Abstract:

Ni-free alloyed steel powder "FM Series" for high strength sintered compacts with excellent machinability has been developed. FM Series are pre-mixed powder based on a low Mo prealloyed (0.45 mass%) steel powder added with copper, graphite and lubricant for high density compaction. The sintered compacts of FM series provide tensile strength of 600 MPa with mesh-belt sintered condition and tensile strength of 1 000 MPa with mesh-belt sintered and carburized condition, which are equivalent to those of the conventional 4 mass% Ni diffusion-alloyed steel powder. The sintered compacts of FM series provide less than one ffth the tool wear of that of the conventional 4 mass% Ni diffusion-alloyed steel powder. The high strength and excellent machinability are caused by microstructure homogenization of the sintered compacts due to low Mo prealloyed steel powder.

Sintered compacts produced by a conventional mesh-belt sintering furnace using Fe-4mass%Ni-1.5mass%Cu-0.5mass%Mo diffusion-alloyed steel powder[1)], in which fne nickel, copper, and molybdenum (Mo) powders are diffusion-bonded to the surface of the iron powder particles, are widely adopted for tensile strength

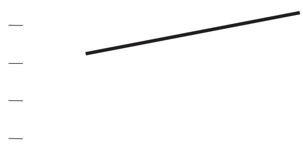
10^7 cycles. The microstructures were observed with an optical microscope after etching the cross-section of the sintered compacts in 3% nital (mixture of 100 m*l* ethanol to 3 m*l* nitric acid).

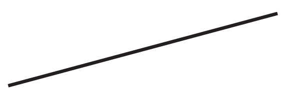
The machinability of the sintered materials was evaluated by measuring the cutting tool wear during turning tests. Machining of the ring specimens was performed using a cermet insert (Grade T1200A, Sumitomo Electric Hardmetal Corp.). The machining conditions were cutting speed: 200 m/min, cutting depth: 0.5 mm, feed rate: 0.1 mm/rev, without coolant. The f ank wear of the inserts was measured after 1 000 m of turning.

The mechanical properties of the sintered compacts made of FM600 and 4Ni alloyed steel powder mixtures are shown in . The tensile strength and hardness of the FM600 material are approximately equivalent to those of the 4Ni alloyed steel. The tensile strength of both materials is 600 MPa at 7.1 Mg/m^3. The Charpy impact value of the FM600 material is lower than that of the 4Ni alloyed steel.

The results of rotating bending fatigue tests of the sintered compacts made of FM600 and 4Ni alloyed steel powder mixtures are shown in . The FM600 material shows a higher fatigue strength of 195 MPa than the 4Ni alloyed steel.

Optical micrographs of the cross-sectional microstructures of the sintered compacts made of FM600 and 4Ni alloyed steel powder mixtures are shown in . The microstructure of the 4Ni alloyed steel consists of ferrite, pearlite, martensite, and austenite. Due to insuf f cient diffusion during sintering of the alloying elements Ni, Cu, and Mo, which are diffusion-bonded to the iron powder particles, this material comprises various microstructures, depending on the alloying content distribution. That is, the ferrite and pearlite





The tensile strength and Charpy impact values of the sintered and carburized compacts were evaluated in accordance with JIS Z 2241 and 2202, respectively. The dimensions of the specimens for the tensile test were 5 mm in diameter and 15 mm in length. The specimens were prepared by machining after sintering. Unnotched specimens 10 mm in width, 10 mm in thickness, and 55 mm in length were used for the Charpy impact tests. Rockwell and Vickers hardness was measured in accordance with JIS Z 2245 and 2244, respectively. The rotating bending fatigue strength of the sintered and carburized compacts was evaluated in accordance with JIS Z 2274. The dimensions of the specimens for the fatigue test were 8 mm in diameter and 15.4 mm in length. The fatigue test was performed using a load ratio *R* of –1 and rotation speed of 3 000 rpm. Fatigue strength was defined as the stress at which failure did not occur in more than half of the specimen at 10^7 cycles. The microstructures were observed with an optical microscope after etching the cross-section of the sintered compacts in 3% nital.

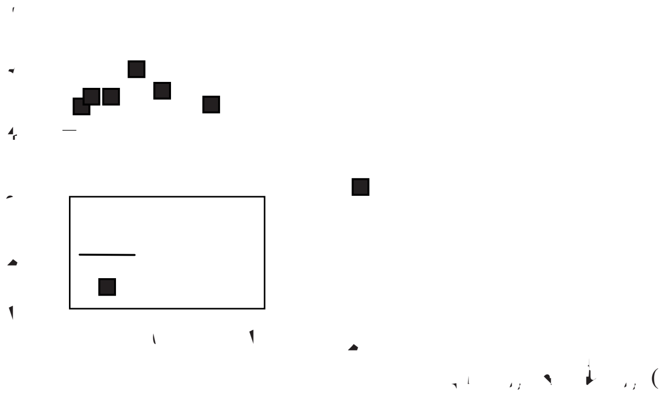
The machinability of the sintered materials before carburizing was evaluated by measuring the cutting tool wear during turning tests. Machining of the ring specimens was performed using a P type carbide insert (Grade ST10P, Sumitomo Electric Hardmetal Corp.). The machining conditions were cutting speed: 200 m/min, cutting depth: 0.5 mm, feed rate: 0.1 mm/rev, without coolant. The flank wear of the inserts was measured after 1 000 m of turning.

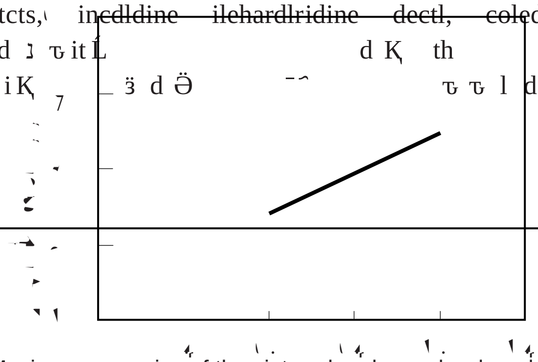
The mechanical properties of the sintered and case-hardened compacts made of FM1000 and 4Ni alloyed steel powder mixtures are shown in . The tensile strength and rotating bending fatigue strength of the FM1000 material are substantially equivalent to those of the 4Ni alloyed s Ml f m l ::

steel. Moreover, the FM1000 material also shows lower tool wear than 4Ni alloyed steel with manganese sulfde as a machinability improvement additive, and thus has extremely high machinability.

The effect of copper on the strength of the sintered and case-hardened compacts made of the molybdenum prealloyed steel powder are discussed in the following.

The effects of the amount of copper addition on the tensile and fatigue strength of the sintered and case-hardened compacts made of the molybdenum prealloyed steel powder are shown in . Tensile strength increases by about 100 MPa and achieves 1 070 MPa with 1% copper powder addition, but reaches saturation with MPa and copper addition this increased





Maximum pore size of the sintered and case-hardened compacts made of the low molybdenum prealloyed steel powder with copper addition

The amount of retained austenite increased very slightly with increasing copper addition. However, it would be extremely diffcult to attribute the sudden drop in fatigue strength to this small increase in retained austenite.

Next, the pore size distribution in the sintered and case-hardened compacts was quantified by image analysis (0.96 mm^2) of photographs of the cross section. shows the relationship between the maximum pore diameter and copper addition.

The maximum pore size increases with increasing copper addition. Coarse pores are thought to be generated by copper liquid phase outfow and become an origin of fatigue fracture due to stress concentration.

The stress concentration at coarse pores in the quenched and tempered materials should increase, because these materials are more sensitive to stress concentration due to their higher hardness in comparison with as-sintered material. Therefore, the coarse pores should have a stronger effect on fatigue strength than on tensile strength.

It has also been reported that 2% copper addition of 600 MPa and rotating bending fatigue strength of 195 MPa, which are equivalent to those of the conventional 4%Ni diffusion-alloyed steel powder.

(2) Sintered and case-hardened compacts of FM1000, based on low Mo prealloyed (0.45%) steel powder with added copper (1%), graphite (0.5%) and HDX (0.5%), provide tensile strength of 1 070 MPa and rotating bending fatigue strength of 330 MPa, which [illegible] equivalent to those of the conventional 4% whichh[illegible]

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