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THE USE OF JIGS IN MACHINING AND ASSEMBLY OPERATIONS 1/

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1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

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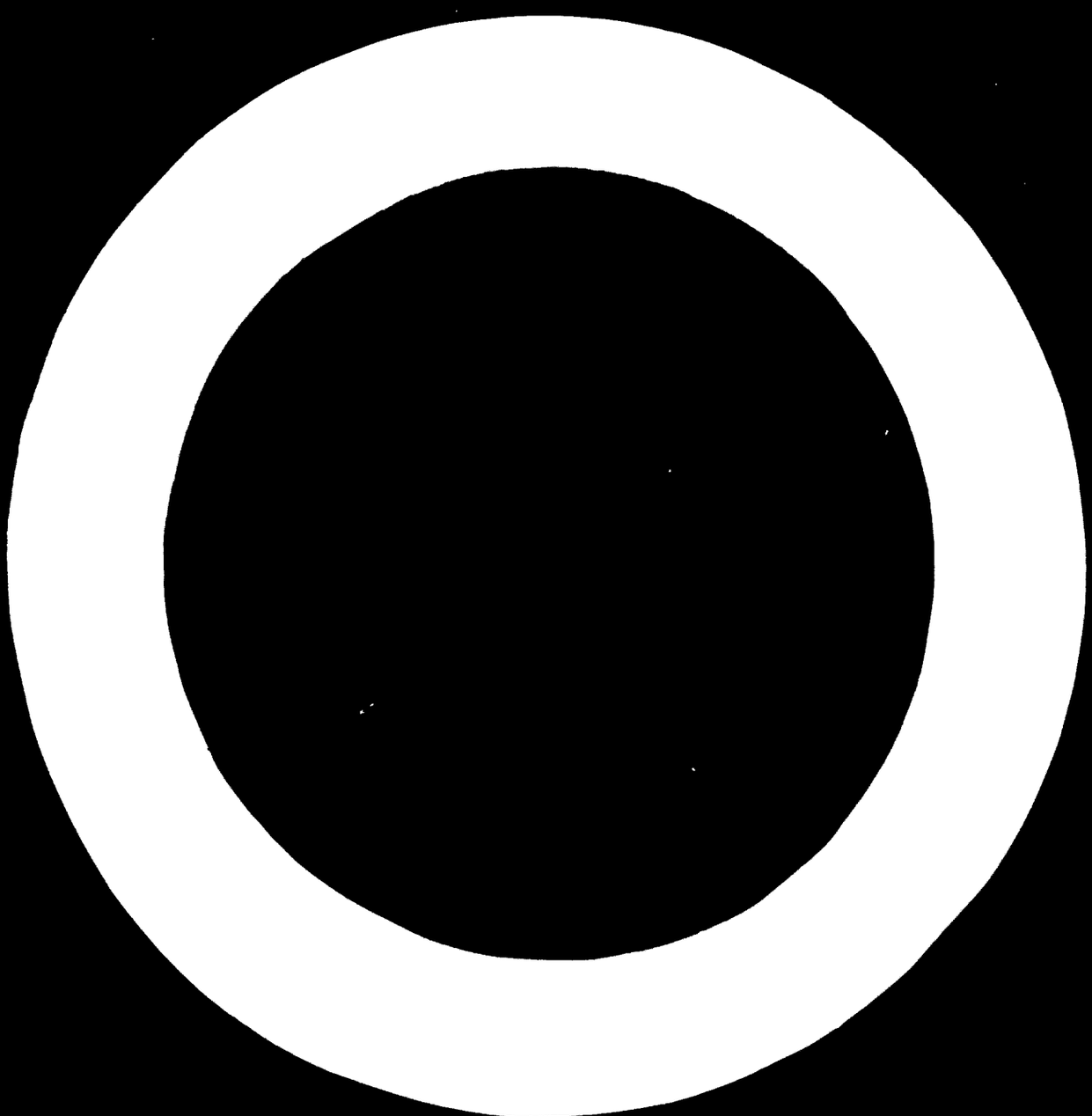


The industrial output of the developing countries is characterized by the relatively small numbers and limited ranges of articles produced. In most cases, this output consists of articles for local industry, agricultural equipment and implements, various consumer goods and household requirements, and simple spare parts for means of transport, agricultural equipment, and other machinery. Some countries may also, depending on local conditions and the level of their industrial development, produce more complicated articles, including items for use in machinery and instrument production.

The industrial production of developing countries is intended mainly for the home market, except in some special cases where it may also be intended for export to neighbouring countries. Its distinguishing characteristics are the smallness of production runs, the relatively wide range of articles produced, and the frequent changes made in the products manufactured, because of the appearance on the market of new and more highly perfected articles. There are no national standards or specifications for most of the articles produced. The design of these articles is usually based on foreign designs which come nearest to meeting local requirements. No attempt is made to comply with the principle of interchangeability in the production of industrial goods. There is, however, a demand for the goods produced to be of quite high quality, because of the presence of competition and because of efforts to eliminate dependence on foreign countries.

The above brief description of the main characteristics of the industrial production of developing countries is of a very general nature. Depending on the level of development of these countries, their general industrial characteristics may range from very poor to quite good.

The existing industrial enterprises in these countries have little experience in the production of goods. They are equipped mainly with multi-purpose equipment of foreign manufacture which is quite often of obsolete design and in a worn out state. The tools and measuring instruments are mostly purchased on the commercial market. Multi-purpose production equipment is purchased in the same way, while special equipment is either made abroad to special order or else, more rarely, is produced in the developing country if it is of relatively simple design.

There is a surplus of labour in the developing countries, but there are few skilled workers, and there is also a shortage of engineering and technical staff.

In present conditions, the development and comprehensive rationalization of industrial production is greatly influenced by the correct choice of the production equipment, and particularly of the jigs, which are the most difficult and expensive parts of that equipment to manufacture. The term "jigs", as used in connexion with production and assembly shops, means the auxiliary equipment used in the machining and hand-working of parts, the assembly of units and whole finished products, and in technical checking operations.

In well-equiped machine and assembly shops, a large number of the most varied types of jigs are used. In series production, an average of ten jigs are used for each part produced, and expenditure on the manufacture and maintenance of jigs amounts to 15-20 per cent of the total equipment costs. The design and manufacture of the necessary sets of jigs frequently accounts for 70 per cent of the labour and 80 per cent of the time needed to prepare for the production of new parts.

A considerable proportion (80-90 per cent) of the total stock of jigs is accounted for by machine tool jigs used for the mounting and fastening of work pieces which are to be machined.

The use of machine tool jigs can bring the following benefits: improvement of productivity and precision of machining; easing of the operative's working conditions; widening of the range of technological possibilities of the equipment, even to the point of being able to use, in a number of cases, obsolete and worn machines without any reduction in accuracy and productivity; improvement of operating safety and prevention of damage to equipment.

The improvement in productivity is achieved by the elimination of the need for setting-up and checking of the workpiece, reduction of the time spent on mounting and fastening it, the possibility of machining at a number of points without readjustment, and the possibility of using more than one tool at a time to carry out a given operation. The improvement in precision is achieved through the elimination of the influence of the subjective factor, due to the fact that jigs enable machining operations to be carried out on a pre-set machine tool in accordance with the principle of automatic setting of dimensions.

The use of jigs enables fuller use to be made of normal multi-purpose machine tools. Thus, for example, relatively cheap and widespread pillar-type drilling machines can take the place of more expensive boring machines. Single-spindle pillar-type drilling machines, if fitted with multi-spindle heads, can take the place of multi-spindle special drilling machines. Precision holes can be machined on an obsolete horizontal boring machine by using a boring device fitted with jig bushes which guide the boring head accurately with respect to the workpiece to be machined.

In the conditions prevalent in developing countries, where industry is as yet insufficiently organized, it is very often impossible to replace obsolete equipment promptly. In these circumstances, the decisive role in improving the productivity of labour must be played by jigs, whose use is economically and technically feasible for any enterprise. The use of jigs also enables production costs to be reduced. The cost of manufacturing jigs with a narrow range of applications limits, however, their use in enterprises with only a small production programme for a given type of part. The advisability of using such jigs must therefore be verified in each individual case by means of economic calculations.

An effective method of introducing some measure of automation into series production processes is that of equipping multi-purpose machine tools with automated jigs and control gear. If versatile, quickly-exchangeable jigs are used, this method of automation can also be entirely suited for use in enterprises producing a wide range of articles. There are many designs of such jigs which are quite simple, reliable and profitable in use, do not require skilled operators, and can be used for various machining operations in factories in developing countries.

The jigs used in machining and assembly work can be classified, according to their function, into five basic groups:

1. Machine tool jigs used for mounting workpieces so that they can be machined in accordance with the requirements of the production process. These jigs are divided up, according to the type of machining to be carried out, into drilling, turning, milling, boring and other types of jigs. This group, which is the most numerous, also includes special purpose jigs (jigs for bending, straightening and other specific operations in the production of parts from sheet or bar on a machine or by hand).

2. Jigs for mounting and fastening the working tool on machine tools. A characteristic of this group of jigs, which are also called auxiliary tools, is that it contains a large number of standardized items because of the extensive standardisation and normalization carried out among working tools themselves. In most cases, jigs of this group are purchased by factories in finished form, and only a relatively small number of special jigs are designed and made to special order.

The manufacture of general-purpose jigs is best carried out in specialised factories manufacturing production equipment, while special-purpose jigs are best made in tool shops.

3. Assembly jigs are used for assembling parts into units or whole finished products. Regardless of the types of assemblies and the methods of assembly, the following types of assembly jigs are used: those for the firm fastening of the base parts (or units) of the item to be assembled; those whose job it is to maintain the parts which are to be assembled in the correct and accurate mutual relationship to each other; those for the preliminary deformation of flexible parts (such as springs, split rings, etc.) so that they can be assembled, and those used in pressing, riveting, expanding and other operations, where heavy force must be applied during assembly.

Many designs of assembly jigs are of standardized type. They are used not only in the production of various articles, but also in repair shops and technical servicing departments.

4. Checking jigs are used for checking the original blanks, for the intermediate and final checking of parts during machining, and for checking the proper assembly of units and complete articles. The use of jigs of this group increases productivity and raises the standard of technical checking operations, frees a considerable number of inspectors for other work, and also facilitates the work of technical inspectors. Manual, semi-automatic and fully automatic checking jigs may be used, depending on the production programme and the type of articles produced. In mass production conditions, fully automatic checking and grading machines with highly specialized functions are used. At the present time, with the general tendency towards continuous improvement of the quality of goods, the role of checking jigs is continually increasing in importance.

5. Jigs for the clamping, raising, transfer and rotation of workpieces and units in the course of assembly are used for heavy parts whose movement by the physical effort of the worker would be impossible or tiring. Where production processes are fully or partially automated, however, jigs of this group are also used for light objects. In order to reduce the costs of these jigs and devices, quite extensive use is made of standardized jig designs. These jigs can most advantageously be manufactured in special enterprises, so developing countries, whose requirements for jigs of this type are quite small, would be best advised to purchase such equipment in finished form.

Jigs are divided up, according to the degree of specialization of their functions, into universal jigs, specialised jigs, and special purpose jigs.

Universal jigs used in one-off or small-series production can be divided up into standard-type jigs and specially designed jigs.

Standard-type jigs are usually manufactured by specialist enterprises in accordance with valid technical specifications or standards and are acquired (purchased) by factories in the finished form. This group of jigs includes: machine vices, chucks for fastening workpieces on lathes, chucks for holding bits on drilling machines, indexing heads for milling machines, turntables, lathe centres, faceplates, and other similar equipment. These items of equipment are not designed or manufactured by the factories which use them. They are used for the machining of a wide range of parts of different dimensions. In industrially developed countries, these items of equipment are produced in special production equipment factories. They may also be produced by machine tool manufacturing firms in order to equip the machine tools produced by them, or else to customers' special order. Many factories produce large quantities of such items of equipment both for the home market and for export.

Universal jigs of special design are designed and manufactured on an individual basis, primarily for use in the one-off or small-series production of parts of a given type but of different dimensions. In use, these jigs are altered to take parts of a different size by moving stops or altering the position of bushes, clamps and other devices. Among such jigs are those used in the drilling of radial holes in parts such as shafts, bushes and sleeves, those used to drill holes in flanges of various dimensions, and other types of similar jigs. In the conditions prevailing in developing countries, special universal jigs can be extensively used in factories producing a wide range of parts.

Specialized jigs are constructed on the basis of normalized or standardized universal jigs. They are set for the machining of specific parts by the installation of additional or exchangeable devices (special jaws for machine vices and lathe chucks, special locating and mounting plates for plunger jigs, etc.). Because they can be relatively easily re-set to carry out different production operations, these jigs are used in series production. The manufacture of these jigs is neither an expensive nor a lengthy process, as they are constructed on the basis of existing standard universal jigs.

Special jigs are intended for the execution of certain specific machining operations on a given part, and are therefore single-purpose jigs. They are most advantageously used in mass production conditions, where identical parts must always be clamped in the same way and the production programme provides for the manufacture of a large number of parts over a considerable length of time. These jigs are the most expensive and labour-consuming to produce, as on account of their wide range of designs they must each be manufactured individually. Special jigs become useless and must be written off when a change is made in the parts produced, and this often takes place long before they are physically worn out. When new types of parts are introduced, it is necessary to design and construct new special jigs: this may take up 70-80 per cent of the total time required for the technical preparations for production.

For series production conditions, it is extremely important to develop and introduce on an extensive scale convertible and quick-change jigs, as well as jigs suitable for variable production line conditions and production lines manufacturing groups of parts. Considerable experience has been accumulated in the Soviet Union in these fields, and it can be passed on for use by the industries of developing countries. In recent years, the design of production equipment has been considerably developed in the direction of improving its versatility. Considerable use is now being made of universal built-up jigs, universal exchangeable-component jigs, jigs which can be assembled and dismantled, exchangeable-component magnetic jigs, and so on. The principles and applications of these jig systems are dealt with below. The question of the standardization of jigs is also very important for developing countries, although in small countries the scale of standardization measures can obviously not be very great. In these circumstances, the standardization of jigs is best carried out in selected directions and in accordance with pre-planned stages and target dates. The standardization of production equipment must be carried out in accordance with a carefully thought-out plan. The importance of this measure is evident from th following considerations.

The launching and development of the production of already familiar or new parts is closely linked with the preparation of the production equipment and particularly the preparation of the most expensive and labour-consuming part of that equipment: the machine tool jigs.

The rapid development of modern manufacturing and the constant improvement of the articles produced makes it essential to replace products from time to time with new and improved types.

In these circumstances, the previously-used special equipment, except in a few cases, becomes unsuitable for further use and must be written off, as new special equipment has to be designed and constructed in order to begin production of the new articles. When a large amount of complicated equipment is required, the production preparation period is frequently so long that by the time a new article has come into full production it is already, in effect, beginning to become obsolescent.

At the same time, there is a tendency to try to increase the amount of modern equipment used in production processes, both in large- and small-output enterprises, so as to achieve increased productivity of labour and lower production costs.

This contradiction has given rise to attempts to find ways to speed up and cheapen the development and manufacture of production equipment as a whole and of special jigs in particular. Efforts to solve this latter problem have mainly been based on the normalization (and, in subsequent stages, the standardization) of the parts and units of jigs.

Such normalization reduces the volume of design work, reduces the number of different parts, and increases the number of parts of identical function and dimensions which have to be produced. Normalized or standardized parts can be produced in large batches or even manufactured by a single specialized enterprise, thus considerably reducing production costs. In particularly favourable circumstances, normalized and standardized parts and units can be taken out of used jigs and put into temporary storage, if necessary after partial overhaul, for later use in the assembly of new jigs.

At present, as many as 70 per cent or more of the components of special jigs are normalized or standardized parts. In order to give them a special incentive, jig designers are frequently paid not only on the basis of the number and complexity of the drawings which they produce, but also in the light of the extent to which they use normalized elements in their designs.

The first stage of the normalization of jigs consists of the normalization of their general design and dimensions. The objective of normalization is to establish dimensional classes for the various elements and units of jigs, to lay down overall dimensions and dimensions for mating elements, to normalize design elements (such as screws, fastening elements, pins, keys, tapers, etc.), to specify the accuracy with which parts must fit together, and to establish tolerances for the main parts.

The second stage of normalization concerns the component parts of the jigs. Among the parts which are thus normalized are the components of special jigs (the adjusting parts, the parts making up the clamping devices, the jig bodies and their components, the fittings for checking the position of tools, and the component parts of auxiliary devices) and the blanks (castings and forgings) for all these components.

The third stage of normalization covers jig components with various other functions. Thus, among the components to be normalized in this stage are units forming part of clamping systems (pneumatic cylinders, pneumatic barrels, the locks of rack and lever clamping devices, etc.), units making up auxiliary mechanisms (indexing and turntable mechanisms, index pins, ejectors) and other mechanisms forming part of special jigs.

Technical standard specifications are established by the leading machinery manufacturing works, technical planning and scientific research institutes, and other organizations. The standards established may be internal standards (works standards) or State standards. The issue of State standards is preceded by extensive preparatory work on the collation and correction of previously issued works standards.

In practice, extensive use is also made of works standards established for body components and units of jigs which are designed to be assembled and disassembled (SRP jigs). A feature of this system is that the normalized elements are suitable for repeated use.

Normalized units are stored in ready assembled form. They are designed to be installed, not within the body of the jig, but on its periphery, so that additional machining of the body parts can be avoided. The machining of the body (drilling, cutting of apertures, etc.) does not prevent its repeated use in other versions. Jig bodies are assembled from normalized interchangeable components of simple geometrical shape which are designed to be fastened together by screws, bolts, and also by means

of synthetic adhesives. These types of fastenings make possible the easy and rapid stripping of jig bodies and whole jigs into their component elements, as must be done when the part being produced is changed. This system can be used for jigs fitted with both normal and quick-acting (pneumatic, hydraulic, etc.) clamping mechanisms, and its use makes it possible to cut down on the time spent on the design and manufacture of special equipment.

What are called universally adaptable jigs are used in series production conditions. These jigs are so designed that their components can be rapidly exchanged as often as desired, so that they can be used for several part/operations. They are therefore extremely effective in promoting high-productivity machining methods in series and one-off production and in reducing the preparation time for production equipment.

In recent years, two main systems of universally adaptable jigs have found special favour, namely, jigs with universally exchangeable components (USP jig) and universally adjustable jigs (UNP jigs).

The USP system consists of a set of normalized parts from which it is possible to assemble various single-function jigs. This system began to be used in experimental and small-series production in many countries in the mid-forties. After the assembled jig has been used, it is dismantled and its component parts are returned to store, from which they can be withdrawn at a later date for assembly into a new type of jig. Thus, the USP system is only universal from the point of view of the assembly of different kinds of jigs. The jigs themselves are not universal, but are special (single-function) jigs.

In factories where the USP system has been used for a number of years, the stock of individual elements may amount to 25,000-30,000 parts, together with a certain quantity of normalized units which cannot be dismantled. As many as 300 jigs can be assembled at one time from such a set of parts.

The parts in the basic set are divided up into eight groups, the parts in each group being of several types and dimensions. The groups are as follows: base parts (square and rectangular plates, face plates, angled base sections, rings), the faces of these parts being provided with T-section intersecting grooves so that the various components of the jig can be fastened on them in different layouts; body and supporting parts (blocks, angles, packing pieces and supports of various shapes), likewise

provided with T-section grooves, slots and apertures so that different assemblies can be built up; fitting parts (keys, dowels, intermediate bushes, fixing pins); guide parts (various types of jig bushes, guide strips, pillars and spindles); clamping parts (various types of clamps and other parts); universal jig fastening parts (screws, bolts, threaded pins, nuts and washers); miscellaneous parts (handles, strips, eccentrics, springs, pivot units, and so on); and normalized units which cannot be dismantled (adjustable-height supports, clamps, indexing mechanisms, etc.

In the initial period of their operation, small factories frequently use a reduced set of USP jig components consisting of 1.5-2.5 thousand parts. Such a set is sufficient for the assembly of 300-400 jigs per year.

Jig body and support components are manufactured to the second class of precision, and their mating surfaces are ground to the ninth or tenth class of surface finish. The dimensions of these components, on which the accuracy of the various other components which are assembled together depends, must come within a tolerance of 5-10 microns. The tolerances for corners or angles are set at 5 microns in 100 millimetres. Parts on which the accuracy of machining does not depend must come within the third to fifth classes of precision.

The parts in a USP set must be strong and wear resistant, and must retain their exact dimensions and shape for a long period. The base parts are made from 12 KhNZA steel, with subsequent carburizing and case hardening to a hardness index of 60-64. Fastening parts are made from 30 KhA steel, hardened to an index of 40-45 and annealed. Guides and adjustment parts are made from U8A and U10A steel and hardened to an index of 50-55. The remaining, less vital parts are made from No. 45 steel (clamps, etc.) or No. 20 steel (washers, etc.).

Practical experience of use of the USP system in factories shows that wear of the base parts over 10 years amounts to less than 0.01mm.

When a set of USP parts is available, the preparation of jigs amounts simply to the assembly of the parts in accordance with a given scheme. There is usually no need to make any parts for the jigs. In exceptional cases it may be necessary to make special parts, but such parts do not usually amount to more than 1-1.5 per cent of the total number of parts in the system. Use of the USP system reduces the time taken for the manufacture of jigs to a small fraction of that otherwise required. The assembly of jigs of average complexity requires 2.5-5 hours of working time.

Jigs are assembled in conformity with a drawing of the part to be machined in a particular operation or else on the basis of an actual metal specimen of the part. Jig assembly is carried out by highly skilled workers, without any preliminary preparation of drawings for the jigs, on the basis of what is considered to be the best selection of components. If a particular jig may be required again at a later date it is therefore desirable to photograph it from several angles, indicating the identification numbers of the various components used to make up the jigs on the photograph, instead of making drawings of the jig. If this is done, repeat models of the jig can be made in a shorter time.

The USP system saves a considerable amount of time and considerably reduces the cost of preparing for the production of new parts. It enables jigs to be remodelled easily and quickly if the part being produced is changed, and it also enables individual jig parts to be used a number of times for the assembly of different kinds of jigs. This system makes it possible to use jigs in factories with only a small output, where the preparation of jigs in the normal way would be uneconomic.

Among the shortcomings of the USP system are the lower rigidity of USP jigs because they contain a large number of joints, their unsuitability for the incorporation of quick-acting power-driven (pneumatic, hydraulic, etc.) clamping mechanisms, and the high initial cost of a set of USP parts due to the large number of parts and the high degree of accuracy with which they must be made.

As a complete set of parts for a USP system may cost 50-80 thousand roubles, this system may not be economic for a single factory. In this case, it is advantageous to arrange for one or more USP sets to be available for hire to interested enterprises in a given economic area. Practical experience of the operation of such hire sets both in the Soviet Union and abroad shows that their original cost is relatively quickly repaid (in two or three years), while their total service life is about fifteen years.

Experience shows that the majority (about 60 per cent) of the parts in USP sets are used for making drilling jigs, about 30 per cent of them are used for making milling jigs, and about 7 per cent for making turning jigs. The remaining 3 per cent are used for making checking jigs, grinding jigs and shaping jigs. These proportions vary, however, according to the degree of development of the system.

The main users of USP sets are textile machinery manufacturing firms, general machinery manufacturing enterprises, printing machinery manufacturers, pump manufacturers, and firms in other branches of machinery manufacturing.

The average utilization period of each jig (the average hire period of a USP set) is fifteen days, including one day for assembly, two days for transport and one day for dismantling.

A need is now becoming felt for the further development of the USP system by the provision of narrower or wider T-shaped grooves for different branches of industry (instrument manufacturing and heavy machinery manufacture) and the incorporation of pneumatically or hydraulically operated units for the clamping of workpieces.

The system of universal exchangeable-component jigs (UNP jigs) is based on the use of exchangeable mounting, clamping and guide elements (units), fastened on a universal normalized jig base. The mounting elements of such jigs are frequently designed to be adjustable so that the jigs can take workpieces of different types and dimensions.

In both cases, the principle of easy conversion is observed: i.e., the jigs can be used for carrying out a number of different part/operations.

Universal exchangeable-component (UNP) jigs can be effectively used in series production conditions. When a batch of new parts is to be produced, these jigs are not removed from the machine tools: all that is done is to replace certain of their exchangeable elements with different ones, or to adjust their stops to take the new parts.

Because of these advantages, the time spent on preparatory and terminal operations can be cut down and a higher degree of utilization of the machine tools can be achieved.

The use of the UNP jig system enables the expenditure of time and money on the preparation of the production of new articles to be cut down. The exchangeable parts and units of the UNP system are not returned to store, but are kept at the workplace by the machine tools. They are installed on the jig by means of centering spindles, pins or guide channels, without the need for any adjustments. Only a very short time (2-3 minutes on average) is needed for the replacement of exchangeable parts.

Among the normalized jigs which are used as a basis for the UNP system are machine vices, plunger jigs, pneumatic chucks with exchangeable jaws, faceplates with adjustable brackets for the boring of parts of irregular shape on a lathe, and expanding jigs for the drilling of holes in the periphery of parts such as flanges of different diameters.

The number of normalized jigs is continually increasing, thus forming a solid foundation for the further development of the UNP jig system.

For the machining of small parts on milling and other machine tools, UNP jigs with exchangeable adaptors are used. Each adaptor serves to locate parts of a given type and size. In this system, resetting of the jigs amounts only to replacement of the appropriate adaptor.

Various designs of UNP jig systems prepared in recent years by many planning and technical design organizations and enterprises are being successfully used in factories engaged in the series production of parts.

On variable production lines, in addition to the universal exchangeable-component jigs already described, combination-type jigs are used for the mounting in sequence, without resetting or re-adjustment, of the various parts which are to be machined on a given machine tool. Jigs of this type are usually designed to take all the parts in a given class.

In recent years, extensive use has come to be made of these combination-type jigs for the simultaneous mounting of several different workpieces on production lines where a whole group of parts are manufactured. Good results have been obtained in the practical operation of such jigs in a number of machinery manufacturing works. Jigs of this kind are suitable for the machining of parts of different types and dimensions, and they can be used for carrying out drilling, milling, flat grinding and other types of machining operations.

The simplest layout, which does not call for the preparation of a combination-type jig, operates in the following manner. The rotating table of a vertical milling machine is equipped with jigs capable of taking parts of different types and dimensions. The worker operating the machine tool loads these jigs in a given sequence and removes the machined workpieces from the unloading section of the table.

The use of this system on variable production lines may not be so effective, however, as the saving of time on the exchange of jigs will not make up for the considerable amount of time lost through the empty travel of the table when machining batches of identical parts.

In group production line conditions, combination-type jigs with exchangeable parts can also be used. In this case, the workpieces of different types and dimensions which can be accepted by these jigs can be sent down the production line either individually or in batches.

The use of combination-type jigs for variable production lines and group production lines makes possible maximum utilization of the equipment. The design of these types of jigs calls for a great deal of work on the selection of the right layouts and the general make-up of the jigs, however.

Group-adaptable jigs can be widely used in the industry of developing countries, both in existing factories and in newly constructed ones.

Jigs are manufactured by various production methods. Universal-type jigs are produced in considerable quantities to supplement newly-manufactured machine tools forming part of the existing range of production equipment, and a considerable proportion of them (3- and 4-jaw chucks, plates, and other equipment) are standardized or else are manufactured to comply with official specifications. These jigs are produced in specialized factories or in special departments of machine tool factories, by mass-production methods or at any rate in large series. Normalized jigs and the various units and individual parts for them are produced in a similar manner.

Special jigs are manufactured individually or in small batches in the tool shops of machinery manufacturing factories (for the requirements of the factory itself) or in machine tool factories (for fitting to special machine tools). They are delivered to the purchaser in finished form. In many developed countries, special jigs are also produced by specialized factories. The manufacture of special jigs is usually in the nature of a one-off process. Where extensive use is made of normalized and standardized parts in their manufacture, however, they can be manufactured on the principle of series production.

The workpieces from which the parts for special jigs are to be made are likewise manufactured by one-off production methods. Cast workpieces are produced by sand casting with wooden cores, forgings are produced by free forging, and small parts are cut out of various kinds of sections. Items of medium and large dimensions and of complicated shape, such as jig bodies, uprights, brackets, etc., are of welded construction.

Castings for important parts such as jig bodies may advantageously be subjected, before being sent for final machining, to rough working and natural or artificial ageing so as to remove any internal stresses.

Welded elements are fabricated from previously prepared parts such as plates, strips, angles, corner plates, discs and bushes. These parts, thoroughly cleaned of rust and grease, are assembled in clamps or other mechanical locating devices, the accuracy of their location with respect to each other is carefully checked, and they are then tack welded at various points. After the clamps have been removed they are again checked for accuracy, and the final welds are then made.

In order to reduce distortion, it is best to use electric arc welding. Gas welding is used for thin parts not more than 4 mm thick. The danger of distortion of welded units is reduced by making non-continuous welded joints.

In order to remove internal stresses, welded components are annealed for 1.5-2 hours at a temperature of 600-650°C. If a component is of large dimensions and is difficult to anneal, the welds are peened with a hammer. The components of special jigs are of a varied nature and must normally be made to the second or third class of accuracy, so they must be machined by highly skilled workers. Normalised parts are machined in batches on preset machine tools, frequently with a progressive, parallel or parallel-progressive arrangement of machining operations.

The manufacture of parts with holes that must be very accurately located with respect to one another (bodies for drilling and boring jigs, laid-on jigs, discs, indexing mechanisms, etc.) is a very special process. Because of the very close tolerances (hundredths and thousandths of 1 mm) for the distances between centres, normal methods of laying out and boring do not give satisfactory results. If a large amount of work involving the boring of extremely accurately located holes is to be carried out, it is best to use a jig boring machine, which bores holes with great accuracy not only along parallel axes, but also, if the machine tool is fitted with a rotating table, along intersecting or cross axes. By fitting special planetary heads, these machine tools can also be used for the grinding of accurately located apertures, circular grooves and curved surfaces described along the arcs of circumferences.

The use of plastics offers great possibilities for the reduction of the amount of time and money spent on the manufacture of jigs for series production. Epoxy compounds are usually used in machine tool jigs, as these compounds are the strongest kinds of plastics. A good epoxy resin moulding compound consists of 100 parts by weight of ED-5 or ED-6 epoxy resin, 200 parts by weight of filler (iron powder, iron oxide, marshallite, cement, etc.), 15-20 parts by weight of plastifier (dibutylphthalate) and 8-9 parts by weight of hardener (polyethylene-polyamine). This composition can be moulded in various ways to make the basic and auxiliary components of special jigs. After hardening, the epoxy compound has the following mechanical properties: hardeners MV 20, ultimate tensile strength 6 kg/mm^2, ultimate compressive strength 13 kg/mm^2, specific impact strength of up to 12 $kg/cm/cm^2$. Depending on the filler used, the specific gravity of the compound varies from 1.2-2.0. Shrinkage of the compound in hardening is about 0.1 per cent. The wear resistance of the compound is close to that of aluminium alloys, and the rigidity of parts made from it can be increased by the incorporation of a steel frame.

The disposable moulds used for shaping the compound can be made of plaster of paris (using a wax model of the part to be cast as the core), cardboard (by drawing, cutting out and then sticking together the developments for parts of simple shapes) or Plasticine. Only a small amount of time (frequently about 1-1.5 hours) is required for the preparation of such moulds.

Epoxy compound can be used to mould housings (negative impressions) for the mounting of workpieces. The base for the housing is a welded box into which the epoxy compound is poured. A negative impression of the part to be machined is then made in the surface of the compound with a standard specimen of the part.

Epoxy compound can also be used to make jig bush plates with accurately located holes. The jig bushes are placed in the required position on a flat base with the aid of guage blocks, and are then fixed in place with clamps or adhesive. A frame determining the external shape of the jig bush plate is then fastened in place and the space between the jig bushes and the frame is filled with epoxy compound. The low coefficient of shrinkage of the compound ensures the accurate location of the bushes relative to one another.

The assembly of special jigs involves a good deal of alignment work and machining "in situ". In order to obtain high-precision assemblies, careful filing, scraping and lapping is necessary.

The assembly of jigs can advantageously be broken down into the operations of assembling individual units and that of assembling the jig as a whole. This makes possible a reduction of the total length of time needed to prepare jigs.

In the assembly process, the mutual positions of the parts and units of the jig must be adjusted and accurately checked. The correct positions are usually determined by means of locating pins, suitable holes being drilled and reamed in the mating surfaces for this purpose. For non-removable assemblies and units of jigs which operate under compression or shear, it is better to use adhesive joints instead of mechanical fastenings. Epoxy adhesives can give a shear resistance of 3-3.5 kg/mm^2. Locating pins must, however, be used for the accurate fixing of parts relative to each other. Assemblies of parts which are cemented together can be dismantled by heating them to a temperature of 150°C.

In order to achieve increased accuracy, several parts are often machined together after their assembly. Thus, in order to achieve strict coaxility of apertures running through several parts, such aperatures are bored or reamed out after the parts are assembled together. In order to achieve a smoother finish on multi-component mounting surfaces, such surfaces are often ground in one piece after the components have been assembled in the jig body. When assembling jigs, attention must be paid to the proper alignment of the parts by means of which the jig body is fixed to the machine tool.

THE INSPECTION OF JIGS AND THEIR PERIODIC CHECKING DURING USE

Newly manufactured jigs must be carefully inspected before they are put into operation. Such inspections should comprise a visual inspection, a check that the jigs are complete in accordance with the drawing, a check of the basic elements and assemblies of the jig to ensure that they have been properly manufactured (smoothness and ease of movement, freedom from jamming, etc.), an operational test of the jigs, including the necessary adjustments and setting operations (checking of the operation of the mounting and clamping mechanisms, the rotating devices, fasteners, ejectors, etc.), and a check of the precision of the work done with the jig.

Checking of the precision of manufacture of machine tool and assembly jigs is usually carried out in one of three ways: by direct measurements of the various dimensions of the jig on which the precision of its work depends; by the test machining of several workpieces (or the assembly of several units) in the jig,

with subsequent checking of their precision with normal universal measuring instruments, gauges, or other checking instruments; and by the use of specially-made specimen gauge parts.

The first method, involving the use of universal measuring instruments, is labour-consuming and can only be carried out by highly skilled inspectors. The second method is purely functional and is more suitable for production conditions, but it involves the wastage of the test workpieces. The essence of the third method is that a special gauge part is placed in the jig and its position with respect to the various guide elements is then checked.

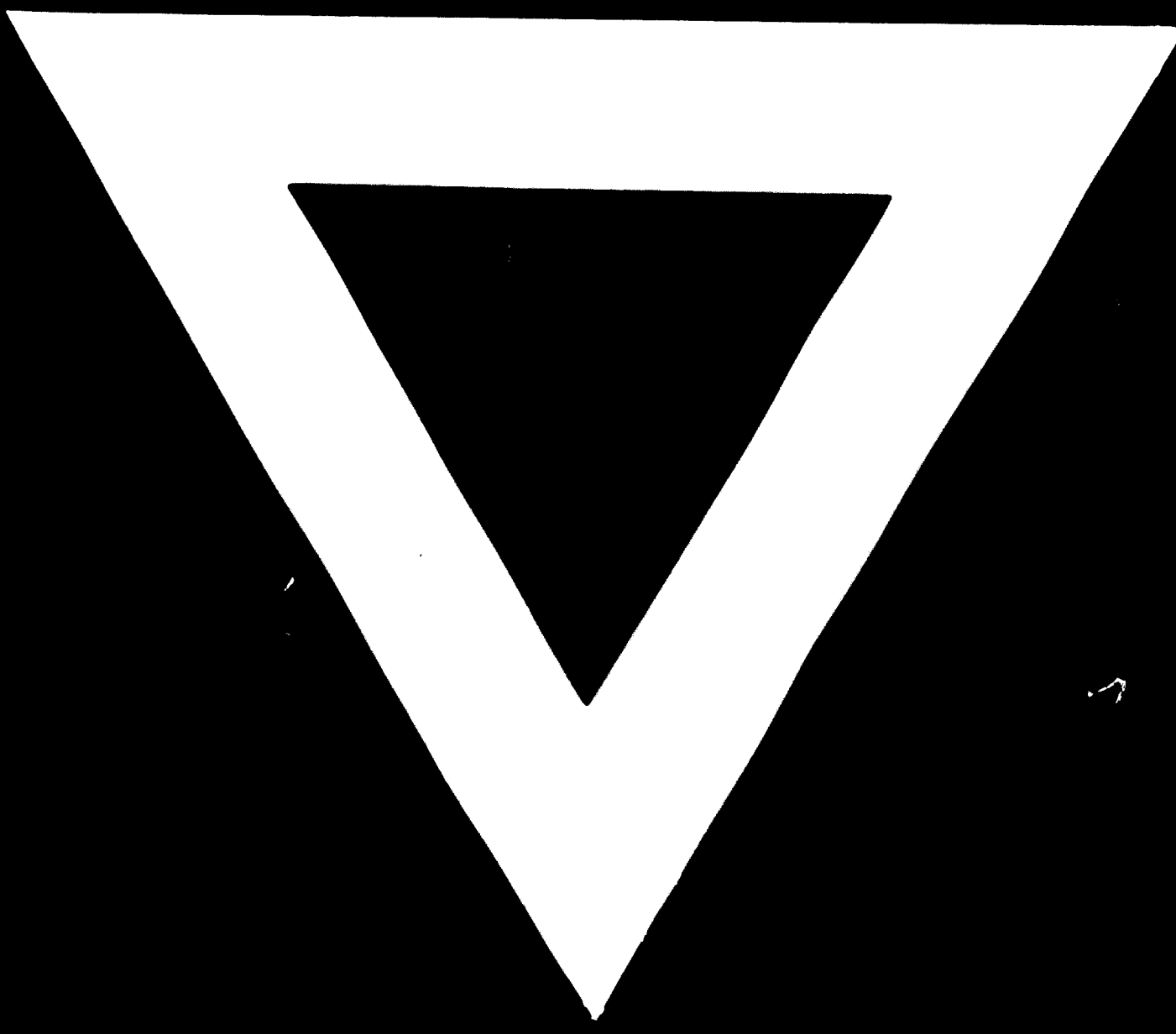
Jigs used in factories must be subjected to periodic inspections and checked by special inspectors. In series production conditions, jigs are periodically removed from the machine tool and either returned to store or else kept at the workplace. This period of inactivity can be used for inspecting them and checking them for accuracy. In mass production conditions, however, the jigs must be inspected on the machine tool during times when they are not being used. In these circumstances, checking by means of standard gauge pieces is more convenient. In large factories, periodic checks of jigs are carried out by a special group of technical inspection workers. The results of the check are recorded in a card index. These periodic inspections and checks may show up the need for preventive maintenance or overhaul, or for the replacement of worn parts and units in the jigs. New checking jigs must be adjusted and tested before being put into service, and must thereafter undergo periodic checks at the workplace and in checking laboratories.

On receipt, checking jigs must be subjected to a full metrological inspection. This inspection is carried out by comparing the results of measurements made with the jigs on special test parts with the results of measurements of the same parts carried out with universal measuring instruments. The degree of error in the measurements is analysed, and the reliability of the measuring operations carried out with the checking jigs is then determined. An inspection certificate, a set of operating instructions, and a periodic checking card are then prepared for the checking jig.

The periodic testing of checking jigs during utilization is carried out in the technical checking department. If the total stock of jigs is not large (not

more than 100-150 jigs), inspection is usually carried out by inspectors from the central measuring laboratory (TsIL).

Inspections are carried out in accordance with instructions prepared by the machine setting section. In order to carry out the inspection, it is necessary to have drawings of the jig and its periodic checking card at hand. After overhaul, jigs are subjected to inspection in the central checking department. The measurements of the jigs effected in the course of these inspections are made with universal measuring instruments and with special standard test parts. These special test parts, which are used also for the periodic adjustment of checking jigs, are provided with direct-reading measuring devices such as gauges, minimeters, etc. Certificates of accuracy are prepared for these special test parts, which must themselves undergo periodic inspection in the central measuring laboratory.



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