Economic uses and substitution of non-ferrous metals and alloys

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MOST commonly used non-ferrous metals at the present stage of industrialsation in India are aluminium, copper, zinc, lead and tin. These metals and their alloys form the basis of innumerable engineering applications as well as domestic uses. Unfortunately, except aluminium and negligibly small quantity of copper, zinc and lead, India does not produce at present any of the other non-ferrous metals. Without going into the statistics of Fourth Five-Year Plan period demand and production figures for these metals which undoubtedly have been dealt in some other papers of this Symyosium, it is sufficient to point out that jointly these four non-ferrous metals cause an annul drainage of about rupees forty crores of foreign exchange. Further, the anticipated production capacity of copper, zinc and lead in near future fall far short of anticipated demand. The situation regarding tin is still worse because uptil now no tin bearing ores have been found in India.

Under such circumstances, it is essential to economise the use of these non-ferrous metals by either replacing them with less efficient and cheaper material, finding out substitute material and minimising their use by various impoverisation and similar efforts. In the following chapter some of the methods which will help in achieving these ends have been suggested.

Use of clad and composite material

Clad and composite materials are those where two or more metals are bonded together to impart to the composite most useful property of each metal. By manipulation of proportion of individual metals of the composite as well as the type of metal combination the composite properties can be adjusted to suit specific application as well as to substitute special type of non-ferrous alloys. It is sometimes possible to predict the property of the composite from properties of the components before bonding. Strength and density of composite are usually an arithmetical average of those values of the components. Electrical and thermal conductivities, Young's modulus and ductility can also be calculated, though in some cases the calculations are slightly complex. In many applications surface property of the components is the most important one. In such applications marked economy from the point of view of cost as well as quantity of material can be achieved when cheaper and abundantly available materials are clad with a material of desired surface property. Thus when corrosion resistance is the basic consideration use can be made of thin layer of corrosion resistant metal or alloy on thicker strength giving basic material.

Successful experiments were carried out in this laboratory by the author and his colleagues to develop the technical know-how for cladding of stainless steel on mild steel. Use of such clad vessels in chemical industries, where heavy gauge solid stainless steels are used, would cause considerable saving in the comsumption of nickel and chromium.

(i) Textile printing rollers

There are a large number of textile mills in India. Copper textile printing rollers are used throughout textile industries. Government of India, sometime back, wanted replacement of these rollers by aluminium or aluminium alloys. It is felt that aluminium would not be suitable due to its poor wear resistance and difficulty in engraving. Further, high strength aluminium alloys have got poor corrosion resistance. It is suggested that steel rollers clad with copper will be an excellent substitute, as the surface property of the copper rollers will be retained whereas the necessity of replacement of the rollers after third engraving, as done at present due to loss of strength, would not arise as the core of the clad roller is made of steel. The cladding can be done by either immersion casting technique or by welding a preformed copper plate on the steel roller by argon arc welding process.

(ii) Spring material

Large quantity of spring material used in electrical and other industries which are made of either phosphor-bronze or copper-beryllium or some difficult-to-find non-ferrous materials. A simple calculation of electrical conductivity of clad rolled spring steel and copper

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shows that a composite of spring steels with 5 to 6 per cent of copper on both sides will produce electrical contact spring having properties similar to that of phosphor-bronze or beryllium-copper. Such springs would not be too difficult to manufacture and can suitably replace the use of phosphor-bronze and beryllium-copper thereby effecting considerable saving of copper and tin.

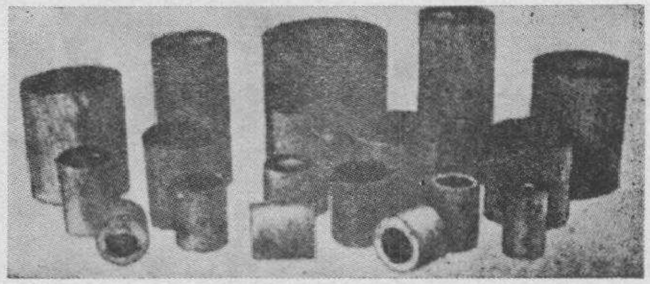
Two to five layer composite springs of copper and various grades of steels are now being marketed by Texas Instruments. Depending on the type of steel used and the relative proportion of steel and copper, various requirements of electrical conductivity and elasticity have been achieved. These springs have been reported to be stronger, stiffer and at the same time costing less than beryllium-copper and phosphor-bronze springs.[1]

There may be innumerable other products where cladding or over-laying technique can be used with economy both from the point of view of cost and saving of scarce non-ferrous metals. Even old coins are being replaced in America by clad coins of cupro-nickel/copper combination for lower denomination coins and silver/cupro-nickel combination for higher denomination coins. Production of non-conventional clad metal substitute will depend on the ingenuity of the producer and technical knowledge of the cladding techniques. A single simple example will show to what extent adoption of a suitable cladding or joining technique may help. A firm in Czechoslovakia has been reported to achieve 60% reduction in the cost of a bronze work gear by substituting a steel blank with bronze overlay for the teeth.[2]

Bearing material

Large demand is made on copper, lead, zinc and tin by the bearing industries. Almost all conventional "bushing" material as well as soft bearing materials are made from these non-ferrous metals. Attempt should be made to replace them either by substitute incorporating mainly indigenous metal or by use of non-metallic bearings or bushing wherever possible. Thin and lead based white metal bearings are being successfully replaced by aluminium base bearing containing tin from 6–20% in various internal combustion engine applications. Extensive use of aluminium-tin bearings, which have got much better wearing as well as fatigue properties, would help in a great extent in conserving copper, lead and tin. Experiments at the National Metallurgical Laboratory, reported in another paper, show the possibility of replacing part of the tin of aluminium tin bearing by small quantities of lead and antimony.[3] This would cause a further saving. Solid bearings or "bushing" which are mostly phosphor-bronzes can be replaced by Alzen type of solid aluminium base bearings containing aluminium and zinc, which will be less costly than phosphor-bronze. There are some suggestions that a bearing of zinc with 30% aluminium and 5%[4] copper can also be used as solid bearing. This will help in some extent to save some copper as well as full quantity of tin.

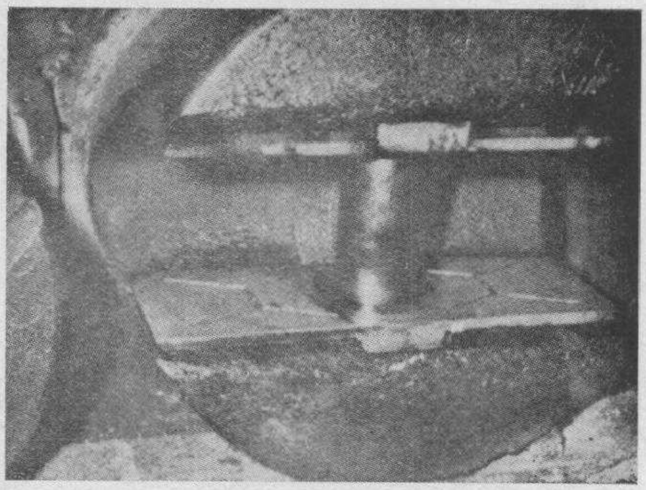
Where the running speed is not very high, the scope of using non-metallic material as solid bearing is very bright. In Soviet Union recently attention has been drawn towards using the bearings made of pressed wood for a large number of applications.[5] As for example, axially pressed wood has been recommended for the manufacture of slide blocks for various machines and mechanism, bearing bush, collar steps, small sleeves and coupling cogs. Woods pressed as plates with a longitudinal direction of the grain have been recommended for use as slide blocks for operation in dry rooms and with mineral oil lubrications.



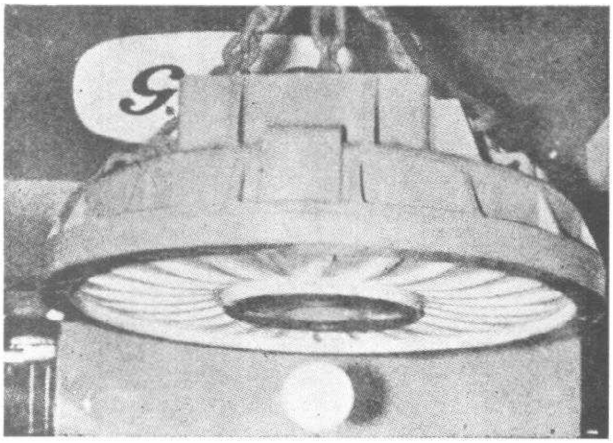
Pressed wood sleeve bearings

Textolite has also been used in Soviet Russia as rolling mill bearing. It has been reported that with proper operation in rolling mills and good care, the service life of textolite exceeds that of bronze by three or four times. Bronze bushing of slowly moving machines operating under non-critical conditions can safely be replaced by such bearings. Bearings of electric fans etc. are examples where such replacement can be tried.

Breakage and wear of manganese bronze slipper blocks on the finishing stands of a 54-in. continuous hot mill strip lead the National Steel Corporation to use cast nylon as a replacement material. The average recorded life of the nylon slippers on the stand with worst record was 1130 hours compared to 670 hours for the former



Nylon replacement of manganese bronze skipper blocks of continuous hot mill



G.E.C. lifting magnet made from anodised aluminium foil

slippers.[6] In another case, introduction of such slipper blocks in a blooming mill has resulted in trebling the tonnage life.

Incidentally it would not be out of place to mention here that experimental work carried out in this laboratory by the author and his colleagues leads to the development of plain sliding bearing material based on thermosetting plastic incorporating P.T.F.E. and asbestos fibers. Though this work was originally taken up with a view to developing a substitute for imported low friction fabric liners used by the Indian Railways, the material has potential use in dry running plain sliding bearing application where a low friction value under bearing is desirable.

Non-ferrous metal economy in electrical industry

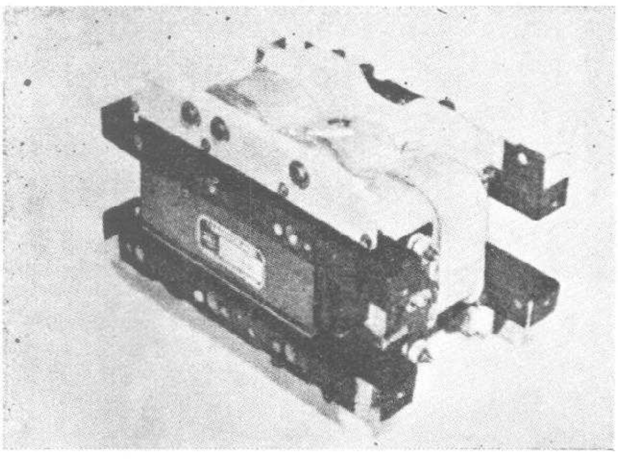
Major consumers of copper and copper based alloys are electrical industries. Replacement of copper by aluminium can achieve a major saving in copper consumption. Aluminium electrical conductors are fast replacing copper conductors in India. This aspect has been dealt in some details in the symposium circular and is also widely known and need not be further discussed. Some other specific cases where copper can be substantially replaced by aluminium are given below:

In electrical transformers, part of the copper used can be replaced by aluminium. In U.S.S.R. at the Zaporozh factory transformers are being manufactured since 1959 with aluminium, replacing almost 50% of the copper used. It has also been suggested in Soviet Union that by use of oxidised aluminium foil instead of copper in the manufacture of contactors, magnetic breaks, relays, electrical lamp, choking coils, etc. huge saving of copper can be achieved. This is a field where our industries should give attention.

In many electrical components copper wire windings can be replaced by anodised aluminium foil. It has three advantages: first it has an improved packing factor, secondly it is necessary only to insulate turn to turn and not layer to layer and thirdly aluminium foil is readily available and cheaper. Anodic insulation alone is sufficient for many applications and it has been stated that a film thickness of 0·001″ is necessary for 1000 volt insulation.[8] In order to prevent short-circuiting of the edges a film thickness of twice that of the surface has been used. A transformer with aluminium foil winding used in some aircrafts is shown in bottom figure.

In heavy electromagnets used in steel industries and fabrication shops for lifting purpose, aluminium foil has been successfully used instead of copper winding. As weight for weight conductivity of aluminium is about double that of copper, much saving in the net weight of the electromagnet can be achieved with consequent increase in lifting capacity. Two Australian companies using such electromagnets have found that 305 pounds of aluminium could be used in place of 420 pounds of copper.[9] Aluminium being much cheaper, saving in cost can also be achieved. The size of the outer casting of the electromagnet will however be bigger. Such electromagnets are in production in Australia.

Huge quantity of electric bulb caps and tube light caps made of brass are used. The possibility of replacing these caps by aluminium ones also needs be examined.



A.E.I. 3KW—6 phases transformer with anodised aluminium winding

Metal economy in domestic items

In sanitary engineering, large quantities of copper, brass and lead are used. Considerable saving of these materials can be achieved by judicious and intelligent use of plastic and ceramic wares. As for example, lead pipes used in wash basins and sinks can easily be replaced with suitable plastic pipes; considering the very large number of such items used throughout India such replacement alone will cause considerable saving of lead.

Food cans

It has been realised for some years in various countries that undue large expenditure of tin results due to inherent imperfection of hot tin plating process. Recent experience on electrolytic tin plating process shows that the consumption of the tin is reduced to practically 1/3 of that of hot tin plating process. Since tin plate industry is a bulk consumer of tin, efforts should be made gradually to utilise electrolytic tin plating process only instead of hot tin process which is universally used in India. Further, attempts should be made to have tin plate on one side only for food tinning cans, the otherside which comes in contact with food should have suitable anti-corrosive lacquer coating. Obviously, substantial economy of tin will result from this.

According to a recent soviet invention[10] chromium plating instead of tin plating of food tinning has been found workable. According to the invention plate for use in the manufacture of tin can is chromium plated on both sides to a thickness of 0·02–0·3 microns. After chromium plating the sheet is coated with food can lacquer on one side. It is reported that plates processed in this way are more resistant to foods and atmospheric corrosions than tin plates. Filled cans can be stored for up to six years. Such chromium plated food cans have been introduced in Japan also recently.

Indirect non-ferrous metal economy

Apart from the suggested direct metal economy indirect economisation can be achieved by adopting improved process to avoid wasteful losses. A very large proportion of the non-ferrous metal foundries in India are in the small scale sectors ; these foundries as well as most of the large non-ferrous foundries utilise flame furnaces for melting and casting. Non-ferrous metal loss when smelting in flame furnaces is almost double that of smelting in electric induction furnaces. Use of electric induction melting in these foundries itself will result in some saving of all the scarce non-ferrous metals. In small scale sectors, where due to financial reason, installation of electric induction furnaces is not a practical proposition, efforts should be made through the help of the government to frame non-ferrous small scale manufacturer cooperative who will help to induce the financier to instal induction furnances.

Another indirect way whereby considerable saving of copper, lead, zinc and tin can be achieved is judicious selection of substitute alloys in which total amount of scarce non-ferrous metals is less than that of a particular traditionally used alloy. However, such intelligent use can result from boldness in adopting new design, doing away with conservative outlook and dissemination of advanced knowledge of material properties, where metallurgical laboratories can be of much help. As an example of what can be achieved by such economical use through utilisation of substitute, it is pointed out in Soviet Russia, that the use of arsenical brass containing less percentage of copper instead of conventional high copper brass in automobile and tractor radiators itself could result saving of fifteen thousand tons of copper during a seven-year plan period of the country.[7]

Conclusion

The example cited in the text are only a few instances where there is an ample scope of saving of non-ferrous metal. Though it is possible to implement the suggestions in most of the cases, it is not the intention of the author to categorically state that immediately all these suggestions can be put in to practice. As for example arguments may be put forward that replacement of tin plating by chromium plating followed by lacquering of food canning steel sheet material would necessitate close down of the existing tin plating installations which may be uneconomic and hence impractical. However, whenever new industrial developments take place the same problem arises and finally more economic and more efficient developments always replace the existing old practices. Since, the shortage of non-ferrous metal is a chronic problem in India, which is likely to take a worse turn with increase of industrialisation in the country, it would be necessary to take steps which in long run will be helpful.

The non-ferrous metal shortage is being faced by many other countries but they are trying to solve their problems by taking bold steps in implementing new advanced ideas some of which have been quoted in the text.

It is finally suggested in order to achieve non-ferrous metal economy, the following steps would go a long way on the matter.

1. Use of composite metal wherever possible.
2. Use of substitute metal and non-metal like plastics, where service condition is not so critical as to prohibit the use of an unconventional and slightly less satisfactory alternate material.
3. Use of substitutes wherein the total quantity of non-ferrous scarce alloying element is less.
4. Use of production technique which would minimise irrecoverable losses inherent in the process of melting, casting and fabrication.

Acknowledgement

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Discussions

Mr **K. C. Choudhuri** (R.D.S.O., Chittaranjan): The author advocated the use of cladded steel as a measure for conserving non-ferrous metals. Has any firm in India been licensed for production of cladded steel to commercial sizes?

In the near future our wagons may be all welded. Has the welding of cladded steel been studied? If we do change over to cladded steel we will face difficulties for utilisation of scrap. I would like to know if the author has considered this point.

Mr **B. N. Das,** (Author): To the best of my knowledge no firm in India has yet started commercial production of cladded steel, but since the pattern of industrial development in India is not very much different from that of other developed countries, I have no doubt that the advantages of using cladded metals in various industries are realised by our industries and consequently it is possibly only a matter of time before clad metals are commercially produced in India. Various advantages of use of cladded metals, a few examples of which I have given in the paper, show that the sooner we give attention to the production of cladded metals the better it would be for us from the point of view of conservation of valuable non-ferrous metals.

Production of cladded sheets or plates of larger width require heavy rolling mill and modifications of the plants. At the first stage of our production of cladded metal, we may, therefore, give attention to the production of small width sheets for use, may be, in heat exchanger tubes, in cycle rims, clad sleeve bearings, etc.

Welding of cladded metal is now a well-known and perfected technique and is not likely to pose much difficulty.

Utilisation of scraps of clad product, of course, will pose some difficulty, but the benefit derived from very much longer life of clad components and their life to price ratio will outbalance such difficulty.