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How to extend tool life

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The paper explores possibilities of extending life of working tools, casting dies, and stamping tools. The entire service life of a tool includes three functional spans of time, i.e. manufacture, use, and repairs of the tool by welding. It is precisely welding, including various additional measures, which is the technology permitting efficient repair of worn-out and damaged tools to make them fit for further use.

1. INTRODUCTION

A tool is any device, instrument, or machine for the performance of an operation. In the present paper only working and stamping tools will be treated.
In general tools can be classified with reference to their application, operating temperature, the material they are made of, the degree of automation etc.
The tool life depends on a number of factors, which, however, are not completely known for all tools. It often happens that a tool damage occurs well before the stated and rightfully expected time. This is particularly true of pressure casting dies, working, and stamping tools.
During operation, some tools are subjected to mechanical loads only, others to thermal loads, and still others to both thermal and mechanical loads. Because of the various loads, tools will become worn, will break, and get cracks which gradually propagate. How can a partially damaged tool be repaired is a very difficult question. Welding is the only technology fit for repair of tools and thus to extend their operation times. Moreover, surfacing by welding may well improve mechanical properties and extend the operation time of a brand new tool since surfacing is applied to those parts of the tool which will be subjected to the strongest loading.

2. THEORETICAL BACKGROUND OF THE PROBLEM

The essentials of the problem have already been presented by the title. The paper aims to describe some measures permitting to extend tool life, i.e., the operating time of the tools designed for different jobs. The tool life depends on a number of factors such as the type of parent metal used, the manufacturing method employed (forging, rolling), the method of machining in tool manufacture (cutting, spark erosion), the type of heat treatment, the way the tool is used in operation, repair welding (process, filler material, measures before and after welding). Some of the factors can be influenced, but others cannot. Everyday practice shows

that only some influences of these factors are known. It is quite a problem nowadays that all the influences exerted by all the factors related with the tool life are not known.
To select optimum values of the above-mentioned factors, various services and experts should co-operate. It is important to engage, as early as at the stage of selection and purchase of the parent metal (chemical composition and size of a blank), experts on tools knowing which steel is to be used for a specific tool, the type of loading the tool will be subjected to in operation, and whether damaged tool can be repair welded or not.

3. TOOL LIFE

The tool life is defined as the time period in which a tool will operate without any unexpected interventions. It is most often measured with the number of products manufactured by the tool. In terms of tool functions, the tool life can be divided into three separate, yet logically linked periods. The first period involves tool manufacture and the second the use of the tool. The third period starts with the occurrence of any damage to the tool which results in a tool repair. Among current technologies welding seems to be the only technology fit for repair of damaged tools so that they may be again put into operation. The tool life after repair, however, almost entirely depends on the quality of welding performed and additional measures taken.

3.1. Manufacture of tools

In the entire tool life, the phase of its manufacture plays a major role. In the manufacture several different factors should be considered. When designing a tool, the type of material to be used shall be selected, taking into account the type of tool and the purpose of its use. As far as the steel selected is concerned, it is also important to know the orientation of its structure, the latter being dependent on the machining process used in the manufacture of the tool concerned. The tool life largely depends on the relationship between the structural orientation of the material and the location of burrs at the tool.
A majority of tools are still being manufactured by cutting-off. The various cutting processes at and below the surface produce various residual stresses. A special chapter in this context is spark erosion machining. In this case the material is removed practically by evaporation. This means that the surface will be considerably changed after such treatment. For an optimum manufacture of tools, all the factors should be considered.
Machining is followed by heat treatment. High-quality heat treatment, however, can be performed only by using advanced devices (vacuum oven), adequate cooling media, and qualified personnel. Nowadays a whole range of different heat-treatment processes and processes increasing hardness and wear resistance of the tool surface are known. One of the processes improving mechanical properties is surfacing by welding.

3.2. Use of tools

After having been manufactured, tools are used for various processes, e.g. casting, forming, punching, and this mostly by non-qualified workers. Consequently, it is extremely important that detailed instructions for use are supplied with each tool. In addition to the instructions, which should be clear and easy to understand by a non-qualified worker, control and reliable measuring parameters should be established in the manufacturing process too.

3.3. Repair of tools by welding

Of the three functional phases mentioned, it is repair of tools by welding which has been studied least and, consequently, applied to practical cases least although the possibilities offered are numerous. An appropriate welding technology, the selection of an adequate filler material and a suitable preheating temperature, forging of beads in the course of welding and an appropriate postweld heat treatment operation make it possible to repair the majority of tools and recondition them for further use, ensuring almost the same life as that of a new tool. The cost of repair can amount to only few percentages, mostly around 10%, and at maximum 50 % of the cost of a new tool.

3.3.1. Selection of a welding process

There are not many welding processes from which to choose a process for repair welding of tools because it should be taken into account that the welding positions used may be different, workpieces may have a difficult access and various shapes. Consequently, manual TIG welding seems to be the most appropriate process to be used. Plasma arc welding may be used as well. Recently manual and automatic laser welding with a filler material being a wire or a powder has been used too. Fig. 1 schematically shows surfacing by laser welding. The same system can be applied to repair welding of tools.

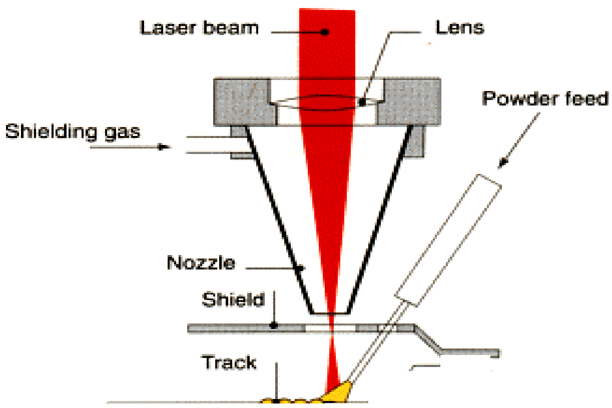

Fig. 1. Schematic representation of laser surfacing with a filler material in powder form

Other welding processes such as MAG/MIG welding with a solid or cored wire and manual metal arc welding are applied to larger tools and in the case that a large quantity of a material shall be deposited. Submerged arc welding, electron-beam welding, electroslag welding or brazing are applied even more rarely.

3.3.2. Selection of a filler material

A filler material is mainly selected with regard to the parent metal used. Because of the burn-off of some elements (Ti, Cr, Al, Zr), slightly overalloyed filler materials should be used. In case of poorly weldable materials it is recommended to use two different types of filler material. With root and filling beads a very tough material can be used, with final runs, i.e., with working tool surfaces, a material ensuring adequate mechanical properties should be used.

The filler materials used can have different forms, i.e., those of a rod, a wire on a spool and a powder. The form of the filler material added depends mainly on the welding process used.

3.3.3. Measures taken before welding

Before welding, a groove should be prepared and a tool heated up to the adequate temperature. In preparing the groove care should be taken of its shape and position. The groove should not show sharp angles or sharp transitions. The root of preparation should be rounded. The location of groove should correspond, if possible, to the type of load applied to the tool during its operation. It is recommended that the groove is affected, via the weld metal, by pure compression stresses, but not by shear, tensile, or combined stresses.

The preheating temperature is determined in accordance with the parent metal. A decisive role is played by the M_S temperature. The tool should not be preheated beyond this temperature. In addition to the preheating temperature, the interpass temperature, being most often the same as the preheating temperature, should be maintained.

3.3.4. Measures taken after welding

For a tool postweld heat treatment is very important. It is selected in dependence of the type of tool material and the type of filler material. For example, tools made of austenitic stainless steels should be welded without preheating, with a very low energy input, the temperature of a bead being reduced below 150 °C before the next bead can be made; after welding, the tool should cool slowly, without any heat treatment being applied. In welding of tools made of martensitic stainless steels, the procedure is precisely the opposite, i.e., the tool should be preheated up to 350 °C, the same temperature shall be maintained during welding, and the tool shall be annealed after welding. A third instance is welding of casting dies with the addition of maraging steel as a filler material. Such a tool, containing a weld, should be aged. The ageing temperature and duration of ageing affect the mechanical properties of the weld, particularly hardness and toughness.

4. CONCLUSIONS

The selection of a suitable parent metal, manufacturing parameters, optimum heat treatment for a tool and particularly an optimum repair of the damaged tool can extend the tool life substantially, in most favourable cases even up to 100 %. In repair welding, the decisive factors are the welding process used, the filler material added, the measures taken before, during, and after welding, and in manual welding, the ability of the welder.