M. C. SHAW ET AL.

METHOD OF REMOVING METAL BY SHAVING

Filed Oct. 22, 1957

Fig. 1

Fig. 2

Fig. 3

Fig. 4 (Stable)

Fig. 5 (Unstable)

INVENTORS
Milton C. Shaw
Prescott A. Smith
Nathan B. Cook

by
Douglas McDougall
William Ried
Attorneys
METHOD OF REMOVING METAL BY SHAVING


Filed Oct. 22, 1957, Ser. No. 691,657
1 Claim. (Cl. 90—24)

This invention relates to the removal of surface metal from bars, rods, tubes, wire and the like elements of repeating cross-section and it relates more particularly to a shaving operation for the continuous removal of metal from the surface of such elements alone or in combination with one or more steps for processing the metal in cold finishing.

This application is a continuation-in-part of application Ser. No. 615,328, filed October 11, 1956, now Patent No. 3,055,102 and entitled “Metal Finishing Means and Method for Use of Same.”

In many of the cold finishing processes, it is desirable to remove unwanted metal from the surface of the work prior to processing of the work in the cold finishing operation. A cold finishing operation may be represented by the advancement of the metal through a draw die, extrusion die, roller die or the like, to effect a reduction in its cross-sectional area. The combination of a shaving tool in advance of the reduction die appears to present an ideal situation since the reduction die can operate to guide the work through the shaving tool while the shaving tool peels unwanted metal from the surface of the work and in a continuous operation with the reduction die.

Others previously have visualized the efficiencies available in a combination of the type described but reduction to practice in the case of steel, from a commercial standpoint, has been blocked by a number of problems inherent in the shaving operation.

One of these problems in the processing of copper wire has been faced by Weaver in Patent No. 2,233,928. To improve surface finish, Weaver provided a plurality of circumferentially spaced apart scores extending longitudinally throughout the length of the wire to a depth corresponding approximately to the thickness of the metal removed to subdivide the surface into smaller segments intended to prevent the build-up of hoop stresses. While the system of Weaver appears to be adequate for the purpose intended, it has been found that Weaver is limited in his application to the practice with copper wire and that other and more efficient and simpler means could be developed for achieving equivalent, if not better, results in a process applicable not only to use with copper but equally applicable to other materials, especially steels.

From the physical determinations which have been made, it has been found that the shaving process introduces large superficial compressive stresses in the metal being cut. The following appears to be a logical explanation as to the origin of these large stresses which have led to many of the difficulties encountered in the formation of a built-up edge on the nose of the tool and poor surface finish. As the metal to be removed (the chip) engages the cutting edge of the shaving tool and is separated thereby from the work, the metal removed is necessarily sheared into shavings while the face of the tool causes strong circumferential tensile stresses to be developed, eventually leading to cracks in the chip. If the region worked can be considered to be a free body, it will be apparent that the bar will automatically be subjected to the hoop stresses of the type intended to be overcome by Weaver, by his longitudinal grooves.

A built-up edge (B.U.E.) comes from the tendency of work material to weld on the cutting edge of the shaving tool during metal removal. The metal welded onto the cutting edge of the shaving tool has become hardened, as by strain hardening, during metal removal, so that that work material built up on the edge of the tool is capable of doing the cutting instead of the tool. As the amount of material builds up on the edge of the tool, the effective cutting edge varies periodically in depth. As a result, the amount of material removed from the surface of the work is incapable of control and a surface replete with hills and valleys is produced. This lack of dimensional control and the described surface roughness interferes materially with the subsequent reduction or other cold finishing steps. The existence of conditions conducive to the build-up of an edge on the shaving tool is further evidenced by poor surface finish on the end product that is secured.

Another problem experienced in the shaving operation is the instability that evidences itself in at least two ways. In one of the more important ways, the work wanders from one side of the tool to another during passage through the shaving tool to produce waviness in the surface and to produce work wherein some of the surfaces are untouched while excessive metal is removed from opposite surfaces. In another way, instability is evidenced by chattering which occurs during the shaving operation to interfere with the smoothness of the surface and the continuity of the shaving process.

It is an object of this invention to provide a shaving operation embodying concepts wherein the built-up of work material on the edge of the shaving tool is minimized thereby to enhance the removal of metal and the control thereof and to improve the surface finish.

Another object of this invention is to provide a shaving operation embodying concepts which harness the stresses developed to the advantage of the properties of the product thereby to produce metal products having new and improved physical, mechanical and stress properties. A further object is to provide a shaving operation of the type described embodying concepts which improve the stability of the shaving operation and reduce waviness in the surface of the metal.

These and other objects and advantages of this invention will hereinafter appear and for purposes of illustration, but not of limitation, an embodiment of the invention is shown in the accompanying drawing in which—

FIGURE 1 is an elevational view in section of a shaving tool embodying the features of this invention;

FIGURE 2 is an elevational view in section of the shaving tool shown in FIGURE 1 in combination with a draw die;

FIGURE 3 is an elevational view in section of the shaving tool shown in FIGURE 1 in combination with a draw die and an outboard guide;

FIGURE 4 is a diagrammatic view in section showing the force relationship existing with a positive vertical component for enhancing stability, and

FIGURE 5 is a sectional view similar to that of FIGURE 4 diagrammatically showing the force relationships when a negative component exists in the vertical force.

The invention will be described with reference to a shaving tool (FIGURE 1) having a body portion 10, a bore 12 extending continuously therethrough dimensioned at its leading edge to have a diameter or shape corresponding to the diameter of the shaving tool to be delivered upon passage through the tool, and a front face 14. The tool may be formed with a land 16 dimensioned to have a length up to 0.014 inch. The rake angle 18 can be varied widely depending upon the material employed, the metal being worked and the characteristics desired to be developed in metal removal, as will hereinafter be pointed out. Generally, as defined in our copending application Serial No. 615,328, filed October 11, 1956, now Patent 3,055,102 of which this application
is a continuation-in-part, the rake angle can vary from 0 to 40° and preferably within the range of from 10° to 30°. The tool may be formed with a clearance angle within the range of from 1° to 15°.

The shaving tool can be formed, at least at its cutting edge, of various metal cutting materials including high speed steel, cemented carbides, ceramics and the like. Ordinarily the shaving tool will be mounted on a stationary support 20 and the metal 22 to be worked is advanced rectilinearly substantially continuously into the shaving tool whereby a surface portion of the metal is removed as a chip 24 which rides up the face of the tool while the body of the work continues on through the bore.

The concepts hereinafter described have application in the use of a shaving tool for the cutting of specific contours including round bars, square bars, bars of various polygonal or elliptical shapes or for cutting into the surface of the work as it is advanced therethrough. For example, the shaving tool may be used for cutting a continuous groove or keyway and the like in the surface portion of the metal. Similarly, the concepts described and claimed herein have application to the use of a shaving tool for the removal of metal in a continuous operation from the inner surface of a tube and the like. In such modification, the cutting edge of the tool is dimensioned to have an effective dimension greater than the outer diameter of the tool to shave off a predetermined thickness of the metal from the inner surface of the tube. The rake angle will still comprise the slope in the face of the tool leading from the cutting edge to a bore through which the chips may be disposed.

The described shaving operations can be used to replace a machining process for the removal of metal from the surface of work to reduce the work to a predetermined dimension or shape or to prepare the surface for a subsequent cold finishing step. Ordinarily it will be used to remove unwanted metal from the surface of work in advance of a subsequent step or steps for cold finishing the metal. Such subsequent cold finishing operation may include a reduction step wherein the work is advanced through a die to take a reduction in cross-sectional area as in a drawing, extrusion or rolling process. Under such circumstances, the reduction step can be carried out as a continuous operation with the shaving step by aligning the reduction die 24 with the shaving tool, as illustrated in FIGURE 2 of the drawings. The work will be advanced continuously first through the shaving tool wherein surface metal is removed from the work and then through the following reduction die wherein a reduction is taken in the cross-sectional area of the work to produce a cold finished bar of the desired dimension and characteristics. A lubricant ordinarily is applied to the surface of the freshly cut metal for use in the shaving operation. The lubricant may be applied to the surface of the work at a time subsequent to the shaving operation and before reduction or the lubricant may be applied as in the aforementioned copending application by filling the space between the shaving tool and the reduction die to provide a lubricating action both in the shaving and reduction step, especially when the lubricant is under positive pressure to force the lubricant into the effective cutting area.

When used alone or in combination with an aligned reduction die, it is desirable to make use of a guide 30 in advance of the shaving tool to enhance the shaving operation and to align the work with the tool in a manner to prevent wandering or other non-uniformities in metal removal. Where stability and control represent an essential requirement, the outfield guide 30 may be in the form of a roller guide, a slide, or other means for engaging the surface of the work for holding the work in the desired aligned relationship in the shaving tool.

It has been found that certain advantages are derived to enhance the shaving operation and the cold finishing of the metal when the outfield guide constitutes a die through which the work is advanced to take a reduction in cross-sectional area while at the same time providing the desired guiding relationship upon advancement of the work therethrough. It will be sufficient to take a reduction of as little as 1 percent but larger reductions can be taken.

Whatever the amount, the reduction step taken in advance of the shaving step will operate to eliminate non-uniformities in the surface of the work and to round out or smooth the surface prior to advancement through the shaving tool. This will insure the elimination of bends and bumps which might otherwise lead to damage of the tool and in shortening the life thereof. It provides for the removal of uniform amounts of metal from the surface of the work thereby to stabilize the shaving operation. Furthermore, it tends to work the material, at least at the surface, to cause a hardening of the surface of the metal to enhance its suitability from the work. It appears to minimize the build-up of metal on the edge of the tool thereby beneficially to effect the subsequent shaving operation.

Referring now to the tendency for the work material to weld onto the cutting edge of the tool and build up the edge with material that is capable of doing the cutting instead of the tool, it has been found that there are a number of concepts which can be employed in the shaving operation to minimize this effect and to improve upon the shaving operation.

It has been found that the built-up edge can be minimized by the use of a cutting fluid which enters into a reaction that prevents the bonding of the work material to the face of the tool. For this purpose, it is desirable to make use of a lubricating material which is capable of fluid flow into the cutting region of the work and onto the edge of the tool to prevent welding and that the desirable effects are secured by a chemical reaction under the conditions existing to produce a reaction with the exposed surfaces of the work or tool wherein the reaction product has a shear strength lower than the shear strength of the metal. Under such circumstances, the low shear strength produced on the face of the work and in contact with the tool will be preferentially displaced by the oncoming material so that welding or bonding is avoided.

Application of such lubricant onto the surface of the work prior to advancement through the shaving tool would be of little benefit because it would be outside of the area affected by the tool. Thus, it is essential to introduce the lubricant into the area between the shaving tool and the cut surface of the work where the fluid can flow into the area engaged between the tool and work to react with the freshly cut surface of the metal. Under such circumstances, use can be made of a lubricant capable of the dual function of reaction to form the low shear strength material or otherwise prevent bonding between the material being cut and the tool face and also of lubricating the shaved surface of the work for the subsequent reduction step. The described combination of anti-welding and lubrication is applicable where use is made of a combination of shaving tool and draw die or other reduction die, as illustrated in FIGURE 2. For such purpose, the lubricant can be applied as described in the aforementioned copending application wherein the lubricant fills the space between the shaving tool and the draw die and is forced into the area of cutting, especially when applied under positive pressure.

It has been found that tendency of work material to build up on the edge of the tool can be further minimized by additional relative movements between the tool and work. In the preferred embodiment, the tool is mounted for turning movement rotationally about its axis for relative movement between the tool and work. While it is preferred to provide for continuous rotational movement in one direction, the desired results can be secured by move-
ment of the tool back and forth about its axis through a relatively short arc as the work is advanced linearly through the tool. Various means may be provided for actuation of the tool in the described rotational movements about its axis.

Various theoretical concepts can be advanced for the improvements which are secured by such additional relative movements between the tool and work. When reliance is had on the temperature concept previously described, it will be apparent that the additional relative movement will provide for further development of heat with corresponding increases in temperature of the material being removed. This leads to additional softening of the material further to reduce the ability of the material to be retained on the face of the tool.

Rotation of the tool in the manner described gives the effect of a tool having a larger rake angle.

In the same sense, the effect secured from rotation or oscillation of the tool can also be secured by axial vibration of the tool. For such purpose, the tool may be mounted on a vibratory support or a support which is capable of being subjected to vibration in the axial direction.

It is common knowledge that the rake angle can be increased with corresponding reduction in B.U.E. until tool life becomes a factor since increased rake angle increases the tendency for the tool to chip. Thus the relation between rake angle and tool life depends somewhat upon the material of which the tool is formed. Stability also is a factor which enters into consideration in the amount of increase that may be made in the rake angle of the tool since the increase in rake angle tends to reduce the stability of the shaving operation. In practice, optimum rake angles within the range described can be selected by a few empirical tests to balance decrease in B.U.E. with tool life.

With reference now to the problems raised by the stresses developed in the drawing operation, Weaver, in Patent No. 2,213,928, describes a means for overcoming hoop stresses by scoring the surface of the work in circumferentially spaced apart lines extending throughout the length of a copper wire. This breaks up the hoop stresses into segments removed with the metal in the subsequent shaving operation. The difficulties with which Weaver was confronted have been overcome in many respects by the process of applicants to carry out the shaving operation at high speeds or by others of the conditions previously described.

In accordance with the practice of this invention, applicants make beneficial use of the stress characteristics developed materially to improve the properties of the finished product produced in the shaving operation. By way of illustration, one of the important concepts resides in the means whereby compressive stresses may be caused to exist in the finished product.

In operation, the chip produced in the shaving process must split for removal. Thus the tool pushes on the chip with the result that the chip will press down on the metal of the work to introduce a compressive stress. This concept can be used in combinations wherein the reduction die follows the shaving tool as well as where the reduced die is in advance of the shaving tool.

With reference now to the problems of stability, as used herein, the term is intended to refer to the maintenance of conditions wherein the work remains centered in the shaving tool during metal removal. When an unstable condition exists, the work wanders from one side to another during passage through the tool to produce undesirable wavy surface. When waviness exists, too much metal is removed from one side while not enough is being removed from the opposite side. Under aggravated conditions, the work may even wander off entirely from the shaving tool. While the most effective way of maintaining stability is to provide a close fitting guide on either side of the shaving tool, as for example a pair of concentrically fitted dies, stability can also be achieved by a combination of conditions that tend to increase the friction force component between chip and tool.

An important concept of this invention therefore resides in the development of means for maintaining a desirable positive radial (friction) force component during the shaving operation. In general, it has been found that factors which increase friction tend to increase stability and likewise tend to increase the radial force component. Likewise, factors which tend to produce a poorer surface finish tend to increase the radial component and hence increase the stability of the shaving process. One such factor comprises the use of a tool having a low rake angle as obtained by a dull or blunted tool or by a tool having a negative rake angle. In practice, it is preferred to make use of a tool having a rake angle within the range of 0–30° depending greatly upon the lubricant.

Another important factor resides in the selection of the lubricant itself. The poorer the lubricant, the higher the coefficient of friction, and the higher the coefficient of friction, the greater the positive radial force component. This provides greater stability in the shaving process. Where lubrication is relied upon for maintaining stability, it may be desirable to make use of a lubricant which has an effect which gives a higher radial force than no lubricant at all. Suitable materials can be selected from the lubricants available in the art. Proper selection of lubricant can be made from the data available as applied to the various metals which may be shaved.

A third factor resides in the thickness of the layer removed. The lesser the thickness, the greater the relative positive radial force component and hence the greater the stability of the shaving operation. In addition to the concepts of adopting factors which tend to increase coefficient of friction and produce a poorer surface finish, the use of chip breakers with the tool has been found to reduce the component operating to drive the work off center with the result that greater stability is secured. The chip breaker, which is arranged in the path of the chip coming up the face of the tool, is engaged by the chip so that the resultant force is downwardly onto the work to center the work. The chip breaker may be provided as extensions from the face of the tool or the breaker may be provided separately and apart from the tool but in position to engage the chip as it rides upwardly on the face of the tool.

Change in contour of the tool or change in the material of which the tool is formed has material effect on the stability. The use of a softer tool material has the same effect as the use of a poorer lubricant. For example, greater stability is secured in the use of tools formed of high speed steel as compared to tools formed of carbide steel for shaving the same metal.

It has been found that stability can be improved by decreasing the clearance angle or the land on the shaving tool. A negative clearance will have the same effect as a draw die to center the work during passage through the tool. A flat portion on the clearance surface near the tool point of 0.01 inch or more is frequently helpful in providing stability.

A negative radial component can be tolerated when external means are employed to provide stability. Thus the outboard guide, previously described, can be used effectively to provide stability in the shaving process. The closer the outboard guide to the cutting edge of the shaving tool, the greater the negative radial force that can be tolerated. However, the outboard guide should not be so close to the tool as to interfere with the release of the chips that are formed and hence promote the formation of a built-up edge. In practice, it is desirable to locate the outboard guide at least one chip thickness from
the cutting edge of the tool. While the guide may be located a greater distance from the tool, it is desirable to maintain the distance between one to ten chip thicknesses.

It will be apparent from the foregoing descriptions that various means have been developed to eliminate difficulties which have heretofore been encountered in the adoption of the rapid and efficient method for removing surface metal from work as in a shaving operation. While each of these concepts are capable independently of providing the desired results, various of these concepts may be used in combinations one with the other greatly to enhance the shaving operation to enable combination of the shaving process for metal removal with subsequent high speed cold finishing steps as represented by the advancement of the metal continuously from the shaving tool through a reduction die and the like.

It will be understood that changes may be made in the details of construction and operation without departing from the spirit of the invention, especially as defined in the following claim.

We claim:

In the method of processing metal work of continuously advancing the cross-section comprising advancing the work continuously through a shaving tool, removing metal continuously from about the surfaces of the work during advancement through the shaving tool and continuously vibrating the shaving tool axially relative to the work during advancement of the work through the shaving tool.

References Cited in the file of this patent

UNITED STATES PATENTS

1,156,892 Clement Oct. 19, 1915
1,292,494 Lorenz Jan. 28, 1919
1,703,232 Gray et al. Feb. 26, 1929
1,907,897 Swegles May 9, 1933
2,233,928 Weaver Mar. 4, 1941
2,267,342 Schwartz et al. Dec. 23, 1941
2,298,418 Roemer et al. Oct. 13, 1941
2,392,481 Kaplan et al. Jan. 8, 1946
2,394,581 Hoern Feb. 5, 1946
2,476,151 Le Jeune July 12, 1949
2,670,528 Brunberg Mar. 2, 1954
2,679,680 Hanks June 1, 1954
2,706,238 Blaser Apr. 12, 1955
2,754,581 Thomas July 17, 1956
2,829,430 Toulmin Apr. 8, 1958
2,831,728 Zwanut Apr. 22, 1958
2,931,263 Johnson et al. Apr. 5, 1960

FOREIGN PATENTS

426,029 Germany Mar. 4, 1926
714,860 Great Britain Sept. 1, 1954

OTHER REFERENCES
