CLAIMS

What is claimed is:

1. A system for detecting defects in a ferromagnetic material, the system comprising:

a plurality of magnetometers disposed about a surface of the ferromagnetic material, the plurality of magnetometers sensing a magnetic field generated by the ferromagnetic material and generating magnetic field data, based on the sensed magnetic field, wherein each magnetometer of the plurality of magnetometers is fixed in position, relative to the ferromagnetic material;

a magnetic field mapper generating data points of a two-dimensional map from the magnetic field data, each data point corresponding to a respective location on the surface of the ferromagnetic material and representing strength of the sensed magnetic field proximate the location; and

a pattern matcher that identifies, in the map, a plurality of data points that conform to a predefined spatial pattern of magnetic field strength and outputs a location proximate the surface of the ferromagnetic material that corresponds to the plurality of data points.

2. A system according to claim 1, further comprising a defect size estimator that estimates a volume of material missing from the ferromagnetic material at the location proximate the surface of the ferromagnetic material, based on amplitude of a feature represented by data in the plurality of data points.

3. A system according to claim 2, wherein the defect size estimator estimates an area of the missing material, based on length in two spatial directions of a feature represented by data in the plurality of data points.

4. A system according to claim 2, wherein the defect size estimator estimates a depth of the missing material, based on the estimated volume of missing material and length in two spatial directions of a feature represented by data in the plurality of data points.

°°°

5. A system according to claim 1, further comprising:

a residual magnetic field strength calculator determining amplitude of the magnetic field generated by the ferromagnetic material at a location distant from the location proximate the surface of the ferromagnetic material, based on at least one of the data points of the map; and

a defect size estimator that estimates a volume of material missing from the ferromagnetic material at the location proximate the surface of the ferromagnetic material, according to amplitude of data in the plurality of data points and the amplitude of the magnetic field generated by the ferromagnetic material at the location distant from the location proximate the surface of the ferromagnetic material.

6. A system according to claim 1, wherein:

each magnetometer of the plurality of magnetometers comprises three orthogonally oriented magnetometers;

each data point of the map represents strength of the sensed magnetic field in each of three orthogonal directions; and

the pattern matcher identifies, for each of the three orthogonal directions, a plurality of data points that conform to a predefined spatial pattern of magnetic field strength and a location proximate the surface of the ferromagnetic material that corresponds to the plurality of data points, the pattern matcher thereby identifying three locations proximate the surface of the ferromagnetic material; and further comprising:

a combiner that calculates a refined location proximate the surface of the ferromagnetic material from the three identified locations and outputs the refined location.

7. A system according to claim 1, wherein:

the pattern matcher calculates a plurality of spatial derivative values from the data points of the map; and

the pattern matcher identifies the plurality of data points that conform to the predefined spatial pattern of magnetic field strength from the plurality of spatial derivative values.

8. A system according to claim 1, wherein the plurality of data points that conform to the predefined spatial pattern of magnetic field strength corresponds to a loss of a portion of the ferromagnetic material due to corrosion or erosion.

°°°

9. A system according to claim 1, wherein the plurality of data points that conform to the predefined spatial pattern of magnetic field strength corresponds to a crack in the ferromagnetic material.

10. A method for detecting defects in a ferromagnetic material, the method comprising:

sensing a magnetic field generated by the ferromagnetic material;

generating data points of a two-dimensional map from the sensed magnetic field, each data point corresponding to a respective location on the surface of the ferromagnetic material and representing strength of the sensed magnetic field proximate the location;

identifying, in the two-dimensional map, a plurality of data points that conform to a predefined spatial pattern of magnetic field strength; and

outputting a location proximate the surface of the ferromagnetic material that corresponds to the plurality of data points,

wherein sensing the magnetic field comprises disposing a plurality of magnetometers about a surface of the ferromagnetic material, wherein each magnetometer of the plurality of magnetometers is fixed in position, relative to the ferromagnetic material.

11. A method according to claim 10, further comprising estimating a volume of material missing from the ferromagnetic material at the location proximate the surface of the ferromagnetic material, based on amplitude of a feature represented by data in the plurality of data points.

12. A method according to claim 11, further comprising:

determining amplitude of the magnetic field generated by the ferromagnetic material at a location distant from the location proximate the surface of the ferromagnetic material, based on at least one of the data points of the map; and

estimating a volume of material missing from the ferromagnetic material at the location proximate the surface of the ferromagnetic material, according to amplitude of data in the plurality of data points and the amplitude of the magnetic field generated by the ferromagnetic material at a location distant from the location proximate the surface of the ferromagnetic material.

13. A method according to claim 11, further comprising estimating an area of the missing material, based on length in two spatial directions of a feature represented by data in the plurality of data points.

°°°

14. A method according to claim 10, further comprising estimating a depth of the missing material, based on the estimated volume of missing material and length in two spatial directions of a feature represented by data in the plurality of data points.

15. A method according to claim 10, wherein:

sensing the magnetic field comprises sensing the magnetic field with a plurality of magnetometers, each magnetometer of the plurality of magnetometers comprising three orthogonally oriented magnetometers;

generating the data points comprises generating the data points such that each data point of the map represents strength of the sensed magnetic field in each of three orthogonal directions; and

identifying the plurality of data points that conform to the predefined spatial pattern comprises, for each of the three orthogonal directions, identifying a plurality of data points that conform to a predefined spatial pattern of magnetic field strength and a location proximate the surface of the ferromagnetic material that corresponds to the plurality of data points, thereby identifying three locations proximate the surface of the ferromagnetic material; the method further comprising:

calculating a refined location proximate the surface of the ferromagnetic material from the three identified locations; and wherein:

outputting the location comprises outputting the refined location.

16. A method according to claim 10, further comprising:

calculating a plurality of spatial derivative values from the data points of the map; and wherein:

identifying the plurality of data points that conform to a predefined spatial pattern comprises identifying a plurality of data points that conform to the predefined spatial pattern of magnetic field strength from the plurality of spatial derivative values.

17. A method according to claim 10, wherein identifying the plurality of data points that conform to a predefined spatial pattern comprises identifying a plurality of data points that corresponds to a loss of a portion of the ferromagnetic material due to corrosion or erosion.

18. A method according to claim 10, wherein identifying the plurality of data points that conform to a predefined spatial pattern comprises identifying a plurality of data points that corresponds to a crack in the ferromagnetic material.

°°°

19. A computer program product for detecting defects in a ferromagnetic material, the computer program product comprising a non-transitory computer-readable medium having computer readable program code stored thereon, the computer readable program code comprising:

a sense module that receives magnetic field data from a plurality of magnetometers disposed about a surface of the ferromagnetic material, the plurality of magnetometers sensing a magnetic field generated by the ferromagnetic material and generating the magnetic field data, based on the sensed magnetic field, wherein each magnetometer of the plurality of magnetometers is fixed in position, relative to the ferromagnetic material;

a data point generator module that generates data points of a two-dimensional map from the sensed magnetic field, each data point corresponding to a respective location on the surface of the ferromagnetic material and representing strength of the sensed magnetic field proximate the location;

a defect identifier module that identifies, in the two-dimensional map, a plurality of data points that conform to a predefined spatial pattern of magnetic field strength; and

a defect location output module that outputs a location proximate the surface of the ferromagnetic material that corresponds to the plurality of data points.

ooo