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Environmentally friendly Manufacturing, processing and materials

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Abstract

The global environment is now exerting great influence on our life. It is not an overstatement to say that there would be no meaning in developing new materials unless due consideration is given to the load they exert on the global environment.

We have been studying a new manufacturing system which is based on both mankind and earth in the coming unavoidable recirculation based society.

One of the solutions is to develop the closed manufacturing system which creates the material where input (fossil energy and natural materials) and output (exhaust gases and waste materials) will be reduced to their utmost limits.

In this report, as one of the examples of developing the material considered for both mankind and earth, details of the development and its actual results on the application of hydrothermally solidified soil (Earth Ceramics) to a house floor are discussed. This was developed from the research on the closed manufacturing system.

Key Words: global environment, recirculation based society, closed manufacturing system, soil, hydrothermal processing

1. HUMAN AND TECHNOLOGY

The global environment has now begun to have great effects on our lives. Far-reaching changes in the social structure are being forced upon us by environmental issues such as global warming, desertization, depletion of the ozone layer, acid rain, etc., which stem from two main problems - global scale expansion of the economic activities of the industrially advanced nations and population expansion in developing countries.

In their book "Beyond the Limits"[1] published in February 1992, Meadows and his co-authors warned that unless countermeasures are taken, the world economy which may still grow until around the year 2020 will cease its growth after that because of various limiting factors and will have collapsed by the year 2100. A number of similar reports supplementing these warnings were published at the same time, and were a great shock to us material scientists.

The United Nations Conference on Environment and Development held in Brazil in June of the same year issued the Rio Declaration and adopted Agenda 21 as its action plan, expressing the need for radical reform in world economic activity in order to build a "recirculation-based society". This declaration was a rejection of the consumption-based economic structure of industrialized countries and means the building of a new society, previously not experienced by mankind in the past. Global environmental problems will lead to great changes in the social structure in the 21st century. These changes will affect not only human living and industrial activity, but will also force significant reforms in fundamental concepts of manufacturing goods.

Under such big changes in the social structure, the criteria under which materials should be developed and goods be manufactured become very important. Although all technologies that we develop are aimed ultimately to be of value to the human life system, it is a basic prerequisite of all technological developments that they are realized by exploiting nature. It is necessary to think about what the fruits of research and development take away from nature in order to confer to human living, and find

means of quantitatively assessing the balance between these two factors.

The authors express in this paper their ideas about how the task of manufacturing goods with due consideration to humans and the earth should be tackled under the prerequisite of a recirculation-based society.

2. FROM RECYCLE TO RECIRCULATION

From the dawn of civilization, man demarcated a border between the human life system and natural ecology. Man cannot sustain his livelihood without exploiting nature. The amount of intake from nature and the resulting amount of release into nature have increased rapidly since the industrial revolution. These amounts now exceed by far what nature can cope with by itself and are having serious effects on the preservation of mankind. Phrases such as "being kind to nature" or "living together with the environment" seem not to have perceived properly the relation between humans and natural ecology. Humans cannot control nature and humans in the new society must first recognize that it is nature that allows them their livelihood.

A recirculation-based society is one that reduces as far as possible its intake from nature (fossil energy, raw materials) as well as its output (exhaust gases, waste materials) into nature, and makes efforts to recirculate and regenerate the intake from nature within the human life system.

In actual practice, most environmental policies and measures appear to have paid attention only to recycling as a means of reducing waste (output). Although the concept of reducing waste by recycling as an initial step in tackling the environmental problem should not be contradicted, it is a fact that the process of recycling itself requires considerable extra energy (intake). As a result, it is frequently misconstrued that that the cost of recycling is high.

In planning production activities within a recirculation-based society, it becomes essential to think about total material balance. Instead of reducing output by using a large amount of additional energy, it is necessary to reduce output by reducing the intake, and, as far as possible, use the output material and energy to synthesize new materials. Specially in the case of inorganic materials where natural ecological mechanisms (such as promotion of decomposition of output by bacteria etc.) cannot be utilized, the concept of recycling needs to be changed to one of recirculation.

Here the question arises as to whether a man-made artifact produced under the concept of recirculation could become a marketable product. We have seen many examples of man-made artifacts produced with due consideration to the earth (environment), but not possessing sufficient value in their properties or performance to attract current users to become saleable commodities. On the other hand, products developed under conventional concepts of "being kind to humans" without considering environmental issues cannot of course be recognized as saleable commodities.

From now on, if a business enterprise is to exist within the recirculation-based society and command respect as corporate citizen, its product development must consider "humans" and the "earth" together (although the balance between these two may vary according to the changes in the global environment).

Of course, the material or product so developed will be strongly competitive if it exhibits new properties or performance possessed by its predecessors. Inorganic materials are in a relatively advantageous position with respect to both intake and output when compared to metals or to petroleum-based materials such as resins. Considerable merits can be expected if it becomes possible to replace these materials with inorganic materials.

3. CLOSED MANUFACTURING SYSTEM

At INAX Corporation, we began tackling environmental issues from 1992. By introducing thorough waste collection / separation schemes and new recycling systems, we have at present achieved a reduction in waste output by 85% compared with 1992 without increasing

the intake . The amount of CO_2 exhaust gas has been reduced by 12% (cf. 1990). However, continuation of the conventional system of production is expected to have its limits. In order to achieve the objectives of waste zero, 20% CO_2 exhaust gas reduction (cf. 1990) and 10% raw material reduction (cf. 1996), development of a new production system is necessary. This production system is called "Closed Manufacturing System"[2] and the technologies that constitute this system are currently being developed.

Unlike glass which is formed through solidification by cooling, the properties and performance of ceramics are dependent on high temperature solid state reactions (sintering). For this reason, it is difficult to reduce the sintering temperature to any appreciable extent. However, the strength of sintered ceramics are much lower than their theoretical strength. Since the strength of a ceramic product is proportional to the square of its thickness, if it were to be possible, for example, to increase the strength of the material four-fold compared to the present, the thickness of the product could be reduced by half. (In actual practice many other properties such as fatigue strength, toughness etc. also need to be examined).

If the thickness is reduced by half, the weight of the product would be halved, and, as a result, the amount of raw materials which is the intake would be halved and the fossil energy required for sintering would be reduced greatly together with the energy required for transport and handling[3].

Although the output will decrease with the reduced intake, in order to further reduce it, utilization of the silicic acid wastes and exhaust gases generated during manufacture to produce new usable materials or commodities without the adding further energy becomes necessary. For achieving this purpose, utilization of the waste heat for hydrothermal treatment at about 200 degrees centigrade is most effective. The silicic acid waste is mixed with a small quantity of slaked lime and solidified by hydrothermal treatment[4),5]. Also, the CO2 in the exhaust gas could be fixed/solidified hydrothermally as carbonates by reaction with alkali earths extracted from other industrial wastes such as fly ash and slag [6].

As described above, a closed manufacturing system established by reassessing the conventional production system from the point of view of material balance, reducing the intake as far as possible and not allowing anything other than the product itself to be output from the system, has the potential for developing many new materials.

4. SOLIDIFYING SOIL

Soil solidified hydrothermally is a new material born from the development of a closed production system. Hydrothermal processing of construction materials was developed in Europe. Sand lime brick is a typical example of this technology which has 100 years of history behind it. In Japan, hydrothermal processing is used in the production of ALC and calcium silicate boards. Usually a mixture of about 10% lime ($Ca(OH)_2$) and 90% quartz (SiO_2) is hydrothermally treated (in saturated steam) at about 200 degrees centigrade to produce acicular calcium silicate hydrates. Strength development is established through the entwinement of these hydrates. But since the presence of impurities will impede the formation of calcium silicate hydrates, the raw materials need to have 90% or higher purity. Typically, the alumina content should be less than 1% and alkali content should be kept as low as possible[7),8)].

Soil which usually consists of clay minerals such as quartz and kaolinite ($Al_2(Si_2O_5)(OH)_4$), contains appreciable amounts of alkalis (about 5%) and alumina (about 30%), is not a suitable material for forming calcium silicate hydrates by hydrothermal treatment. However, by utilizing quartz and a part of the clay minerals to produce a small amount of calcium silicate hydrate together with hydrogarnet (a hydrate mainly consisting of aluminium and alkali earths), it has become possible to obtain soil bodies with sufficient strength[9)].

In the actual process, a small quantity of $Ca(OH)_2$ is mixed with the soil which is

then formed to the required dimensions by dry pressing. The formed body is the hydrothermally processed at 150 degrees centigrade to obtain the solidified soil product. Because of the low treatment temperature, it is possible to add straw or some organics for improving appearance. Although production of conventional ceramics is a low energy material synthesis process, the energy required for the above hydrothermal soil solidification process is even lower, being only about 1/5th to 1/7th compared to that required for chinaware[10].

The strength of the hydrothermally processed soil is equal to or greater than that of concrete building materials (flexural strength = 4 to 6MPa). Its heat capacity is greater than that of wood flooring(1090kJ/m^3.K), tatami(430kJ/m^3.K) and carpet(330kJ/m^3.K). It also exhibits high humidity absorption and desorption ability similar to wood, because of its pore sizes which are extremely small (10 to 20nm) compared to concrete blocks or conventional chinaware. The extremely small pores result from the pores in the raw material (soil) itself and the pores that are formed during hydrothermal solidification.

5. LIVING IN A SOIL FLOORED HOUSE

The hydrothermally treated soil product (Trade name : Earth Ceramics Size: 200 x 200mm) was used as the flooring material for the living room (35m^2 area) in an apartment and the changes in temperature and humidity were measured under normal living conditions over a one year period[11]. Compared with other apartments, changes in temperature and humidity of the soil ceramic floored apartment were smaller throughout the year. In particular, the relative humidity was found to be stable within the range 40 to 70%.

Because the soil ceramic floored apartment needed no dehumidifiers to control humidity and required shorter operating periods for the air conditioner, the amount of electricity (fossil energy) was reduced. The amount of energy used for air conditioning after the use of soil ceramics in 1997 was 25% less than that before the use of soil ceramics in 1996 when the floor was carpeted. In addition, those living in the apartment clearly suffered less from allergic reactions. Biological breeding tests have shown that the breeding rate of the YAKEHYO tick which is one of the causes of allergy was smaller in soil ceramics compared to Vinylon cloth and carpets.

6. CONCLUDING REMARKS

Right now, when the global environment is a very serious problem for mankind, it is most important to develop technologies to preserve the high level resources of nature as far as possible and change them for use in human living using the least possible amount of energy (i.e. utilize the greatness of nature "tight-fistedly"). The hydrothermally synthesized soil ceramics described above, is a product that uses ordinary soil including waste soil together with low energy (at the level of waste heat) for solidification. In addition, when used as a building material, it exhibits the properties of self-detection and self-control with respect to temperature and humidity. It can be returned (as soil) to nature after use, or can be recirculated within the human life system. In addition to this, it may become possible to develop in the near future, a new, room temperature soil solidification technology that requires even less energy for manufacturing this product.

We believe that it is our main responsibility towards future generations to create technology and culture that will change current man-made products into more "tight-fisted" ones.

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