United States Patent [19]

Gibbons et al.

[11] **3,887,764**

[45] **June 3, 1975**

[54] **FEATURE CLASSIFICATION IN IMAGE ANALYSIS**

[75] Inventors: **John Michael Gibbons; William Ralph Knowles,** both of Royston, England

[73] Assignee: **Image Analysing Computers Limited,** Melbourn, Royston, Hertfordshire, England

[22] Filed: **May 5, 1972**

[21] Appl. No.: **250,501**

[30] **Foreign Application Priority Data**

May 6, 1971 United Kingdom..... 13591/71

[52] **U.S. Cl.** **178/6.8;** 178/DIG. 1; 178/DIG. 37

[51] **Int. Cl.** **H04n 7/00**

[58] **Field of Search**...178/DIG. 33, DIG. 36 DIG. 37, 178/DIG. 38, 6.8; 250/219 DP; 356/200, 237; 235/92 PD, 92 DN; 340/146 AQ

[56] **References Cited**

UNITED STATES PATENTS

3,389,789	6/1968	Watson et al.	178/DIG. 1
3,576,976	5/1971	Russo et al.	340/146 AQ
3,674,926	7/1972	Dewey et al.	178/DIG. 37

FOREIGN PATENTS OR APPLICATIONS

906,947	9/1962	United Kingdom	356/200

Primary Examiner—Richard Murray
Attorney, Agent, or Firm—Browne, Beveridge, DeGrandi & Kline

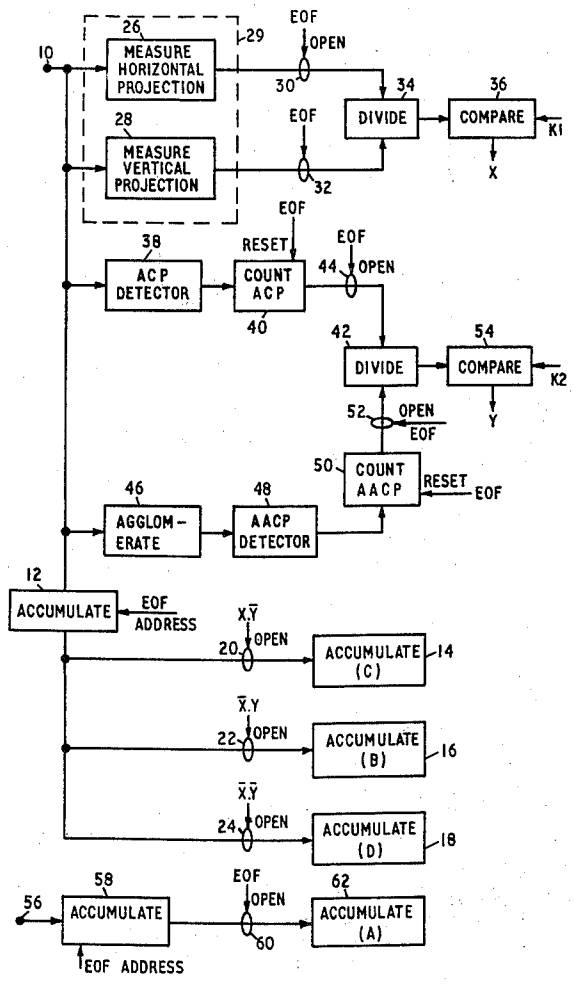
[57] **ABSTRACT**

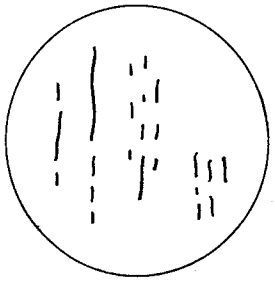
Methods and apparatus employing fixed raster scanning for classifying steels according to the non-metallic inclusion content apparent in a polished surface of a sample thereof. The method allows for individual regions of the surface to be analysed and classified and an overall classification to be made in accordance with the predominant classification of a number of regions making-up the surface.

Signals relating to sulphide and oxide inclusion content are discriminated by virtue of amplitude difference. Areas of each are determined in known manner by accumulating detected signal pulses during a single frame scan.

Signals relating to different types of oxide inclusions are distinguished by making measurements on the detected signal pulses relating to the oxide inclusions.

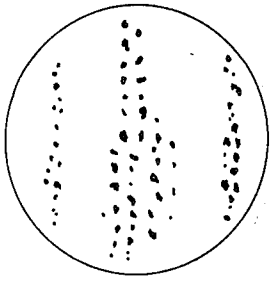
17 Claims, 11 Drawing Figures



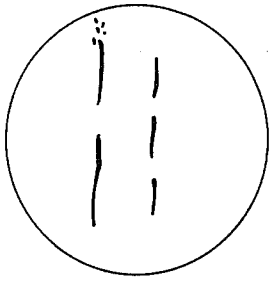


TYPE A
SULPHIDES INCLUSIONS

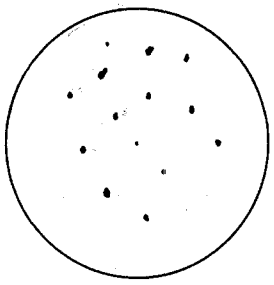
Fig.1



TYPE B



TYPE C



TYPE D

OXIDE INCLUSIONS

Fig. 2

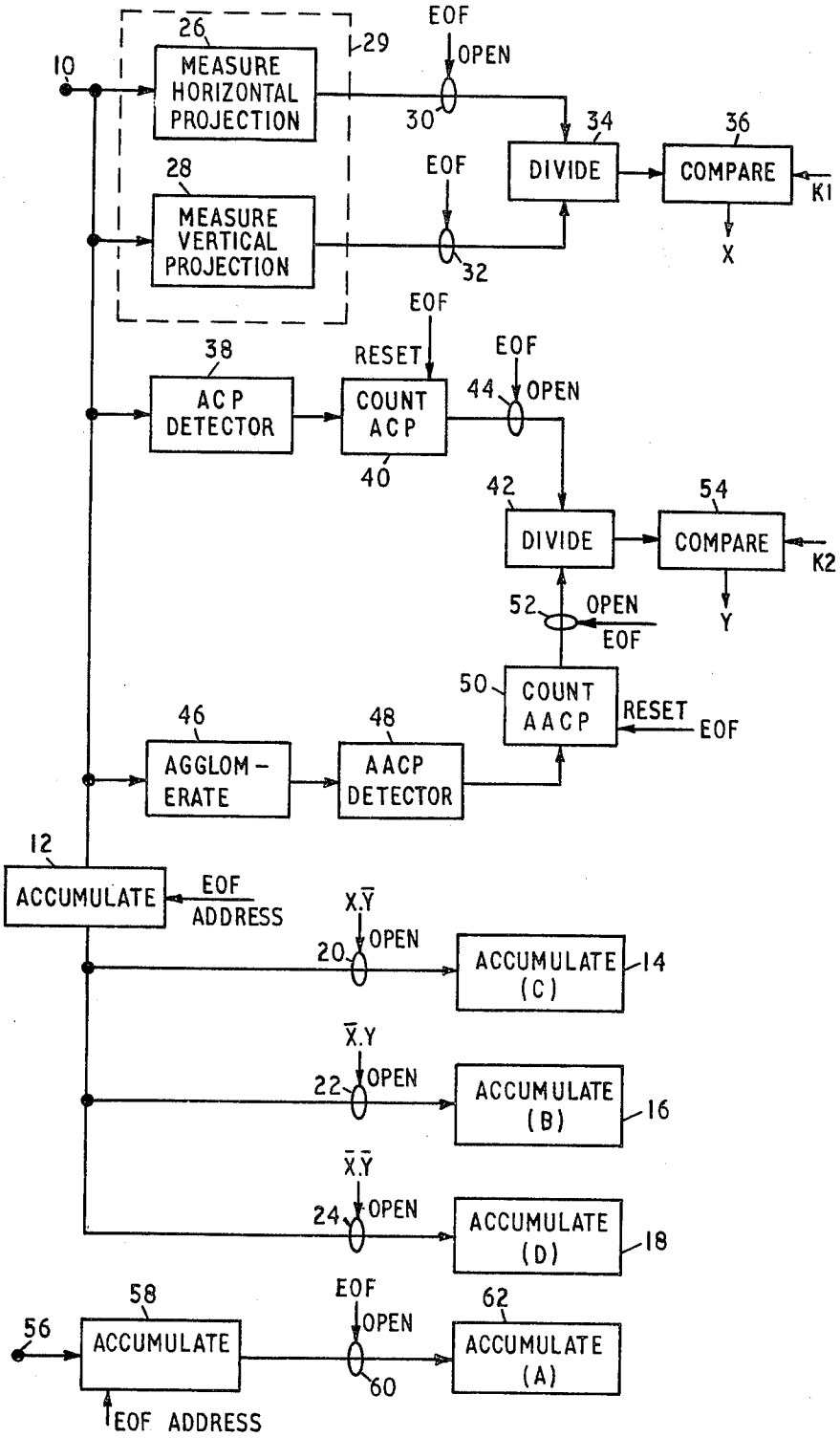

10
26
MEASURE HORIZONTAL PROJECTION
29
EOF
OPEN
30
34
DIVIDE
36
COMPARE
K1
X
28
MEASURE VERTICAL PROJECTION
EOF
32
EOF
38
ACP DETECTOR
RESET
COUNT ACP
40
EOF
44
OPEN
42
DIVIDE
54
COMPARE
K2
Y
52
OPEN
EOF
50
COUNT AACP
RESET
EOF
46
AGGLOM-ERATE
48
AACP DETECTOR
12
ACCUMULATE
EOF
ADDRESS
X.Ȳ
20
OPEN
ACCUMULATE (C)
14
X̄.Y
22
OPEN
ACCUMULATE (B)
16
X̄.Ȳ
24
OPEN
ACCUMULATE (D)
18
58
56
ACCUMULATE
EOF
OPEN
60
62
ACCUMULATE (A)
EOF ADDRESS

Fig. 3

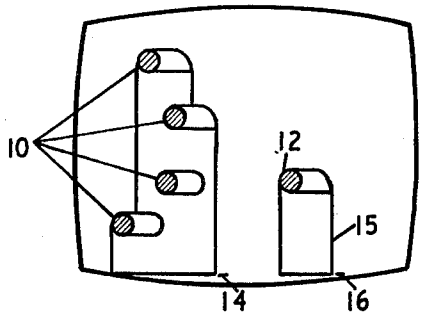


Figure 4.

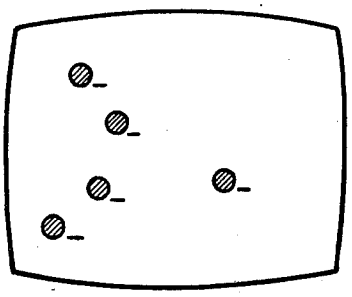


Figure 5.

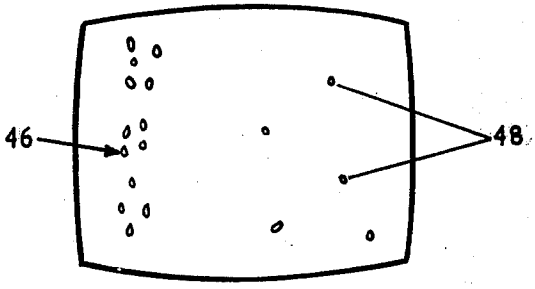


Figure 6.

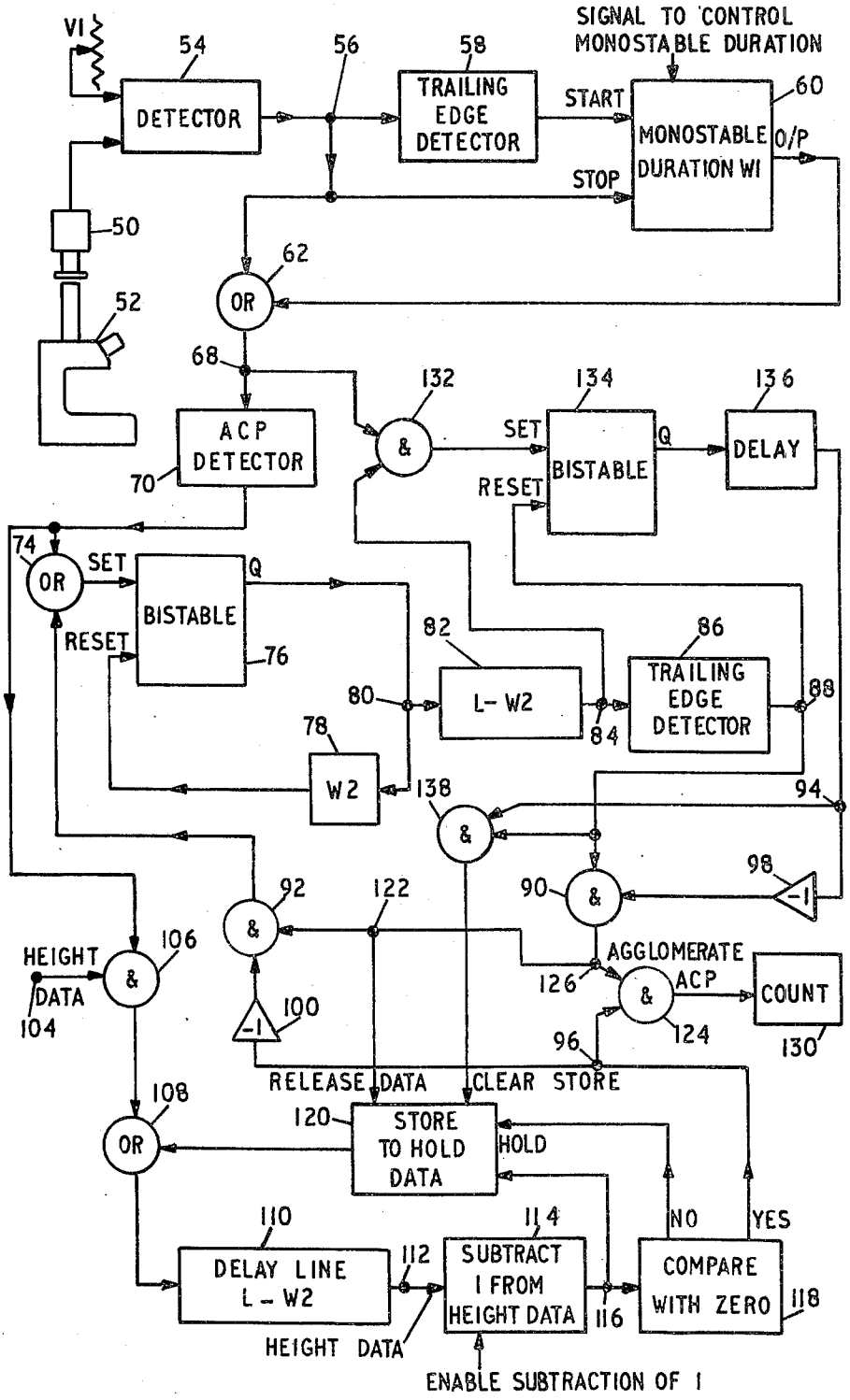

VI
54
DETECTOR
56
58
TRAILING EDGE DETECTOR
SIGNAL TO CONTROL MONOSTABLE DURATION
START
STOP
60
MONOSTABLE DURATION WI
O/P
50
52
62
OR
68
ACP DETECTOR
70
132
&
134
SET
RESET
BISTABLE
Q
136
DELAY
74
OR
SET
RESET
BISTABLE
Q
76
82
L - W2
80
84
86
TRAILING EDGE DETECTOR
88
78
W2
138
&
94
98
-1
90
&
92
&
122
106
HEIGHT DATA
104
&
AGGLOMERATE ACP
126
&
124
COUNT
130
-1
100
96
RELEASE DATA
CLEAR STORE
108
OR
120
STORE TO HOLD DATA
HOLD
110
DELAY LINE L - W2
112
HEIGHT DATA
114
SUBTRACT I FROM HEIGHT DATA
116
NO
YES
COMPARE WITH ZERO
118
ENABLE SUBTRACTION OF I

Figure 7

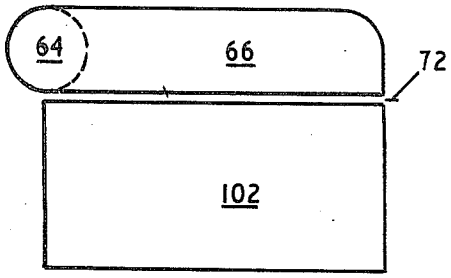


Figure 7a.

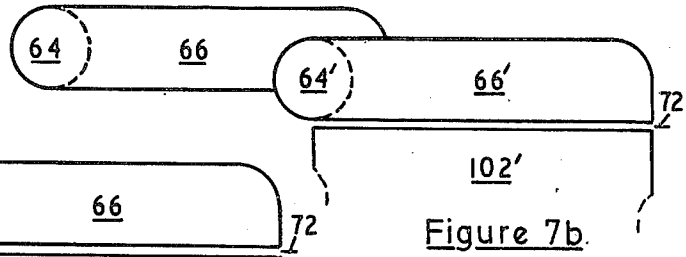


Figure 7b.

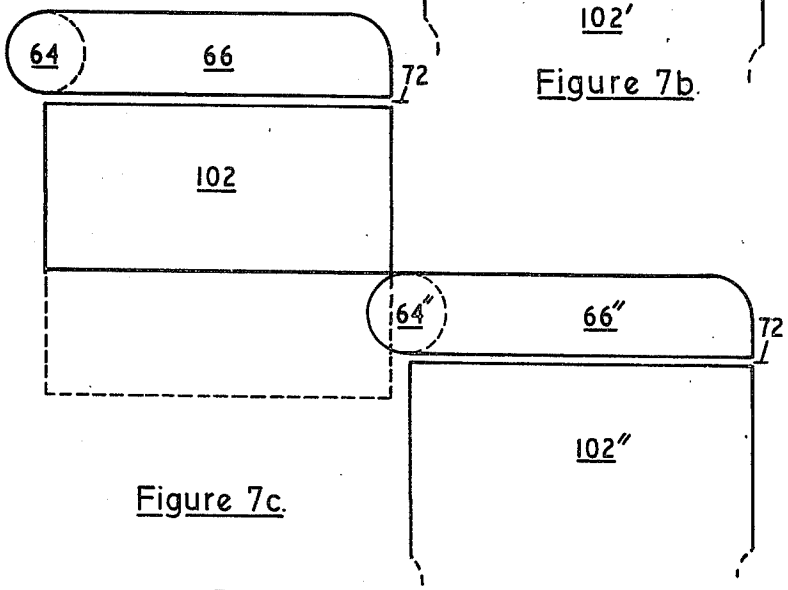


Figure 7c.

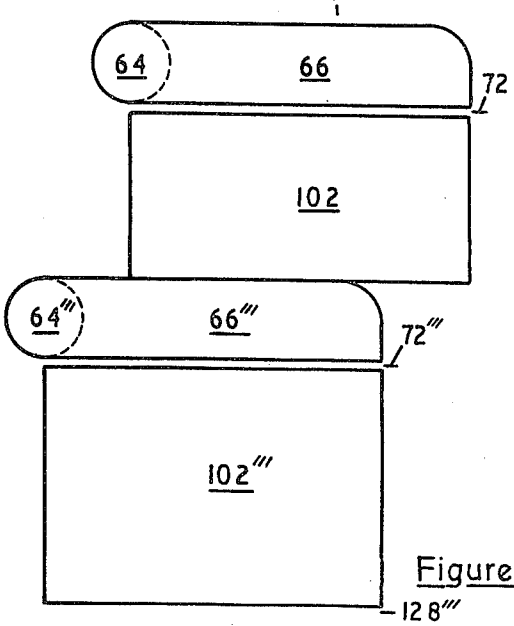


Figure 7d.

FEATURE CLASSIFICATION IN IMAGE ANALYSIS

This invention provides a method and apparatus by which steel samples may be classified automatically according to their non-metallic inclusion content.

Non-metallic inclusions in a steel may be seen using a microscope to view a polished surface of the steel illuminated by reflected light. The inclusions fall into two general categories of sulphides and oxides. The former appear as light grey specks in the white, steel surface while the latter appear as very dark grey or black specks.

Hitherto, steels have been classified in this way by an operator actually looking down the microscope, comparing each field of view with illustrated sample fields and assessing which of the sample fields each field of view most closely corresponds to. This is slow and tedious work and due to operator fatique etc., can be subject to error and inconsistency.

If the steel surface is viewed by a television camera employing fixed raster line scanning, the amplitude of the resulting video signal will vary as the image is scanned, typically, from a high value when the 'white' steel surface is being scanned, to a lower value as a scan line intersects a light grey sulphide inclusion and to a much lower value when a scan line intersects a dark grey oxide inclusion. If the video signal amplitude is compared with a reference voltage and a binary type signal is generated from the comparison such that a 1-value signal obtains whilst the amplitude is below the voltage and a 0-value signal obtains whilst the amplitude exceeds the voltage, a series of electrical pulses will be obtained whose duration equals in each case the time in a line scan during which the spot is on a region of the field whose grey level is sufficient to cause the video signal amplitude to extend below the reference voltage.

By employing a second reference voltage below the first and subtracting the pulses derived from the second from those derived from the first reference voltage it is possible to obtain pulses which only relate to regions whose grey level produce amplitude excursions of the video signal between the two reference voltage levels. It is thus possible to isolate all such pulses (sometimes referred to as intersect pulses) which relate to sulphide inclusions by employing two appropriate reference voltages. Those amplitude excursions which go below the second lower reference and the resulting intersect pulses, obviously relate to oxide inclusions.

Information as to the relative percentages of the different inclusion types in a steel sample, inter alia will give valuable information as to the characteristics of the steel. For convenience sulphide inclusions will be referred to as type A and a field containing predominantly sulphide inclusions would thus be classed or typed as an A field.

The invention will be better understood by reference to the accompanying drawings in which:

FIG. 1 is a diagram of a field containing sulphide inclusions denoted as type A.

FIG. 2 shows diagrams of three fields containing oxide inclusions and denoted as types B, C and D.

FIG. 3 is a block diagram of an image analysis system for typing fields according to their inclusion content.

FIG. 4 is a diagram of a field containing an agglomerate which is counted as a single feature.

FIG. 5 illustrates separate feature counting.

FIG. 6 illustrates non-metallic inclusions in steel.

FIG. 7 is a block circuit diagram of an agglomerator.

FIGS. 7*a* to 7*d* illustrate the capture zones generated by the circuit of FIG. 7.

In general the oxide inclusions are of three different types, alumina type, silicate type and globula type. For simplicity they will be referred to as types B, C and D respectively. Examples of the fields containing the four different inclusions types are illustrated in FIGS. 1 and 2 of the accompany drawings.

It will be observed that the inclusion typing on this basis is similar to that of the so-called JK typing system.

According to the present invention a method of classifying a region of a polished steel surface containing non-metallic inclusions which appear darker than the remainder of the steel surface, comprises the steps of scanning an image of the region in a series of parallel lines forming a raster, generating an amplitude varying video signal from the scanning, in which the amplitude has a first value corresponding to the steel, a second value corresponding to sulphide inclusions and a third value corresponding to oxide inclusions, comparing the video signal with a first reference voltage between the said first and second values and with a second reference voltage between the said second and third values, generating a first detected signal of pulses generated whenever the video signal amplitude has a value between the first and second reference voltages and a second detected signal of pulses generated whenever the video signal amplitude has a value below the second reference voltage, performing measurements on the pulses forming the second detected signal arising from scanning the whole region to produce at least first and second output signals, comparing the relative magnitudes of said output signals and generating a classifying signal for the region in response to the comparison of the output signals.

Thus by separately accumulating the pulses of each detected signal, two output signals are obtained whose magnitudes are proportional to the total areas of sulphide and oxide inclusions in the region. By comparing one with the other the region can be classified as predominantly sulphide or predominantly oxide. Comparison may be effected by forming a quotient of the two output signals and comparing the quotient with a preset reference voltage.

Measurements made on the detected signal pulses corresponding to line scan intersections with oxide inclusions produce output signals for comparison with other output signals or reference voltages, to allow the oxide inclusions too be sub-classified as belonging to one of the three types B, C or D hereinbefore described.

In a first sub-classification, first and second output signals are generated from the second detected signal pulses corresponding to the totals of the horizontally and vertically projected lengths respectively of the oxide inclusions and the magnitude of the first output signal is compared with that of the second output signal and a type C classifying signal generated if the second signal is greater than a given multiple of the first.

A preferred value for the multiple is 1.7.

Methods and apparatus for obtaining signals indicative of the totals of the vertically and horizontally projected lengths of features in a field are described in copending British Patent Application No. 9738/71.

In a second sub-classification third and fourth output signals are generated from the second detected signal pulses corresponding respectively to the total number of oxide inclusions in the field and the total number of any groups of oxide inclusions, each group including all oxide inclusions which are within predetermined distances (measured parallel and perpendicular to the line scan direction) from a given inclusion in the group, the magnitude of the fourth output signal is compared with that of the third output signal and a type B classifying signal is generated if the third signal is greater than a given multiple of the fourth signal.

A preferred value for this multiple is 2.

The process of linking detected signal pulses and therefore the inclusions to which they relate to form a group is termed agglomeration and a method and apparatus for producing agglomeration is described in co-pending British Patent Application No. 13590/71.

As described below when appropriate conditions are satisfied the field may also be classified as type D.

An alternative first sub-classification may be made by generating a length signal corresponding to a length dimension of each inclusion from the intersect pulses relating thereto, applying a first size discrimination to each length signal and generating a count pulse for each inclusion for which the first length signal is greater than the first size, applying a second size discrimination to the length signals and generating a count pulse for each inclusion for which the first length signal is greater than the second size, larger than said first size, counting the two sets of count pulses, comparing the number of count pulses in the two sets and generating a type C classifying signal if the count due to the first size discrimination is not greater than a given multiple of the count due to the second size discrimination.

Preferably the size is the so-called horizontally projected length of the feature.

Preferred ranges of the first and second sizes are 2 to 30μm and 8 to 120μm respectively.

If the comparison is effected by dividing the second count by the first to form a quotient and comparing the latter with a reference value, a preferred range for the reference value is 0.1 – 0.8 and the preferred value in that range is 0.5.

Another alternative first sub-classification may be made by computing from the second detected signal pulses the total projected length (in one direction) of the detected oxide inclusions, computing therefrom a signal corresponding to the arithmetic square of the total projected length to obtain a first area value signal, computing from the second detected signal pulses the actual total area of the detected oxide inclusions, to obtain a second area value signal, comparing the two area value signals and generating a type C classifying signal if a comparison criterion is satisfied.

If the horizontally projected length is measured the criterion is that the first area value signal is greater than the second and vice versa if the vertically projected length is measured.

A further alternative first sub-classification may be made by computing from the second detected signal pulses the total of all perimeters of detected inclusions and generating a total perimeter signal proportional thereto, generating a total area signal by accumulating the second detected signal pulses, comparing the total perimeter signal with the total area signal and generating a type C classifying signal if the ratio of the perimeter signal to the area signal is greater than a given value.

In a still further alternative first sub-classification the longest line scan intersect pulse obtained during scanning of each inclusion is identified and all such pulses during a complete scan, accumulated to form a modified fourth output signal, for comparison with the said third output signal as hereinbefore described. This modification will allow greater misalignment of the longer dimension of elongate inclusions to the perpendicular to the line scan direction, before gross errors appear in the modified fourth output signal value.

The invention will now be described by way of example with reference to FIG. 3 of the accompany drawings which is a block circuit diagram of part of an image analysis system by which fields may be typed according to their inclusion content.

Detected video signal containing line scan intersect pulses from only oxide inclusions in a field (not shown) is supplied to point **10.** Such a signal is obtained by threshold discrimination of the video signal amplitude excursions as discussed in U.S. Pat. No. 3,617,631, incorporated herein by reference.

The intersect pulses which appear during each frame scan are accumulated in an accumulator **12** which is addressed at the end of each frame scan (e.g. by a signal derived from the frame synch. pulses) and then reset. On address the accumulated signal in **12** is directed at the end of each frame to one of three accumulators **14, 16** and **18** depending on which of three gates, **20,** 22 and **24** is opened.

During each frame scan, the total horizontally projected length of the inclusions in the field is measured by **26** and the total vertically projected length of the inclusions is measured by **28.** Measurement devices **26** and **28** comprise a system **29** which is more fully described in U.S. patent application Ser. No. 238,893, allowed on Mar. **7, 1973,** incorporated herein by reference.

The measurement signals are supplied at the end of the frame via gates **30, 32** respectively to a divide circuit **34** in which the signal from **26** is divided by that from **28.** The quotient is compared with a reference signal **K1** corresponding to a value of **1.3** in comparator **36** and an X signal generated if the quotient > **K1.**

Simultaneously, the signal at **10** is supplied to a count pulse producing circuit **38** of the type described U.S. Pat. No. 3,619,494, incorporated herein by reference which generates a single count pulse after the end of the last line scan intersect pulse for each detected feature (inclusion). The pulses are counted by counter **40** which is reset at the end of each frame scan and a signal equivalent to the count for the frame is transmitted to a divider **42** via gate **44.**

The signal at **10** is also applied to an agglomerator **46** of the type described in our co-pending British Patent Application No. **13590**/71 and described in the present application with reference to FIGS. **4** to **7** and **7***a* to **7***d.*

The agglomerator concerns methods and apparatus for analysing features in a field in which a video signal thereof is generated by line scanning the amplitude excursions relating to feature content are detected by comparison with one or more reference voltages and measurements are made on the detected signal pulses. In particular the invention concerns a method and apparatus by which information relating to features and obtained by an associated parameter computer of the type described in British Patent Specification No.

1,264,805 is not released at the end of scanning a feature if another feature is detected as being within a given proximity of the first feature, but is withheld and released for the agglomerate i.e. set, of features as a single associated parameter therefor.

The information signal may for example be a count pulse and it may be desirable to inhibit the count pulse for each of a set of features all within a given distance from each other and to release only that for the last feature in the agglomerate. The action of associating features in dependence on their proximity will be referred to as "agglomeration" and a set of such features is termed as agglomerate.

Line scan information of a feature may be linked with that of another feature by stretching the detected signal pulses from the first feature in a direction parallel to the line scan direction, by the time taken to scan the given distance. If their spacing is less than this distance, the detected signal pulses of the second feature will overlap with the stretched ones from the first and the two informations can be combined.

The present invention allows link up of information in a direction perpendicular to the line scan direction as well as parallel thereto.

In FIG. 4 features **10** are so close as to fall within the individual capture zones formed by the present invention, whilst feature **12** being isolated does not link up with any other feature in the field.

The features **10** form an agglomerate and only a single count pulse is produced for the agglomerate shown at **14.** The usual count pulse **16** for feature **12** is released at the end of its capture zone **15.**

In FIG. 5 each feature is shown as being counted separately by producing a single count pulse at the end of scanning each feature.

The invention is primarily applicable to the assessment of non-metallic inclusions in a steel sample, where the video signal is obtained from a television camera which views the polished steel sample through a microscope. Suitable choice of threshold voltage allows a detected signal to be produced in which the pulses only relate to oxide inclusions.

Some types of oxide inclusion are contributed randomly over the metal surface area. Other types occupy narrow zones running parallel to the rolling direction employed in the manufacture of the steel. This rolling action breaks up a large oxide inclusion into a number of small inclusions which are separated and spread along the rolling direction. Such a group of oxides is known as a stringer and one is shown at **46** in FIG. **1.** Other isolated inclusions, not forming a stringer are shown at **48.**

By counting all the detectable oxide regions (i.e. disregarding whether they are contained in stringers or otherwise) a total inclusion count is obtained and a comparison of the total oxide count and the number of oxide regions when account is taken of the stringers (i.e. the inclusions within a stringer are all counted as one) gives a measure of the proportion of features that are within stringers.

FIG. 7 is a block circuit diagram of an embodiment of the invention in which provision is made for adjusting the size of the capture zones. A first size adjustment is provided by an adjustable stretch producing circuit and a second size adjustment is provided by a control over the number of times the signal is recirculated to generate a box zone beneath a stretch zone of the capture area.

A video signal is generated by a television camera **50** coupled to a light microscope **52** and video signal amplitude excursions relating to desired feature content are isolated from the remainder of the video signal by a detector **54** in which the video signal amplitude excursions are compared with a reference voltage V**1** and detected signal pulses are generated for the duration of each excursion which exceeds the reference voltage. A trailing edge detector **58** generates a start signal for a monostable device **60** from the trailing edge of each detected signal pulse. A reset or stop signal for the monostable device **60** is also obtained from junction **56** direct. Thus, at the beginning of a detected signal pulse, the monostable **60** is reset irrespective of its initial condition and is restarted as soon as the trailing edge of the pulse is detected.

The output from the monostable **60** is applied to one input of OR-gate **62** the other input being derived from junction **56.** The output from OR-gate **62** therefore comprises detected signal pulses each of which is stretched by W**1.** The output from OR-gate **62** thereby defines the original feature **64** (see FIG. 7a) of which the trailing edge is shown in dotted outline together with a stretch zone **66** formed by the monostable output pulses attached to the trailing edge of each detected signal pulse from junction **56.** The detected signal pulses which therefore appear at junction **68** are referred to as modified pulses and can be thought of as relating to a feature formed by the two regions **64** and **66.**

The anti-coincidence point for the feature so defined is detected by an ACP detector **70** of the type described in British Patent Specification No. 1,264,807 in which junction **10** corresponds to junction **68** in FIG. **7** hereof. The ACP is illustrated in FIG. 7*a* at **72** and the signal generated at point **72** is supplied via OR-gate **74** to set a bistable device **76.** The set output signal from bistable **76** is suppled to junction **80** and this signal is delayed by a delay device **78** by a time interval W**2** to provide a reset signal for bistable **76** a time interval W**2** after the bistable device **76** is set. The pulses at junction **80** are applied to a delay device **82** of delay equal to L minus W**2** where L is equal to one line scan period. The leading edge of each delayed signal thus appears a time interval W**2** in advance of the position of the ACP **72** (in FIG. 7*a*) on the next line scan and the trailing edge of the delayed pulse at **84** thus coincides (on the next line scan) with the position of the ACP **72.** This trailing edge is detected by trailing edge detector **86** and the short signal indicating the end of a pulse appears at junction **88** and is applied via gates **90** and **92** as a second input to OR-gate **74** thereby setting bistable **76** at the same point on the next line scan as it was set by the ACP at **72** on the previous line scan. So far it is assumed that zero signal obtained at junctions **94** and **96** so that an enabling signal is provided at the outputs of emplifiers **98** and **100** respectively thereby enabling gates **92** and **92.**

The setting of bistable **76** on each successive line scan defines a box zone **102** (see FIG. 7*a*) the width of which (i.e. measured in the line scan direction) is determined by the duration W**2** and the height thereof (i.e. measured perpendicular to the direction of line scan) is determined by a height data signal supplied from junction **104** as one input to an AND-gate **106**

having the ACP signal from ACP detector **70** supplied to its other input. The height data from junction **104** is applied via OR-gate **108** to a delay line **110** having the same delay (L minus W2) as delay **82** so that the height data is available at junction **112** at the same time on the next line scan after the appearance of an ACP **72** as is the set signal for bistable **76.** The height data at junction **112** is transferred to a subtraction stage **114** to which an enable signal is supplied after complete transfer of the height data, the action of **114** being to subtract one from the numerical height data supplied thereto. The reduced height data appears at junction **116** and this is compared in comparator **118** with zero and a "no" signal generated if the reduced height information does not equal zero which serves as a hold signal for a store **120** to the input of which the reduced height data is supplied from junction **116.**

The reduced height data stored in **120** is released therefrom by the appearance of a signal at junction **122** i.e. by the signal indicating the trailing edge of the pulse of duration W2 from junction **84** on that line scan. The reduced information from store **120** is applied via OR-gate **108** to the input of delay line **110** for recirculation and the process is continued until the reduced height data appearing at junction **116** equals zero at which time the "no" signal is not generated and instead a "yes" signal is generated which appears at junction **96.** This provides an input for phase inverting amplifier **100** thereby removing the signal on the second input of gate **92** and inhibiting the circulation of the trailing edge signal from gate **90** to gate **74.** This prevents bistable **76** being set the box zone **102** is thereby discontinued.

A signal indicating the end of the box zone **102** is generated by an AND-gate **124** one input of which is supplied with signal from junction **96** and the other from junction **126** in the output of gate **90.** Thus the trailing edge pulse from junction **88** which appears in the output of gate **90,** when coincident with a "yes" signal from comparator **118,** causes both input of gate **124** to be satisfied and a short duration pulse is generated known as the agglomerate ACP illustrated at **123** in FIG. *7a.* A pulse counter **130** is set to count the agglomerate ACP signals such as **128** which are generated during a complete frame scan.

In the event that a second feature **64'** lies within the stretch zone **66** of feature **64** (see FIG. 7b) the leading edge of each detected signal pulse from feature **64'** causes the monostable **60** to be reset or stopped and the trailing edge thereof causes it to be restarted so that a fresh stretch zone **66'** is generated from the trailing edge of feature **64'.** No ACP is produced from the original stretch zone **66** since the stretched pulse which would have produced the ACP from feature **64** and stretch region **66** is merged with the detected signal pulse arising from scanning feature **64'** on the same line scan and a fresh ACP **72'** is detected for the new stretch zone **66'.** A box zone **102'** is generated therefrom in the same manner as described hereinbefore.

Referring now to FIG. *7c,* if a box zone **102** intersects a second feature **64''**, a detected signal pulse will appear at junction **56** and therefore via OR-gate **62** at junction **68** sometime during the duration of a delayed pulse at junction **84.** In this event both inputs of AND-gate **132** are satisfied and a set signal is provided for a further bistable device **134** the set output of which is delayed by a short delay device **136** (to prevent a so-called race) thereby producing a signal at junction **94** and causing gate **90** to be inhibited. The trailing edge signal for that pulse at junction **84** is therefore prevented from circulating via gates **90** and **92** to again set bistable **76** and box **102** is therefore stopped at that particular line scan. Coincidence of signal at junction **94** and the trailing edge signal at junction **88** satisfies both input conditions for a further AND-gate **138** the output of which is arranged to clear any signal temporarily stored in store **120.** This removes height data which is currently being recirculated for box **102** and thereby clears the count down circuit as far as box **102** is concerned.

In this way the box zone generating circuit and box height controlling circuit are both inhibited and the detected signal pulses relating to feature **64''** together with the pulses in the output of monostable **60** relating thereto define a new stretch zone **66'** for which a fresh box zone **102''** is generated as before described. No agglomerate ACP signal pulse is generated with relation to box zone **102** and providing that box zone **102''** does not intersect another feature, the agglomerate ACP signal pulse at the end of box **102''** will appear as a single count pulse for the two features **64** and **64''.**

In FIG. *7c* the alternative intersection condition is shown in which a stretch zone **66'''** from a feature **64'''** intersects the box zone **102** from feature **64.** This condition is again detected by coincidence of signal at junction **68** and signal at junction **84** producing a set condition of bistable **134** which is delayed by delay **136** and causes an inhibit signal for gate **90** thereby preventing the continuation of box **102** as before described. The trailing edge signal at junction **88** provides the reset for bistable **134** and also serves to clear the height data stored in store **120** as before described so that the circuitry is ready to generate a new box zone **102'''** after the ACP **72'''** is detected for stretch zone **66'''.** If the new box zone **102'''** does not intersect a further feature the signal appearing at ACP **128'''** constitutes a single count pulse for the two features **64** and **64'''.**

The total count in counter **130** at the end of a complete frame scan will equal the number of agglomerates detected. This count can be compared with that obtained using an ACP detector and counter and supplied with the detected signal pulses from junction **56** of FIG. **7.** The comparison of the two counts will indicate the proportion of features in agglomerates to those not in agglomerates.

As shown in FIG. **3** a count pulse is generated for each agglomerate by AACP detector circuit **48** which is the same as count pulse producing circuit **38** disclosed in U.S. Pat. No. 3,619,494 and incorporated herein by reference. The count pulses are counted by counter **50** during each frame scan. Counter **50** is reset at the end of the frame scan.

The count from **50** is supplied via gate **52** at the end of each frame, to form a second input for divider **42.** The action of divider **42** is to divide the count from **50** by that from **40.** The quotient is compared in comparator **54** with a reference signal K2 corresponding to a value of 0.5 and a Y signal generated if the quotient is not greater than K2.

Logic circuit elements (not shown) generate a control signal for gate **20** if X is present but not Y; for gate **72** if Y is present but not X and for gate **74** is neither X nor Y is present.

X signifies a field in which the features are predominantly those corresponding to the C type of the JK classification, Y those of the B type and neither X nor Y, those corresponding to the D type.

A detected video signal containing only line scan intersect pulses from sulphide inclusions (normally light grey as opposed to the dark grey-black, oxide inclusions) is obtained by threshold discrimination of the video signal amplitude excursions as discussed in U.S. Pat. No. 3,617,631, incorporated herein by reference and this signal is applied to point **56.** The intersect pulses are accumulated in an accumulator **58** during each frame scan and which is reset at the end of each frame scan. At the same time an end of frame signal opens a gate **60** to release the accumulated signals into a total accumulator **62.**

At the end of a frame scan, the value stored in **62** will correspond to the sulphide inclusion area in the field and the value transferred to one of the accumulators **14–18,** the oxide inclusion area in the field, classified as one of the three JK types B, C or D.

An analysis of a sample of steel may involve measuring the inclusion content of **500** small areas of the sample surface and classifying the inclusion content predominance of each area. At the end of such an analysis, the area values in the four accumulators **14–18** and **62** will represent the total area of the four different inclusion types.

Where the projection measurements are made by a system as described in U.S. pat. application ser. No. 238,893, incorporated herein by reference the subdivision of each line scan effectively achieved by so-called clocking of the intersect pulses must be such that the spacing between sampling points along a line scan must be equal to the vertical spacing between adjacent line scans.

Where this is not so, and e.g. the spacing between adjacent line scans is e.g. twice the horizontal spacing between sampling points, then an appropriate scaling correction must be applied to the output from one or other of the two measuring devices, **26, 28** or a different value selected for K1.

The complete analysis of a steel sample may involve analysing and classifying many hundreds of separate regions. An overall classification for the steel sample is obtained by counting in separate registers the number of fields classified as being of the various different types and taking as the characteristic classification for the steel that to which the greatest number of fields have been classified.

In a situation where both type-C and type-B classifying signals are generated for a region, that classifying signal is chosen for which the area of the oxide inclusion type is the greater.

We claim:

1. A method of classifying a region of a polished steel surface containing non-metallic inclusions which appear darker than the remainder of the steel surface, comprising the steps of scanning an image of the region in a series of parallel lines forming a raster, generating an amplitude varying video signal from the scanning, in which the amplitude has a first value corresponding to the steel, a second value corresponding to sulphide inclusions and a third value corresponding to oxide inclusions, comparing the video signal with a first reference voltage between the said first and second values and with a second reference voltage between the said second and third values, generating a first detected signal of pulses generated whenever the video signal amplitude has a value between the first and second reference voltages and a second detected signal of pulses generated whenever the video signal amplitude has a value below the second reference voltage, performing measurements on the pulses forming the second detected signal arising from scanning the whole region to produce at least first and second output signals, comparing the relative magnitudes of said output signals and generating a classifying signal for the region in response to the comparison of the output signals.

2. The method as set forth in claim **1** comprising the steps of accumulating separately the pulses of each detected signal to form two output signals during each scan of the said region.

3. The method as set forth in claim **2** comprising the steps of dividing the one output signal by the other to form a quotient signal, generating a reference signal and comparing the quotient signal with the reference signal to effect comparison of the said two output signals.

4. The method as set forth in claim **1** comprising the steps of generating from the second detected signal pulses a first output signal corresponding to the total of the horizontally projected lengths of the detected oxide inclusions in the region and a second output signal corresponding to the total of the vertically projected lengths of the detected oxide inclusions in the region, comparing the magnitudes of the first and second output signals and generating a type-C classifying signal if the second output signal is greater than a multiple of the first output signal.

5. The method as set forth in claim **4** wherein the preffered value for the first multiple is 1.7.

6. The method as set forth in claim **4** further comprising the steps of generating from the second detected signal pulses a first count pulse for each detected oxide inclusion, associating the detected signal pulses arising from inclusions separated by less than given distances (measured parallel and perpendicular to the line scan direction) from other inclusions and generating for each group of associated detected signal pulses a second count pulse, counting the first and second count pulses to form third and fourth output signals respectively, comparing the magnitude of the fourth output signal with that of the third output signal and generating a type-B classifying signal if the third signal magnitude is greater than a second multiple of the fourth signal magnitude.

7. The method as set forth in claim **6** wherein the preferred value for the second multiple is 2.0.

8. The method as set forth in claim **6** further comprising the step of generating a type-D classifying signal if the comparisons effected on the first and second and third and fourth output signals are both negative.

9. The method as set forth in claim **4** wherein the second output signal is generated by selecting from the intersect pulses arising from scanning each inclusion the longest duration pulse therefrom and accumulating all said longest duration pulses during a scan of the region to form the said second output signal.

10. The method as set forth in claim **1** comprising the steps of generating a length signal corresponding to the length dimension of each inclusion from the intersect pulses relating thereto, applying first size discrimination to each length signal and generating a count pulse

for each inclusion for which the first length signal is greater than the first size, applying a second size discrimination to the length signals and generating a count pulse for each inclusion for which the first length signal is greater than the second size, (larger than the first size), counting the two sets of count pulses to produce first and second count signals (constituting said first and second output signals respectively), comparing the two count signals and generating a type-C classifying signal if the count signal due to the first size discrimination is not greater than a given multiple of the count signal due to the second size discrimination.

11. The method as set forth in claim **10** wherein preferred ranges of the first and second sizes are 2 to 30 μm and 8 to 120 μm respectively.

12. The method as set forth in claim **10** wherein the comparison is effected by dividing the second count signal by the first count signal to form a quotient signal generating a reference value signal and comparing the quotient signal with the reference value signal.

13. The method as set forth in claim **12** wherein a preferred range of values for the reference value is 0.1 - 0.8.

14. The method as set forth in claim **12** wherein the reference value is 0.5.

15. The method as set forth in claim **1** comprising the steps of computing from the second detected signal pulses a signal corresponding to the total projected length (in one direction) of the detected oxide inclusions, computing therefrom a signal corresponding to the arithmetic square of the total projected length to obtain a first area value signal, to form the first output signal, computing from the second detected signal pulses a signal corresponding to the actual total area of the detected oxide inclusions to obtain a second area value signal to form the second output signal, comparing the two area value signals and generating a type-C classifying signal if a comparison criterion is satisfied.

16. The method as set forth in claim **1** comprising the steps of computing from the second detected signal pulses a signal corresponding to the total of all perimeters of detected oxide inclusions to obtain a total perimeter first output signal, generating a total area (second output) signal by accumulating the second detected signal pulses, comparing the total perimeter signal with the total area signal and generating a type-C classifying signal if a comparison criterion is satisfied.

17. A method of analysing a steel sample comprising the steps of analysing separately each of a plurality of regions of the surface thereof in accordance with the method as set forth in claim **1**, counting the number of fields classified as being of each separate type and selecting as an overall classification for the steel that to which the greater number of fields have been classified.

* * * * *