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Technical Report

Reliability of mechanical properties of induction sintered iron based powder metal parts

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ABSTRACT

Reliability and safety are important for machine and construction elements. In this study, iron based powder metal parts (3% Cu, 0.5% Graphite and 1% Kenolube lubricant by weight) were sintered at 1200 °C by medium frequency induction sintering mechanism (30 KW powered and 30 kHz frequency). Mechanical property values of components were determined according to changing sintering time. Three point bending, % maximum strain, MicroVickers hardness (HV) and Rockwell-B hardness tests were applied. Statistical distribution functions were drawn and ultimate strength, ultimate strain, MicroVickers and Rockwell-B hardness values were determined depending on various reliability. As a result of the experiments, it was concluded that, the hardness of powder metal materials should not be based on MicroVickers hardness.

1. Introduction

Powder metal parts are widely used as machinery and construction elements. Powder metallurgy is one of the highly preferred production method because of its widely advantages. Powders which have different composition are pressed and then sintered at this method. Sintering is one of the most important issues of powder metallurgy because sintering causes significantly an increase in resistance of pressed powders [1]. The sintering process is generally performed in the sintering furnaces. It is done in batch furnaces and continuous furnaces [1]. In addition, induction sintering method is an important alternative of conventional sintering method. The advantage of this process allows very quick densification to near theoretical density and prohibition of grain growth [2]. Sintering and additional heat treatments of powder mixtures generate the microstructure to meet the performance as required [3].

Sintered materials are generally have a porous structure, with the increase in the amount of porosity, powder metal parts become brittle [1]. Mechanical Strength measurements of brittle materials or of metals under conditions where they behave in a brittle manner show a high variability of results which requires statistical analysis [4]. While classical construction method is based on safety, statistical construction method is based on reliability. Reliability values are range from 0 to 1, so $F + R = 1$ has a relation from Failure and Reliability [5]. Reliability is characteristic of an item, expressed by the probability that the item will perform is required function under given conditions for a stated time interval [6].

Normal distribution, also called Gaussian distribution, a probability distribution is very important in many areas. Normal distribution has important applications in engineering and reliability [7]. Normal distribution is used to model of the physical, mechanical or chemical properties of a variety of systems. Gas molecule velocity, clothing, sound, tensile strength of aluminum alloy steels, capacity variation of electrical condensers, electrical power consumption in a field, generator output voltage and electrical resistance are shown as examples application of the normal distribution [8]. In another application, it is using analysis of the materials produced and analysis of their ability to perform of their functions [7]. Also, it is usually considered a normal distribution for Ultimate stress and nominal stress values [9–13].

Stress–Life diagrams can be drawn for for 0.1%...99.9% reliability. It is possible to realize the life values for 0.1%...99.9% reliability according to the load intensity [14]. It is not proper to realize the life analysis considering 50% reliability, for a machine element which has a vital importance. It is also possible to determine life values by using 90–99.9% reliability. However, these values become more important only in the case of competition of firms [15]. Similarly life values, ultimate stress values of materials can be found in the range of 0.1%...99.9% reliability [8]. Normal distribution is defined in the range of $(-\infty, +\infty)$. However, the reliability theory is dealt with periods of life of object. Therefore, the distribution of objects on the duration of life is assumed to be in the range $(0, +\infty)$ [16].

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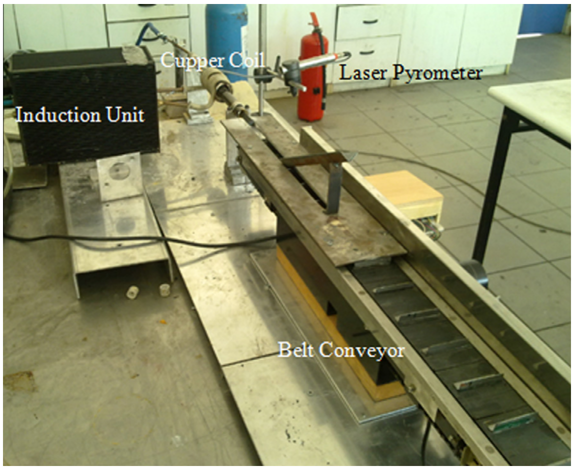

Fig. 1. Induction sintering mechanism.

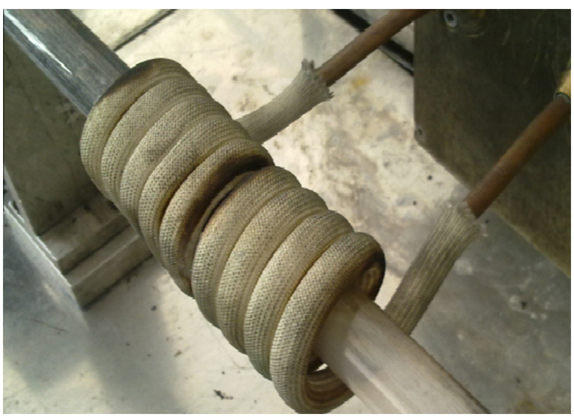

Fig. 2. Cupper coil.

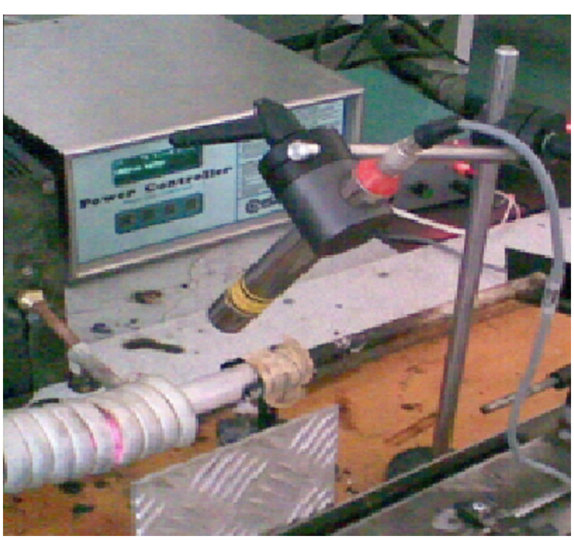

Fig. 3. Laser pyrometer.

Fig. 4. Sintered samples.

Table 1
Three point bending results of 8.4 min sintered samples.

Sample number	Ultimate stress (N/mm^2)	Ultimate strain (%)
1	425.94	3.9
2	510.26	3.93
3	484.45	3.62
4	510.78	3.79
5	509.75	3.9
6	653.86	4.63
7	575.55	3.5
8	524.99	3.6

Table 2
Three point bending results of 15 min sintered samples.

Sample number	Ultimate stress (N/mm^2)	Ultimate strain (%)
1	562.64	3.37
2	426.07	2.93
3	525.41	4.05
4	603.51	5.35
5	613.22	4.29
6	533.06	4.19
7	533.33	4.2
8	464.72	3.49

Table 3
Three point bending results of 30 min sintered samples.

Sample number	Ultimate stress (N/mm^2)	Ultimate strain (%)
1	467.26	3.24
2	539.43	3.79
3	579.15	4.4
4	517.78	4.28
5	577.69	5.04
6	653.92	5.57
7	570.05	4.66
8	534.15	4.81

In previous studies, induction sintering was generally carried out with high frequency induction sintering unit at the same time pressing process (HFIFS) [17–23]. In this study, sintering was carried out after pressing process with medium frequency induction unit (30 kHz). In general, the average values of experimental results were given at powder metallurgy studies. Instead of average values of mechanical properties, most of the time mechanical properties values which have high reliability are more important at usage areas of powder metal parts. In this study, mechanical properties of powder metal parts were determined with mechanical tests. The results of these tests were evaluated statistically and the results which have 10%, 50% and 90% reliability were identified and compared with each other. Reliability analysis of ultimate stress, ultimate strain, Rockwell-B hardness and Vickers hardness were done. The most suitable sintering time according to the