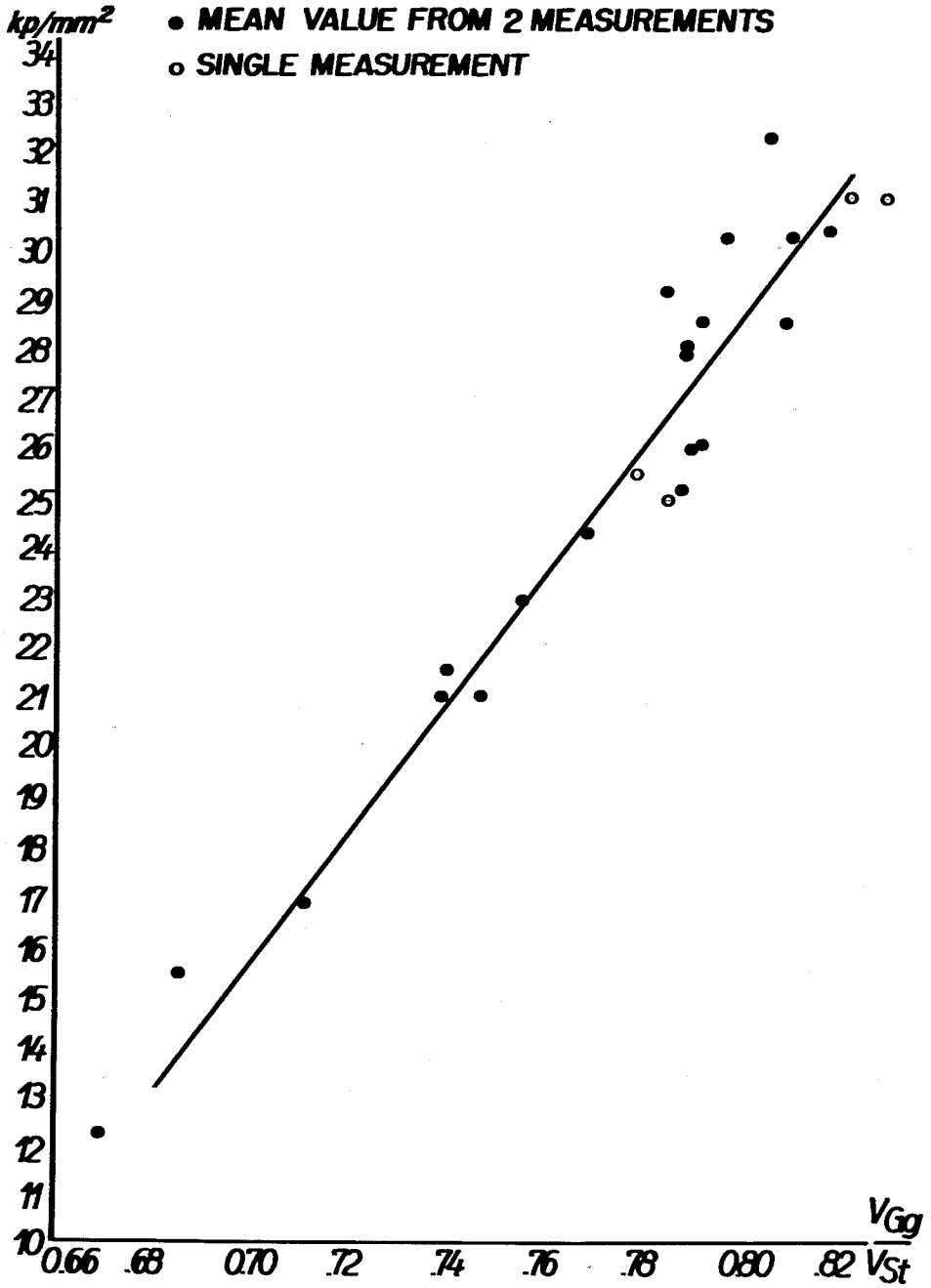
Oct. 10, 1961 R. ZIEGLER ET AL 3,003,351

NON DESTRUCTIVE PROCESS FOR ASCERTAINING THE TENSILE STRENGTH OF GREY IRON CASTINGS

Filed Aug. 12, 1957



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United States Patent Office 3,003,351 Patented Oct. 10, 1961

3,003,351

NON DESTRUCTIVE PROCESS FOR ASCERTAINING THE TENSILE STRENGTH OF GREY IRON CASTINGS

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Filed Aug. 12, 1957, Ser. No. 677,421
3 Claims. (Cl. 73—67.5)

Tensile strength is one of the most important properties of castings as it is the basis for designing the dimensions of the same. In the case of grey iron castings the tensile strength does not only depend on the chemical composition but also largely on the wall thickness and the cooling conditions. It is therefore extremely difficult to ascertain the tensile strength of grey iron castings at certain areas of the respective pieces.

For verifying the tensile strength of grey iron castings it is therefore not sufficient in general to ascertain the strength on separately cast test bars but it would be necessary to cut out from a casting itself at the area where the strength is to be measured a test bar which can be ruptured by well known test bar pulling devices.. This method is complicated, costly and time-wasting as it causes considerable expense in the workshop and besides entails destruction of the casting.

Colland has developed a new process for finding out the tensile strength of a casting in an indirect manner. According to the Colland process a test bar of about 30 mm. in diameter is cast out of the same charge from which the casting is to be made. This test bar is used to ascertain the tensile strength of the casting by standard pulling methods. Because of the varying wall thickness of grey iron castings the value obtained on the test bar is not identical with that of the casting itself. Colland requires that in addition the Brinell hardness of the casting area and the test bar be ascertained. The tensile strength at the respective area of the casting may then be calculated according to the following formula:

$$TSx = TS_{30}\left(\frac{HBx1.53}{HB_{30}}\right)$$

TS_x=tensile strength at the area in question of the casting.
TS_{30}=tensile strength of the separately cast test bar.
HB_x=Brinell hardness of the casting at the point in question.
HB_{30}=Brinell hardness of the test bar separately cast.

The advantage of this method is that the casting need not be destroyed. It presupposes however that the casting is perfectly faultless at the area in question and that it does not have at such area segregations, piping, blisters and other faults due to inhomogeneousness. Besides this method is also intricate and time-wasting. Finally it is difficult in some cases to measure the Brinell hardness on the castings themselves unless special presses are available for this purpose.

The evaluation of the tensile strength of the casting from the chemical composition and the wall thickness by means of suitable graphs can only yield approximate figures and will never provide exact measurements.

The uncertainty of the true tensile strength of castings due to the difficulties described above results in castings which are in many cases designed overstrength, thus increasing the costs considerably and unnecessarily.

The present invention provides a simple and exact operating method for ascertaining tensile strength of grey iron castings.

In the single figure of the drawing there is shown a graph on the horizontal leg of which is shown the projection of results obtained from first measuring the actual thickness of a plurality of test bars by mechanical means

and dividing such thickness by the apparent thickness as indicated by the speed of an ultra-sonic impulse. The vertical leg of the graph is a projection of the tensile strength of the same test bars as determined by pulling them in a standard tensile testing machine. The straight line indicates the relationship between the variables on the horizontal and vertical lines of the graph.

According to the invention it has been found that there exists a certain relationship between the speed of ultra-sonic impulses through grey iron castings and the tensile strength existing at the same area of the casting. Therefore the determination of the speed of the ultra-sonic impulses in the part of the casting being tested for tensile strength can be easily read from an empirically arranged graph which will have been established for solidified grey iron castings whose metal was melted in the same type of melting equipment. The invention will determine the tensile strength values ranging between 12 and 32 kilograms per square millimeter.

It is not absolutely necessary to measure the absolute value of the ultra-sonic impulses. Usually it is sufficient to ascertain simply the relationship between the sound speed of the ultra-sonic impulses through the casting to be tested and the speed of the ultra-sonic impulses in steel.

By way of example of such a process for determining the tensile strength of grey iron castings there is now described in detail a method which has been developed on the basis of a great number of experiments.

The invention employs a standard ultra-sonic impulse instrument, such as a Sperry reflectoscope, which is usually employed for ascertaining flaws in metals. This instrument is additionally provided with a device for measuring the wall thickness of metal and which has been calibrated to the speed of ultrasonic impulses in steel. The speed of ultrasonic impulses in steel is used as a constant.

By means of this device for measuring the wall thickness the wall thickness of the grey iron casting under investigation is ascertained at the area selected. However the thickness so determined does not agree with the actual wall thickness of a grey iron casting at the selected area as the instrument used is calibrated for steel whereas grey iron castings have a different ultra-sonic impulse speed. The wall thickness ascertained in this manner is therefore designated as apparent wall thickness. At the same time the real wall thickness of the area in question of the grey iron castings is determined mechanically for instance by means of a calipers. The relationship of the speed of ultra-sonic impulses in the grey iron casting being tested and the speed of ultra-sonic impulses in steel equals the relationship between the actual thickness of such grey iron casting as determined by calipers or other mechanical means and the apparent thickness of such casting as determined by the speed of the ultra-sonic impulses in such casting as measured by an instrument calibrated for the speed of ultra-sonic impulses in steel. This relationship may be expressed by the following formula:

$$\frac{v_{Gg}}{v_{St}} = \frac{d_{real}}{d_{apparent}}$$

In the above formula V_{Gg} stands for the speed of an ultra-sonic impulse in grey iron. V_{St} stands for the speed of an ultra-sonic impulse in steel. D_{real} stands for actual thickness as measured by calipers. $D_{apparent}$ stands for apparent thickness as measured by ultra-sonic impulses.

In carrying out experimentation on the invention several castings of different chemical composition and wall thickness were used for ascertaining the relation

$$\frac{v_{Gg}}{v_{St}}$$

whereupon at the same areas test bars were cut out and

their tensile strength measured. The test bars used in this connection had the following chemical composition:

Bar No.	C	Si	Mn	P	S
1103	3.02	1.52	0.44	0.119	0.030
1104	3.17	1.78	0.66	0.204	0.074
1105	3.27	1.63	0.55	0.204	0.084
1106	3.27	2.11	0.65	0.200	0.067
1158	3.18	2.23	0.59	0.236	0.086
1176	3.40	2.21	0.50	0.149	0.028
1196	3.39	3.10	0.56	0.173	0.049
1197	3.41	2.50	0.48	0.195	0.055

The tensile strength of cast iron does not only depend on the carbon content but also on the content of the silicon and the phosphorus. The influence of these three elements is ascertained by way of the so-called saturation or carbon equivalent value which is computed according to the following formula:

$$S_c = \frac{C}{4.23 - 0.312.Si - 0.275.P}$$

We have used the above formula wherein S_c stands for the saturation value for calculating the saturation values of the given bars as follows:

Bar No.:	Saturation value
1103	0.81
1104	0.88
1105	0.89
1106	0.93
1158	0.92
1176	0.97
1196	1.05
1197	1.00

The examples cited comprise the range of the saturation values from .81 to 1.05. Within this range, however, are practically all marketable types of cast iron. This is proved by the fact that the actual tensile strength values measured range from 12–32 kilograms per square millimeter.

The wall thicknesses of the above bars range between 7.5 and 45 mm.

The values measured have been plotted in the graph shown in the drawing. The relation of the tensile strength to the relative speed of the ultra-sonic impulse can be shown as a straight line as indicated on the graph. This is then used as a determination for future measurements of tensile strength. The straight line corresponds to the following equation:

$$TS_B = 131 \cdot \frac{v_{Gz}}{v_{St}} - 76$$

TS_B = tensile strength in kp./mm.²

$\frac{v_{Gz}}{v_{St}}$ = relative speed of ultra-sonic impulses as described above

The deviation of the individual points from the straight line drawn is found to be reasonable and results from segregations and other faults of homogeneity deficiency in the material. It is known that the results of rupturing tests originating from the same charge and being cast under the same conditions are subject to an error of about plus or minus 2 kp./mm.². In the case of the normal means of rupturing test bars irregularities have a greater effect as the volume on which the determination is based is very small. The measurements of the ultra-sonic instrument cover a much greater volume as the probe is large and covers a large area as compared to the wall thickness and the margin of error is reduced.

The straight line of the graph applies to cast iron of standard texture. But cast iron of a different textural formation, for instance, that with a different graphite arrangement, can be investigated by this method, although a separate graph would have to be developed.

The test bars used for this purpose were produced under utterly different conditions from those which had been employed for establishing the straight line of the graph. For example, some of the test bars were cast in shell moulds and the following table shows the relationship of the tensiles obtained:

Tensile Strength measured by means of rupture test, kp./mm.²	Tensile Strength ascertained by means of ultra-sound implement, kp./mm.²	Deviations, kp./mm.²
14.8	15.5	0.7
16.2	17.2	1.0
18.9	20.8	1.9
26.3	25.2	1.1
30.7	31.9	1.2

It appears that the deviations are within the domain of ± 2kp./mm.².

Various embodiments of the invention may be employed within the scope of the accompanying claims.

What is claimed is:

1. A non-destructive testing method for determining the tensile strength of a grey iron casting, which comprises the steps of subjecting a plurality of grey iron test castings of varying chemical composition to ultrasonic impulses induced by a machine calibrated for steel to determine the apparent thickness of each of said castings, rupturing each of said test castings to determine the tensile strength of each, producing a graph by plotting the quotient obtained by dividing the actual thickness of each of said test castings as determined by mechanical means by the respective apparent thickness of said castings against the tensile strength thereof and thereafter drawing a substantially straight line through the plotted points, and subjecting a grey iron casting of unknown tensile strength to ultrasonic impulses induced by a machine calibrated for steel to determine the apparent thickness of said casting, said apparent thickness being divided into the actual thickness of said casting and the resulting quotient located on said graph to establish the tensile strength of said casting.

2. A non-destructive method for determining the tensile strength of a grey iron casting, which comprises the steps of subjecting a series of grey iron test specimens of varying chemical composition and of known wall thicknesses to ultrasonic impulses to determine the velocity of propagation of said impulses through each of said specimens, rupturing each of said grey iron test specimens to ascertain the tensile strength thereof, producing a graph by plotting the quotients obtained by dividing the velocity of propagation of said impulses through each of said grey iron test specimens by the velocity of propagation of ultrasonic impulses through a steel test specimen having an actual wall thickness equal to that of the corresponding grey iron test specimens against the tensile strength of the respective grey iron test specimens and thereafter drawing a substantially straight line through the plotted points, and subjecting a grey iron casting of unknown tensile strength to ultrasonic impulses to determine the velocity of propagation of said impulses therethrough, said velocity of propagation of said impulses then being divided by the velocity of propagation of ultrasonic impulses through a steel test specimen of the same actual wall thickness and the quotient obtained being used in connection with said graph to establish the tensile strength of said grey iron casting.

3. A non-destructive testing method for determining the tensile strength of a grey iron casting in any given area, which comprises the steps of subjecting a series of grey iron test castings of varying chemical composition to ultrasonic impulses induced by a machine calibrated to a constant to determine the apparent thickness of each of said castings, rupturing each of said grey iron test castings to determine the tensile strength of each, producing

an empirical relationship between the tensile strength of said test castings and the quotient obtained by dividing the actual thickness of each of said test castings as determined by mechanical means by the apparent thickness of said castings, and subjecting a given area of a grey iron casting of unknown tensile strength to ultrasonic impulses induced by a machine calibrated to a constant to determine the apparent thickness of said area of said casting, the actual thickness of said area then being divided by the apparent thickness and the resultant quotient employed in the previously determined empirical relationship to determine the tensile strength of the said area of the casting.

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