COLLISION TESTS ON COLLABORATIVE ROBOTS

The Fraunhofer IFF has extensive equipment for systematic analyses of human-robot collisions, including various force measurement systems, a high-resolution pressure measurement system and a high-speed camera. The Fraunhofer IFF additionally owns a KOLROBOT measurement system, which was developed by the German Social Accident Insurance DGUV’s Institute for Occupational Safety and Health IFA. This system, which delivers accurate biomechanical responses, makes it possible to measure impact and clamping forces directly on collaborative robots. A combination of springs and shock-absorbing material reproduces various regions of the human body. Fully automatic analysis allows immediate use of the results to analyze risks in workplaces. The Fraunhofer IFF incorporates the findings and results from its studies of biomechanical loads directly in its work with the KOLROBOT measurement system.

Our Services
Our extensive equipment enables the Fraunhofer IFF to quantify every relevant independent variable in a human-robot collision. Our flexible and, in part, mobile measurement systems allow us to test your collaborative robots, mobile platforms or newly set up collaborative workplaces against normative standards (biomechanical thresholds).

Your benefits
The results of a collision test facilitate the implementation of effective safeguards when collaborative workplaces are being set up. Moreover, process flows and clock speeds can be studied and optimized without exceeding applicable maximum loads in the process.

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**ACCEPTABLE STRESSES IN HUMAN-ROBOT COLLISIONS**

Human-robot collaboration is growing increasingly common in industrial manufacturing. More and more frequently, humans and robots are sharing a commonly used work areas in which they collaborate directly and interact with each other. Humans are being protected by technical measures such as sensor systems or safe manipulators rather than protective barriers.

Primarily DIN EN ISO 10218-2 has to be applied to safeguard work areas. It defines different forms of collaboration and is supplemented by ISO/TS 15066, which defines specific safety standards. The closest form of collaboration is physical collaboration of humans and robots side by side, allowing when contact between the two.

Whenever contact is possible in principle or even necessary, decisions have to be made during the risk analysis about potentially intended or unintended contact. Different biomechanical thresholds, which were defined by the Fraunhofer IFF together with medical examiners from Otto von Guericke University Magdeburg in a study for the Commission for Occupational Health and Safety and Standardization, apply in each case.

In the event that contact is intended, the stresses on humans may not reach pain onset, i.e. desired and necessary contact with a person by a robot may only cause pressure that is not perceived as pain. Dangerous collisions or situations that trap a person must be treated as unintended contact. In such cases, the stresses on humans may not exceed injury onset. The sole attributes of this threshold are slight swelling or light bruising.

**OTHER FOCI OF ONGOING STUDIES**

The biomechanical studies completed also focused on the independent physical variables such as force, pressure and energy, which have the demonstrably greatest influence on pain or injury onset. Which variable correlates best with which of the two thresholds has not yet been established beyond doubt. The findings from the tests with subjects are delivering new and promising possibilities.

**Different Collisions**

Situations in which robots can collide with humans were analyzed in experiments in another study. Contracted by the German Social Accident Insurance DGUV’s Institute for Occupational Safety and Health IFA, the Fraunhofer IFF established in tests with subjects that the maximum permissible loads in collisions that do not trap the affected body part are significantly higher than in collisions that trap the affected body part. A human body model, which reliably converts the maximum loads of collisions that trap a body part to collisions that do not, was developed on the basis of tests with subjects.

**STUDIES THAT ASCERTAIN MAXIMUM LOADS**

The Fraunhofer IFF has completed several studies intended to ascertain maximum loads for safe human-robot collaboration. Verified thresholds were compiled from load tests on subjects and can be used to gauge and safely limit the consequences of a collision or situations that trap a person. Otto von Guericke University Magdeburg’s ethics commission approved the different studies. Physicians from the university’s different facilities and clinics oversaw the studies with subjects.

**Studies on Injury Onset**

A pendulum was applied to several regions of a total of twenty-five subjects’ bodies to study their injury threshold. This entailed incrementally increasing the impact energy over a period of several weeks until slight swelling or light bruising was detected in the loaded regions of the body or the load caused a subject to feel moderately severe pain. Different impactors were employed. The study was supported by Daimler AG and KUKA AG.

**Studies on Pain Onset**

The same pendulum was used in the first phase of another study to strike over twenty regions of twenty subjects’ bodies with increasing energy. The impact energy was increased during the tests until a subject’s pain threshold was reached. In a second phase of the study, the Institute for Occupational Safety and Health IFA’s pressure algometer was used to subject the same area of forty subjects’ bodies to quasi-static clamping force. The analyzed area of the body was subjected to slowly increasing clamping force until a subject’s pain threshold was reached. This study was contracted by the Berufsgenossenschaft Holz & Metall.

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1 Direct human-robot collaboration.
2 Impact tester.
3 Impact testing on a subject’s shoulder.
4 Test setup for the study of collisions that trap body parts.