows that in 1871 Spencer, in the U.S. made automatic screw machines where he used "roll burnishing" on certain parts, and it is reported that roll burnishing was used on railroad axles and journals in 1848. In 1872 Lauth, in the U.S., patented his three high rolling mill for cold rolling shafting, which was said to

*Refers to citation in References.

produce bending strengths up to 3½ times that of hot rolled shafts. About 1880 the Canadian National Railway was using cold rolled shafts for improved strength and finish.

Gensamer*(1949 P. 30, #21) reports that J. Bauschinger presented his thesis "Changes in the Elastic Limit and the Modulus of Elasticity on Various Metals", a noteworthy paper. Rinehart* (1954) reported classical studies by J. Hopkinson in 1872 - 1901, on "Rupture of Iron Wire by a Blow", and other work by his son, B. Hopkinson and himself.

Rinehart* reported substantial work done in Paris by F. Helie in 1884, presenting formulae for computing depth of penetration on impact of round shot on metal.

The S.A.E.* (1962) "Supplement on Surface Rolling", J-811, reports work by H. Hertz in 1895, presenting a mathematical analysis for determination of stress in the contact areas of two bodies.

The Twentieth Century

The closing of the nineteenth century finds the beginning of increased activity in the studies of mechanical prestressing, and more serious search for a scientific analysis of the phenomenom. The twentieth century will see the desperate drive of World War I and World War II to maximize the performance of steels and increase their reliability.

In 1900 J. Muir published "The Recovery of Iron From Overstrain" in Philosophical Transactions, Vol. 193; which is referred to in Gensamer* (1949) page 199, in a discussion on plastic after effects. This subject is important in evaluating mechanical prestressing since the effects may be more extensive in the work-piece than is detected on surface after peening or rolling. In this year Dr. Brinell announced his new hardness tester, the first practical machine for this purpose. It is still in production use, (Petrenko* (1936).

Petrenko* (1936), O'Neill (1934), and Small (1960), Lysaght (1942), and Williams (1942) describe hardness tests by Brinell and many others, in the period 1909 - 1924. The penetration of metals by penetrators of different size or shape, at different loading rates, and at different loads is discussed in detail with ample supporting references. This mechanism of hardness testing is similar to that of shot peening, and deserves careful scrutiny. Hard steel balls, work-hardened balls, and tungsten carbide balls are compared, along with many other variables.

Rinehart* reports further on work by B. Hopkinson in measuring the impact of bullets in 1914. Work by N. M. Belajef "On the Problems of Contact Stresses", 1917, is reported in S.A.E.* (1962) "Supplement on Surface Rolling", J-811. Rinehart*, again, reports on Hopkinson's paper "The Pressure of a Blow", 1921.

The post World War I years saw a continuation of the momentum of scientific effort in examining cold-working of metals, residual stress studies, fatigue characteristics and ballistic studies. Rinehart* reported on impact tests of metals at both high and low temperatures.

The Start Of Mechanical Prestressing

In 1923 E. G. Herbert, in England, invented the Pendulum Hardness Tester, Small (1960), which produced rolling a hard steel ball on the surface of the test piece. This introduced a cold work effect which inspired special interest in that phenomenom as related to all hardness tests. W. D. Kunezow, in 1931, invented a similar machine using two indentors. Shortly afterward P. Rehbinder used it to detect the effect of various lubricants on cold work action.

Meanwhile, in 1927, Herbert (1927) was developing a machine called the Cloudburst Machine, which dropped quantities of steel balls from a height of 2 to 4 meters, to impact a workpiece, and (1), thus observed any soft spots by the rough areas produced, or (2), produce a cold-work surface of increased hardness. The cloudburst machine, in conjunction with the pendulum tester are believed to provide the first reliable information on cold-working by multiple impact of balls.

In 1924 Axel Hultgren, also of Sweden, developed a method of rolling steel balls under pressure, O'Neill (1934), so as to work-harden them for improved operation in Dr. Brinell's hardness tester. This is believed to be the first production use of mechanical prestressing under controlled conditions.

Development of the Art

After 1927 investigation and development went rapidly, with papers by Almen, Zimmerli, Straub, Foppl, Zener, Horger, Weible and many others. Reference to these works are best found in the seven source references cited earlier (*). Notable among these are the development of auto-frettage hardening of gun barrels, Hayes* p. 164 and 190,; and the massive accumulation of production test results described by Mattson and Almen (1945) in "Effect of Shot Blasting on the Mechanical Properties of Steel".

The technology of shot peening has advanced to sound production status as described in Wheelabator (1962) and the several Society of Automotive Engineers publications. Shot peening is being done in high production in shops of Metal Finishing Service, Chicago and Metal Improvement Co. in New Jersey; and hundreds of local manufacturing plants around the world.

Today

There is, in our hands now, the physical ability to produce mechanical prestressing of parts by several means, at established cost, and often with background experience that indicates the benefits to be gained. The one most important drawback is our inability to accurately measure the depth, intensity and distribution of the cold-worked effect on the production part without destructive examination.

The references list only U. S. Patents that seem of interest at this time, others may exist. No attempt has been made to search patents of other countries. The references given here are only a token list for the purpose of illustrating the trend of development of mechanical prestressing.

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