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[54] **TOOTH FORMING TOOL**

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[51] **Int. Cl.** **B21h 5/02**

[58] **Field of Search** ..... 72/469, 88, 90, 467; 76/107 R

[56] **References Cited**

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3,672,203	6/1972	Anderson	72/469

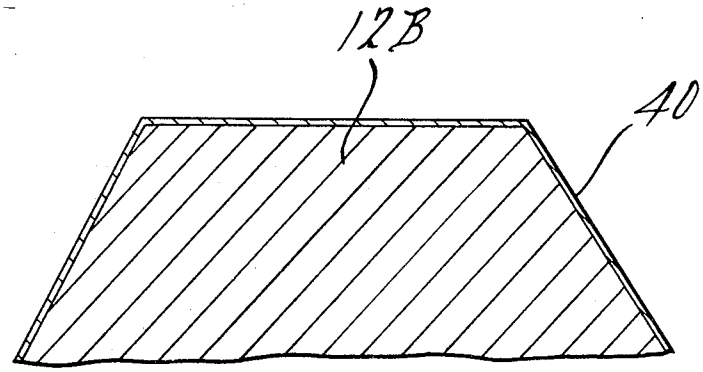
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[57] **ABSTRACT**

An improved tool for pressure generating teeth on the periphery of a cylindrical workpiece, the tool preferably being formed of tool steel and defining tooth forming teeth, selected teeth on the tool being plated whereby the tool teeth exhibit increased resistance to wear and fatigue and the flow characteristics of the workpiece metal are improved during the tooth generating process.

18 Claims, 6 Drawing Figures



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SHEET 1 OF 2

Fig. 1.

Fig. 4.

Fig. 5.

Fig. 2.

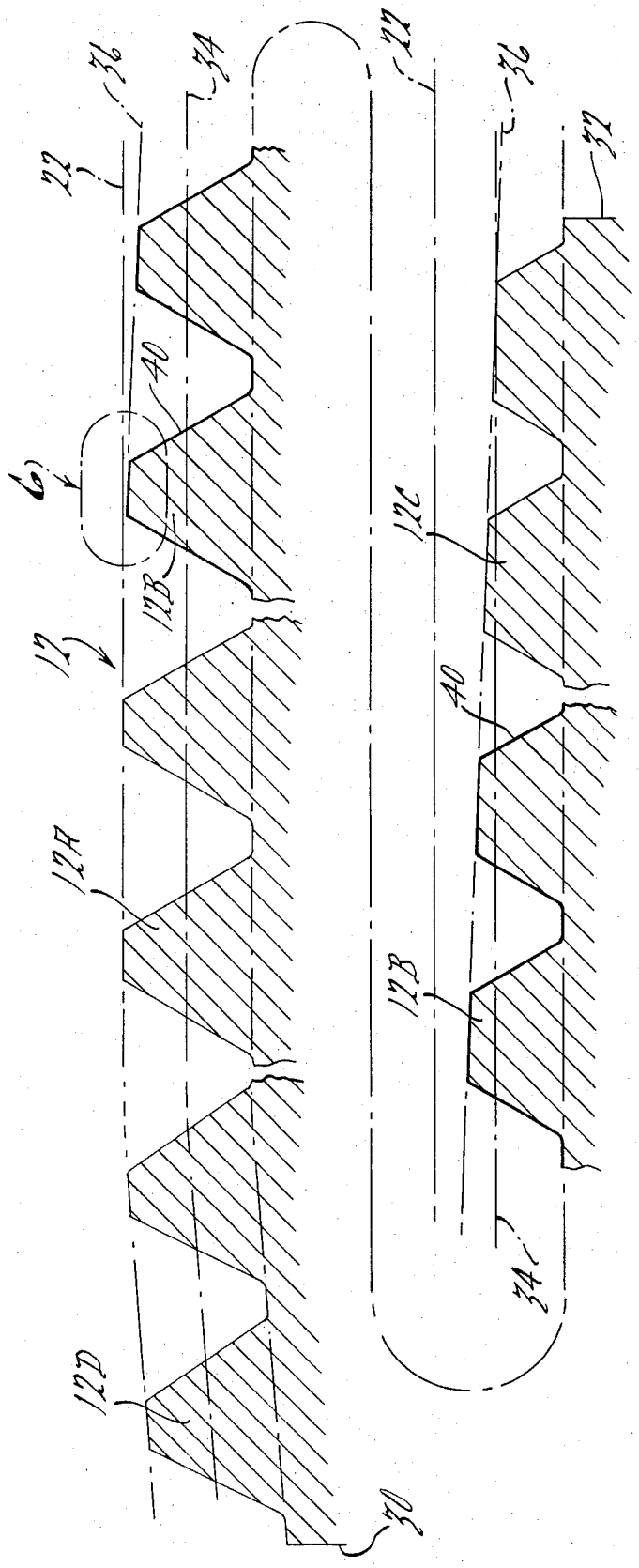


Fig. 5.

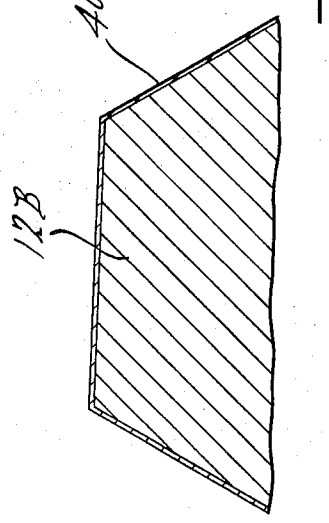


Fig. 6.

TOOTH FORMING TOOL

BRIEF SUMMARY OF THE INVENTION

This invention relates to tools for pressure forming toothed elements and, more particularly, to an improved tool for pressure generating teeth, such as spline teeth, gear teeth, worm teeth and the like, on the periphery of cylindrical workpieces while the workpieces are at ambient or room temperature and without removal of material from the workpieces. Heretofore, various tools have been used commercially to pressure form spline teeth, gear teeth, worm teeth and the like on the periphery of a cylindrical workpiece while the workpiece is at ambient or room temperature and without removing material from the workpiece. Examples of prior art tools which have achieved commercial success in this field are disclosed in U.S. Pat. Nos. 2,994,237 and 3,015,243, such tools being utilized, for example, in machines of the type disclosed in U.S. Pat. No. 2,995,964.

An object of the present invention is to provide an improved tooth forming tool of the indicated character having improved tooth generating teeth thereon whereby the resistance to wear and fatigue and the useful life of such tools is increased.

Another object of the invention is to provide an improved tool for pressure generating toothed elements incorporating improved means for increasing the tooth generating efficiency of the tooth generating teeth thereon.

Another object of the invention is to provide an improved tooth forming tool having improved tooth generating teeth thereon which improve the flow characteristics of the workpiece material during the tooth generating process.

Still another object of the invention is to provide an improved tool for pressure forming toothed elements which enables the cost of generating teeth on a workpiece to be reduced.

The above as well as other objects and advantages of the present invention will become apparent from the following description, the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevational view of a rack type tool embodying the present invention;

FIG. **2** is a fragmentary view of a typical involute spline that can be pressure formed by tools embodying the present invention;

FIG. **3** is an enlarged, fragmentary and diagrammatic side elevational view of the teeth of the tool illustrated in FIG. **1**;

FIG. **4** is an elevational view of the left end of the tool illustrated in FIG. **1**;

FIG. **5** is a fragmentary, top plan view of the tool illustrated in FIG. **1**; and

FIG. **6** is an enlarged sectional, elevational view of a portion of one of the teeth of the tool illustrated in FIG. **1**.

DETAILED DESCRIPTION

Referring to the drawings, a preferred embodiment of the invention is illustrated in FIGS. **1, 3, 4, 5** and **6** thereof. The illustrated embodiment of the invention comprises a specific tooth configuration and composition for a rack type tool generally designated **10,** such

tool preferably being utilized in substantially identical pairs to pressure form involute spline teeth, involute gear teeth and the like, as well as other types of teeth on the periphery of a cylindrical workpiece. A machine in which a pair of rack type tools embodying the present invention may be used to pressure form a workpiece by metal displacement is described in detail in the aforementioned U.S. Pat. No. 2,995,964 although it will be understood that tools embodying the present invention may be utilized in other types of machines. In general, a workpiece is positioned between a pair of tools **10** embodying the present invention, the tools being reciprocated in opposite directions across the workpiece to form teeth on the periphery of the workpiece. The workpiece is preferably supported by means which permit it to rotate freely about the longitudinal axis of the workpiece when urged to do so by tools embodying the present invention. The tools **10** are provided with teeth, generally designated **12,** on their working faces that engage the periphery of the workpiece and, in use, the tools are moved lengthwise by suitable means effective to move the tools simultaneously in opposite directions at the same velocity. The space between the working faces of the tools is less than the diameter of the workpiece with the result that the configuration of the working faces of the tools is impressed or conjugated on the periphery of the workpiece.

In forming teeth of the desired configuration on the periphery of the workpiece, the material from which the workpiece is made (ordinarily steel) will flow adjacent the surface in radial and tangential directions so that there are grooves of less diameter than the original outside diameter of the workpiece and ridges of greater diameter than the original outside diameter of the workpiece. since the final configuration of the workpiece usually must be accurately maintained, this flow of material should be taken into account in selecting the diameter of that portion of the workpiece which is subjected to the action of the tools embodying the present invention.

To illustrate by consideration of a common but very important shape that may be rolled by tools embodying the present invention, there is shown in FIG. **2** a portion of a cross-section of a workpiece **14** in finished form in which the workpiece has involute teeth or splines **16.** Since no metal is removed from the workpiece in the cold rolling operation, the diameter of the workpiece prior to rolling cannot be either the final outside diameter or the root diameter. The rolling diameter D_1 of the workpiece **14** is selected so that the area **18** of displaced tooth material below the D_1 periphery is equal to the area **20** of tooth material on a greater diameter than D_1. The diameter D_1, or substantially this diameter, defines the pitch line for rack type tools such as the tool **10.** As will be described hereinafter in greater detail, the pressure angle or angle of obliquity of certain of the teeth on the tool **10** under rolling pressure is the angle whose cosine is D/D_1 multiplied by the cosine of the pressure angle at the pitch diameter of the teeth **16** where D is the pitch diameter of the workpiece **14.** The base pitches of the tool and the workpiece are identical. With such a construction, the linear pitch of the teeth on the tool, as measured on the pitch line thereof, corresponds with the circular pitch of the teeth on the workpiece. The whole depth of at least some of the teeth on the tool **10** which engage the

workpiece **14** is preferably such that the tool teeth are fully conjugate to the teeth on the workpiece.

In use, a pair of tools **10** are spaced apart so that at a position near the trailing ends thereof, the working faces of the tools provide a clearance equal to the root diameter of the workpiece **14** less a few thousandths of an inch to take up elasticity of the members and compression of oil films under rolling pressure. Only one pass of the tools with no reversal of direction during the working stroke is preferred.

In accordance with the present invention, certain selected teeth on the tools are plated, preferably with copper, silver or gold although other suitable metals such as nickel or chromium may be utilized, to increase the rolling efficiency of the teeth and reduce the stresses imposed on the tool teeth contributing to wear and fatigue of metal thereby increasing the resistance to fatigue and increasing the useful life of the tools. In accordance with the present invention, the convergence of the tool faces toward each other is accomplished while maintaining the pitch line of all sections of the tool teeth from the leading end of the tool to and including the plated teeth and the section containing the fully conjugate teeth constant, a divergent section of the teeth being provided between the section containing the fully conjugate teeth and the trailing end of the tool to provide relief at the end of the working stroke of the tool.

FIGS. **1, 3, 4, 5** and **6** illustrate a tool **10** embodying the present invention, it being understood that the tooth formation of the mating tool will be substantially identical. The numeral **22** designates a theoretical reference line which shows a "no taper" condition so that if the tops of the teeth on the tool remained on the line **22** there would be no change in spacing between the working faces of the tools as the tools moved relative to each other across the periphery of the workpiece. The teeth of the tool **10** are designated generally by the numeral **12** and, in the preferred embodiment of the invention illustrated, the teeth **12** are divided into four sections delineated by the vertical reference lines **24, 26** and **28** and the trailing and leading ends **30** and **32,** respectively of the tool. As shown in FIG. **3,** the pitch line **34** of all of the tool teeth **12** is parallel to the reference line **22** from the leading end **32** of the tool **10** to the reference line **24,** and the pitch line of the tool teeth **12** tapers downwardly away from the reference line **22** between the reference line **24** and the trailing end **30** of the tool. The tops of the tool teeth in the sections between the reference line **26** and the leading end **32** of the tool taper downwardly toward the leading end of the tool while the pitch line of the teeth in the sections of teeth between the reference line **24** and the leading end **32** of the tool remains parallel to the reference line **32.** In accordance with the teaching of U.S. Pat. No. 3,015,243, the teeth **12A** between the reference lines **24** and **26** are full sized and fully conjugate to the teeth to be formed on the workpiece and the pressure angle or the angle of obliquity of the teeth **12A** under load is the angle whose cosine is D/D_1 multiplied by the cosine of the pressure angle at the pitch diameter of the teeth of the workpiece. The teeth **12A** between the reference lines **24** and **26** conjugate the final form of the teeth on the workpiece. Also, in accordance with the teachings of U.S. Pat. No. 3,015,243, and as previously mentioned, the pitch line of the teeth **12D** between the reference line **24** and the trailing end **30** of the rack tapers downwardly away from the reference line **22** and the teeth **12D** between the reference line **24** and the trailing end **30,** while being substantially full-sized, are also preferably relieved on the sides or flank faces thereof. This relief eliminates seam lines and other errors that might otherwise be formed on the teeth of the workpiece at the end of the stroke due to the decreased total area of the contact between the tools and the workpiece as the rolling pressures are reduced at the end of the stroke.

In accordance with the present invention, the pitch line of all of the teeth on the tool between the reference line **24** and the leading end **32** of the tool is determined by the diameter D_1 of the workpiece in the manner previously described so that the linear pitch of the teeth on the tool, as measured on the pitch line thereof, corresponds with the circular pitch of the teeth on the workpiece as measured on a circle having the diameter D_1 of the workpiece. The pressure angle, under load, of all of the teeth between the reference line **24** and the leading end of the tool **32** is the angle whose cosine is D/D_1 multiplied by the cosine of the pressure angle at the pitch diameter of the teeth on the workpiece where D is the conventional pitch diameter of the workpiece. The base pitches of the tools and the workpiece are identical. With such a construction, the linear pitch of the teeth on the tool, as measured on the pitch line thereof, corresponds with the circular pitch of the teeth on the workpiece as measured on a circle having the diameter D_1 of the workpiece. The whole depth of the teeth **12A** between the reference lines **24** and **26** is such that the teeth **12A** are fully conjugate to the teeth on the workpiece. The top lands of the teeth between the reference line **26** and the leading end **32** of the tool **10** taper downwardly towards the leading end **32** of the rack while the pitch line of such teeth remains parallel to the reference line **22** as previously mentioned, the taper being provided by removing the theoretical addenda of the teeth, as by grinding the teeth on a taper. The top land of the leading tooth adjacent the leading end **32** of the rack may be located substantially at the pitch line **34** of the rack as shown, or may, for example, be disposed a half to a few thousandths of an inch above the pitch line. The portions of the teeth between the reference line **28** and the leading end **32** are relatively shallow, relatively wide and the leading edges have sharp corners as shown in FIG. **3,** the sharp corners serving to grip the workpiece and initiate rotation thereof. The length of the zone of teeth **12C** between the reference line **28** and the leading end **32** is preferably such that approximately one complete revolution of the workpiece is achieved in such zone. The top lands of the teeth **12B** and **12C** in the zones between the reference line **26** and the leading end **32** slope upwardly toward the full sized teeth **12A,** as indicated by the reference line **36.**

The length of the zone of teeth **12B** between the reference lines **26** and **28** is preferably such that at least several complete revolutions of the workpiece are achieved in the zone containing the teeth **12B,** and the teeth **12C** and **12B** account for approximately 100 percent of the total desired depth of penetration of the workpiece. The length of the zone of teeth **12A** between the reference lines **24** and **26** is preferably such that approximately one and one-half revolutions of the workpiece are achieved in such zone and the top lands of the teeth **12A** are disposed in a plane parallel to the

reference line **22**, the full size teeth **12A** generating the final form of the teeth on the workpiece.

The body **38** of the tool **10** including all of the teeth **12** is initially formed of high grade tool steel, such as M-50, which is preferably hardened by nitriding to provide a hard exterior surface and a tough, but not brittle, core or substructure. It will be understood that other means of heat treating or hardening may be utilized if desired.

In accordance with the present invention, and as shown in FIGS. **3** and **6**, (on a greatly exaggerated scale) the tip, flank and root surfaces of the teeth **12B** only are plated, as at **40**, the plating preferably being approximately 0.0001 to 0.0003 inches thick while the tool steel surfaces of the teeth **12A**, **12C** and **12D** are not plated. It is preferred to plate the surfaces of the teeth **12B** with copper, silver or gold, although it will be understood that other suitable metals, such as nickel or chromium may be utilized. It is also preferred to utilize conventional electrolytic plating techniques, as opposed to chemical deposition techniques, in effecting the plating of the surfaces of the teeth **12B**. The plating of the surfaces of the teeth **12B** fills the grinding asperities and relieves boundary lubricant problems inherent in heavy gear loads. Such a construction increases the rolling efficiency of the tool teeth, reduces the stresses imposed on the tool teeth contributing to wear and fatigue of metal, minimizes surface spalling or pitting of the tool teeth and reduces the cost per piece of the workpieces formed by the tool **10**.

Thus, in accordance with the present invention, approximately ten percent or less of the total desired depth of penetration of the workpiece is achieved by the unplated teeth **12C** in one initial revolution of the workpiece, the teeth **12C** serving to grip the workpiece and initiate rotation thereof without slippage after which the additional approximately 90 percent or more of the total desired depth of penetration of the workpiece is achieved by the plated teeth **12B** in at least several successive revolutions of the workpiece and the final configuration of the workpiece teeth is generated by the unplated teeth **12A** in one and one-half or more additional successive revolutions of the workpiece. Such a construction also increases the useful life of the tools, improves the flow characteristics of the workpiece material during the tooth generating process and improves the quality of the finished workpieces.

If desired, the leading and trailing edges of the tapered teeth **12B** and **12C** may be provided with varying radii as disclosed in U.S. Pat. No. 2,994,237 and, if desired, one or both of the top corners of the tool may be provided with a chamfer or radius, to eliminate the necessity of undercutting the workpiece. FIG. **5** illustrates a plan view of the teeth **12** when such teeth are intended to generate spur teeth on the workpiece. It will be seen that the tool teeth **12** are perpendicular to the sides of the tool, i.e., perpendicular to the direction of tool movement but it will be understood that if the tools are to generate helical teeth on the workpiece, the tool teeth will be inclined to the sides of the tool or direction of tool movement.

If the preferred embodiment of the invention illustrated, the body **38** of the tool is illustrated as being provided with lugs **42** and transversely extending openings **44** which facilitate mounting the tool in machines of the type disclosed in U.S. Pat. No. 2,995,964, but it will be understood that other means may be utilized to mount the tools.

While a preferred embodiment of the invention has been illustrated and described, it will be understood that various changes and modifications may be made without departing from the spirit of the invention.

What is claimed is:

1. A tool for pressure forming teeth on the periphery of a cylindrical workpiece, said tool including a body formed of tool steel and having a leading end and a trailing end and being provided with a working face having a plurality of teeth thereon, a first section of said teeth being disposed between said leading end and said trailing end, each of said teeth in said first section having a configuration conjugate to the configuration of the teeth to be formed on the workpiece and having a pitch line, second and third sections of teeth being disposed between said first section of teeth and said leading end, the tops of the teeth in said second and third sections sloping toward said leading end, the tip, flank and root surfaces of said second section of teeth only being plated.

2. A tool as set forth in claim **1** wherein the length of said second section of teeth is greater than the length of said first and third sections.

3. A tool as set forth in claim **1** wherein the tool thickness of all of said teeth in said sections as measured on the pitch line thereof is constant from section to section from the teeth in said first section to said leading end.

4. A tool as set forth in claim **1** wherein all of said teeth have a common pitch line.

5. A tool as set forth in claim **1** wherein the distance between the teeth of successive sections as measured on the pitch line thereof is constant from said leading end to said first section of teeth, and wherein the plating on the surfaces of said teeth in said second section has a thickness of approximately 0.0001 to 0.0003 inches.

6. A tool as set forth in claim **1** wherein said surfaces of said second section of teeth are plated with a metal selected from the group consisting of gold, silver, copper, nickel and chromium.

7. A tool as set forth in claim **1** including a fourth section of teeth adjacent said trailing end, the tops of the teeth in said fourth section sloping toward said trailing end.

8. A tool for pressure forming teeth on the periphery of a cylindrical workpiece, said tool including a body formed of tool steel and being provided with a working face having teeth thereon and including a leading end and a trailing end, a first section of teeth between said leading end and said trailing end being fully conjugate to the teeth to be formed on said workpiece and having a pitch line, second and third sections of teeth disposed between said first section of teeth and said leading end, the addenda of said second and third sections of teeth successively decreasing in height with respect to the height of the addenda of the teeth in said first section, the tip, flank and root surfaces of the teeth in said second section being plated.

9. A tool as set forth in claim **8** wherein the length of said second section of teeth is greater than the length of said first and third sections of teeth.

10. A tool as set forth in claim **9** wherein all of said teeth have a common pitch line and wherein the distance between the teeth of successive sections as mea-

sured on the pitch line thereof is constant from said leading end to said first section of teeth.

11. A tool as set forth in claim **10** wherein the linear pitch of all of the teeth in all of said sections is constant, and wherein the plating on the surfaces of said teeth in said second section has a thickness of approximately 0.0001 to 0.0003 inches.

12. A tool as set forth in claim **11** wherein said surfaces of the teeth in said second section are plated with metal selected from the group consisting of gold, silver, copper, nickel and chromium.

13. A tool for pressure forming teeth on the periphery of a cylindrical workpiece, said tool including a body formed of M-50 steel and being provided with a working face having teeth thereon and including a leading end and a trailing end, a first section of teeth between said leading end and said trailing end being fully conjugate to the teeth to be formed on said workpiece and having a pitch line, second and third sections of teeth disposed between said first section of teeth and said leading end, the addenda of said second and third sections of teeth successively decreasing in height with respect to the height of the addenda of the teeth in said first section, the tip, flank and root surfaces of the teeth in said second section being plated.

14. A tool as set forth in claim **13** wherein said body is formed of M-50 steel hardened by nitriding.

15. A tool as set forth in claim **14** wherein said surfaces of the teeth in said second section are plated with metal selected from the group consisting of gold, silver, copper, nickel and chromium.

16. A tool as set forth in claim **15** wherein the plating on the surfaces of said teeth in said second section has a thickness of approximately 0.0001 to 0.0003 inches.

17. A tool as set forth in claim **16** wherein the length of said second section of teeth is greater than the length of said first and third sections of teeth.

18. A tool as set forth in claim **17** wherein all of said teeth have a common pitch line and wherein the distance between the teeth of successive sections as measured on the pitch line thereof is constant from said leading end to said first section of teeth.

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