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COMMENTS ON THE ENERGY AND MATERIALS CONSERVATION ASPECTS OF IMPACT TREATMENT PROCESSES*

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Industrial summary

This paper is divided into two parts: the first deals with the conservation and energy utilisation aspects of shot-peening, and the second with blast-cleaning for the purposes of protection and recycling of metallic components. In order to examine the effectiveness of these impact treatment processes, six cases are examined. Taken as specific examples of shot-peening are springs, gears and aircraft panels, each emphasizing the value of the treatment to industry. Similarly, three contrasting examples are given of cases of recycling where the impact treatment combined with a protective coating assists in the conservation of materials.

Introduction

Impact treatment processes involve the bombardment of metallic components with high velocity shot or grit. These processes take several different forms, the main ones of interest to this study being referred to as shot-peening and blast cleaning, which together, have application in the manufacture and protection of a wide range of components.

The primary justification for impact treatment processes is that their use would allow engineering components to be employed at high stress levels under cyclic loading and in aggressive environments. In the case of the aircraft industry, this means a reduction in structural weight for a specified reliability level. In automotive applications, it means that relatively low-cost components can be upgraded for conservative operation at stress levels which would represent unsound practice without shot-peening. Springs, torsion bars, connecting bars, connecting rods, tie bars and gears are examples of compo-

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nents which can be upgraded without the use of increased sections or of costly alloys in their manufacture. The ability to upgrade the mechanical properties of a component by peening offers obvious opportunities: (i) when correcting for under-sized components; (ii) when fatigue failures occur after a product is standardised; or (iii) in field service.

Although shot-impingement methods have been employed for many years, the full potential of these processes has not yet been exploited. The aim of the present paper is to provide helpful quantitative information about the process potential, together with accounts of experience gained in the application of impact treatment processes. In addition, the difficulties facing the industry are described along with a discussion pertaining to the Standards and Codes of Practice currently used in the impact treatment industry and to the approach used to overcome some of these difficulties.

The paper is divided into two parts, the first dealing with the conservation and energy utilisation aspects of shot-peening, and the second with blast-cleaning for the purposes of protection and recycling.

Energy saving aspects of shot-peening

Pretreating of new component parts from the point of view of conservation of material and efficient use of energy to prolong life is best demonstrated by shot-peening. This is a cold working process in which the energy is transmitted to the component through a stream of high velocity metallic and non-metallic shot. The shot may be projected by means of either centrifugal or air-blast peening systems, shown in Figs. 1 and 2.

In order to demonstrate the effectiveness of this peening treatment, it was decided to use as examples springs (leaf and coil), gears and aircraft panels.

In earlier years, a common break-down of automobiles was due to fatigue failure of the leaf springs, and several attempts were made to overcome this. One method was to insert thin strips of zinc between the leaves, not only to minimize the shear stress between the rubbing layers, but also to protect the spring against corrosion: this did not solve the problem. It was also considered that road grit was partially responsible for the spring failure, and in many instances the complete spring was encased in a leather gaiter for protection: again this was not a complete success. However, observations were made by the spring manufacturers that grit blast-cleaning after heat treatment resulted in improvement of the life of the spring. This initiated interest among researchers, including Herbert [1], Weibel [2] and Zimmerli [3] who investigated the problems associated with the cleaning of springs, discovering that spherical shot produce better results than grit. Figure 3 illustrates the method used in peening leaf springs by conveying them beneath a shot-throwing wheel. The outcome is an improvement in the fatigue life of these springs. Even greater improvement would be achieved if the springs were peened while stressed: specially designed machines have been manufactured to carry out these operations.

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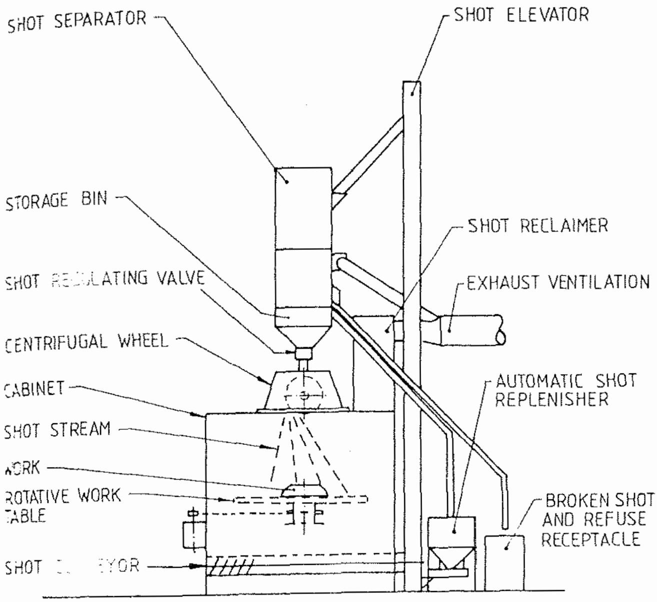


Fig. 1. Centrifugal peening machine.

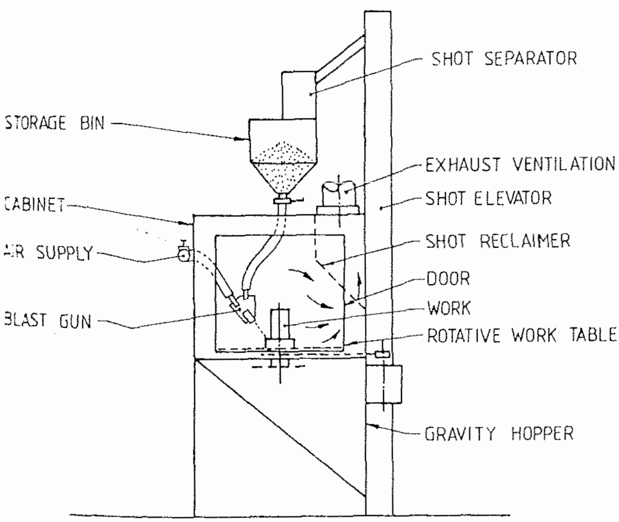
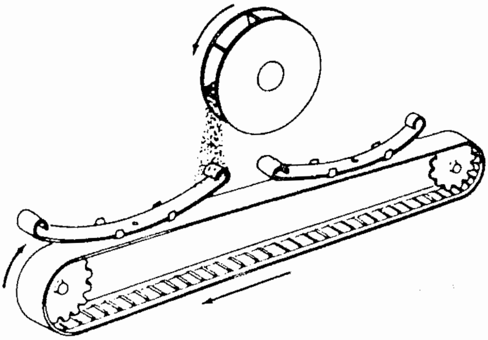


Fig. 2. Gravity fed air-blast system.

Figure 4 demonstrates the general technique used in the shot-peening of coil springs which are sufficiently large to be conveyed individually. A method of dealing with small coil springs is to tumble them under the blast wheel.

Shot-peening has proved to be invaluable in the production of gears, securing an increase in fatigue life together with an improvement in the pitting



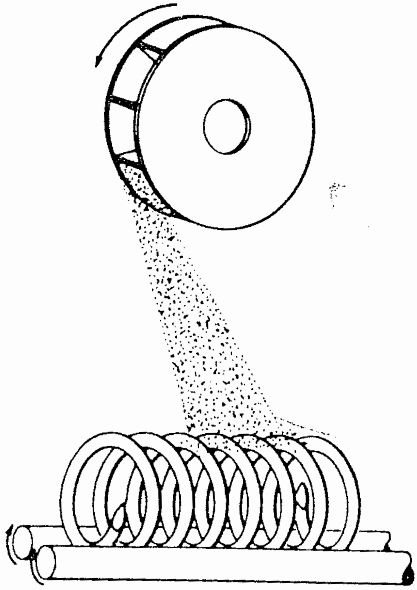


Fig. 3. A schematic diagram of the general arrangement for the shot-peening of leaf springs using centrifugal peening (left).

Fig. 4. Centrifugal peening of coil springs which are large enough to be conveyed individually (right).

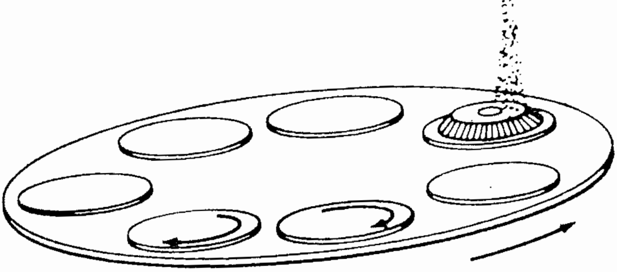


Fig. 5. The general arrangement used in the shot-peening of bevel gears.

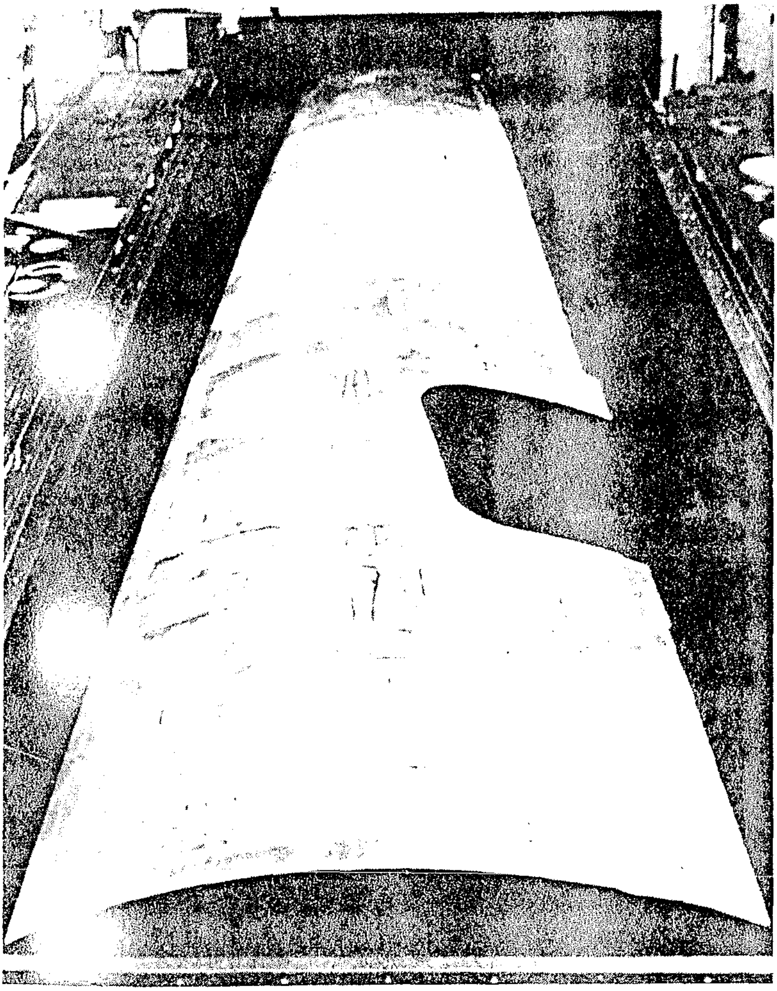


Fig. 6. A panel for the Concorde supersonic aircraft leaving the exit of a shot-peening machine having been curved to precise dimensions by peen-forming (courtesy of British Aircraft Corporation, Weybridge).

and scoring resistance. The introduction of shallow peening indentations effectively provides oil pockets, thus favourably affecting the lubrication characteristics of the gears, and at the same time reducing the noise level. The technique used in peening gears generally depends upon their type, size and shape. Figure 5 illustrates the general arrangement used in the peening of bevel gears. It is worth noting that even the size of the peening media must be selected with great care otherwise the roots of the gear teeth may not be adequately treated.

Upgrading a motor car gear box for an engine of 2000 cc capacity to meet the requirement of an engine of 3500 cc is an excellent example of the use of shot-peening in efficient energy utilisation and material conservation [4].

A sophisticated use of the peening process is that of the peen-forming of aircraft panels [5,6]. In this context, the jetstream strikes a flat plate, thus providing small curvatures, i.e. shaping the light-alloy sheet without resorting to conventional metal forming techniques. Figure 6 shows a panel for the Concorde supersonic aircraft leaving the exit of a shot-peening machine having been curved to precise dimensions by a peen-forming operation. The inducement of surface compressive residual stresses together with the increased surface hardness assists in the improvement of the fatigue and erosion resistance of the panel.

Protection and recycling by means of blast-cleaning

The "re-cycling" of energy storage containers in the form of liquid gas — propane and butane — cylinders may be a very apt example of the merits of the blast-cleaning treatment. In numbers these now amount to many millions — possibly as many as 50 millions in Europe alone — and are not only a specific example of a continuous process of reconditioning but also an outstanding example of the ravages of corrosion.

The cylinders are of pressed steel construction, designed to withstand a working pressure of 1 MPa, and are made in varying sizes, the largest having a charge of 46 kg. The ubiquitous general purpose cylinder of 10 kg, being of an ideal portable size, is found in every walk of life — in homes, caravans, farms, dockyards, and in every type of industry: sometimes resting in fields, on ashes, in farm yards, even to be found on ships decks — and is subject to every form of insidious corrosion. This, compounded by abuse in mishandling causing material damage, makes this form of container probably the greatest challenge for design and corrosion protection.

All such cylinders are made to critical standards and are subject to Home Office Regulations. They are pressure tested during manufacture at 2 MPa, and are then subject to a surface protection specification of exacting standards. The cylinders are finally hand stamped with a serial number and the date.

Because of the rough handling the cylinders receive during use, they are withdrawn periodically for examination, testing and reconditioning. The main problem lies in the corrosion at the base of cylinder, which is intensified by the considerable variation in the environment in which they are used. The cylinders are superficially examined for loss of metal through excessive corrosion, the metal thickness is checked, and if they are found to be sound they are passed through a grit-blasting machine of the automatic centrifugal type, shown in Fig. 7. This machine is fitted with two blast wheels which throw the abrasive upon the cylinders as they are conveyed upon a diabolo-type conveyor. As has been pointed out, the base of the cylinder is the critical area. The convex shape at this point being surrounded by a "skirt", results in a converging area where the two are joined. The corrosion products are heaviest at this point and must be completely removed to reveal a perfectly clean and roughened surface, able to receive the sprayed zinc coating.

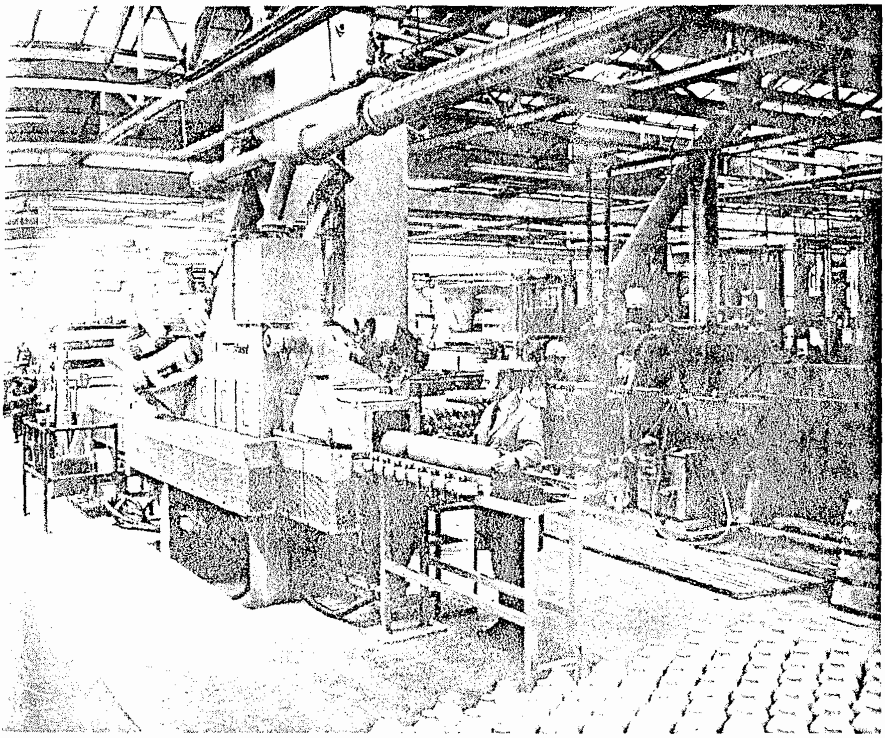


Fig. 7. Grit blast-cleaning of liquid gas containers.

The protective zinc coating is applied to a thickness of 0.07mm by means of a wire-fed metal spraying unit over the whole of the cylinders as they are conveyed from the blast machine. The zinc is of high purity and the wire is drawn to 9.5mm in diameter. By the careful mechanical manipulation of the metal spraying unit, an even and consistent coating is achieved. The cylinders are then coated with two applications of a compatible paint, forming a high standard of surface protection.

Whilst the foregoing deals with "bottled" energy, gritblasting is also an essential factor in another energy conveying system, that of ships' tankers* used internationally for the conveying of fuel oils. The problem with such vessels is that they are not designed to ply completely empty, so that after discharging a cargo of oil, they are required to re-load, usually with sea water to act as ballast.

It is obvious that these two liquids are in complete contrast, and are en-

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*Ship's Tankers is the term used in the blast-cleaning trade to collectively describe all the different areas of the ship to be blast cleaned, and does not refer only to the interior of the storage compartment(s): Fig. 8 illustrates the blast cleaning of part of the outside of the hull.

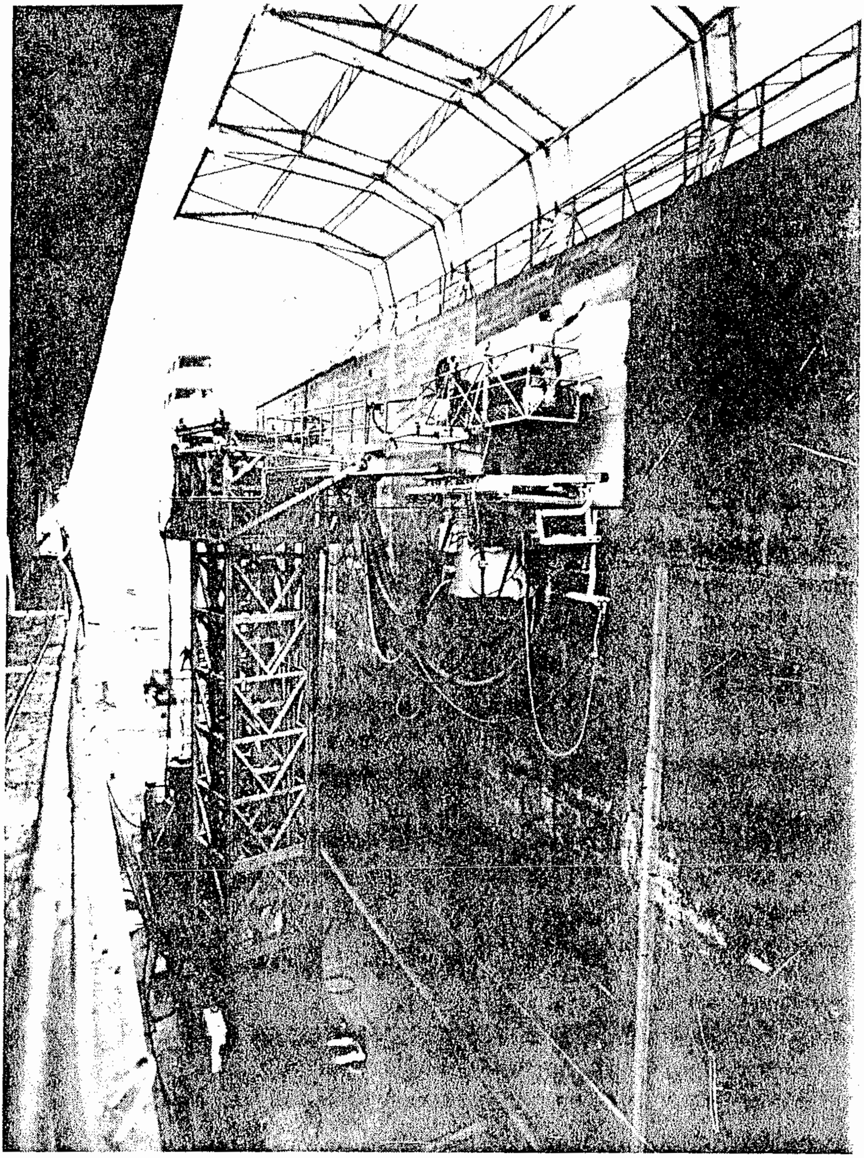

Fig. 8. Blast-cleaning of ships' tankers: in this case, part of the outside of the hull.

tirely incompatible, resulting in rapid rate of corrosion. The space between the bulkheads — which in many vessels is a single oil carrying compartment — is of very great dimensions, and because of the necessary strengthening required for the vessels to be able to carry the tonnage involved a large part of the interior of the storage compartments is complex and difficult to gr[illegible] last. Beams, stringers, angles, etc. — which have hidden and concealed areas —

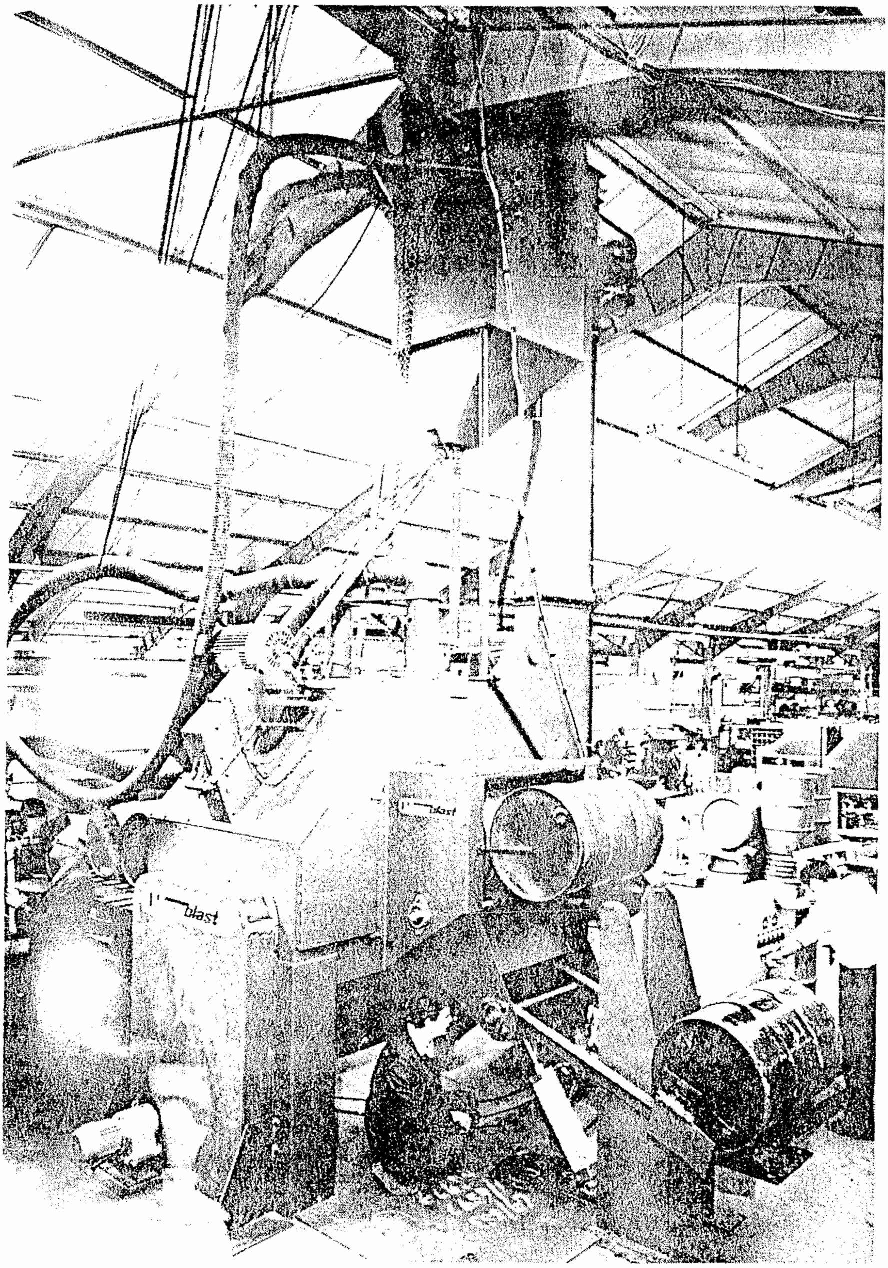

Fig. ...st-cleaning of steel drums.

present difficulty for the operators, and yet must receive the same adequate treatment as the rest of the compartment. In addition the hull is not double-skinned and the cargo is carried next to the water line, which may in itself add to the complexities of the corrosion problem caused through humidity. If the vessel is not treated in time the corrosion may be such that it can be broken off as layers of rust, up to 10 mm in thickness: because of this, it has been necessary at times to chip away this excessive corrosion with hammers, before the gritblasting operation.

Despite their size, each compartment is turned into a blast chamber and the operation is carried out manually. A further difficulty is the height of the compartment, compelling the use of scaffolding and making the work very difficult for the operators, who work clad in protective clothing and using a heavy blast hose. The blasting operation is carried out by the use of an expendable abrasive, usually in the form of a copper slag, which is reasonably economical. Though this is a dusty medium, it does not carry the extremely dangerous health hazards of silica sand. Very large ventilation systems are required to remove the dust which is generated during the operation and frequently de-humidifiers are incorporated to minimise the moisture that can build up during the operation and cause problems with the paint films.

Another valuable field of re-cycling is related to the use of 204 litre (45 gallon) steel drums. These are produced in prodigous quantities to carry a wide range of products, in the form of liquids, semi-liquids and powders. Whilst they may have been produced for a specific product, they can be cleaned and re-cycled for quite dissimilar products. The reconditioning of the drums is carried out by specialist companies who use impact treatment machines — usually of the centrifugal type — designed for the purpose. In some cases machines are made to blast clean the lids as well as the drum whilst in other cases the lids are cleaned in a separate machine. The dry process of blasting with a grit or shot, illustrated in Fig. 9, is preferred to the alternative of pickling with acid, for in the latter case the acid may be trapped in the overlapped joints of the drum, and, if not washed out thoroughly, may cause not only corrosion of the metal but also possible contamination of the contents.

Standards and codes of practice

In a production situation there is no practical, satisfactory means of simply measuring the intensity of shot-peening or the magnitude and depth of the compressive residual stresses by means of direct non-destructive examination of the peened component. It is, therefore, necessary to resort to indirect methods of inspection in the form of process control, in order to maintain consistent and satisfactory results. This is currently performed using the Almen strip and gauge [6].

It is worth noting that the most comprehensive list of Standards and recommended Practices designed to control the peening conditions are those published by the Society of Automotive Engineers and are widely used by all the Western manufacturing nations. Although some "in-house" specifications on shot-peening do exist in this country, no British Standards are available on the subject.

Existing Standards in popular use for steel surface preparation are: the UK - BS. 4232, dealing with blast-cleaning; the American SS.P.C.- SP Series, covering a range of cleaning methods; and the Swedish S.I.S. 05. 59.00, giving visual examples of rust and preparation grades for steels not previously coated. None of these Standards provides comprehensive definitions of the range of surfaces confronting the surface preparation industry, the means of achieving those surfaces, and how they are to be measured or how effective they will be [7].

A International Committee met in 1978 to draw together from existing Standards and current Practice, an International Standard covering the range of uncoated and previously coated steel surfaces, the means of achieving and measuring these surfaces, together with the field of application and effectiveness of each method. Three working groups were formed: Surface Profile, Surface Cleanliness and Methods of Surface Preparation, and considerable progress has been made by these groups.

Concluding remarks

What has been cited herein is a very limited number of interesting applications in the impact treatment field, which has yet to be fully exploited and appreciated. The authors hope that this insight will lead to a furtherance of these important processes.

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