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WELDING RESEARCH IN SCANDINAVIA: AN ASSESSMENT(U)
OFFICE OF NAVAL RESEARCH LONDON (ENGLAND)
K D CHALLENGER 11 JUN 86 ONRL-R-2-86

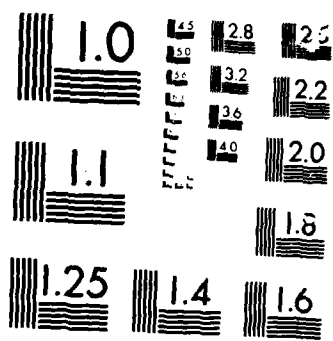
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Welding Research in Scandinavia:
An Assessment

Kenneth D. Challenger

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REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS		
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) R-2-86			5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION US Office of Naval Research Branch Office, London		6b. OFFICE SYMBOL (If applicable) ONRL	7a. NAME OF MONITORING ORGANIZATION		
6c. ADDRESS (City, State, and ZIP Code) Box 39 FPO, NY 09510			7b. ADDRESS (City, State, and ZIP Code)		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER		
8c. ADDRESS (City, State, and ZIP Code)			10. SOURCE OF FUNDING NUMBERS		
			PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.
11. TITLE (Include Security Classification) Welding Research in Scandinavia: An Assessment					
12. PERSONAL AUTHOR(S) Kenneth D. Challenger					
13a. TYPE OF REPORT Technical		13b. TIME COVERED FROM TO		14. DATE OF REPORT (Year, Month, Day) 11 June 1986	
15. PAGE COUNT 5					
16. SUPPLEMENTARY NOTATION					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) Metallurgy Industrial Processes Welding		
FIELD	GROUP	SUB-GROUP			
11	06				
13	08				
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The Scandinavian countries--Denmark, Finland, Norway, and Sweden--are making significant contributions to the science and technology of welding. Specific research topics which should be closely followed by US researchers are hyperbaric welding, CAD/CAM applications to welding, mathematical modeling of the weld process, and hydrogen assisted cracking of steel welds.					
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL C.J. Fox			22b. TELEPHONE (Include Area Code) (44-1) 409-4340		22c. OFFICE SYMBOL

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WELDING RESEARCH IN SCANDINAVIA: AN ASSESSMENT

1 INTRODUCTION

Despite their small size the Scandinavian countries (Denmark, Sweden, Finland, and Norway) are making significant contributions to the science and technology of welding. With a combined population of about 22 million they have about half as many people as the UK, yet their research effort in welding is larger. This is because of the importance of the metal-working industries to Scandinavia and the importance of welding research to these industries. (While the rest of the world struggles to compete with the quality of Japanese steel, Swedish and Finnish steels have retained their reputation for the highest quality.)

For the past decade, three Scandinavian industries have forced the advancement of welding technology: nuclear power, offshore oil and gas, and transportation. Development funds for nuclear power and the offshore industries have come primarily from government resources, whereas the transportation industry performs most of the welding research in its own industrial laboratories.

The Scandinavian countries have common industrial goals and problems; this, combined with their common ancestry, has made collaboration in research a natural event. Norway has been fortunate in having had oil discovered in the recent past in its regions of the North Sea. The resulting wealth has spread throughout Scandinavia by the creation of service industries in support of the exploration and production of oil and gas in the North Sea. One of the principal problems in exploiting this natural resource is the fabrication of the massive structures required to extract the oil from the ocean floor. These platforms are fabricated by an all-welded construction using newly developed high-strength low-alloy steels. Weld reliability and attendant inspections have been, and continue to be, major

problem areas. The attack on these problems is shared by all four countries.

Because of their many common goals these countries established a Nordic Council of Ministers to deal with those questions of interest to all. This council has formed several organizations to promote collaborative research among the countries. Some of the organizations of interest to welding research are:

- Nordtest (develops test methods)
- The Nordic Industrial Fund (provides funding for joint research projects)
- The Nordic Cooperative Organization for Applied Research (initiates and coordinates joint research projects)

Although there are common objectives for the research among these countries, the methods by which these objectives are met in each country vary. Denmark has a national welding institute. Finland and Norway have large divisions devoted to welding within national laboratories. Sweden does not have any central research organization, but has welding research performed in small university, institute, and industrial laboratories. Some industrial laboratories in all the countries are involved in welding research and development, but this research is almost universally devoted to promoting or improving specific products; the automotive (Sweden), nuclear power (Finland), shipbuilding (Finland), and offshore oil (Norway, Finland, and Denmark) industries all have large in-house welding research programs. However, I am not informed on the details of this research.

Some of these countries have centralized organizations to coordinate this research in that country, others do not. In all instances where a centralized body exists, it is comprised of members from both government and industry. The Scandinavian countries certainly realize that their resources for research are limited and thus that they must make projects contribute toward the national goals. Welding research in

Scandinavia is, in my opinion, well coordinated with the needs of Scandinavian industry.

2 GENERAL OBSERVATIONS RELEVANT TO US INTERESTS

My knowledge of the welding research and the researchers themselves in these countries has led me to certain conclusions and observations. These are as follows:

1. A significant fraction of the research is published in Scandinavian journals. These are published in English, but not widely read in the US.

2. Materials research in the US is, in general, greatly admired and closely followed. This is not true for welding research. Scandinavian countries work closely with Europe on welding research, but interaction with the US is practically nonexistent.

3. The US has much to gain by association and collaboration with the welding research in Scandinavia.

4. The recently signed agreement on scientific and technical cooperation between the US and Finland should be used to encourage some collaborative research on welding.

The next few sections of this report will highlight the welding activities in each of the four countries.

3 FINLAND

Welding research in Finland is carried out by the Technical Research Center of Finland (VTT), two of the four Finnish technical universities (Oulu and Lappeenranta), and Finnish industry. VTT, however, is the focal point for all of this research. It is reported that VTT performs over 50 percent of the welding research in Finland; it is my opinion that they control, or at least strongly influence, the remaining 50 percent also. The details of the welding research at VTT can be found in ESN 40-6: 203-207 (1986). The two key people at VTT (and within Finland, for that mat-

ter) involved in welding research are Drs. K. Vartiainen and R. Karppi. They have collaborative research projects with other Scandinavians, and also major projects with Japanese and West German researchers.

Many of these research projects are directly relevant to the US Navy's needs because the researchers work closely with the shipbuilding and offshore oil and gas industries. For example, computer-aided design and manufacturing (CAD/CAM) for welded construction and automation on a grand scale (gantry robots for shipbuilding) are currently under development; these projects require the development of control and optical sensing systems. Very little fundamental research is performed because this is indirectly discouraged by the funding mechanisms in Finland; industry and government usually cosponsor most projects. Although this may be a disadvantage in some respects, it has the advantage that all of the research is relevant. Technology transfer is not a problem in Finland.

Researchers at VTT are pursuing research on a variety of subjects:

- Automation and mechanization (2 years ago there were no welding robots in Finland, today there are over 100)
- The use of CAD/CAM for welded construction
- Weld procedure development (multiwire submerged arc welding of thermomechanically processed steel)
- Hydrogen assisted cracking of steel welds (a model to predict cracking as a function of composition and the welding parameters has been developed)
- Mechanical properties of welds (a large collaborative program with the Technical University of Aachen West Germany)
- Fracture toughness of weldments

High energy density welding is scheduled to become a new focus for VTT. They have placed an order for a 15-kw Leabold-Heraeus electron beam welding machine. This will be used for both

research and for demonstration purposes to Scandinavian industry.

The other two sites performing welding research (outside the industrial laboratories) are the Technical University of Oula and The Technical University of Lappenrenta. Professor P. Karjalainen (Oulu) is doing research on welding metallurgy, and Professors T. Moisio and Niemi (Lappenrenta) are performing research on hot cracking and weld design, respectively. I have not visited these people, so I am not familiar with the details of their research.

4 SWEDEN

Sweden does not have a centralized body to coordinate welding research, nor does it have a national center for welding research. Welding research is carried out at the universities, institutes for metals research, and in private industry. The primary site for the more fundamental research is the University of Lulea (Professor K. Easterling). The focus in this laboratory is on welding metallurgy and mathematically modeling both the welding process and the effects of the process on the metal being welded. (The details of the research at Lulea are given in *ESN* 39-5:193-199 [1985].)

Sweden has one of the most automated manufacturing industries in the world (*ESN* 40-1:18-21 [1986]). The Swedish Institute for Production Engineering carries out most of the research projects associated with the automation of welding. CAD/CAM application to welded design and construction is a high-priority research topic, just as it is in Finland. Swedish industry and the Swedish government (National Board for Technical Development) equally share the cost of these projects.

Easterling (Lulea) has a large research program on modeling the residual stresses and deformation that result from the thermal cycle of welding. This research is closely coordinated with the research of Professor M. Ashby (University of Cambridge). Most of the funding for this project comes from the National

Board for Technical Development, STU; the rest comes from Swedish industry.

Easterling is also involved in a project sponsored by the STU on the use of lasers for metals processing (cutting, welding, surface hardening, and surface alloying). Several Ph.D. theses have been completed on these topics.

I have the impression that welding research in Sweden suffers somewhat because of the lack of a central organizing and coordinating body. Transfer of information from the laboratory to the industrial user is not as reliable or predictable as that in Finland. For example, Easterling's models for predicting the effects of the process parameters on the resulting surface hardness and hardness profile for laser surface hardening are potentially very useful. Yet I am not aware of any industrial applications of this model.

Other laboratories that pursue welding research include Saab Skania Research Laboratory (automobiles, trucks, and aircraft), ESAB Research Laboratories (welding electrode and equipment manufacturers), and Volvo Central Research Laboratories (automobiles, trucks, and aircraft components). As one might expect, the focus of most of this research is on automation.

5 NORWAY

Welding research in Norway is carried out mainly at the Foundation of Scientific and Industrial Research (SINTEF) at the Norwegian Institute of Technology, Trondheim. The details of this research are given in *ESN* 39-6:261-264 (1985). As in the other Scandinavian countries, some welding research is carried out in the larger industrial laboratories; Norsk Hydro and Det Norske Veritas are good examples.

The government supports welding research through grants from the Royal Norwegian Council for Scientific and Industrial Research (NTNF). There is no central organization for the coordination of welding research. There is a Norwegian Welding Society, but like the

American Welding Society it is a professional association with only limited staff and funds.

Norwegian welding research is focused on problems associated with the design, construction, and maintenance of offshore oil and gas structures; specifically, on welding high-strength steels (hydrogen assisted cracking), underwater welding, and the effect of the sea environment on the mechanical properties of steel weldments.

Det Norske Veritas' contribution is mainly on the topic of the fatigue and fracture properties of the weldments used in the offshore structures and in nondestructive examination of these welds. SINTEF investigators focus on hydrogen assisted cracking, welding metallurgy, and hyperbaric (underwater) welding of steel. The research team at SINTEF was skillfully led by Professor N. Christensen until his unexpected death last year. His shoes will be very difficult to fill because he has made many significant contributions to not only the Norwegian welding program, but to the development of welding worldwide. I assume that the emphasis of the SINTEF research will not change as a result of his death because he worked closely with the Norwegian industry on his research. SINTEF should continue to make contributions to the fields of welding metallurgy, hydrogen assisted cracking and, especially, hyperbaric welding. (To my knowledge only two research programs of any size exist in Europe on hyperbaric welding: SINTEF and the Armed Forces University, Hamburg, West Germany [Professor H. Hoffmeister]). The European community depends on the research from these two centers in order to improve the methods of welding for repair of the offshore structures.

6 DENMARK

Denmark is the only Scandinavian country with an institute devoted specifically to welding. The Danish Welding Institute (Dansk Svejseteknisk Landsforening) is funded primarily by the National Agency of Technology and

performs over 90 percent of the welding research in Denmark. I have not visited this institute so I do not have personal impressions of the facilities or the research here, but I have met some of the personnel at meetings and will report what I have learned.

The speciality of this institute is the development of nondestructive testing equipment to be used for the quality control and inservice inspection of welded structures. Ultrasonic and eddy current testing systems and acoustic emission monitoring systems have been developed and used for this application.

Other types of research related to welding are also performed at the institute. These include:

- Weldability of high-strength steels
- Welding of stainless steels with flux-cored welding wires
- CAD/CAM (Nordic Council project)
- Plasma spraying of ceramic materials (Nordic Council project)
- Synergic pulse metal inert gas welding
- Projection welding
- Corona discharge treatment of metals
- Adhesive bonding
- The health aspects of welding

The key person at the Institute for welding and nondestructive testing research is Dr. Bent Koch.

7 SUMMARY

Welding technology and the research supporting it is as advanced in Scandinavia as anywhere in Europe. In certain fields, such as automation and hyperbaric welding, the Scandinavian countries are very much the leaders. The most fundamental research is performed at the University of Lulea, Sweden, by Professor K. Easterling. The other countries have a stronger industrial involvement in the research planning; thus, their research is more carefully focused to their own specific industrial needs. The greatest need at present is improved automation; this is occurring in the Finnish shipyards (where more than 60 percent of the world's ice breakers are built), the

Swedish automotive industries and--to a more limited extent--in the various Scandinavian sites where offshore structures are built. The second priority appear to be to eliminate the risks of hydrogen assisted cracking in welding high-strength steels. VTT (Finland) and SINTEF (Norway) are leaders in this project.

Funding from individual governments, the Nordic Councils, and industry for welding research is healthy in these countries. I did not hear a single person complain about the lack of support for their research during my travels in Scandinavia. However, the currently depressed oil prices will probably have a significant effect on the research funding to support the offshore oil industry; this industry is a major supporter of welding research in Scandinavia. The cries for financial support for welding research may begin soon.

7 RECOMMENDATIONS AND COMMENTS

1. US researchers in the field of welding science and technology should make it a point to read the relevant Scandinavian journals.

2. The US Navy should begin to develop some collaborative research on welding with Scandinavian institutions. My suggestion is to begin with VTT because of their close interaction with the Finnish steel and shipbuilding industries and their impressive facilities for welding research.

3. The Scandinavian countries are well connected with welding research in Western Europe, Japan, and, perhaps better than any western country, to Eastern Europe. This occurs because of their strong participation in the International Institute of Welding. The US is the only major industrialized country in the

world that does not have a strong participation in this organization.

4. At the present time welding research has strong support from the Scandinavian governments and industries. The current oil crisis may, however, change this situation.

5. Four specific research topics should be closely followed by the US:

- a. Hyperbaric welding
- b. CAD/CAM application to welding
- c. Mathematical modeling of the weld process
- d. Hydrogen assisted cracking of steel welds.

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