Recognizing MAG Process Parameters on the Basis of the Sound Emitted

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Manufacturing companies and enterprises are faced with two big challenges: accomplishing constant product quality with a lower price. These are the conditions for survival of production in the increasing competition both at the regional and global levels. Another very important characteristic of manufacturing systems is the flexibility and agility of manufacturing processes because companies are forced to respond to market demands where buyers' wishes must be particularly satisfied. Furthermore, this requires efficient manufacturing systems focused on automation, computers and software.

Development of robotic welding systems is indeed impressive and that technology nowadays represents one of the leading branches in the application of industrial robots. The scientific challenge is contained in the tendency to make the performances of technological equipment approximate to human capabilities or even surpass them.

During a welding process, sound is emitted as one of the physical and natural phenomena. This phenomenon is treated with attention by using modern measuring equipment, i.e. directed microphones which allow separation of sound emission of the process from the total emission.

Control of robots based on visual, acoustic and energy feedbacks represents the basis for their further development and application in this technology.

Keywords: welding, robots, control, noise, feedback

1. ACOUSTICS

1.1. Term acoustics

If it is necessary to give a definition at the very beginning, then it can be said that acoustics is the science of sound. It covers the study of sound generation, its propagation in different environments and effects it causes in an environment. During its long-standing development, acoustics has passed through the process of expansion from a purely theoretical science to a science applied in broad fields of engineering. In recent times, acoustics has expanded even to the fields beyond physics and engineering, such as the functions of the sense of hearing, human speech... On the other side, the specific field of acoustics refers to development of electro-acoustic transducers as sensors and noise generators. It is a synthesis of various disciplines, such as mechanics, micro-mechanical engineering, technology of materials...

1.2. Definition of sound

Acoustics is the science of sound, and the definition of sound which is nowadays most generally accepted and which covers all its forms reads: sound is any time variable mechanical deformation in the elastic environment.

The accent in the definition of sound is on the time variability of elastic deformations. Namely, it is possible for deformations in material environments to be time invariable and as such, they are not sound. This, for example, refers to various forms of plastic deformations of materials.

Such a definition is not quite connected with human empirical experiences of sound and one can easily guess that it covers a lot of physical phenomena that are far from human perception, i.e. human empirical knowledge of sound phenomena. Exactly that mechanical nature of sound is important for understanding the nature of sound phenomena and many practical problems that arise from sound application. Hence, all the phenomena related to sound, e.g. sound radiation, propagation, ... are, by their physical nature, mechanical phenomena. [4]

1.3. Sound in engineering

If the view is narrowed only to the fields of engineering disciplines, acoustics covers different practical aspects of application of sound in life, including the theoretical bases for sound as a physical phenomenon, to the extent necessary for understanding and use of sound phenomena in possible applications.

In the field of action which is understood in this way there are several aspects where sound appears as a subject of engineering interest. It can be said that three types of sound are dominant:

- a means of communication,
- an ecological topic, and
- a tool.

Basically, speech is an acoustic phenomenon and all principles to which it is subjected result from that. Another very specific form of communication by means of sound is music as a field of artistic action of sound. In communication, there are circumstances when the sound wave is used as the carrier of information on the same principles as the electromagnetic wave in radio technique.

Excessive sound energy may jeopardize the health of people by its action, and therefore sound has become one of inevitable topics within the ecological action in modern society.

In different circumstances, sound assumes the role of a tool in the form of an active or passive means. The role of active tool is realized through the execution of a certain operation or a special function, and the passive role is realized through registration and analysis of sounds that

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occur spontaneously and thus form information or complete some working operations.

1.4. Energy and information aspects of sound

Each engineering use of sound is reduced to sound as energy in space or as signal.

When sound is observed as signal, then it is a carrier of information, Figure 1.1. Excitation of the acoustic transmission system from the figure is sound pressure or sound power, which depends on the circumstances.

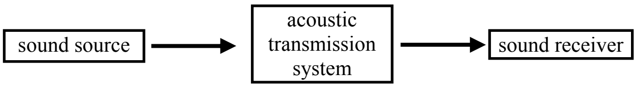


Figure 1: Information block diagram of acoustics phenomena

In the engineering fields in which sound is observed as signal, human sense of hearing frequently appears at the end of the acoustic transmission system, at the point of receiver, which is represented by the block diagram, Figure 2.

Although there are different physical models, sound as energy and sound as signal are combined in engineering conditions, because both aspects are important for the problem.

1.5. Term acoustic image

The ultimate result of hearer’s perception is a complex impression, i.e. complex sound. The expression “sensation” is used and it denotes everything that makes a response to the excitation of a sense. In case of the sense of hearing, the sensation is composed of a multitude of received sound information. The mechanism of the sense of hearing serves as a mediator, and the sensation arises in the consciousness of the hearer and is called “acoustic image”, Figure 2. [6]

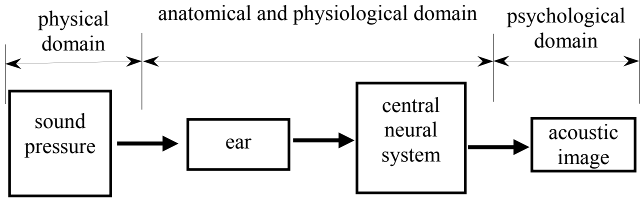


Figure 2: Relation between acoustic field and acoustic image

1.6. Noise

Sound can be simple or complex. Simple sound is a pure harmonic change, with one constant frequency. Complex sound is a complex periodical change which consists of several components with different frequencies. The first component with the basic frequency represents the basic harmonic, whereas the others are higher harmonics. [3]

Figure 3 shows time functions and the corresponding amplitude-frequency spectra of simple and complex sounds and noise.

The basic values that characterize sound are its intensity, pitch and timbre. Sound intensity represents, at a certain point in the acoustic field, energy which, in the unit of time, passes through the unit of area which is perpendicular to the direction of sound propagation. Pitch, where tone represents simple sound, is defined by frequency. Timbre is characteristic of complex sound, and it is defined by the number of higher harmonics and their intensities. [3]

A machining system represents, in a general case, a complex source of noise. Noise, due to its physical properties and nature, is connected with the operation regime, rigidity, variability of load, manner of machine support... The main sources of noise in a machining system are:

- machine/device with its sources in the whole kinematic system, and
- the machining process.

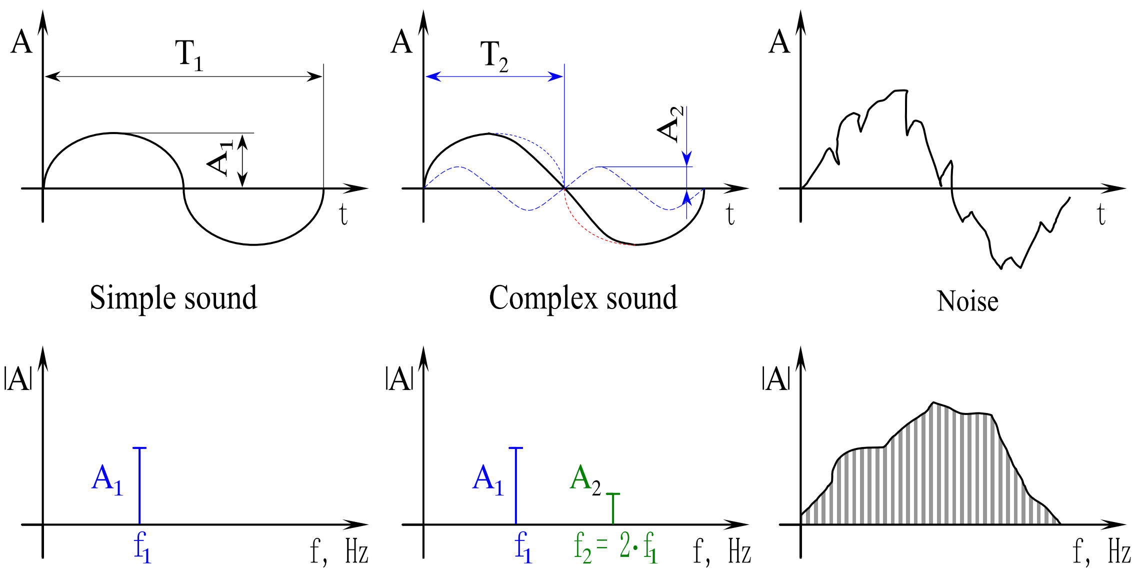


Figure 3: Time functions and frequency spectra of simple and complex sounds or noise [3]

2. SPATIAL DIMENSIONS OF ACOUSTICS IMAGE

In the transmission of sound information to the hearer or the measuring instrument-sensor, one of the information components is the information about the space with sound sources.

For the hearer, all sources of sound which he can recognize are at the point where the speaker is placed, and spatial information are reduced only to reverberation, which, in a reduced way, gives the image of the space with sound sources.

In direct hearing of a sound source, two global levels of spatial information that are integrated into a unique whole can be recognized in the acoustic image which then arises in the consciousness of the hearer:

sound comes from individual sound sources, i.e. localization of the places in space with sound sources whose sounds are recognized, and

- integrated information about the space where the hearer and sound sources are, which is often called "acoustic ambience".

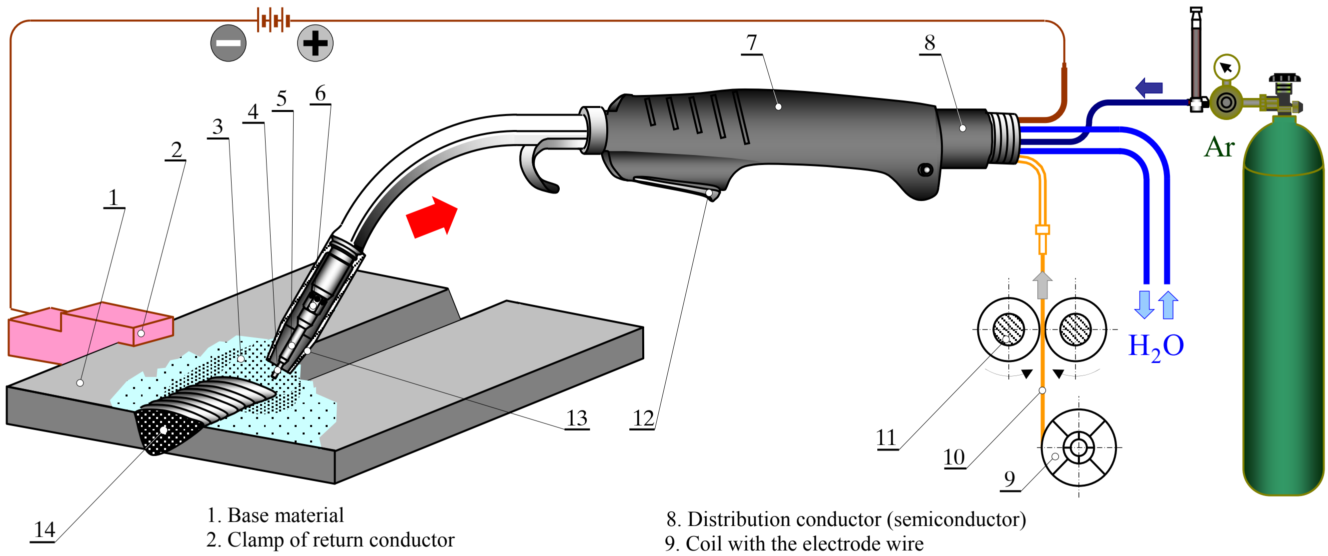
Transmission of sound information on audio systems starts, as a rule, by placing a microphone in the input acoustic environment. The first step in that job is generation of adequate signals which will, together as a package, also carry the information about the space. It is realised by the application of several microphones placed in an appropriate way in the space of the input acoustic environment.

information about directions from which direct

3. CHARACTERISTICS OF THE GMEL WELDING PROCESSS

3.1. Principle

When it is established, the electric arc is maintained, and the electrode wire is uniformly introduced/added (automatic-alectromotor, rollers for flattening, drawing and/or pushing the wire). Shortening of the electrode is the consequence of its melting (consumption).



1. Base material
2. Clamp of return conductor
3. Protective atmosphere
4. Free end of the electrode wire
5. Contact guide
6. Conductor of protective gas
7. Insulated handle
8. Distribution conductor (semiconductor)
9. Coil with the electrode wire
10. Electrode wire
11. Drive and push system
12. Switch
13. Nozzle
14. Solidified metal of the weld

Figure 4: Schematic presentation of the GMEL process

The created mixture of molten metals of the electrode and the workpieces makes a weld pool, which, during the cooling period, turns into the solidified metal of the weld.

During the whole process, the weld zone is covered with protective gas whose task is to prevent air penetration whose components produce harmful chemical links with liquid and/or heated base and additional metal.

Therefore, this process is defined as the process of creation of permanent joint by applying heat energy of activation accomplished by transformation of electrical energy by means of the electric arc formed between the base material and the electrode wire (additional material) in the zone of protective atmosphere of inert or active gas or mixtures of technical gases, Figure 3.[2]

3.2. Application

Production welding, surfacing and repair welding of most metal material. In welding, there are numerous ways of expressing the effectiveness of the process. It is most frequently done by means of deposit (kg/h), in certain conditions the indicators are the intermittence of process, the time used for subsequent cleaning of welds and the surrounding area... GMEL is applied for welding profiles, sheets and pipes whose wall thickness is 1÷20 mm (in some cases far above those thicknesses when it is economically and technologically justified). Originally, it is a semi-automatic process, but it is very often used as an automatic and robotic procedure.

According to the degree of automation, GMEL process is:

- semi-automatic; automatic bringing of the electrode wire to the zone of electric arc, manual control of the welding gun, i.e. additional material and electric arc,
- completely mechanized; application of mechanical systems for planar or spatial guiding of the welding gun, i.e. electric arc and the workpiece,
- automated; besides the previously mentioned, it covers the application of system for automatic guiding of the process (regulation of process parameters) and all other systems of the process on the basis of computer application,
- robotic; the process is led by computers with the application of robot.

The GMEL process is used for welding low carbon, low alloyed and stainless steels with the thicknesses 1÷30 mm. For the thicknesses $\delta>4$ mm, welding is performed in several passes.

GMEL processes are used for welding non-ferrous metals, particularly for:

- aluminium and its alloys,
- magnesium and its alloys,
- copper and its alloys,
- titanium...

GMEL only terminologically differs from the common and standardized term MIG/MAG because there is no technical difference between them – the difference is only in the type of utilized protective atmosphere. As modern industry mainly uses gas mixtures, it is the reason to apply the mentioned terminological difference.

3.3. Parameters

Although it is common to divide the welding process parameters into primary and secondary ones, here they are mentioned without making such a difference:

- $U_z = 16 \div 26$ V, the welding voltage,
- U_0 = 60 V, the open circuit voltage (most frequently),
- $I_z = 80 \div 180$ A, and more than 500 A, the current intensity,
- $j_z = 100 \div 200$ A/mm^2, even more than 450 A/mm^2 – the current density,
- $V_z = 2 \div 4$ mm/s = 7.2÷14.4 m/h, the welding speed,
- $d_0 = 0.7 \div 4$ mm, the electrode wire diameter,
- $\eta = 75 \div 85\%$, the energy efficiency.

For welding by the GMEL process, JSEP is most often used. It accomplishes a stable electric arc, uniform transfer of additional material, reduction of losses in material due to splashing and bigger depth of penetration. JSEN is more rarely applied because the electric arc becomes unstable, despite the increase in the melting coefficient, except for welding of light weight metals and in surfacing. The application of alternating current is avoided because of the intermittent electric arc in every semi-cycle and its difficult renewal, especially if the cathode is sufficiently cooled. [2]

4. MAN OR ROBOT?

The dilemma indicating by this title has resulted from the necessity of planning an experiment which can be realized at a robotic or conventional work post.

The correlation of kinematic schemes of manipulators (mechanical structure of the robot) and the welding processes for which they are intended or suitable, is presented in Figure 5. Various jobs are covered by manipulators with basic translatory motions (Descartes coordinate system). They are mostly applied in the field of welding both for positioning of workpieces and for positioning of executive bodies, i.e. welding guns. When the latter domain is in question, i.e. welding robots, their manipulators are, to the largest extent, realized on the basis of spherical and polar coordinate systems. Manipulators with the cylindrical coordinate system have primary application in positioning workpieces. [1] [5]

From the aspect of comparative characteristics of man and robot, the advantage is given to robot because it possesses better characteristics:

- precision in the execution of operations,
- repeatability of operations,
- willing-physiological character...

5. CURENT RESEARCH

The use of noise as a feedback element in control systems is based on the analogy of welder's role in the welding process and the facts that he uses the sense of hearing in order to estimate the state of the process. Enabling the robot control system to make decisions on the basis of change of sound emission of the welding process represents a significant scientific challenge and has a great practical importance.

The aim of planned research is the elaboration of methodology for procession of sound emitted during the realization of the considered process which provides the control system with quality information for the purpose of establishing corrections of development and maintenance of the process in the desired state. That aim is accomplished by establishing a correlation between three groups of characteristics of the process: sound emission characteristics, values of the main parameters of the process and qualitative indicators of the process.

The achieved results of the research should increase the levels of knowledge about the possibilities of using sound in control processes as well as encourage other researchers to use their ideas in order to add to the developed methodology.

6. EPILOGUE

The challenge set by this paper is contained in the ambition of engineering copying of nature, which is, in this case, reduced to recognizing human characteristics that could be mapped to an artificial object, i.e. robot. Those goals can be achieved when certain scientific and technical possibilities are reached.

The result of the research should be a robot enabled to "hear", which would imitate one of the human abilities. As the robot has already been enabled to "see", and also to feel, the sense of hearing is another human ability it would be provided with.

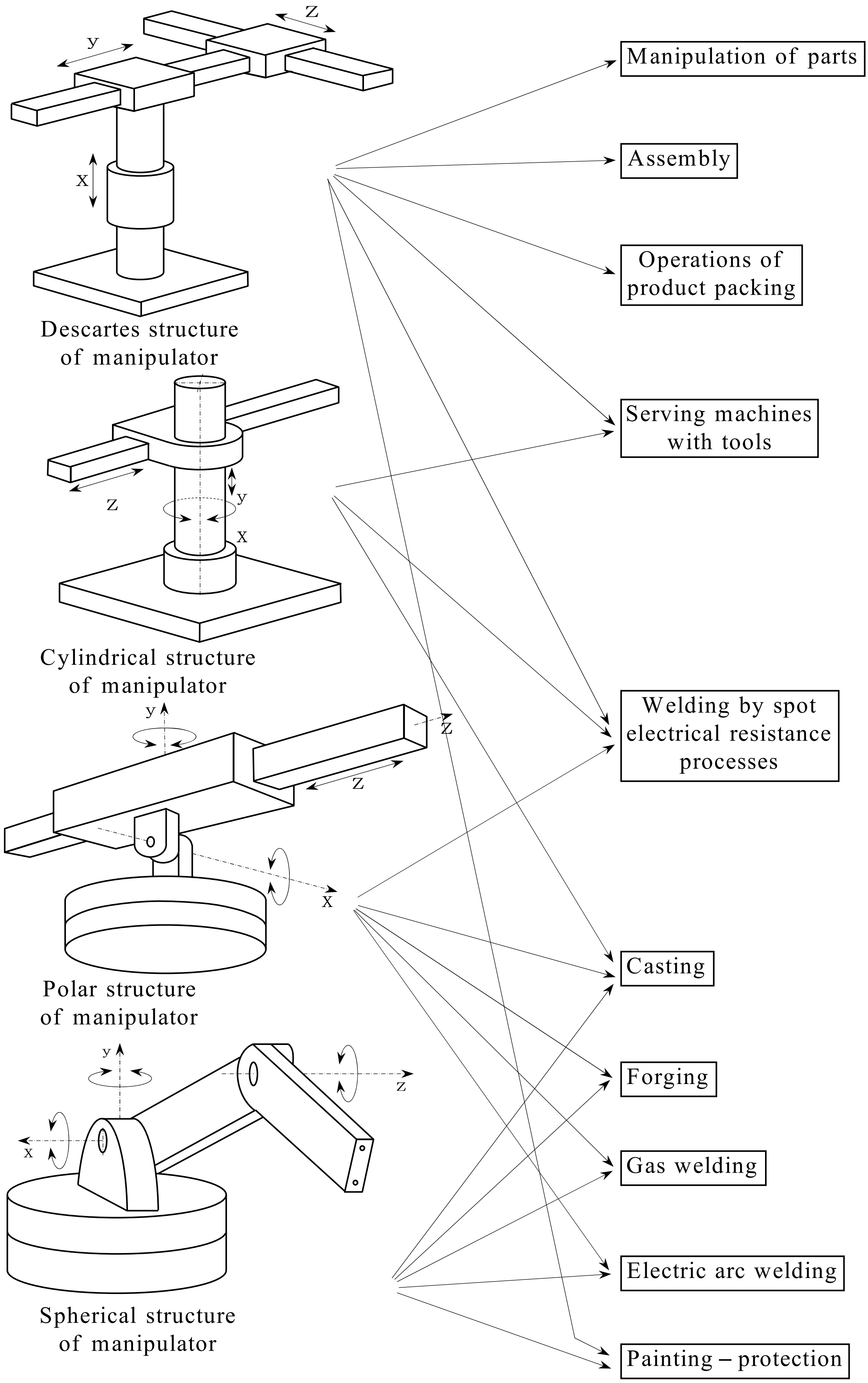


Figure 5: Schematic presentation of main types and condition of manipulator application

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