United States Patent [19]

Dunn

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[54] **COMPOSITE HIGH-STRENGTH MACHINE ELEMENT AND METHOD OF MAKING THE SAME**

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[73] Assignee: **Federal-Mogul Corporation**, Southfield, Mich.

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[52] **U.S. Cl.** **29/191**, 29/196.1

[51] **Int. Cl.** **E04c 2/08**

[58] **Field of Search** .... 29/196.3, 191, 196.1, 29/191.2, 420.5, 474.3; 75/208, 123 J

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[57] **ABSTRACT**

This composite high-strength bushing consists of a heavy-load-bearing sleeve of sintered powdered high-performance alloy and a lesser-load-bearing support sleeve of sintered base metal such as sintered powdered iron. The outer sleeve has an internal taper while the inner sleeve has a matching external taper, both sleeves being separately formed from their respective powdered metals by suitable dies in conventional briquetting presses and thereafter sintered and forged by forcing them together in a hot-forging press at a high temperature. The outer and inner sleeves are thereby firmly and inseparably joined by high heat and pressure and interlocked by the migration of minute portions of one of the metals past minute portions of the other metal across the tapered interface therebetween, thereby forming an intermediate zone of the intermingled metals encircling the interface. A modification employs tapers of slightly different convergence between the outer and inner sleeves but also results in a similarly-inseparable interlocking connection by a similar migration of the metals into an intermediate zone encircling the interface.

3 Claims, 11 Drawing Figures

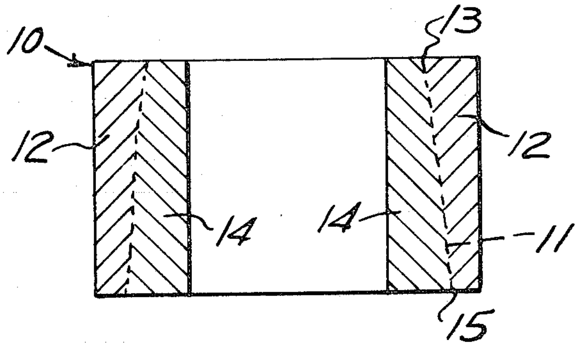


FIG. 1

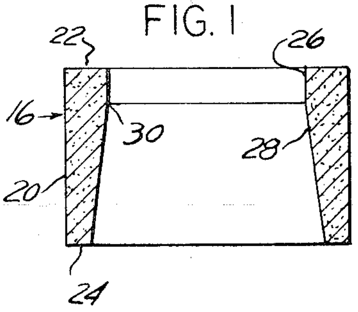


FIG. 2

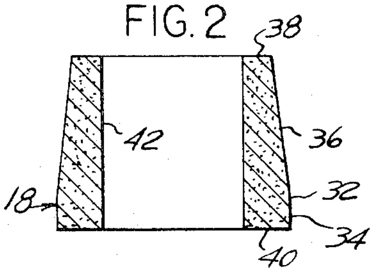


FIG. 4

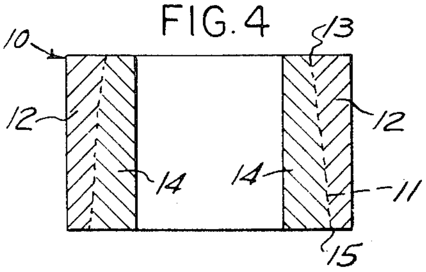


FIG. 3

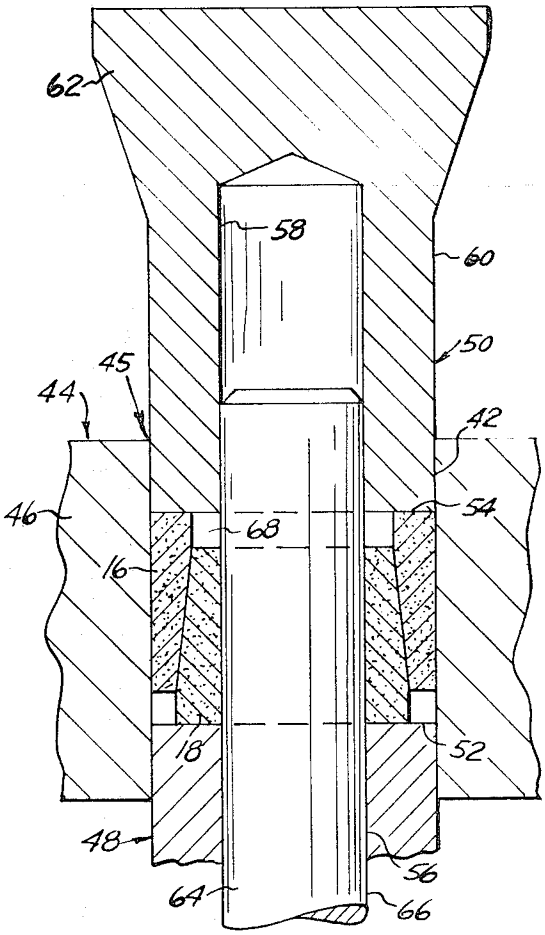
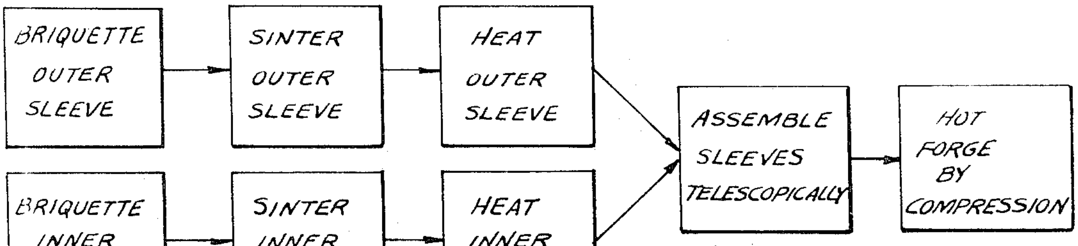


FIG. 5



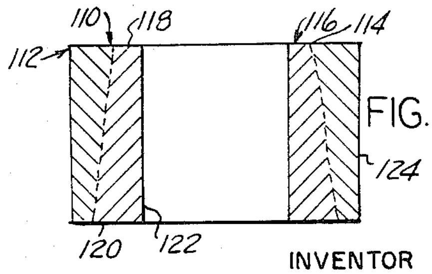


FIG. 11

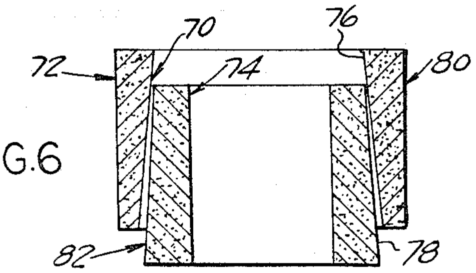


FIG. 6

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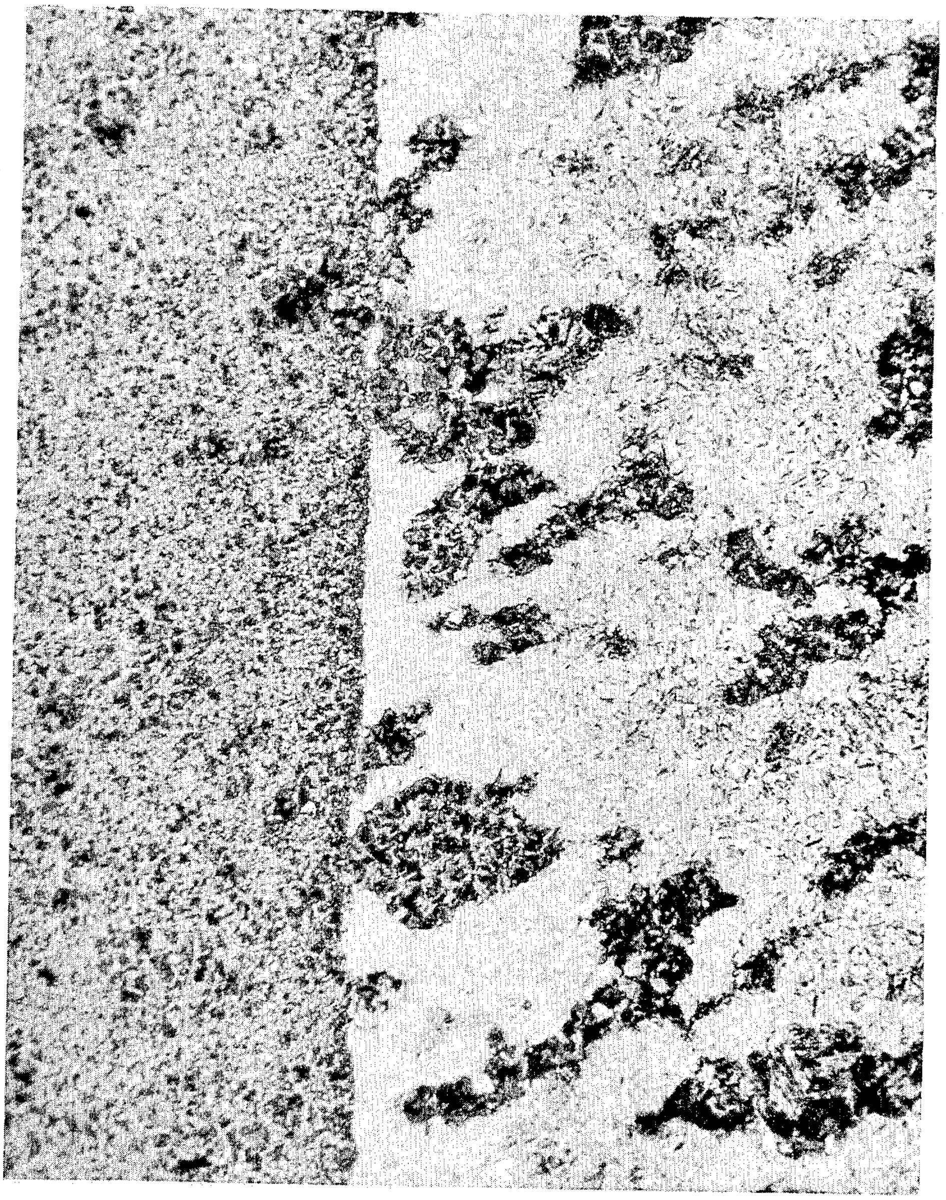

FIG. 7

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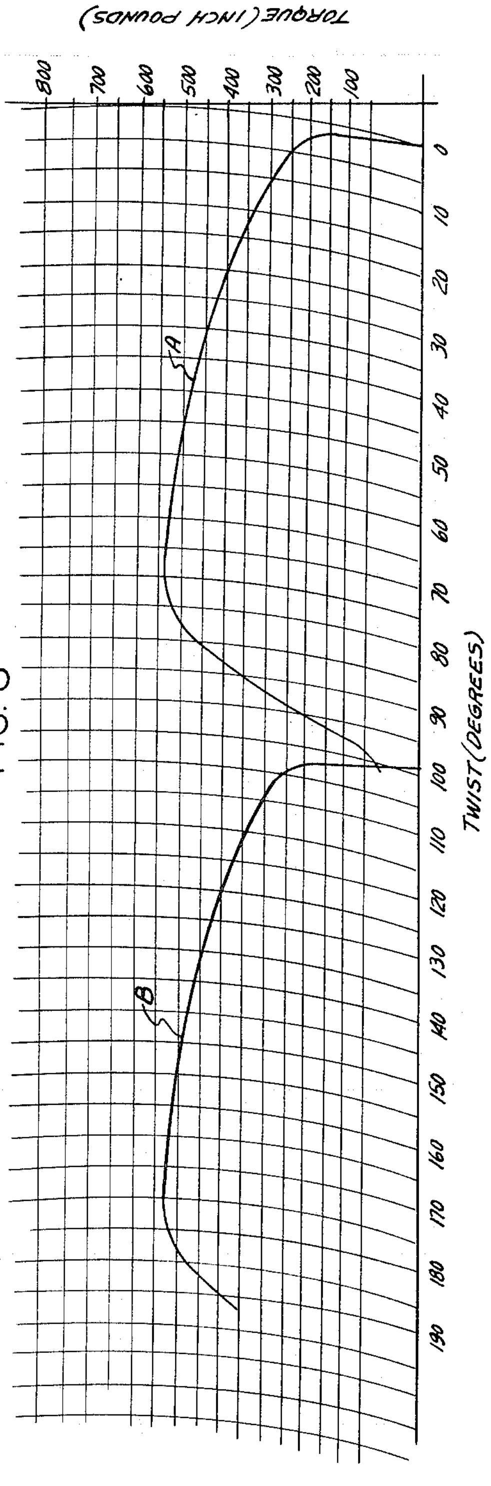

FIG. 8

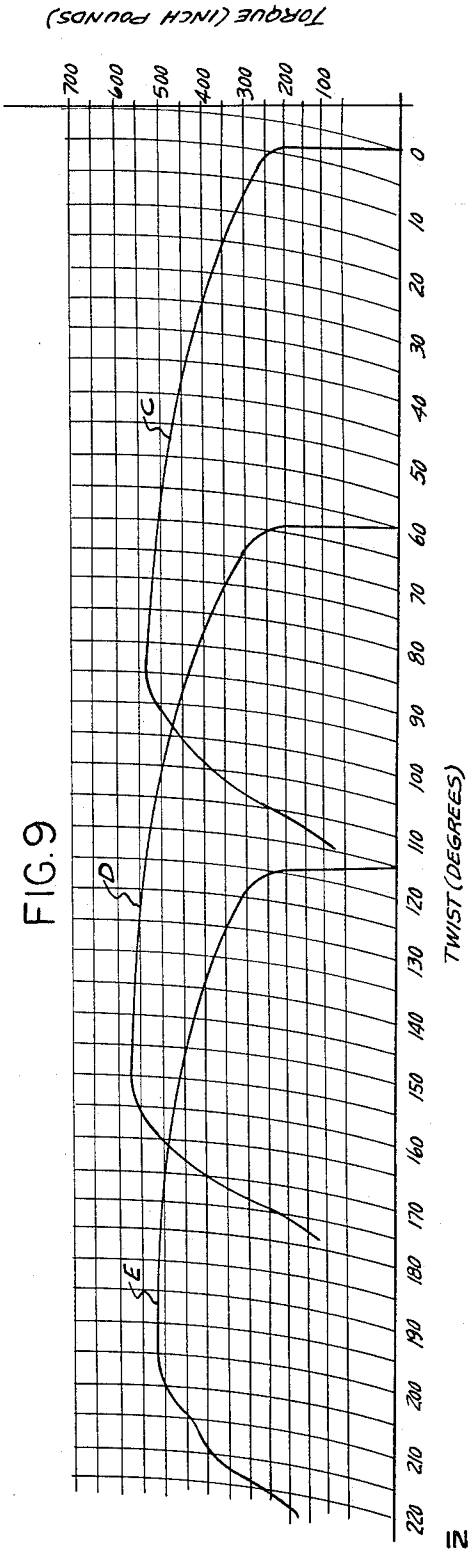

FIG. 9

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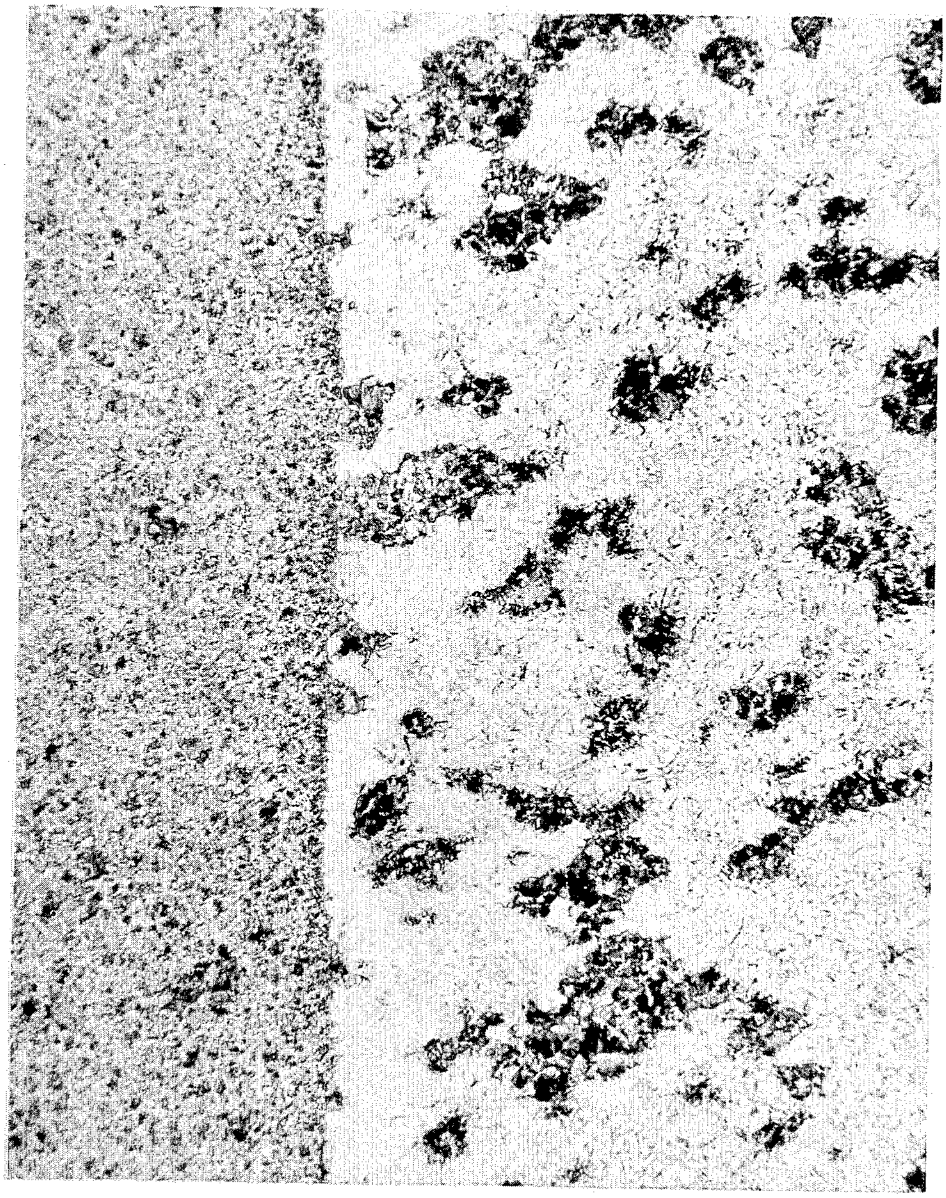
FIG. 10



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COMPOSITE HIGH-STRENGTH MACHINE ELEMENT AND METHOD OF MAKING THE SAME

In the drawings,

FIG. **1** is a longitudinal section through the outer powdered metal sleeve, after briquetting and sintering, according to one form of the invention;

FIG. **2** is a longitudinal section through the inner powdered metal sleeve, after briquetting and sintering, according to the same form of the invention;

FIG. **3** is a longitudinal section through a hot-forging die in a hot-forging press, showing the outer and inner sleeves of FIGS. **1** and **2** at the start of the hot-forging operation of uniting them into a composite bushing;

FIG. **4** is a longitudinal section through the composite bushing, after forging;

FIG. **5** is a flow diagram of the steps involved in the method of making the composite bushing of FIG. **4**;

FIG. **6** is a longitudinal section through a modification of the invention shown in FIGS. **1** to **5** inclusive, wherein the outer and inner sleeves possess slightly different converging tapers, with the components assembled immediately prior to hot forging as in FIG. **3**;

FIG. **7** is a photomicrograph of a longitudinal section of the composite bushing of FIG. **4** showing the interlocking of the different metals at the interface;

FIGS. **8** and **9** are reproductions of graphical test charts produced by tension tests made upon specimens cut from the composite bushings, as shown in FIG. **4**;

FIG. **10** is a photomicrograph similar to FIG. **7** but showing the interlocking of the metals of the different metals at the interface of a longitudinal section of the modification involving the differently-tapered sleeves shown in FIG. **6**, after hot-forging; and

FIG. **11** is a longitudinal section through the composite bushing, after forging, with the positions of the components of FIG. **4** reversed.

Referring to the drawings in detail, FIG. **4** shows a composite high-strength bushing, generally designated **10**, according to one form of the invention, as composed of a high-performance alloy outer sleeve **12** joined at an approximately conical or tapered interface **11** to a plain iron inner sleeve **14** with opposite flat annular end surfaces **13** and **15**. The sleeves **12** and **14** are formed from sintered powdered metal outer and inner components **16** and **18** respectively (FIG. **3**) according to the procedure shown in the flow chart or diagram in FIG. **5**. The outer and inner components **16** and **18** (FIGS. **1** and **2**) are formed by briquetting a suitable high performance alloy and iron respectively in the die cavities of conventional briquetting presses (not shown), each having a core rod and upper and lower punches, by briquetting procedures well known to those skilled in the powdered metallurgy art. The dies for briquetting the outer components **16** are so formed as to impart to the outer component **16** an outer cylindrical surface **20**, upper and lower annular surfaces **22** and **24**, a relatively short upper inner cylindrical bore surface **26**, and a lower tapered or conical bore surface **28**, with the surfaces **26** and **28** collectively forming a partially tapered and partially cylindrical inner surface **30**.

The dies for briquetting the inner component **18**, on the other hand, are so formed as to provide an outer surface **32** consisting of a relatively short lower cylindrical surface **34** and an upper conical or tapered surface **36**, the surface **36** having the same taper as the surface **28** of the outer component **16**. The short cylindrical surfaces **26** and **34** provide clearances with the adjacent tapered surfaces **36** and **28** respectively. These clearances receive the sidewise flow of metal during forging and thereby prevent "folding over" at the opposite ends **13** and **15**. The inner component **18** has upper and lower flat annular surfaces **38** and **40** respectively and an inner cylindrical surface **42**. The outer component **16** is formed by briquetting a powder of a suitable high performance metal or metal alloy, the particular alloy being used as exemplary in the present invention being the so-called S.A.E. 4600 alloy powder. The inner component **18**, which does not require the load-bearing characteristics of the outer portion **12** of the composite sleeve **10**, is formed from plain iron powder. The tapered surfaces **28** and **36** are both formed with matching tapers of 3°. Briquetting is carried out to produce a density of approximately 75 percent in the finished briquettes **16** and **18**. Separate sintering is then carried out at a temperature between 2,100° and 2,150° F., individually for each piece.

The sintered powdered metal outer and inner sleeves **12** and **14** are then placed in telescoped relationship, the temperatures of both components are then brought to a predetermined forging temperature within the range of 1,500° to 2,100° F. and then placed in the cylindrical die bore **42** of a forging press **44**. The latter is provided with a hot-forging die set **45** including a die plate **46** containing the cylindrical die bore **42**, a lower tubular punch **48** and an upper tubular punch **50** adapted to telescope with the die bore **42** and having flat annular facing surfaces **52** and **54** respectively adapted to produce the flat annular end surfaces **13** and **15** respectively in the composite high strength sleeve or machine element **10** (FIG. **4**). The lower tubular punch **48** (FIG. **3**) is provided with a cylindrical bore **56** while the upper punch **50** is provided with a cylindrical bore **58** of the same diameter formed within a tubular lower portion **60** depending from a main tapered upper punch portion **62**. A cylindrical core rod **64** with an outer cylindrical surface **66** is adapted to telescope with the lower and upper punch bores **56** and **58** and with the die bore **62** to define a die cavity **68**.

In carrying out the method (FIG. **5**) of making the composite high-strength machine element **10** of FIG. **4**, the outer high performance alloy component **16** and the inner low performance component **18** are separately briquetted to densities of approximately 75 percent in separate briquetting dies to produce the configurations described above. The briquettes **16** and **18** (FIGS. **1** and **2**) are then separately sintered at temperatures preferably between 2,100° and 2,150° F. with the upper tubular punch **50** retracted upward so as to leave the mouth of the die cavity **68** open. The sintered outer and inner sleeves **12** and **14** are then removed from the sintering oven and transferred to the die cavity **68** of the forging die set **45** of the forging press **44** at a predetermined temperature between 1,800° and 2,100° F. alternatively, it may be more convenient to reheat the sintered sleeves **12** and **14** prior to placing them in the forging die cavity **68**, due to loss of heat sustained in making the transfer from the sintering oven to the forging press **44**. The thus heated sintered outer and inner sleeves **12** and **14** are placed in the forging die cavity **68** in telescoping relationship (FIG. **3**). The upper punch **50** is moved downward with the cylindrical surface **42** of the die plate **46** preventing lateral metal flow and the top surface **52** of the lower punch **48** acting as an anvil to effect axial motion of the outer sleeve **12** relatively to the inner sleeve **14**. This hot forging operation is carried out with sufficient force to drive the outer sleeve **12** with the internal tapered surface **28** of the outer component **16** axially downward upon the outer tapered surface **36** of the inner sleeve **14** and to raise the density of the composite element to about 98 percent, or substantially solid metal. This action causes the end surfaces **22** and **24** of the outer sleeve **12** to move into substantially co-planar relationship with the end surfaces **38** and **40** respectively of the inner sleeve **14** (FIG. **4**). This relative axial motion between the tapered surfaces **28** and **36** of the outer and inner sleeves **12** and **14** under the effect not only of the initial heating of the outer and inner sleeves **12** and **14** but also that generated by the force of compression, causes a scrubbing action at the interface **11** which results in an excellent and continuous welding between the two sleeves **12** and **14** and produces a migration of the metals of the two sleeves **12** and **14** across the interface **11** into an intermediate zone of intermingled metals encircling the interface **11** and which results in an inseparable and continuous interlocking thereof along the interface **11**, as shown by the photomicrograph (FIG. **10**), wherein the light-colored portion is the high strength alloy and the dark-colored portions the iron.

Torsion tests (FIGS. **8** and **9**) of standard specimens cut longitudinally from the composite bushing **10** at the interface **11** therebetween confirm the exceptional interlocking obtained at the interface **11**. These specimens comprised rectangular blocks one inch in length and 0.312 inches square with the interface **11** disposed midway between the longitudinal side surfaces. The tests were performed in the torsion testing machine disclosed and claimed in the Haller U.S. Pat. No. 3,122,915 of Mar. 3, 1964 for Torsion Testing Machine. In these two graphic charts, the abscissae represent the applied twist to the specimen in degrees whereas the ordinates indicate the applied torque in inch pounds. The curves obtained were drawn by a pen moving transversely to the motion of the chart. The peaks of the curves A, B, C, D and E represent the peak torque measured in inch pounds obtained when the test specimen began to fracture or fail, and the rotation or twist of the test specimen in degrees at which such failure occurred is indicated by the reading of the horizontal scale designated by the words "twist (degrees)". Thus, it will be seen that test specimen A failed after a rotation of 82° at a peak torque of 545 inch pounds, specimen B after a rotation of 82° at a peak torque of 540 inch pounds, specimen C after a rotation of 94° at a peak torque of 540 inch pounds, specimen D after a rotation of 101° at a peak torque of 555 inch pounds, and specimen E after a rotation of 85° at a peak torque of 500 inch pounds.

Long experience and extensive experimentation with the torsion testing machine identified above prove that empirical formulae could be developed which would employ the results of experimental tests to indicate the tensile strength and the percentage of elongation for a given rotation which could be expected in such test specimens. These empirical formulae are as follows:

Tensile strength (lbs. per square inch) = peak torque (inch pounds)/0.007

Percentage of elongation = peak rotation (degrees)/5

Thus, the estimated tensile strength for specimen A is 77,850 p.s.i. with 16.4 percent elongation; for specimen B a tensile strength of 77,143 p.s.i. with 16.2 percent elongation; for specimen C a tensile strength of 77,143 p.s.i. with 19 percent elongation, for specimen D a tensile strength of 79,286 p.s.i. with 20 percent elongation; and for specimen E a tensile strength of 71,430 p.s.i. with 17 percent elongation.

By forging the modified construction shown in FIG. **5** in the die cavity **68** of the die set **45** of the forging press **44**, according to the same procedure described above, there is produced a composite high-strength bushing **70** which is substantially identical in appearance to the composite high strength bushing **10** shown in FIG. **4**, hence is not separately illustrated in its finished form. The sole difference in the construction is that the composite bushing, generally designated **70**, consisting of the outer sleeve **72** of high performance alloy with the inner sleeve **74** of base metal, such as plain iron, brings together differently tapered internal and external conical surfaces **76** and **78** of the outer and inner sleeves **72** and **74** respectively. In particular, the internal conical surface **76** of the outer sleeve **72** is provided with an approximately three-degree taper, whereas the outer conical surface **78** of the inner sleeve **74** is provided with a two-degree taper. The briquetting, reheating, sintering and forging procedures, including the temperatures and pressures involved, remain substantially the same as those set forth above in connection with the production of the composite high performance bushing **10** of FIG. **4** and achieve similar results. A similar interlocking at the interface corresponding to the interface **11** is also produced, with a similar migration of the two metals into one another at that interface, as shown by the photomicrograph in FIG. **10**. Torsion tests of the modified construction of FIG. **6** using converging tapers instead of identical tapers also resulted in no failures along the interface but where the test was carried out to the point of failure or rupture, such failure occurred at locations other than at the interface, in a manner similar to results of the torsion tests of the form of the invention shown in FIG. 4.

The above-mentioned nickel-content S.A.E. 4600 iron alloy powder has the following composition:

manganese	0.20%	with the remainder iron, plus carbon to suit
nickel	1.75%	
molybdenum	0.25%	

The nickel-free high-performance iron alloy powder also mentioned above has the following composition:

manganese	0.48%	with the remainder iron, plus high carbon 0.59% or low carbon 0.28%
nickel	none%	
molybdenum	0.59%	

Heat treatment of the composite bushing **10** or **70** is carried out in the usual and customary manner. It will of course be understood that the word "iron" as used herein includes iron having carbon therein for controlling the hardness desired, as achieved by such heat treatment. It also includes carburization for providing a hardened external surface, such as by case hardening.

In a further modification of the invention, FIG. **11** shows a composite high-strength bushing, generally designated **110**, as consisting of a reversal of the components shown in FIG. **4**, namely as composed of an iron outer sleeve **112** joined at an approximately conical or tapered interface **114** to a high performance alloy inner sleeve **116** with opposite flat annular end surfaces **118** and **120**. The sleeves **112** and **116** are formed from sintered powdered iron and high performance alloy outer and inner components shaped like the components **16** and **18** (FIG. **3**) according to the procedure described above for producing the composite high-strength bushing **10** of FIGS. **1** to **4** inclusive shown in the flow chart or diagram of FIG. **5**. Accordingly, it is believed that no further explanation is needed. It will be understood that the composite bushing **10** of FIG. **4** is suitable for the inner race of a roller bearing, whereas the composite bushing **110** is suitable for the outer race thereof, with conventional cylindrical rollers disposed in the annular space therebetween. It will also be understood that the modified composite bushing **110** is suitable for use as a high performance plain sleeve bearing for rotatably supporting a shaft (not shown) in its bore **122** while its outer cylindrical surface **124** is mounted in the usual counterbore or seat in the machine frame or other supporting structure (not shown).

I claim:

1. A composite high-strength bushing comprising

an inner sleeve of a base sintered powdered metallic material having a tapered external surface thereon,

and an outer sleeve of a high-strength powdered metallic material having an internal bore tapered correspondingly to said tapered external surface and fusibly joined thereto in snugly-fitting telescoped mating engagement with said tapered external surface at a substantially frusto-conical interface therebetween,

minute portions of one of said metallic materials extending irregularly past minute portions of the other of said metallic materials across said interface into interlocking engagement with one another in an intermediate zone encircling said interface and containing the thus intermingled metallic materials,

said base material being iron and said high-strength material being a manganese-molybdenum iron alloy.

2. A composite high-strength bushing, according to claim **1**, wherein said high-strength material is a nickel-content manganese-molybdenum iron alloy.

3. A composite high-strength bushing, according to claim **1**, wherein said high-strength material is a nickel-free manganese-molybdenum iron alloy.

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