COLD FORMING AND SOME OF ITS RECENT DEVELOPMENTS

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1. Introduction

Though metal forming is a very old art dating back to prehistoric times Cold Forming seems to have started only less than a. century ago. It has undergone rapid development during the second world war. Many materials which were earlier considered to be non formable were formed, and new technologies developed. For example, scarcity of brass during war made Germans to try steel for cartridge cases, causing vast improvements particularly in Cold Forming.

Metal forming for a long time remained an art more than a science and even now to a certain extent. Much of the predictions of metal movements were obtained by relatively inaccurate calculations, trial and error methods or empiricisms often involving guesses based on past experience. Following the formulation of mathematical relationships of plastic behaviour of metals and alloys, several notable advances were made by Prandtl, Geleji, Tresca, Unksov etc., who obtained certain solutions for the strain distribution, force and energy required for the compression of an ideally plastic solid. Later, the development of slip line field theory, upper and lower bound methods etc. made much advance in this field. Analysis done by Kudo[1] et al in 1970 of the stress distribution inside a die, by numerical methods with the use of an electronic computer, was a great step forward in the design of dies for volume forming.

A metal could be formed while it is above its recrystalization temperature or below it. Forming a metal while it is above its recrystalization temperature is referred to as Hot Forming, while below recrystalization temperature as Cold Forming. Care must be taken not to confuse it with the hotness or coldness of the working temperature relative to its surroundings, e.g. working lead at room temperature is a hot working process as it is above its recrystalization temperature.

2. Advantages of Forming

Essential difference of forming to machining is that a product is made in forming by flowing the material in the required manner rather than by removal. One of the principal advantages of forming is the saving of material due to no—or very little—scrap formed. This is considerable in most of the processes and is very important in the case of expensive materials. Better grain structure, thus superior properties and high production rates are some other advantages.

Cold forming has further advantages of better strength and hardness properties due to work hardening, enabling the use of cheaper materials for an end product with the same qualities, which otherwise would have required superior materials which are more expensive. Very high tolerances could be obtained with cold forming, in some cases better than a good commercially ground surface and the surface finish is also very good. Cold forming particularly volume forming, is very suitable for high speed mass production.

3. Trends in Forming

As the capacity of machines, design and quality of tools improve, more and more items which were earlier formed only by hot process or by machining, finds their way into Cold Forming. Present day multistage transfer presses which in some cases have as much as 14 stages or more, has enabled the production of many items by Cold Forming which were earlier formed exclusively by hot process.

In recent years, there has been a fair amount of development not only in tool design, but also in materials used for tooling as well as of formable materials. Work hardening properties of formed materials are being more and more exploited to their best advantages. Certain Boron Steels developed in USA[2], containing about 0.002% boron, offer new possibilities in cold forming parts of high strength from steels with a relatively low flow stress. Reduction of Silicon content to less than 0.05% is said to be reducing the flow stress, thus the force required to form them, still further.

4. Tool Materials

4.1 In general, for tools the highest possible toughness and strength is required and should have reasonably good fatigue properties too. In selecting a material and heat treatment, due consideration must be given to the retention of material properties under the expected working conditions which may be fairly demanding with modern high speed machines. Production economy requirements call for proper balance of wear resistance, length of run, initial and manufacturing costs and availability of materials and facilities.

There are two principal categories of materials used at present for tools, namely: Sintered Carbides—mainly for dies—and tool steels. As representative of two main groups of steels used for tools can be given M-2 and D-2 of AISI series[3]. AISI 4340 and 4140 or equivalents are recommended for stress rings where stressing of die assembly is not too high and H 13 for higher stress levels.

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New special high speed steel—Matrix Steel—recently developed in USA by a vacuum melting process and containing about 0.55% C and 12-20% alloy elements are said to be having a very finely and evenly distributed secondary carbide. Thus with an initial hardness of 62 to 64 HRC, these steels are said to be having a fatigue strength 5 to 10 times higher than that of M-2 Steel, even when notch effects are present. It is claimed that the life of a Matrix steel is more than double that of M-2. Another development, Maraging Steel, which is capable of developing a tensile yield strength of 160-200 kp/mm^2, finds use as stress rings for very highly stressed dies as in the case of dies with carbide inserts with an overall diameter ratio of 3 or less. However their high cost limits their usage to applications of exceptional nature.

4.2 Sintered Carbides

Sintered Carbides are used mainly for die inserts, but sometimes find application in punches and rollers too. Sintered carbides contain two principle constituents, hard particles—usually tungsten carbide—and a metallic binder, usually Cobalt. By varying the proportions of these constituents widely differing properties could be obtained. Grades with the least amount of binder is hardest, most wear resistant and least tough.

Sintered carbides are usually used only if high wear resistance is of paramount importance, i.e., for long runs and close tolerance products. Even then their usage is restricted due to high notch sensitivity and low tensile strength to cases where those disadvantages could be circumvented by effective design. Softer grades with 25-30% Co are the most commonly used, with harder grades of 19-24% Co where greater wear resistance is required.[4] With recent developments in die design, much harder grades containing around 10% Co are being tried out in Czechoslovakia[5]. Life of a sintered carbide is usually about 10-100 times that of tool steels.

Certain recent developments in the manufacture of sintered carbides, such as Isostatic Hot Pressing is claimed to have improved the performance of Cold forming tools.[6] Among the advantages claimed with I.H.P. are (1) Production of Sintered Carbides free from porosity and improved surface integoty, (2) Substantially improved strength, with a much better combination of toughness and hardness. At high cobalt contents—25%—the increase in strength is modest—only about 7%—at low cobalt content—6%—increase in strength is high, even more than 30%. Further, the increase observed is higher with fine grains.[7] For cobalt contents below 6%, in normal alloys strength falls off very rapidly making them practically unsuitable. But with IMP alloys, good strength is maintained down to below 3% cobalt. But the cost of IMP alloys are still high and real economy of their use has yet to be evaluated.

Another somewhat recent addition is "FERRO-TIC" steels[8]. These Ferro-tic steels containing titanium carbides are about 51% lighter than tool steels or 50% lighter than hard metals. These find use in cold forming tools particularly in blanking. Life is said to be about 10-30 times that of 12% chromium steel.

5. Processes

5.1 Hydrostatic Extrusion

Hydrostatic extrusion is one of the processes which has undergone a lot of development in recent years. The principle of hydrostatic extrusion is well known. Fluid surrounding the billet in all sides except at its front end, which bears against a cone shaped die, transmits the pressure applied to the ram not only forcing the billet into the die, but also compressing the billet circumferentially. Thus a hydrostatic compressive stress component is also imparted to the billet, thus the name. Absence of friction between billet and container eliminates back end defects. Cold extrusion of mild steel could be accomplished by this method without the need for a phosphate coating. Many materials of limited ductility, which could not be extruded successfully by conventional methods, could be extruded as the secondary tensile stress components developed are being suppressed by the component of hydrostatic compressive stress imparted. Even then some materials with much less ductility may crack as it emerges from the die. This can also be prevented to a large extent if extrusion is made to emerge into a chamber containing a suitably pressurized liquid which balances to some extent the secondary tensile forces present in the die region. But in this case the pressure required in the billet chamber is much increased and chambers have to be designed to withstand much higher pressures.

There was a claim that the above crack could be prevented if double stage reduction is used in the die. That is, after the first reduction, extrusion is given another small reduction by making it to pass through a second throat in the same die just below the first throat and before relief. Explanation given was that this acts very much in a similar manner to extruding into a pressurized chamber in countering the secondary tensile forces present in the die region.

Another advantage of hydrostatic extrusion is that there is no friction between billet and container, or ram —allows the billet to rotate enabling extrusion of helical shapes. Fluid pressure acting also on the outside of the die supports the die and assures close tolerences. Composite as well as thin walled tubes could be extruded hydrostatically. An example is cladding aluminium bars and rods with a thin layer of copper, with a perfect bond between the two metals resulting in an aluminium conductor with the superior contact properties of copper.

Thick layer extrusion where there is only a layer of fluid between the chamber and the billet could be considered a modification of the above method. Here too friction between container and billet is absent. Only at the start of the extrusion process is it more like conventional extrusion but the hydrostatic component is developed immediately giving almost all the advantages of hydrostatic extrusion. This process has the advantage over hydrostatic process that no large quantities of fluids are required and no time wasted in pressurising the fluid.

A helical hydrostatic extrusion machine developed by Marshall Richards Barcro Ltd.[9] is another novel

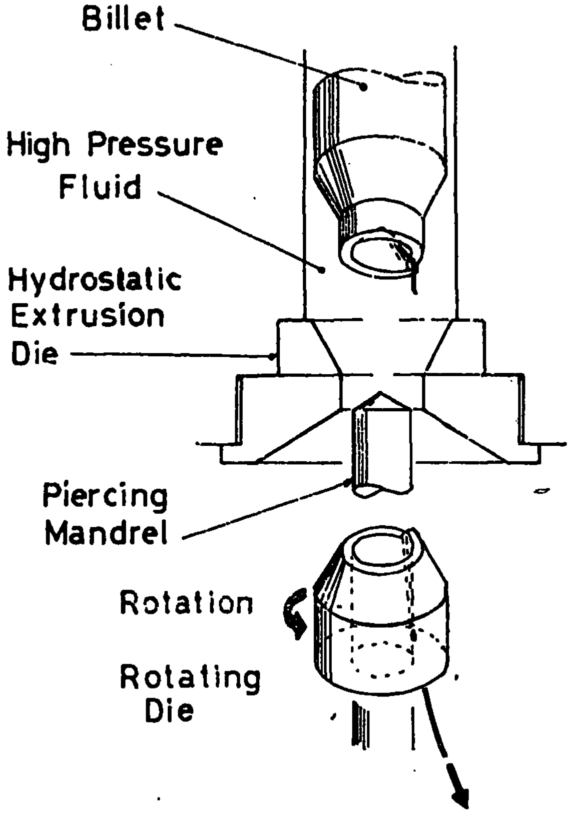

Fig. 1. Helical Hydrostatic Extrusion Machine

addition in this field. As shown in the diagram (Fig. 1) it consists of a pressure chamber, a hydrostatic extrusion die, and a piercing mandrel on which rotates another die. The extruded part that comes out of the die is slightly pierced by the piercing mandrel. The die rotating on it has a slight step as shown, which as it rotates squeezes the metal in the region and extrudes through the orifice provided. Extrusion passes through the passage provided and is laid in a drum placed below or in separate coilers.

It is claimed that this is ideal for breakdown use where production requirements are not high. As a result of a two stage reduction, extremely high reduction ratios upto 1000: 1 and above are possible on copper and copper alloys.

Another system developed by the same company called "conform" is primarily developed for continuous extrusion of non-ferrous materials. The diagramatic sketch (Fig. 2) shows the basic principle. Feedstock, either rod or preformed section is drawn into the machine by the frictional force exerted through the slowly rotating wheel. The grip developed is sufficient to cause increasing deformation of the material and produce a final pressure sufficient for extrusion to occur. Reduction ratios upto 250 : 1 and above on aluminium and copper are achieveable.

5.2 Dynamic Forming

High energy rate forming—also known as dynamic forming—was much improved during recent years. This high energy rate may be obtained by chemical explosives, high voltage electric discharge, electromagnetic fields or by pneumo-mechanical methods.

Initial enthusiasm and promise attached to explosive forming seems to have died down or reduced during recent years. However this method is suitable for forming large parts required in small quantities, particularly for prototypes. Dies out of concrete etc. have also been tried out with different claims of success. In electro-hydraulic forming high energy rate is obtained by a high voltage discharge. But the cost of capacitor banks etc. required are fairly high, particularly when large quantities of energy are required for higher deformations. In electro-magnetic forming instead of discharging the energy stored across a spark gap, energy is released through a coil causing rapid build up of a magnetic field to an extremely high density. These two types are usually used. for shrinking or expanding of tubes or collars on tubes. Under the group pneumo-mechanical comes Dynapak machines which utilises potential energy of a compressed gas to move a mass at high speed, petroforge which utilizes the combustion of a mixture of fuel and air like in a piston engine, to drive the mass and like.

5.3 Metal Spinning

Metal spinning has been an old art, but flow turning which was developed later seems to be having high potential which is not yet fully exploited. Flow turning could be regarded in essence as single point cold rolling operation. Initially this process was developed for purposes of manufacturing completely seam free stainless steel containers of cylindrical and/or conical form for the dairy industry. But now it is used even to make parts like jet engine combustion chambers and rocket components etc.

5.4 Powder Metallurgy

Powder metallurgy and sintered components were also highly developed during recent years. In this process powder is first compacted, sintered and then finished and sized. Powder metallurgical products could be divided

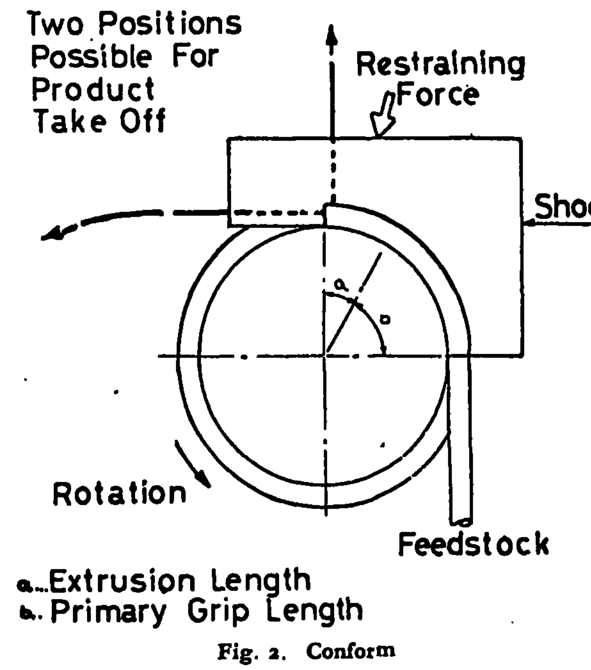

Fig. 2. Conform

into two main groups: (1) porous materials, such as are used in bearings, (2) dense materials such as sintered carbides. Recent improvements in press design, such as wire wound presses, made possible the use of very high pressures, thereby compacting powders to very high densities approaching that of parent materials. Powder metallurgy is also being used to make many difficult alloys, which were otherwise impossible as the constituents may react or be converted to other forms during melting.

5.5 Volume Cold Forming

Another field which made tremendous progress during recent years is volume cold forming in multi-stage transfer presses. Certain problems with tools such as transverse fatigue fracture of highly loaded dies which were supposed to be due to so-called "breathing effect" and was earlier considered to be an inevitable evil[10] are now successfully solved. Analysis by Kudo et al showed it to be due to a tensile component of stresses developed in the die. Many solutions such as axial end/or transverse division of dies were only partially effective only at the lower critical point. Post stressing methods of die inserts used by Sieber[2], Krupp[11]; etc., increased the life but was not a complete solution. Further those could be used only where the die holder is large enough.

Certain investigations, theoretical as well as practical, carried out in Czechoslovakia[12] showed that die inserts could be effectively pre-stressed compressively by the application, by external means of a compressive stress maintained on insert during shrinkage union of the ring (s) and insert. It was also shown that by using a post stressed assembly of such pre-stressed inserts, this fracture could be suppressed effectively, making possible the use of much harder grades of carbides. This pre-stressing method developed by Fernando[12] is at the moment being tried out in production machines in Czechoslovakia and is reported to be showing encouraging results.

There are conflicting claims as to the dependence of die life on initial surface smoothness. Certain authors claim that initial finishing of a die bore to a mirror finish increases life considerably, but others say that the initial finish of the bore is destroyed within the first few hundred of strokes, thus showing that it has no appreciable effect on die life.

6. Forming in Sri Lanka

Sri Lanka is still in its infancy in the field of Cold Forming. Even though it is true that the high cost of modern forming machines is a great obstacle for the development of this industry, there are yet so many other ways of improvement which are more or less ignored. There are many products at present imported which could have been manufactured locally with the existing machines or with simple machines which could easily be fabricated locally. Many automobile spares, engineering components, bolts and nuts etc. fall into this category.

Not only the design of most of the articles and tools required could be locally done, but also the manufacture of most of the tools. Of course it is too early to start too complicated ventures such as for example, manufacture of sintered carbides. But almost all tools out of tool steels could be made locally. Even with hard metals, assembly and finishing of dies could easily be done here. It seems that in making tools, most of the manufacturers are not giving due consideration for heat treatment and final finishing, which are two vital factors on which tool life mostly depends. Steel manufacturers recommendations are usually ignored and even the significance of proper tempering is often underestimated.

There should be no hesitation for consultation and discussion of problems among those involved in this business. Improvement of quality of product, of processes, of technical know-how needs research and development institutions such as NERD Centre of Sri Lanka are in a position and are willing to help and co-operate in these aspects.

References

1. Kudo. H., Yokohama, Sh. Matsubaya—*Analyse der Spannungen in zylindrischen Werkzeugen endlicher Lange, die einer inneren Druckspannungsverteilung ausgesetzt zind.* Industrie Anzeiger 92 jg.Nr.30, pp. 631-634.
2. Sieber, K.—*Design of Cold Forming Tools, Theoretical Principles and Practical Experience.* Metal Forming, 1971, pp. 128-131 and 128-131.
3. I.C.F.G. Data Sheets, 6/72, *Dies (die assemblies) for cold extrusion of steel.* Metallurgia and Metal Forming, 1972. May, pp. 161-163, June, pp. 209-215.
4. Babor, K., Cvilinek, A., Fiala, T., *Obje ove tvareni oceli*, pp. 205-211, SNTL-Nakladelstvi, Praha, 1967.
5. Kuzdas and collective, still unpublished—personal consultation.
6. *Isostatic hot pressing improves the performance of cold forming tools*, Metallurgia and Metal Forming, Jan. 1974, pp. 8-12.
7. *Hard metals in metal forming operations*, Metallurgia and Metal Forming, March, 1974, pp. 63-64.
8. Fritz Frehn, *Hohere standzeiten beim schneiden, Stanzen und Umformen durch den einzigen bearbeitbaren und hartbaren Hartstoff "FERRO-TIC"*, Blech, Nr 11/1967, pp. 537-540.
9. "FORMA"—International Conference on Forming, in BRNO, August, 1974.
10. Sieber, K., *Tooling Design for Cold Forming, with particular reference to multi-stage transfer presses.* Sheet Mtl. Ind., Feb. 1966, pp. 111-129.
11. Blum, J., *Hartmetal-Werkzeuge zur Massivformung Konstruction und Einsatzmoglichkeiten*, Widia-Tagung 1972, pp. 11-14.
12. Fernando, M. A. R. V., *Improvement of Calculations and Construction of Dies for Volume Cold Forming.* Dissertation—Aug. 1974, Technical University of Brno.

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මූර්තික ලෝහවල ප්‍රධානතම ප්‍රයෝජන වූකලී ඒවා වඩා හොඳ කණිකා ව්‍යුහයකින් හා උච්ච නිෂ්පාදන ශීඝ්‍රතාවකින් යුක්තවීමය. ශීත මූර්තිකරණයේ දී කලින් විස්තර කළ ගුණාංගයනට අමතරව වැඩ ගැනීමෙදී ද්‍රව්‍යවල දෘඪ බවට පත්වීමේ ගුණයන් ද ඉතාම ප්‍රයෝජනවත් අන්දමට භාවිත කළ හැකි අතර ඔරොත්තුදීමෙ ශක්තීන්ද ඉතාම ආසන්නව පටත්වා ගත හැකිය. මෑත අවුරුදුවලදී උපකරණ සැලසුම් කිරීම, උපකරණ තැනීම සඳහා භාවිතා කරන ද්‍රව්‍ය හා මූර්තික ද්‍රව්‍ය යනාදිය සම්බන්ධයෙන් කරන ලද වැඩි දියුණුකිරීම් සමග කලින් යන්ත්‍ර භාවිතයෙන් හෝ තප්ත මූර්තිකරණයෙන් පමණක් සාදන ලද බොහෝ දේ දැන් ශීත මූර්තිකරණයෙන් කරනු ලැබේ.

කෝෂ්ය නිර්මාණය පිළිබඳව මෑතදී කරන ලද වැඩිදියුණු කිරිටවලින් පසුව මෙවලම් තැනීම පිණිස වඩා දෘඪ වර්ගයේ සින්ටරීකරණීත කාබයිඩ පාවිච්චිකරනු ලැබේ. ජලස්ථිතික හා ඝනස්තර නිෂ්කාස ක්‍රම නිෂ්කාසනයට ආධාර වී ඇත. එයත්, අඛණ්ඩ නිෂ්කාසයත් ෆෙරස් නොවන ද්‍රව්‍ය නිෂ්කාසනය සඳහා අලුතෙන් එක්වූ ක්‍රම දෙකකි.

ස්ඵෝටන මූර්තිකරණය පිළිබඳව දක්වන ලද උනන්දුව අඩුවී ගොස් ඇති සෙයක් පෙනෙන්නට තිබේ. ගැලීම් ක්‍රමයෙන් සෑදී මෙ කාර්යාවලියෙහි මෙතෙක් ප්‍රයෝජනයට ගෙන නොමැති හැකියාවක් ඇත්තේය. ශක්ති ලෝහවිද්‍යුත් සින්ටරීකරණීත කාබයිඩ නිෂ්පාදනත් බොහෝ සෙයින් දියුණුව ඇත. සම්පීඩක යන්ත්‍රවල උච්ච පීඩනයක් ලබාගත හැකිවීමෙ ප්‍රතිඵලයක් වශයෙන් ද එම දියුණුව සැලසී ඇත. සම්පීඩක යන්ත්‍රවල එම පීඩනයක් ලබාගත හැකිව ඇත්තේ කම්බි එතුම ක්‍රමය මගිනි.

අතිශයෙන් බර පටවන ලද කෝෂ්යවල දක්නට ලැබී ඇති තිර්යක් ආයාස බිඳුම් සඵලදායක ලෙස මැඩ පැවැත්විය හැකිව ඇත්තේ මෑතදී සොයාගන්නා ලද කෝෂ්ය සැලසුම් කිරීම හා නිර්මාණය හේතුකොටගෙනය. මෙය පරිමා ශීත මූර්තිකරණයෙහි විශාල දියුණුවකි.

ශ්‍රී ලංකාවේ ලෝහ මූර්තිකරණ කර්මාන්තය තවමත් ළදරු වියෙහි පවතී. තවමත් පිටරටින් ගෙන්වනු ලබන බොහෝ උපකරණ මෙහිම සාදගත හැකිය. ඒ සඳහා පර්යේෂණත්, සංවර්ධනයත් අවශ්‍යය. ශ්‍රී ලංකාවේ මූර්තිකරණ කර්මාන්තයේ තත්ත්වයන් ඉහළ නැංවීම පිණිස තත්ත්ව පාලනයක් අවශ්‍යව ඇත්තේය.

குளிரல் உருவாக்கலும் அதன் சில அண்மைக்கால அபிவிருத்திகளும்

எம். எ. ஆர். வி. பெர்னாண்டோ

சுருக்கம்:

உலோகங்களை உருவாக்குவதிலுள்ள முக்கிய நன்மை சிறந்த வரைக் கட்டமைப்பைப் பெறுவதும் உயர் உற்பத்தி வீதங்களுமாகும். குளிரல் உருவாக்கலில் மேற்சொன்ன நன்மைகளுடன் வேறு இரு முக்கிய நன்மைகளும் உண்டு. பதார்த்தங்களின் வன்மைத் தன்மை பெறும் இயல்புகளைச் சிறந்த முறையில் உபயோகிக்க வழி செய்தலும் அவற்றின் தாங்கும் தன்மையைப் பாதுகாத்தலுமே அவ்விரு நன்மைகளுமாகும். உபகரணங்களை அமைப்பதில் ஏற்பட்ட அபிவிருத்திகளும் உபகரணங்களை உற்பத்தி செய்வதற்கு உபயோகிக்கப்படும் பதார்த்தங்களிலும் ஏற்பட்ட அபிவிருத்திகளும் முன்பு வெப்பம் மூலம் உருவாக்கப்பட்ட பொருட்கள் அண்மைக் காலத்தில் குளிரல் முறையில் உருவாக்கப்படுகின்றன.

அச்சு வார்ப்புக் கட்டுமானங்களில் அண்மைக் காலங்களில் ஏற்பட்ட அபிவிருத்திகளின் விளைவாக உபகரணங்களை உற்பத்தி செய்வதற்கு வன்மை மிக்க வெந் நீரருவிப் படிவக் காபைட்டுகள் உபயோகிக்கப்படுகின்றன. நிலை மின்னியல் கடின படை வெளியேற்ற முறைகள் ஆகியவை கஷ்டமான உபயோகங்களையும் உலோகப் பொதிவையும் வெளியேற்ற உதவியுள்ளன. திருகு சுழல் நிலை மின்னியல் வெளியேற்றியும் தொடர் வெளியேற்றியும் இரும்பல்லாத பதார்த்தங்களின் வெளியேற்றலுக்கு உதவும் புதிய முறைகள்.

வெடித்தல் மூலம் உலோகங்களை உருவாக்குவதில் இருந்த ஆர்வம் இப்பொழுது குன்றி விட்டது போல் தெரிகின்றது. ஓட்டத் திருப்பல் முறை நன்ருக ஆராயப்பட இல்லை. அது நல்ல பயன் அளிக்கக் கூடும். கம்பிச் சுற்றுத் தொழில் நுட்ப முறையால் அமுத்திகள் மூலம் பெரிய அமுக்கத்தை உருவாக்கக் கூடியதாக இருப்பதன் விளைவாக தான் உலோகவியலும் வெந்நீரருவிப் படிவக் காபைட்டு விளைவுப் பொருட்களும் நன்ருக அபிவிருத்தி செய்யப்பட்டுள்ளன.

அச்சு வார்ப்பு மாதிரிகள் தயாரித்தலிலும் கட்டுமானங்களிலும் அண்மைக் காலங்களில் ஏற்பட்ட அபிவிருத்திகள் உயர் பாரமுள்ள அச்சுவார்ப்புகளில் அவதானிக்கப்பட்ட குறுக்கீட்டு மெலிவு வெடிப்பதைத் தவிர்ப்பதற்கான வழிகளைக் கொடுத்துதவியுள்ளது. கனவளவு குளிரல் உருவாக்கத்திற்கு இது பெரிதும் உதவியுள்ளது.

உலோக உருவாக்கல் கைத்தொழில் இலங்கையில் ஆரம்ப நிலையிலே இருக்கிறது. இறக்குமதி செய்யப்படும் பல பொருட்களை உள்ளூரிலேயே உற்பத்தி செய்யலாம். இத்துறையில் ஆராய்ச்சியும் அபிவிருத்தி முயற்சிகளும் தேவை. இலங்கையில் உருவாக்கல் கைத்தொழிலின் தரத்தை உயர்த்துவதற்கு தரக் கட்டுப்பாடு தேவை.