Oct. 7, 1952 T. G. LEWIS 2,612,736

LAPPING METHOD AND APPARATUS

Filed Feb. 8, 1952

Fig. 1.

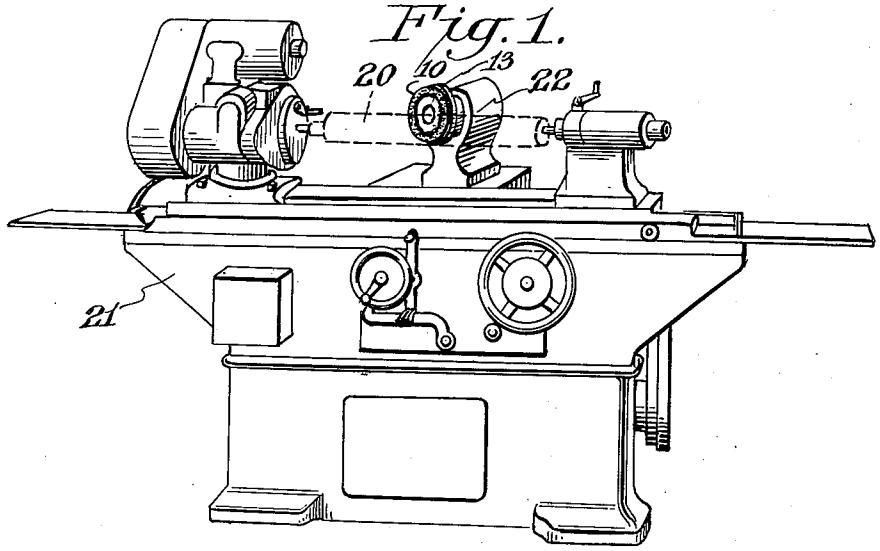


Fig. 2.

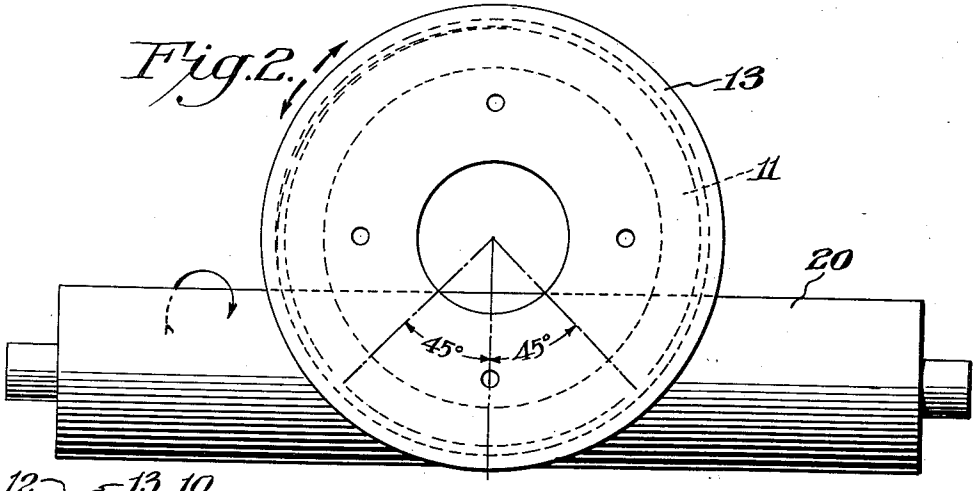


Fig. 4.

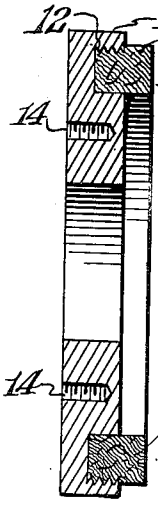
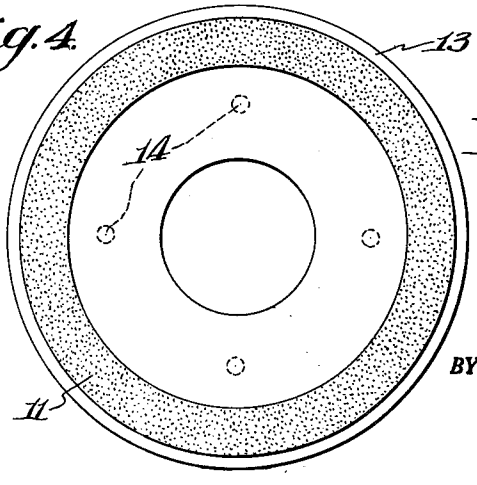


Fig. 3.



INVENTOR:
Thomas G. Lewis
BY
Harry J. McCauley
ATTORNEY.

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LAPPING METHOD AND APPARATUS

Thomas G. Lewis, Wilmington, Del., assignor to E. I. du Pont de Nemours & Company, Wilmington, Del., a corporation of Delaware

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7 Claims. (Cl. 51—289)

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This invention relates to improvements in method and apparatus for lapping metallic articles, and particularly to a method and apparatus for the lapping of articles fabricated from non-homogeneous or inclusion-bearing metal alloys and metals to develop thereon a high quality surface finish.

Metal alloys and some metals, to varying degrees, are non-homogeneous to abrasion and therefore it is difficult to lap these materials at a substantially uniform rate necessary to develop high quality surface finishes with good dimensional control. Typical examples of such materials are the high tungsten, vanadium and chromium content alloy steels, wherein relatively rich carbide concentrations exist at the grain boundaries or at other points. These carbides are usually much harder than the metal of the grain interiors and, in the case of vanadium carbide, at least, may be of a greater hardness than aluminum oxide abrasive itself. An even more serious problem from the standpoint of lapping is that of the impurity inclusions which are found in all commercial grades of metal alloys. These inclusions may comprise small amounts of silicates, sulfides or other substances, or refractory particles picked up from the smelting furnace, which may be either harder or softer than the primary metal constituent and thus possess a different abrading characteristic. When metal alloys are lapped by the conventional methods now known to the art, inclusions invariably tear away from the surrounding metal, leaving pits behind which reduce the quality of the finish. Usually the dislodged inclusions join the abrasive and are forced against the work surface one or more times during later passes of the lapping tool, thus producing scratches which additionally mar the finish. Yet another cause of pitting is believed to be point welding, which may occur between the tool and the work under the high temperatures which exist within the small area of contact. The breaking of point welds under the relative movement of the lap and the work tears small pieces of metal away, with resultant pitting, and the free metal particles intermingle with the abrasive and deface the work surface upon being carried into the contact area during subsequent operation. The combined effect of non-homogeneities, inclusions and point welding has thus hitherto prevented the attainment in metal alloys of lapped surfaces having qualities of the order of 1–2 microinches root-mean-square, which are essential to certain uses of the

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materials in polymeric material film casting wheels, polishing rolls for coated fabrics and the like. Pure metals, such as electroplated chromium, for example, are generally free of inclusions but are apparently still non-homogeneous to abrasion, since it is very difficult to secure a high quality surface finish thereon while still retaining good dimensional control.

I have now found that it is possible to lap metal alloys and also metals to finishes in the range of 1–2 microinches with high dimensional accuracy by forcing a diamond dust abrasive against the work with a lignum vitae wood lap while maintaining a predetermined pressure of contact and a high relative speed of translation of the surfaces, whereby all areas are abraded at substantially the same rate and inclusions are not torn from the matrix metal. A primary object of this invention, therefore, comprises providing a method and means for the lapping of articles fabricated from metal alloys or metals to high quality finishes. Other objects include the provision of a method of lapping articles fabricated from metal alloys or metals which is rapid and economical, and which is subject to high dimensional control, so that the finished articles conform to very precise size standards. The manner in which these and other objects of this invention are attained will become apparent from the detailed description of this specification and the following drawings, in which:

Fig. 1 is a perspective view of an apparatus adapted to lap a work-piece of cylindrical shape according to this invention, the outline of the work in set up position being shown by broken line representation;

Fig. 2 is a rear elevational view showing a preferred disposition of lap in relationship to a work-piece of cylindrical shape;

Fig. 3 is a front elevation of one embodiment of lap according to this invention; and

Fig. 4 is a sectional view taken along the vertical axis of the lap shown in Fig. 3.

Lapping according to this invention may be conducted either with a free suspended diamond abrasive, or a charged lap may be prepared incorporating the diamond abrasive therein, or a charged lap may be used in conjunction with free suspended abrasive, and each of these procedures may have particular advantages, depending on the circumstances. Thus, the use of free suspended abrasives solely obviates the molding of a charged lap as hereinafter described in greater detail; however, appreciable quantities of diamond are unavoidably

lost during suspension lapping operations, and charged laps are more economical in this respect. The use of free suspended abrasive in conjunction with a charged lap affords the advantage of somewhat greater flexibility in the control of the rate of lapping and may be preferred in instances where this consideration is important.

The embodiment of this invention utilizing free suspended diamond abrasive will be first described, it being understood that much of the detail applicable hereto is equally applicable to the practice with charged laps, either when used alone or together with suspended abrasive.

The lap of this invention may conveniently comprise a single piece of lignum vitae wood cut transverse the trunk, the ends of the fibers presented constituting a more uniform surface than is obtained when the wood is cut with the grain. Large laps can be built up by assembling a multiplicity of pieces cut across the grain into the lap configuration desired and holding the pieces rigidly together by a suitable device such as that hereinafter described with reference to Figs. 3 and 4, so that a substantially continuous surface is provided for forcing the abrasive against the work. Since it is necessary to maintain high relative surface speeds during lapping, it is preferred to employ laps of annular shape in the practice of my method, for the reason that this configuration is stable and strong enough to withstand very high rotational speeds.

In Figs. 3 and 4, the lignum vitae wood lap **10** comprises a unitary annulus cut transverse a block of the wood, so that the ends of the wood fibers make up the working face **11** which contacts the work during lapping. The outside circumference of lap **10** is cut with screw threads **12** engaging with mating threads on the inside periphery of circular metal holder **13**, the inner face of lap **10** being drawn into tight abutment against the bottom of the annular recess in the front face of holder **13** and supported thereby under the heavy lapping loading. The rear face of holder **13** is provided with tapped holes **14** for the reception of bolts for attachment of the lap to the flange of a powered rotating spindle. The lap shown in Figs. 3 and 4 is adapted to the lapping of cylindrical work pieces and the working face **11** is therefore machined to a plane, smooth surface throughout. Where it is desired to lap plane surfaces, it is preferred to machine the outer edge of face **11** on a bevel and maintain holder **13** during operation at an inclination such that the beveled edge is parallel to the work surface, whereupon substantially equal areas of the lap contact the work as in the case of cylindrical work when the same loading pressures are used.

Lapping according to this invention can be carried out with conventional machine shop equipment of the type shown in Fig. 1, wherein the cylindrical work piece **20**, in broken line representation, is set up between the centers and turned by a standard grinding machine **21**, such as a Brown & Sharpe, Model No. 4, Universal Grinding Machine. The lap, of the design shown in Figs. 3 and 4, is powered by a heavy duty motorized spindle **22**, such as a Pope Machinery Corporation Series P–2500 design, which is substituted for the conventionl grinding wheel of the grinding machine but is made to traverse the lap lengthwise of the work piece **20** by operation of grinding machine **21** in the usual manner. The in-feed of the lap against the work is conveniently gauged by maintaining the horsepower input to the spindle motor at a sufficient level for each of the sizes of abrasive used to maintain high quality lapping at a satisfactory rate. A power demand meter, not shown, of the type represented by the Weston Model 639 Industrial Analyzer is connected in circuit with the motor of spindle **22** to provide the operator with an indication of the existing loading during operation. It will be understood that the particular apparatus hereinabove described constitutes but one arrangement of many which can be employed for the purpose, and that numerous other arrangements known to those skilled in the art may be used, depending on the size and shape of the work to be lapped and the practicable speeds at which the work or the lap can be turned.

In the lapping of cylindrical work, good results are obtained when the surface of the lap is disposed substantially tangent to the surface of the work, as indicated in Figs. 1 and 2. The center line of the lap-powering spindle may be coplanar with the longitudinal axis of the work or may be disposed thereabove; however, it is preferred to locate the lap as shown in Fig. 2, wherein the angle between the median line of contact of the lap with the work and the vertical is approximately 45 degs. With this disposition, the right-hand area of contact of the lap passes the work at an inclination of 45 degs. to the right while the left-hand area of contact passes the work at an inclination of 45 degs. to the left, thus providing a broken pattern which is desirable in lapping regardless of the particular method involved. Equally good results are obtained when the lap is turned in either a clockwise or counter-clockwise direction as viewed in Fig. 2.

The beneficial results obtained with a lignum vitae wood lap appear to be due, in part at least, to the high resin content of the wood, although other factors, such as the density, modulus of elasticity and other characteristics specific to the material itself, are undoubtedly contributory, and this theory is merely advanced as the most logical supported by my observations and is not to be construed as a limitation of the method of this invention if further investigation adduces a different explanation. In any event, when a fresh lignum vitae lap is put into service it has been observed that little lapping action takes place until sufficient heat is developed at the face of the lap under the combined action of the loading pressure and the relative speed of translation of the surfaces of the lap and the work to cause substantial discoloration, or charring, of the face of the lap. Once charring has occurred, it is necessary to maintain the loading and the relative speed of translation within the same general range necessary to initiate charring in order to obtain the highest lapping rates, therefore, the presence or absence of charring affords the operator a convenient index for control of the method.

All lapping according to this invention is conducted in the presence of a liquid which serves as a combined lubricant, coolant and purging medium for the removal of metal abraded away during operation. Vegetable oils, such as olive oil, and animal oils, such as sperm oil, are satisfactory for all sizes of diamond dust employed, and water has proved suitable for laps charged with 3200 grit size diamond dust made as hereinafter described. The lapping of surfaces from their original state to the final finish is a progressive operation, involving the use of a series of diamond dust sizes ranging from relatively coarse at the

beginning through successively finer sizes to the end. The faces of the lignum vitae wood laps employed during each lapping step become charged locally with diamond dust of the particular size used, and it will be understood that a lap which has been previously used with a coarser size of diamond dust should not be employed to attain a higher quality finish with a finer size unless the charged region is first removed and a fresh surface exposed to the work. This can be accomplished conveniently by cutting away the face of the lap to a depth of about $\frac{1}{32}$'' in a lathe with a diamond point tool. In addition, lignum vitae laps wear unevenly in the course of use, which is evidenced by a periodic "bumping" sound during operation, which becomes more noticeable as high spots develop. It is therefore preferred to dress the lap to restore an even contacting surface before bumping becomes serious enough to cause blemishes in the work, and this can be accomplished by trimming the face of the lap to a depth of 0.005''–0.010'' with a diamond point tool at intervals of about one hour's operation. Upon completion of lapping with a given size of abrasive, the surface of the work is cleaned by flushing or gently washing with a solvent, such as carbon tetrachloride, followed by a final wash with water containing a detergent. Soft absorbent paper or cotton are preferably used to dry the lapped surface and to remove any remaining traces of abrasive, after which lapping is started with the next finer size of abrasive.

In the practice of my method, I have found that it is necessary to maintain a relative speed of translation between the contacting surfaces of the lap and the work of the order of about 5,000 ft./min., and preferably 7,500–10,000 ft./min. The total loading of the lap against the work will, of course, depend upon the extent of the areas in contact and the physical properties of the metal alloy or metal from which the work piece is fabricated. Lapping according to this invention has proved particularly effective for the high quality finishing of the relatively hard stainless steels, of which the following alloys are representative, and the loadings for these materials, typified by the 440A example hereinafter reported in detail, constitute a guide which, supplemented by observations in the course of lapping other materials, will enable others to practice my method:

Material	Analysis, in percent									Surface Rockwell C Hardness
	C	Mn	P	S	Si	Cr	Ni	Cu	Fe	
Armco Iron R1104	0.06	0.55	0.013	0.012	0.39	16.34	4.00	3.90	Balance	39
AISI 440 A	0.60	1.0	------	------	1.0	15.0	1.25	------	Balance	55
	C	Mn	P	S	Si	Cr	Mo	V	Fe	
Latrobe Electric Steel Co.'s BR–4	2.4	0.40	------	------	0.40	12.8	1.1	4.0	Balance	65

A 6'' dia. solid roll 12'' long fabricated from commercial quality 440A steel of the analysis and hardness tabulated was lapped according to this invention in the following manner, using the apparatus shown in Figs. 1–4. The lap comprised a 1'' thick unitary lignum vitae wood ring of 7'' inside diameter and 9'' outside diameter, thus providing a working face of 1'' width.

The roll was first reduced to a diameter 0.005–0.006'' above the desired finished diameter, using conventional powered grinding equipment, and was then mounted in the apparatus and turned at a speed of 27 R. P. M. The lap spindle was turned at 3600 R. P. M. and the lap was traversed lengthwise of the work at a speed of 30'' per minute, under which conditions the relative transitory speed between work and lap at the mean diameter of the lap was calculated to be about 7600 surface ft./min. Maintaining the speeds of the work and lap at the recited values throughout, and dressing the lap periodically as required by the development of irregularities in the working face, the roll was finished in four separate steps, as follows, the work being cleaned thoroughly after lapping with each grade of abrasive:

Step 1

Diamond dust of 500 grit size suspended in olive oil in a concentration of 40 carats/1000 cc. was used, sufficient suspension being applied to the work to maintain a concentration of 1–2 carats of diamond per square foot of surface. The lap was maintained against the work under a loading of 2 H. P., as calculated from the reading of a demand meter in circuit with the spindle motor, which resulted in almost immediate charring of the lap face. The overall surface temperature of the work was kept from exceeding about 212° F. by stopping operation occasionally and spraying the work with cool, clean water. Lapping was continued in this manner until all grinding defects were removed, which required a total of about 8 hrs. time. The quality of finish secured was of the order of 10–15 microinches R. M. S. The lap was thoroughly washed with carbon tetrachloride and the outer face was cut away with a diamond point tool to a depth of about $\frac{1}{32}$'' to provide a fresh surface for Step 2.

Step 2

The abrasive employed here was 800 grit diamond dust suspended in olive oil in a concentration of about 30 carats/1000 cc., the suspension being applied to maintain about 1 carat of diamond per sq. ft. of work surface. The loading was increased to a level of 2½–3 H. P. during this phase, the work being cooled intermittently as described for Step 1, and, after 4 hrs. time, the quality of finish was found to be improved to 8–10 microinches R. M. S. Operation was then discontinued and the outer face of the lap removed as hereinabove described to permit reuse in Step 3.

Step 3

Diamond dust of 1600 grit size suspended in olive oil in a concentration of about 20 carats/1000 cc. was used, a quantity of about 1 carat of diamond/sq. ft. of work surface being maintained. The loading was increased to a level of 3 H. P., or slightly greater, and cooling was effected by occasionally directing a small stream of cool, clean water on the work without discontinuing operation. It was found that cooling by this procedure had no adverse effects when lapping with 1600 grit or finer sizes of diamond

and had the advantage that it shortened the time required somewhat. After 4 hours of operation the quality of finish attained was about 3–7 microinches R. M. S. The lap was then removed and provided with a fresh surface as described for Steps 1 and 2.

Step 4

In this final operation, diamond dust of 3200 grit size was used in a concentration of 10–15 carats/1000 cc., between 0.5–0.75 carat of diamond being maintained/sq. ft. of work surface. The loading of the lap against the work was increased to the level of about 4 H. P. and the work was cooled as described in Step 3. After 4 hours operation, a surface finish of a quality of 1–2 microinches R. M. S. was obtained and the work was found to be within the dimensional tolerances specified. Inclusions and non-homogeneities in the work piece were apparently evenly abraded away together with the surrounding metal, and there were no scratches such as would be caused from inclusions or weld metal tearing away and joining the abrasive.

A different cylindrical roll of the same dimensions as that hereinabove described for the lapping of 440 A alloy was electroplated with chromium to a thickness of about 0.012", after which it was ground to a preliminary finish, thus reducing the thickness of the chromium to about 0.010". The hardness of the chromium plate was measured and found to be 60 Rockwell C. This roll was then lapped by the identical procedure hereinabove described for the 440 A alloy steel, except that the quality of finish attained upon the completion of the lapping of the chromium-plated roll with 1600 grit size diamond dust was found to be of the order of 1–2 microinches R. M. S., and operation was therefore terminated without lapping with 3200 grit size abrasive.

From the foregoing it will be understood that, after protracted use, natural wood lignum vitae laps become sufficiently charged with diamond so that a certain amount of lapping can be conducted without the use of additional suspended diamond, or at least by the use of somewhat more dilute concentrations. However, it is preferred to make up charged laps by molding lignum vitae wood flour under heat and pressure, supplying the diamond by the incorporation of predetermined amounts of diamond dust uniformly distributed therein. The molded lignum vitae is completely homogeneous in structure and uncharged molded material may, in fact, be used to advantage as a substitute for the natural wood in suspension lapping where an exceedingly uniform lapping contact is desired. Furthermore, natural lignum vitae frequently develops cracks when exposed to dry air which render the piece unsuitable for use in lapping, whereas the molded material is considerably more stable under changing humidity conditions.

The lignum vitae wood flour can be prepared by mounting a block of the wood in a high speed powered spindle turning at a speed of 3600 R. P. M. and making successive cuts across the face of the block with a lathe tool to a depth of about 0.001". The cut away material is a flour-like powder in texture and has a uniform particle size of 0.001" or somewhat finer. The lignum vitae flour is molded by subjecting the material to a pressure of at least 5000 lbs./sq. in. and maintaining the mold and its contents at a temperature of 375–400° F. while under this pressure for a period of one hour. At this pressure and temperature the lignum vitae resin flows freely around the wood particles and, on cooling, a molded block is obtained having a specific gravity of 1.38 to 1.42, within the same range as that of the natural wood. The duration of the heating and the temperature employed are both rather critical, insufficient heating resulting in a weak bond, while excessive heating produces brittle compacts. Molds provided with exteriorly disposed channels for the circulation of heating oil have proved entirely satisfactory, the female component of a mold for the production of annular blocks constituting a metal piece machined with a circular groove of the dimensions desired in the molding, while the male component consisted of a metal ring sized to fit slidably within the formative groove. If desired, the lignum vitae can be molded integral with the ring part of the mold, a very strong bond being obtained if the ring member is provided with suitable recesses anchoring a portion of the wood filling to the metal. In one construction the entire face of the molding ring was machined at a pitch of 0.10" with a succession of concentric grooves 0.05" deep and 0.05" wide and the top surface of the metal was pressed inwardly with a knurling tool applied radially with respect to the ring. This treatment produced groove cross sections of somewhat smaller width at the top than at the bottom, providing a strong key structure for attachment of the wood. Integrally bonded wood-metal laps are of sufficiently high strength so that no additional supports for the wood are necessary and the lap may be secured to the turning spindle by merely bolting the metal backing to the spindle flange directly.

Molded laps are conveniently formed by charging the female part of the mold with successive increments of the wood flour and pressing after each addition until the desired thickness is obtained, then carrying out the heating while retaining under pressure. Charged laps are made by incorporating diamond dust of the appropriate grit size uniformly distributed throughout the flour. In a specific case, an annular lap integrally bonded to a metal backing plate was prepared having a 7" inside diameter, a 9" outside diameter and a thickness of $\frac{3}{16}$". The female part of the die was loaded in six separate increments, the diamond charge being limited to the first wood flour increment, which weighed 0.63 ounce, and comprising 5 carats of diamond dust of 3200 grit size. This lap performed well and there was no indication that the strength of the bond was effected adversely by the incorporation of the diamond.

Charged laps made as hereinabove described can be employed successfully for all purposes for which suspended diamond is utilized. In fact, it appears that charged laps have an enhanced abrading action over the natural wood used in conjunction with suspended diamond, in that laps charged with finer sizes of diamond, such as sizes in the region of 3200 grit, may be employed using water, as distinguished from oil, as the purging liquid lubricant-coolant. This is advantageous, since it permits somewhat lower loadings of the lap against the work, for the reason that the surface tension of water is appreciably lower than that of most oils.

From the foregoing it will be understood that my invention may be modified in numerous ways obvious to those skilled in the art without departing from the essential spirit, wherefor it

is intended to be limited only by the scope of the following claims.

What is claimed is:

1. A method for the lapping of an article fabricated from a metal alloy or metal comprising forcing a diamond dust abrasive against said article in the presence of a liquid with a lignum vitae wood lap while maintaining a relative speed of translation between the surfaces of said lap and said article above about 5000 ft./min. and a loading pressure sufficient to char the surface of said lap in contact with said article.

2. A method for the lapping of an article fabricated from a metal alloy or metal in two separate contactings of the lap with said article wherein the direction of translation of the lap with respect to the surface of said article during one of said contactings is maintained substantially normal to the direction of translation of the lap with respect to the surface of said article during the other of said contactings, each of said contactings comprising forcing a diamond dust abrasive against said article in the presence of a liquid with a lignum vitae wood lap while maintaining a relative speed of translation between the surfaces of said lap and said article above about 5000 ft./min. and a loading pressure sufficient to char the surface of said lap in contact with said article.

3. A method for the lapping of an article fabricated from a metal alloy or metal comprising forcing a diamond dust abrasive suspended in a liquid against said article with a lignum vitae wood lap while maintaining a relative speed of translation between the surfaces of said lap and said article above about 5000 ft./min. and a loading pressure sufficient to char the surface of said lap in contact with said article.

4. A method according to claim 3 wherein the liquid comprises olive oil.

5. A method for the lapping of an article fabricated from a metal alloy or metal comprising contacting said article with a diamond-charged lignum vitae wood lap in the presence of a liquid while maintaining a relative speed of translation between the surfaces of said lap and said article above about 5000 ft./min. and a loading pressure sufficient to char the surface of said lap in contact with said article.

6. A method for the lapping of an article fabricated from a metal alloy or metal in a succession of steps employing progressively finer graded particle sizes of diamond dust abrasive comprising forcing each of said sizes in turn against said article in the presence of a liquid with a fresh lignum vitae wood lap while maintaining a relative speed of translation between the surfaces of said lap and said article above about 5000 ft./min. and a loading pressure sufficient to char the surface of said lap in contact with said article, and cleaning the surface of said article after each said step before beginning the next succeeding step.

7. A charged lap comprising molded lignum vitae wood flour incorporating a diamond dust abrasive substantially uniformly distributed throughout the region wherein contact is made with the work.

THOMAS G. LEWIS.

No references cited.